NUTRIENT - MOISTURE INTERACTION UNDER PHASIC STRESS IRRIGATION OF SWEET POTATO IN SUMMER RICE FALLOWS

BY

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DECLARATION

I hereby declare that this thesis entitled " Nutrient - moisture interaction under phasic stress irrigation of sweet potato in summer rice fallows " is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellow ship or other similar title, of any other University or Society.

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CONTENTS

	Page
INTRODUCTION	1
REVIEW OF LITERATURE	7
MATERIALS AND METHODS	39
RESULTS	60
DISCUSSION	143
SUMMARY	206
REFERENCE	i-xix
APPENDIX	I-II

LIST OF TABLES

Table no:	Particulars	Page No:
1	Soil characteristics of the experimental field	42
2	Effect of treatments on the length of vine (cm)	61
3	Interaction effect of irrigation and nitrogen on the length of vine (cm)	63
4	Effect of treatments on the number of branches plant^{-1}	65
5	Interaction effect of irrigation and nitrogen on number of branches plant^{-1}	66
6	Effect of treatments on the number of leaves plant^{-1}	68
7	Interaction effect of irrigation and nitrogen on number of leaves plant^{-1}	70
8	Effect of treatments on LAI at various stages of growth	72
9	Interaction effect of irrigation and nitrogen on LAI	73
10	Effect of treatments on NAR (g m^{-2}day^{-1})	76
11	Interaction effect of irrigation and nitrogen on NAR (g m^{-2} day^{-1})	77
12	Effect of treatments on CGR (g m^{-2}day^{-1})	79
13	Interaction effect of irrigation and nitrogen on CGR (g m^{-2} day^{-1})	80
14	Effect of treatments on specific leaf weight (mg cm^{-2})	82
15	Interaction effect of irrigation x nitrogen on specific leaf weight (mg cm^{-2})	84
16	Interaction effect of nitrogen x potassium on specific leaf weight (mg cm^{-2})	85
17	Effect of treatments on the dry matter content of leaves (g plant^{-1})	87
18	Interaction effect of irrigation and nitrogen on dry matter content of leaves (g plant^{-1})	89
19	Effect of treatments on dry matter content of shoots (g plant^{-1})	91

20 Interaction effect of irrigation and nitrogen on dry matter content of shoots ($g\ plant^{-1}$) 93

21 Interaction effect of nitrogen and potassium on dry matter content of shoots ($g\ plant^{-1}$) 94

22 Dry matter content of fibrous roots as affected by treatments ($g\ plant^{-1}$) 95

23 Interaction effect of irrigation and nitrogen on dry matter content of fibrous roots ($g\ plant^{-1}$) 97

24 Dry matter content of tuber as affected by treatments ($g\ plant^{-1}$) 98

25 Total dry matter production ($g\ plant^{-1}$) in the first season 100

26 Total dry matter production ($g\ plant^{-1}$) in the second season 102

27 Interaction effect of irrigation and nitrogen on dry matter production ($g\ plant^{-1}$) 103

28 Tuber bulking rate ($g\ week^{-1}\ plant^{-1}$) as influenced by treatments 105

29 Length and girth (cm) of tuber at harvest 107

30 Effect of treatments on the number of tubers $plant^{-1}$ 109

31 Interaction effect of nitrogen and potassium on number of tubers $plant^{-1}$ 110

32 Effect of treatments on mean tuber weight (g) 113

33 Effect of treatments on tuber yield ($t\ ha^{-1}$) 115

34 Interaction effect of I x N and I x K on total tuber yield ($t\ ha^{-1}$) in 1990 116

35 Interaction effect of nitrogen and potash on tuber yield ($t\ ha^{-1}$) 118

36 Effect of treatments on the vine yield ($t\ ha^{-1}$) 120

37 Utilization index (UI) and Harvest index (HI) as affected by treatments 122

38 Effect of treatments on the cooking quality of tubers 124

39 Starch and sugar content of tuber (% on FW basis) 126

40 Effect of treatments on the uptake of nitrogen ($kg\ ha^{-1}$) 128

41	Effect of treatments on the uptake of phosphorus (kg ha^{-1})	130
42	Effect of treatments on the uptake of potassium (kg ha^{-1})	132
43	Available nitrogen content of the soil (kg ha^{-1})	134
44	Available phosphorus content of the soil (kg ha^{-1})	135
45	Available potassium content of the soil (kg ha^{-1})	137
46	Effect of treatments on water use efficiency (kg ha^{-1} mm^{-1})	139
47	Interaction effect of nitrogen X potassium on water use efficiency (kg ha^{-1} mm^{-1})	141
48	Total quantity of water received (mm)	142
49	Net income (Rs ha^{-1})	201
50	Benefit - cost analysis	204

LIST OF ILLUSTRATIONS

Sr.No:	Particulars	Page No:
1	Weather parameters (I season)	40-41
2	Weather parameters (II season)	40-41
3	Layout plan	44-45
4	Effect of irrigation on leaf area index	73-74
5	Effect of nitrogen and potassium on leaf area index	73-74
6	Effect of treatments on net assimilation rate	77-78
7	Effect of treatments on crop growth rate	80-81
8	Effect of irrigation on dry matter partitioning	103-104
9	Effect of nitrogen and potassium on dry matter partitioning	103-104
10	Effect of treatments on tuber bulking rate	105-106
11	Effect of treatments on total number of tubers	110-111
12	Effect of treatments on number of marketable tubers	111-112
13	Effect of treatments on total tuber yield	116-117
14	Effect of treatments on marketable tuber yeild	118-119
15	Effect of treatments on vine yield	120-121
16	Effect of treatments on uptake of nitrogen	128-129
17	Effect of treatments on uptake of phosphorus	130-131
18	Effect of treatments on uptake of potassium	132-133

INTRODUCTION

1 INTRODUCTION

Sweet potato (Ipomoea batatas L. Lam.) is considered to be native of Central America. But some Scientists are of the opinion that it is of Polynesian origin. The distribution of this species had been very much influenced by Portuguese and Spanish sailors who during the Sixteenth Century brought them to the Philippines, Indonesia, India, Japan and Malaysia.

According to the FAO, sweet potatoes are grown in 111 countries, of which 101 are classified as developing nations. Asia accounts for about 81% of the area under cultivation and the major share (69%) goes for China (FAO, 1992). As regards production, 92% is accounted by Asia where the contribution of China is to the extent of 85%. India ranks fifth in area (2.3%) with a productivity of 7.9 t ha^{-1}.

The area and production of sweet potato in India showed a decline over time. In 1979-80, sweet potato was grown in an area of 0.207 million hectares with a production of 1.348 million tonnes (ASI, 1981). In 1989-90, the area was reduced to 0.133 million hectares and the production came down to 1.148 million tonnes (ASI, 1992). Even though the crop is grown in almost all states and union territories, Orissa, Uttar Pradesh and Bihar together account for 65% of the area and 71% of the production. In Kerala, sweet potato is grown to an extent of 3169 hectares with a productivity of 8.34 t ha^{-1}. The area under sweet potato showed a decline of 37% over a decade, but the productivity registered an increase of 86% in Kerala.

Sweet potato is an important source of carbohydrate. Certain varieties having yellow flesh are rich in carotene, the precursor of vitamin A. Sweet potatoes may be consumed after cooking in water or converted into several food products like noodles, purees, flakes, pickled sweet potato etc. Sweet potato is pickled in sucrose syrup and forms an important dish in USA. Dehydrated sweet potato is used in various confectionary items like cake, biscuit and bread. Sweet potato starch is used in textile and paper industries and for the production of liquid glucose and high fructose syrup. The young shoots and leaves are used as vegetable and also in animal feed. The vines can be directly fed to cattle and swine or ensiled and given. NASA in USA has identified sweet potato as a future crop for interplanetary missions.

The feeding root system of sweet potato is more or less fibrous and is relatively extensive both in depth and lateral spread. The edible sweet potato is variously referred to as a root, a root-tuber or a tuber. Sweet potato is a short maturity crop, tolerant to a wide range of growing conditions. It is relatively cold tolerant and hence is grown in many tropical high land zones.

In 1985, the Consultative Group on International Agricultural Research (CGIAR) decided to put more resources into this valuable crop and encouraged International Potato Centre (CIP) to include sweet potato in their programme which had a mandate only for potatoes. Now 40% of CIP's total resources go into sweet potato research. The basic aim is to fit sweet potato into cèreal-based and other food systems.

Available literature and early results of field studies indicate that the sweet potato has a broad ecological and agroeconomic adaptability which is related to the genetic diversity within the cultivated species (CIP, 1989). The crop is grown from 35^{0} N to 35^{0} S and from sea level to almost 300 m above sea level. The comparative short duration, coupled with its innate power for tremendous dry matter production has enabled sweet potato to rank as the foremost tuber crop in respect of caloric value.

Next to cassava, sweet potato is an important tuber crop of Kerala, cultivated under both upland and lowland situations. Sweet potato is grown as a rainfed crop (June-September) and as an irrigated crop (October-January) in uplands whereas in the lowlands it is cultivated during February to May as an irrigated crop after the harvest of second crop of rice.

However, at present there is only a general fertilizer recommendation based on trials conducted in the uplands. Positive response of sweet potato to nitrogen fertilization has been well established. Moderate application of nitrogen is found to result in high tuber yields, though excessive supplies were unfavourable for tuber production. The response to phosphorus has not been conspicuous as is shown in earlier studies. Differential response to applied potassium has been reported from several parts of India. As lime has been found to be helpful in increasing the yield and quality of sweet potato tubers (Nair and Mohankumar, 1984), application of lime @ 500 kg ha^{-1} is expected to enhance the efficiency of applied nutrients.

Cultivation of sweet potato in summer rice fallows is being practised in many parts of Kerala where an assured supply of irrigation water is available. The high rate of evaporation dictates a matching supply of water during summer months. However, it is impossible to irrigate sweet potato throughout the growth period at a rate equivalent to the evapotranspiration requirement of the crop due to scarcity of water in summer months. Therefore, it becomes necessary to restrict the supply of water. Measures to enhance the water use efficiency by phasing out the irrigation schedule in consonance with critical stages of plant growth would enhance the productivity of sweet potato. Preliminary studies conducted at Central Tuber Crops Research Institute, indicated that imposing water stress during tuber initiation and/or tuber maturity phase drastically reduce the tuber yield of sweet potato (Indira and Kabeerathumma, 1988).

As regards nutrients, both nitrogen and potash play a dynamic role in modifying the tuber yield of sweet potato. It is expected that the fertilizer use efficiency will be considerably higher for a crop planted in summer as the leaching loss will be minimum. A concerted effort on phasing out the irrigation schedule in conjunction with a judicious fertilizer supply will enhance the productivity and profitability of sweet potato as a catch crop in summer rice fallows.

The present investigation on nutrient-moisture interaction of sweet potato has the following objectives :-

1. To find out the critical stage of plant growth for phasing out irrigation,
2. To assess the nitrogen and potash requirement in conjunction with irrigation, for sweet potato as a catch crop and
3. To work out the economics of sweet potato cultivation in summer rice fallows.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

The study enlightens the interaction of nutrients and moisture on sweet potato var. Kanjangad raised as a catch crop in summer rice fallows. Relevant information on effect of nutrients and irrigation on growth, dry matter production, yield, quality and nutrient uptake of sweet potato and related crops are presented.

2.1. Catch crop

Sweet potato has great potential as a catch crop in rice fallows (Sasidhar, 1978) because of its innate capacity to produce tremendous dry matter within a short period of three to four months. Catch crop is usually a quick growing crop, planted and harvested between two regular crops in consecutive seasons (Somani and Tikka, 1984).

2.2. Fallowing

In field trials laid out at four locations in Thiruvananthapuram district, Kerala state (Nair and Hrishi,1974) reported that a successful crop of sweet potato can be raised in summer rice fallows by applying FYM @ 10 t ha^{-1} and NPK @ 75:50:75 kg ha^{-1}. Fallowing is the practice of leaving the land idle in order to restore productivity through accummulation of moisture. Summer fallow is common in regions of limited rainfall where cereal grains are grown (Herren and Donahue, 1991).

2.3. Effect of nutrients on growth characters and dry matter production

2.3.1 Nitrogen

Growth of plants is limited more often by deficiency of nitrogen than by any other element. Thomas (1965) reported maximum number of shoots in sweet potato plants that received 80 kg nitrogen and 80 kg potash per hectare. Liberal application of nitrogen resulted in heavy vine growth which led to low yield and poor quality tubers (Samuels, 1967). Haynes et al. (1970) suggested that the leaf area development of sweet potato cultivars was influenced by nitrogen, foliage display and spacing and that there was an optimum leaf area index for a particular foliage display system. Early nitrogen application caused vigorous vine growth in clay loam soils as reported by Morita (1970).

Knavel (1971) could notice a highly significant correlation between nitrogen application and vine dry weight. He further stated that excess leaf area index had an unfavourable effect on dry matter production resulting from intense shading. Austin and Lang (1972) observed a linear increase in dry matter distribution in leaves, stems and roots with time. They also concluded that the final accumulation of dry matter varied with cultivars, spacing, location and season. Wilson and Lowe (1973) suggested that early tuber growth is the slow stage of tuber development which preceeds rapid tuber bulking. In both cultivars under trial, the onset of early tuber growth was inversely related to the level of nitrogen supply.

Carter and Traveller (1981) reported that adding more nitrogen fertilizer than that needed for optimum plant growth or proportion of the photosynthate is used for increased top growth at the expense of dry matter and sucrose accumulation in the roots of sugar beet. An increased concentration of nitrogen in the plant led to an increase in dry matter production of the aerial parts throughout the growth period as reported by Tsuno (1981). He also observed that a linear relationship existed between nitrogen absorption and leaf area index and a linear decline in net assimilation rate.

Bouwkamp (1983) in a study on sweet potato observed that harvest indices and dry weight accumulations of storage roots and total plant dry weights increased throughout the growing season. There was a slow increase in vine dry weight that reached a peak at 14 - 16 weeks after transplanting and then slowly decreased with maturity.

Bourke (1985) from a series of experiments conducted in Papua New Guinea observed an increase in leaf area duration by nitrogen which could influence the mean tuber weight and tuber yield. An increase in plant height and number of leaves plant^{-1} as a consequence of nitrogen application was reported by Rajanna et al.(1987) in potato. Wahua and Ordu(1986) in their studies observed that fertilizer application increased leaf area and branching that led to an increase in leaf and stem dry weights.

Walker et al.(1988) grew sweet potatoes hydroponically in either a 3.5 or 15.0 mM N solution for 65 days and observed that the shoot dry weight was 20-144% greater in 15 mM N as compared to those grown in 3.5 mM N. Oommen (1989) recorded an increase in vine length and number of branches when nitrogen supply was increased from 50 to 100 kg ha^{-1}. Nitrogen application also increased the leaf area and dry weight of leaves and stem.

2.3.2 Phosphorus

In general, the response of sweet potato to phosphorus application has been poor probably due to its very low uptake. Constantin et al.(1977) after conducting trials in four locations with phosphorus levels ranging from 0 to 73.9 $kg.ha^{-1}$ observed that phosphorus had no effect on dry matter production.

2.3.3 Potassium

The total dry matter production per unit area was most remarkably governed by the amount of potassium absorbed by sweet potato (Tsuno and Fujise, 1964 a). They also observed that potassium was effective for the translocation of assimilates from the top to the developing tubers(Tsuno and Fujise, 1964b) and explained that potassium content in the leaf had an intimate correlation with the rate of photosynthesis.

The dry matter content of tuber was reduced in the experiments of Constantin et al.(1977) as the level of potassium was increased from 0-140 $kg.ha^{-1}$. Bautista and Santiago (1981) conducted pot culture studies in sweet potatoes grown on silt loam, sandy loam or clay loam.

Potassium application increased growth and tuber yields from 0.36 kg pot^{-1} with no potassium to 0.57 kg with 600 ppm potassium.

In a fertilizer trial involving 0, 125 and 375 kg ha^{-1} of K_2O to investigate on the influence of potassium on growth and yield of sweet potato, Bourke (1985) observed an increase in total plant dry weight, mean leaf area and harvest index.

Levels of potash or its times of application did not exert any influence on the length of vine or its dry matter production in sweet potato (Nair, 1987). Oommen (1989) observed that higher levels of potassium influenced LAI, NAR and CGR at different stages of growth. The leaf, stem and tuber dry matter production were the highest at the highest levels of potassium.

2. 4. Effect of nutrients on yield and yield attributes

2. 4.1 Nitrogen

Significant yield increases as a consequence of nitrogen fertilization was observed by Mac Donald (1963) who also reported a decrease in tuber yield by excessive nitrogen application. Significant positive response to nitrogen fertilization in terms of tuber yield of sweet potato was observed by Paterson and Speights (1964) where the dose of nitrogen was increased from 0 to 112 kg $hectare^{-1}$ in the case of sweet potato grown in rotation.

Greig (1967) stated that more than 56 kg $hectare^{-1}$ of nitrogen decreased the yield of sweet potato and recommended the application of @ NPK 28:56:56 kg $hectare^{-1}$ to secure highest yield. Tsuno and Fujise (1968) concluded that to secure high yields of tuber, nitrogen application should be moderate in order to regulate excessive growth of tops at the expense of tuber development.

Knavel (1971) found that the nitrogen content of the medium greatly influenced the size of tubers while the number of tubers per plant remained unaffected. Mandal et al (1971) obtained maximum tuber yield in the red loam soils of Kerala by applying 100 kg nitrogen per hectare which was on a par with 75 kg nitrogen. They also observed that the size of tuber was not influenced by nitrogen but higher levels of nitrogen resulted in an increase in the number of tubers $plant^{-1}$.

Increase in yield of vine with increasing levels of nitrogen from 50 to 100 kg ha^{-1} was recorded by Nair (1972). Nair and Sadanandan (1973) could not observe any significant increase in tuber yield over levels of 50, 75, and 100 kg ha^{-1} of nitrogen in the red loam soils of Vellayani.

Nambiar *et al*. (1976) observed no effect of applied nitrogen on the length of individual tubers but that the number of tubers per plant was significantly increased. He also found that the tuber yield increased with increasing levels of applied nitrogen. Increasing the rates of applied nitrogen from 0 to 120 kg ha^{-1} increased the yield of sugar beet from 34.50 to 60.06 t ha^{-1} but decreased sugar content from 19.40 to 15.55% (Rathee *et al*.,1978).

Muthuswamy *et al*.(1981) recorded increased tuber yield with increasing rates of nitrogen. It was reported by Jana (1982) that added nitrogen may reduce the tuber yield of sweet potato. He found that the tuber yield decreased with heavy doses of nitrogen supply by increasing the vine yield.

In a study by Adams *et al*.(1983), it was found that an amount of nitrogen @ 90 kg ha^{-1} or less was required for optimum total recoverable sucrose ha^{-1} than for maximum whole root yield of sugar beet. Nitrogen fertilizer was very important for higher yield in sugar beet and throughout the growth of the crop it greatly increased the dry matter yield (Last *et al*.,1983). An increase in nitrogen fertilizer, increased the root yield of sugar beet (O'connor,1983) when the soil nitrogen was limiting.

Constantin *et al*. (1984) recorded an increased root weight and percentage of top grade roots with increased nitrogen supply. Kim(1984) while studying the influence of three levels of nitrogen on the growth and development of sweet potato, observed that high nitrogen supply delayed root enlargement. Varying the nitrogen supply could not bring about any significant improvement in root yield.

In a fertilizer trial involving nitrogen at 0, 75, 150 and 225 kg ha^{-1}, Bourke (1985) found that higher levels of nitrogen increased the mean tuber weight and tuber yield. Mascianica *et al*.(1985) observed maximum sweet potato yield at a nitrogen level of 75 kg ha^{-1}. Prasad and Rao (1986) reported that nitrogen at 75 kg ha^{-1} recorded the highest yield in sweet potato under Bhubaneswar conditions. Singh *et al*. (1986) from field experiments in Bihar observed that increasing nitrogen rates from 0 to 80 kg ha^{-1} increased the tuber yield.

Tuber yields of potato increased with increasing rates of applied nitrogen (Castro, 1988) from 19.0 t ha^{-1} with 50 kg nitrogen to 22.5 to 24.1 t ha^{-1} with 125 and 200 kg nitrogen respectively as a direct influence of increased proportion of large tubers. Gupta(1992) observed an increase in total tuber yield with increasing nitrogen rates upto 180 kg ha^{-1} in potato.

2.4.2 Phosphorus

Rajput et al.(1981) observed significant yield increase as a result of application of phosphorus at 50 kg ha^{-1} over no phosphorus treatments in Maharashtra state. Navarro and Padda (1983) reported that phosphorus had no effect on yields of sweet potato. In a field experiment in North Carolina, USA, Nicholaides et al.(1985) could not find any effect on yield by varying the rates of phosphorus application from 0 to 100 kg ha^{-1}.

2.4.3 Potassium

Potassium is essential for the synthesis and translocation of carbohydrates from the tops to the roots. Fujise and Tsuno(1962) reported that dry weight of tuber in plots receiving high potassium was 20 per cent higher than that of the control plot while the dry weight of tops showed no difference which showed that higher levels of potassium promoted the growth of tuber. Muthuswamy et al. (1981) reported that potassium had no effect on the tuber yield of sweet potato. Wargiono (1981) also reported that potassium application could not result in increased yields.

Purcell *et al*.(1982) observed that potassium application increased root yields. Similarly, Villareal (1982) was of the opinion that to secure maximum sweet potato yields, the level of potassium in the soil should be increased several times to that of nitrogen. The most economic dose of potash for upland sweet potato was found to be 60 kg ha^{-1} at Trichur in Kerala state (Ashokan *et al*.,1984). Hammett *et al*.(1984) found that the marketable tuber yield was higher at higher rates of potassium application.

Bao *et al*.(1985) on an analysis of 392 experiments came to the conclusion that potassium fertilizer was very effective on sweet potato, yield was always increased by applying potassium. On an average, applying 70 kg ha^{-1} potash increased the yield by 3.7 t ha^{-1}. They also observed that potassium fertlizer increased the yield of sweet potato by increasing both the number of tubers and the ratio of large/small tubers. Potassium influenced the tuber yield through an increased diversion of dry matter to the tubers (Bourke, 1985).

From a field trial with different rates of potassium application ranging from 0 to 279 kg ha^{-1}, Nicholaides *et al*.

(1985) reported a linear increase in yield due to potassium application, particularly in soils of low potassium status. Gowda *et al*.(1990) in an experiment on red sandy loam soil with potash at 40, 80 and 120 kg ha^{-1} applied as basal or in splits at planting and 30 days later recorded higher tuber yield compared to NP alone. Yields were higher with 40 kg potash applied as basal.

An increase in total tuber yield of potato by potash application upto 50 kg ha^{-1} was noticed by Gupta (1992). Increasing the dose of potash above 50 kg could not result in any increase in yield. Herlini(1992) reported that the primary agronomic effect of potassium was to increase yield, with minimal effects on sugar concentration of sugar beet.

2.5. Effect of irrigation on growth and yield

Cultivation of sweet potato in summer rice fallows is successfully practised in many parts of the state where assured supply of irrigation water is available. Field trials conducted in the sweet potato growing areas have conclusively proved the beneficial effect of irrigation. However, shortages in supply of water reduce the yield considerably and makes sweet potato cultivation unattractive.

In an experiment by Jones (1961), irrigating sweet potatoes whenever the available soil moisture fell to 20% of the total available capacity, produced as high yields of No.1 grade sweet potatoes, as those obtained under higher levels of moisture supply. Irrigating at 20% available moisture required approximately 15 inches of water (380 mm).

A study on the main effects and interactions of irrigation levels, variety and fertilizer application was conducted in a split plot design over a three year period by Peterson (1961). Irrigation treatments consisted of 0.5, 1.0, 1.5 inches (12.5 mm, 25 mm and 37.5 mm) of water applied at weekly intervals. Application of 25 mm water applied at weekly intervals appeared to be efficient for producing high yields. In an earlier study, Hernandez and Barry (1966) could not find any increase in the yield of sweet potato by maintaining the soil moisture level above 50% of the available moisture capacity.

Hernandez and Hernandez (1969) reported that sweet potato required on an average of 0.25 hectare cm of water per day in the early part of the growing season. This gradually increased to 0.63 hectare cm of water in summer, depending on the stage of plant growth and other environmental conditions. They also reported that high soil moisture levels over a period of several days (40 to 50 days) after transplanting resulted in excessive vegetative growth at the expense of storage root formation. Inducing drought at 40 days after planting and allowing the soil moisture to drop much below 20% for a few weeks before fleshy root set, caused great reduction in yield. Also, droughts in the later part of the growing season slowed down fleshy root growth and reduced yields of marketable roots.

Constantin et al.(1974) reported that whenever supplemental irrigation was applied to sweet potato, the root quality was reduced. The dry matter content, colour of both fresh and processed sweet potatoes, firmness of the canned product and the per cent protein decreased as the moisture content of the soil increased.

Jain and Jain (1976) reported that the root and top yield of sugar beet grown for fresh fodder were similiar with irrigations applied at IW/CPE (irrigation water/ cumulative pan evaporation) ratios of 0.60, 0.75 or 0.90 and also with 100-250 kg N, 35-80 kg P_2O_5 and 35-80 kg K_2O ha^{-1} applied in four combinations, indicating that an IW/CPE ratio of 0.60 and application of 100 kg N + 35 kg P_2O_5 + 35 kg K_2O were sufficient for sugar beet in Rajasthan. Ehlig and LeMert

(1979) observed that neither sucrose content nor yield of sugar beet was affected by irrigation. They noted that with limited irrigation, sucrose yield/unit^{-1} water use increased 22% above the treatment that matched lysimeter evapotranspiration.

Watanabe (1979) found that when soil moisture was high or the soil was compacted, sweet potato had luxuriant vegetative growth with little or no tuberization. In sweet potato, over application of irrigation water reduced root formation and the quantity of rain water received was negatively correlated with root yield (Gollifer, 1980). Temporary drought stresses during the growth period triggered root formation and stimulated root development whenever vegetative growth was suppressed for short periods. On a sandy loam soil, sugar yields of sugar beet increased with irrigation rates upto 100% of estimated evapotranspiration (Miller and Hang, 1980).

Irrigation schedules and amounts were varied to produce a wide range of water stress severity, duration and timing by Winter (1980). Sugar beet made efficient use of limited rainfall and soil profile water even when subjected to periods of water stress upto 5 months. Irrigation water was used most efficiently when water application was adequate to maintain a nearly full canopy with no periods of major water stress or excessive water.

Excessive irrigation should be avoided as poor aeration may cause poor storage root induction or development (Chua and Kays, 1981). According to Roberts et al. (1981), deficit irrigation of 50% ET replacement regime decreased beet yields by 10 t ha^{-1} for a net loss of sugar yield. Hammett et al. (1982) reported that yields were similiar when sweet potatoes were irrigated at soil moisture contents >20%.

In another study, delaying first irrigation until 60 days after planting, gave the best root yield, with better root enlargement in a rainfed crop of sweet potato (Sajjapongse and Roan, 1982). Sweet potato is mostly cultivated without irrigation as a monocrop, relay or intercrop in different farming systems. In a survey conducted in 26 countries, drought was ranked as the most serious abiotic factor to depress yield (Lin et al., 1983).

Jorgenson (1984) obtained higher yield, more tubers and higher starch content in tubers by irrigating potato more frequently (0.4 bar) at tuber initiation period than with irrigation at high water stress.

Irrigation every four days gave 50% greater canopy development than the control, highest tuber yield and lowest number of small tubers in potato. Yield increased from 10 t ha^{-1} without irrigation to 28 t ha^{-1} with more frequent irrigation (CIP, 1985).

Hang and Miller (1986) found that at final harvest, maximum dry matter production occurred at irrigation rates equivalent to 40-50 % of estimated evapotranspiration. With adequate water, root sucrose concentration increased until harvest. Dry matter production increased with increasing water applied upto about 85% of estimated evapotranspiration.

Varughese et al.(1987) studied the effect of irrigation on sweet potato at Agronomic Research Station, Chalakudy, Kerala state and reported that irrigation at IW/CPE ratio of 1.2 with 50 mm water during dry months profoundly influenced the growth, tuber yield and net income as compared to irrigation at 0.8 and 0.4 ratios.

Indira and Kabeerathumma (1988) imposed water stress for 20 days to sweet potatoes grown in lysimeters during the early growth phase (10-30 DAP), tuber development phase (30-50 DAP) and tuber maturity phase (75-95 DAP) and observed significant reduction in tuber yield for the stress induced during early growth phase. Stress induced during tuber development phase, however, slightly improved the yield while stress during tuber maturity phase resulted in a slight reduction in yield. Martin (1988) stated that sweet potato could not tolerate dry conditions at planting.

Bourke (1989) concluded that extended wet periods leading to water surplus reduced tuber yield and were frequently associated with food supply shortages. The combined effect of a long wet period during tuber initiation and a drought during tuber bulking depressed the yield significantly. Bouwkamp (1989) stated that reduced mid-day wilting increased the yield in high yielding genotypes due to increase in net photosynthesis and partitioning of assimilates to the storage roots. Increased storage root weight was associated with the percentage of water in the vines at near full turgor.

Davidoff and Hanks (1989) reported that unlike continuous irrigation throughout the season, when irrigation was terminated in mid-season, there was no increase in total dry matter, fresh root yield and sucrose content of sugar beet. Jana et al.(1989) observed that soil moisture stress imposed during planting to early bulking and/or early bulking to late bulking decreased yields. Irrigation at 0.3 bar gave the highest tuber yields of potato.

Winter(1990) observed an increase in sucrose yield by an average of 0.54, 1.76 and 2.65 t ha^{-1} in response to nitrogen for irrigation levels averaging 0, 234 and 435 mm respectively. Yassen (1990) studied the effect of eight levels of irrigation and observed that irrigation improved organoleptic colour scores and reduced firmness of canned roots. A regression model which included leaf water potential and soil moisture level at a depth of 45 cm during the final 30 days of the growing season accounted for 71% of the variability in marketable yield.

Yield reductions of potato were greatest when irrigation deficits were imposed during the early and mid or mid and late stages of bulking (Stark and McCann, 1992). Yield reductions in U.S No.1 grade tubers were proportionately greater than reductions in total yield.

2.6. Interaction effects of nutrients and irrigation

In an experiment by Lantican and Soriano (1961) highest yields of tubers were obtained by the application of 100 kg N, 90 kg P_2O_5 and 90 kg K_2O per hectare. Fujise and Tsuno (1962) observed that increase in tuber weight was parallel to the K_2O/N ratio in the tuber. In addition, they noticed that combined application of nitrogen and potassium resulted in considerable yield increase in sweet potato.

Based on the experiments conducted at Vellayani, Thomas (1965) concluded that the best fertilizer combination for economic yield was 80:50:80 kg of nitrogen, phosphorus and potassium per hectare. Morita (1967) stated that a high proportion of potassium as compared to nitrogen favoured tuber formation.

Samuels (1967) observed an increase in sweet potato yield with an NK ratio of 1:2 as compared to the ratios of 0:2 and 2:2 in loamy sands and clay loam soils of Puerto Rico. Spence and Ahmad (1967) reported that inadequate potassium did not result in storage root formation. Ho (1969) recorded maximum yield of sweet potato at 60 kg nitrogen, 50 kg P_2O_5 and 120 kg K_2O per hectare in Taiwan.

Chew (1970) after conducting field experiments came to the conclusion that sweet potato on virgin peat soil should be dressed with 20 to 40 kg nitrogen, 20 kg phosphoric acid and 60 kg to 120 kg potash per hectare for maximising tuber yields and to get quality tubers. Knavel (1971) observed that the number of roots were influenced more by potassium than by nitrogen and that the addition of nitrogen without potassium was responsible for long roots while addition of potassium reduced the root length at all nitrogen levels.

Li (1971) obtained increased tuber yields of sweet potato with the application of 80 kg nitrogen and 200 kg potash per hectare both under irrigated and rainfed conditions.

Nandpuri _et al_.(1971) based on a study on the influence of fertilizers and irrigation on the growth and yield of sweet potato, observed that application of potassium at various irrigation intervals did not affect the plant growth significantly. It was observed that a combination of 34 kg potash at 5 and 7 days irrigation intervals and one without potash at 3 days irrigation intervals were equally effective in increasing the root thickness. Irrigation with nitrogen and potash increased the number of roots per plant and the length and thickness of roots. The best combination were nitrogen 84 kg and potash 34 kg at 3 and 7 days irrigation intervals and nitrogen 84 kg without potash with 5 days irrigation interval.

Sweet potatoes utilize fairly high rates of nutrients in some soils if adequate moisture was available (Constantin _et al_., 1974). He also reported that excessive moisture at high N rate was harmful to the quality and quantity of tuber and that vines became excessively vegetative.

Aggrey (1976) in Sierraleone studied the frequency of potassium application to sweet potato at different rates in three cropping systems. Fertilizers that contained higher potassium rates and an NK ratio 3:4 registered maximum tuber and vine yields with low vine/tuber ratios on intensely cropped areas. On the contrary, fertilizer containing lower potassium rates and an NK ratio of 3:1 recorded the maximum but relatively low tuber yields with a high vine/tuber ratios on newly cropped areas.

Nair et al.(1976a)reported that application of nitrogen @ 60 kg ha and potash @ 90 kg ha was beneficial to get higher tuber yield and good quality tubers from sweet potato. Prabhakar et al.(1977) registered maximum tuber yield in sweet potato by the application of NPK @ 100:75:100 which was significantly superior to no fertilizer treatment and on a par with NPK @ 75:50:75 kg/ha.

Rajput et al.(1981) found that closest spacing, lowest nitrogen level and higher levels of phosphorus and potassium were the best of all other treatments. Mishra and Mishra

(1982) recommended 40 kg nitrogen, 40 kg K_2O and 40 kg P_2O_5 per hectare as the economic fertilizer dose for sweet potato cultivation.

Ravindran and Nambisan (1987) got the highest marketable tuber yield of sweet potato under upland conditions with an NPK dose of 75:50:75 kg ha^{-1} for the variety Kanjangad.

Ashokan *et al*.(1984) recorded maximum tuber yield for the rainfed crop of sweet potato by applying 90 kg nitrogen and 60.4 kg potash per hectare. Nair and Mohankumar (1984) found that NPK @ 75:50:75 kg per hectare was superior to other combinations of 25:25:25, 50:25:50 and 100:75:100.

After conductiong field experiments in sweet potato with nitrogen and potash each at three levels, Nawale and Salvi (1984) noticed that the tuber yield was significantly increased by the highest levels of nitrogen and potash. Interaction effect of nitrogen and potash was also significant.

Hossain *et al*. (1987) from their field studies in Bangladesh reported that fertilizer application of three equal splits at 15, 45 and 75 days after planting accompanied by two irrigations at 30 and 60 days gave the highest tuber yield. Fertilizer application of two equal splits at 30 and

60 days each followed by irrigation, also gave an appreciably high tuber yield. They concluded that two irrigations in combination with two or three split applications of fertilizers resulted in the highest tuber dry matter, starch, ash and protein contents. Nair (1987) did not observe any significant improvement in yield at NK levels of 50,75 and 100 $kg.ha^{-1}$ or its time of application.

Sharma and Arora (1987) reported that increased nitrogen and potassium rates decreased the number and yield of small (<25g) tubers m^{-2} and increased those of medium (25 - 75 g) and large (>75 g) tubers of potato. They also observed that the increase in yield due to nitrogen and potash application resulted from an increase in the number of medium and large tubers.

Varughese et al. (1987) studied the influence of irrigation at varying levels of nitrogen and potash but failed to observe any influence of nitrogen or potash alone or in combination on the tuber yield of sweet potato. Li and Yen (1988) obtained increased top and tuber yields by applying 60:30:180 $kg.ha^{-1}$ of N, P_2O_5 and K_2O compared to no fertilizer application. Doubling the nitrogen and potash rates could only increase the top and not the tuber yield.

Oommen (1989) reported an increase in vine yield upto the highest level of nitrogen and potash (100 kg ha^{-1} each). Mean tuber weight and tuber yield were maximum at 75:75:100 kg ha^{-1} of N, P_2O_5 and K_2O. An increase in tuber yield to the extent of 4-19% was recorded when nitrogen @ 30 kg ha^{-1} was applied to irrigated plots shortly before tuber development of potato when the tubers were 30 mm in diameter. Reust (1989) observed that this increase in tuber yield was the net result of an increase in the number of large tubers. He further noticed that irrigation and additional nitrogen delayed ripening and reduced starch content in tubers. Yassen (1990) did not observe any irrigation x N interaction for any grade of tuber. He also observed that application of N at 0, 40 or 80 kg ha^{-1} did not increase the yield in an irrigation cum fertilizer trial.

Khan _et al_.(1991) reported an increase in tuber yield of potatoes upto 160 kg ha^{-1} nitrogen and was highest with irrigation equivalent to 150% ET. Water use efficiency was highest with irrigation equivalent to 100% ET at one location and 50% ET in another location. At all irrigation levels in both sites, higher nitrogen application rates decreased total water use and increased water use efficiency.

7. Plant uptake of NPK as influenced by irrigation and fertilizers

Fujise and Tsuno (1962) reported that higher dose of potassium probably might have increased the potassium level in the leaves of sweet potato which in turn might have accelerated the photosynthetic activity of leaves resulting in higher starch accumulation in roots.

As a consequence of nitrogen application, an increase in nitrogen content of sweet potato tuber was noticed in the experiments of Knavel and Lasheen (1969). A positive correlation between nutrient contents of tubers and vegetative parts during the growth period was observed by Mica (1969). There was however, no significant relation between nutrient content of tubers and rates of fertilizer application.

Bodniuk et al.(1971) found a deposit of potassium most clearly in the meristem zone while its effect was considerably feebler in the extension zone. Alexander et al. (1976) reported that the uptake of nitrogen was more when nitrogen was applied in two split doses, i.e., half at planting and the remaining half as foliar spray at 35 days after planting. Full basal application resulted in the lowest uptake of nitrogen. It was also observed that there was translocation of considerable portion of nitrogen from vines to the developing tubers.

Feliciano and Lopez (1976) after conducting field trials in Puerto Rico on sweet potato with different levels of NPK, came to the conclusion that with the exception of nitrogen, the amount of a given element absorbed by the plant was not consistently related to the amount applied.

Nair *et al*. (1976b) observed that nitrogen uptake by tubers and the total uptake were increased by increased rates of nitrogen application. Last and Draycott(1979) observed that increased nitrogen supply favoured an increase in N uptake by roots and tops.

Tsuno (1981) reported that in the aerial parts, the nitrogen content was the highest in the blade and it reached a peak at about 40 days after planting. Afterwards, the nitrogen content continued to decrease upto harvest. He also found that the nitrogen content throughout the subterranean part was lower than that of the aerial part. The content of potassium in the sweet potato plant was relatively low. It was highest at the time of initiation of growth, after which it rapidly decreased. Phosphorus content in the subterranean part was lower than that in the aerial part.

Purcell *et al*. (1982) found that the application of nitrogenous fertilizers to sweet potato increased the root nitrogen content but did not affect the root yield. Sekhon and Singh (1982) reported that tuber crops removed substantial amounts of potassium from the soil. Hammett *et al*. (1984) obtained a positive response in root potassium content to increased rates of potassium application.

Increased rates of NPK application increased the total nutrient uptake and the nutrient uptake by roots (Stulin and Yeckov, 1985). Armstrong *et al*.(1986) could not find any relation between initial uptake rates or total nitrogen uptake and soil mineral nitrogen content at the start of rapid growth. Substantial nitrogen losses occurred when the crop was actively growing due to excessive rainfall following early irrigation, with serious consequences for nitrogen uptake, nitrogen concentration in developing leaves and the overall growth of the crop.

Anand and Krishnappa (1989) reported that the uptake of N, P and K ranged from 112.1 to 201.0, 9.5 to 15.8 and 106.5 to 207.4 kg ha^{-1} respectively in potato with the application of different combinations of N and K. They also observed that about 58, 66 and 72% of the total N,P and K taken up was accumulated in the tubers.

In potato, nitrogen and phosphorus accumulation in tubers continued upto maturity while potassium accumulation was observed upto 80 days after planting by Krishnappa (1989). In haulms and roots, N, P and K contents decreased at later growth stages. Sharma and Arora(1990) observed an increased uptake of P and K by tubers and haulms with increased rates of nitrogen application.

2.8. Influence of irrigation and fertilizers on quality of tubers

Tsuno and Fujise (1968) reported that for producing tuber of high starch content, nitrogen application should be moderate in order to avoid excessive development of tops at the expense of tuber growth. As a consequence of increased supply of nitrogen, Knavel and Lasheen (1969) observed significant decline in both total sugars and starch content in sweet potatoes. However, Mandal et. al. (1971) noticed maximum starch content in tuber at a nitrogen dose of 75 kg ha^{-1}.

Last and Draycott (1979) observed a decrease in sugar content and juice purity of sugar beet with increased rates of nitrogen application.

Muthuswamy *et al*. (1981) did not find any effect of nitrogen on the starch content of sweet potato. An increase in starch content of tubers was observed by Bartolini (1982) by increasing the supply of nitrogen. Astill (1983) was of the opinion that high rates of nitrogen increased root and sugar yields, but reduced percentage sugar irrespective of application method. Applying nitrogen above 200 kg ha^{-1} improved the uptake of nitrogen, but did not increase the sugar yield. sugar yield was maximum when nitrogen was applied @ 125 kg ha^{-1} or less and irrigation had little effect on the sugar content of sugar beet (Last *et al*.,1983).

O'connor (1983) reported a decrease in sugar percentage and percentage extractability of sucrose from sugar beet as a result of nitrogen application. There was no improvement in the yield of extractable starch by applying nitrogen above 35 kg ha^{-1}. Ashokan and Nair (1984) found that starch content in tuber was increased by higher levels of potash. Increasing nitrogen rates enhanced the yield of potato but decreased the dry matter and starch contents (Sarir *et al*,1984). Increased rates of potassium applied alone could improve the dry matter and starch contents, but when applied along with nitrogen, the most favourable dose of potash was 50-75 kg ha^{-1}. Sharafuddin and Voican (1984) also reported that when the rate of nitrogen was increased from 50 to 100 kg ha^{-1}, the starch and protein contents of sweet potato were increased with enhanced supply of nitrogen. Bao et al.(1985) reported an increase in starch, reducing sugars and total sugar contents by enhanced rate of potassium application in sweet potato.

Highest tuber and starch yields of potato on deep, stone-free soils were obtained by large applications of FYM or slurry and green manuring in autumn and 80-120 kg ha^{-1} nitrogen in single application (Stricker, 1986). Nitrogen in excess of yield requirement decreased starch content and tuber quality and increased storage losses. Ravindran and Nambisan (1987) could not notice any variation in starch and sugar contents of sweet potato involving different combinations of NPK with 5 and 10 t ha^{-1} of FYM. Reust (1989) opined that the taste and processing quality of potato, particularly reducing sugar content was not markedly affected by nitrogen application.

Reducing sugar content of potato was significantly increased by nitrogen application upto 125 kg ha^{-1} in tubers having a diameter of 60 mm. Dunham (1988) found that the effect of irrigation on percentage sugar content appeared negligible in potato. Response to nitrogen fertilizer application was on an average 1.9 t ha^{-1} with irrigation as opposed to 1.2 t ha^{-1} without but the amount of nitrogen required for maximum sugar yield was the same with or without irrigation. Halvorson and Hartman (1988) observed that application of nitrogen significantly increased the total and recoverable sucrose yields, but reduced the sucrose content of sugar beet.

Sahota et al.(1988) reported an increase in starch, total sugars, reducing sugar and ascorbic acid content of potato tubers by the application of potash. Das and Behera (1989) observed a progressive increase in the starch content of sweet potato tubers as the dose of potash was increased from 0 to 150 kg ha^{-1}.

Per cent sucrose content of sugar beet (Davidoff and Hanks, 1989) was not significantly affected by irrigation regimes but tended to increase as the amount of applied irrigation water increased. Oommen (1989) reported maximum starch content in sweet potato at 100 kg ha^{-1} of nitrogen and potash.

Enhanced application of nitrogen and potash resulted in an increase in protein, starch and reducing sugars of sweet potato (Patil *et al*,1990). Nishimune (1991) observed an increase in concentration of root sugar by the application of nitrogen upto 150 kg ha^{-1} and a decrease in sugar content of sugar beet as the rate of nitrogen was increased further.

A thorough scanning of the literature reviewed here reveal the response of sweet potato to different levels / timings of irrigation and applied nutrients. It is also clear that very little work has been carried out in sweet potato as a catch crop in summer rice fallows.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

Field experiments were conducted for two consecutive seasons in the low lands of the Instructional Farm, College of Agriculture, Vellayani during the summer season of 1990 and 1991. The study is intended to work out the optimum irrigation schedule for sweet potato in summer rice fallows and to make an objective fertilizer recommendation for a catch crop of sweet potato. The details of the materials used and the methods adopted in the experiment are given in this chapter.

3.1 Materials

3.1.1 Field location

The experiment was laid out in the C block of the Instructional Farm, College of Agriculture, Vellayani. The Instructional Farm is located at 8^{o} 30' north latitude and at 70^{o} 54' east longitude at an altitude of 29 metres above sea level.

3.1.2 Weather and climate

The experimental area enjoys a tropical humid climate with an average annual rainfall of 2053 mm. The mean maximum

FIG. 1. WEATHER PARAMETERS (I SEASON)

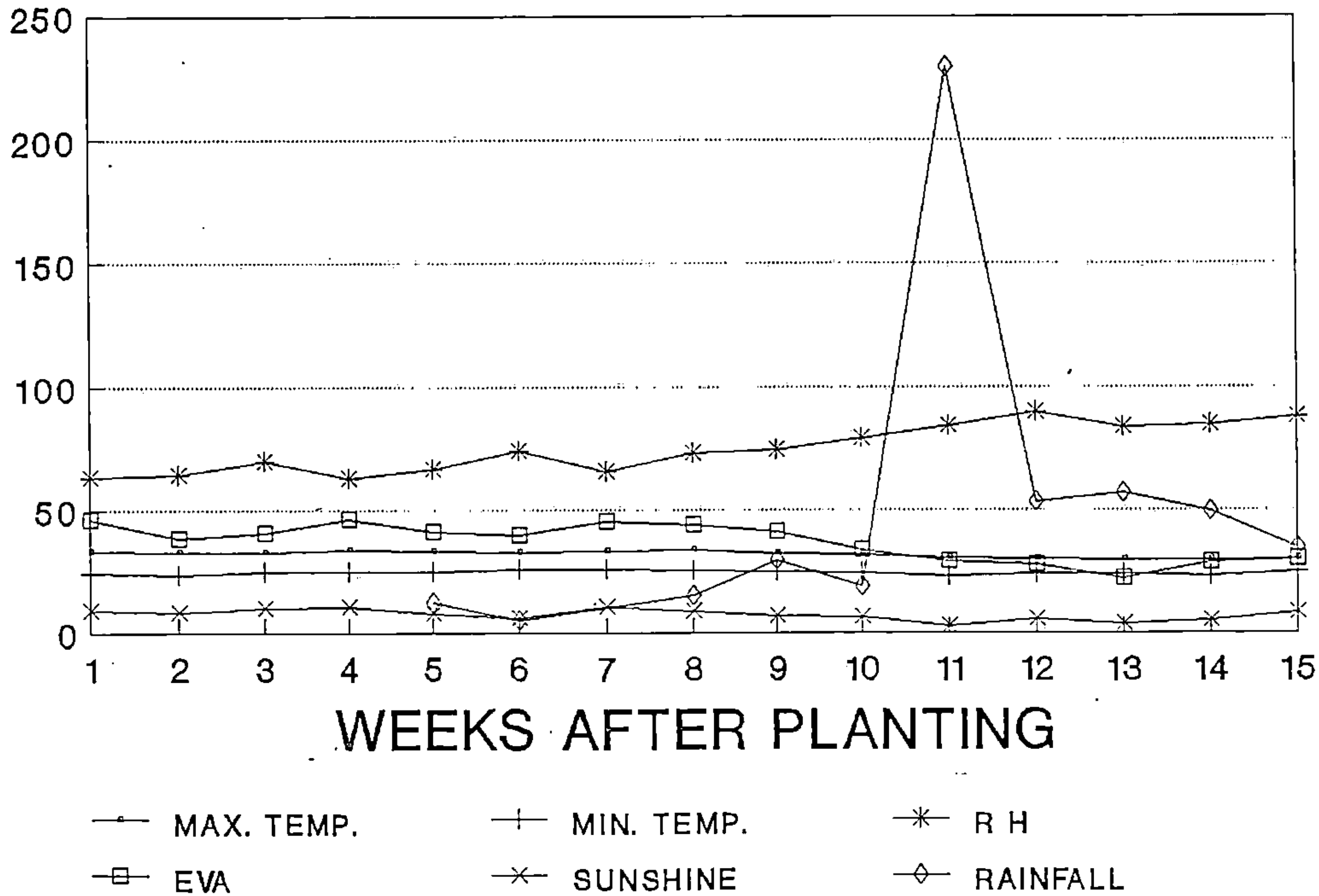
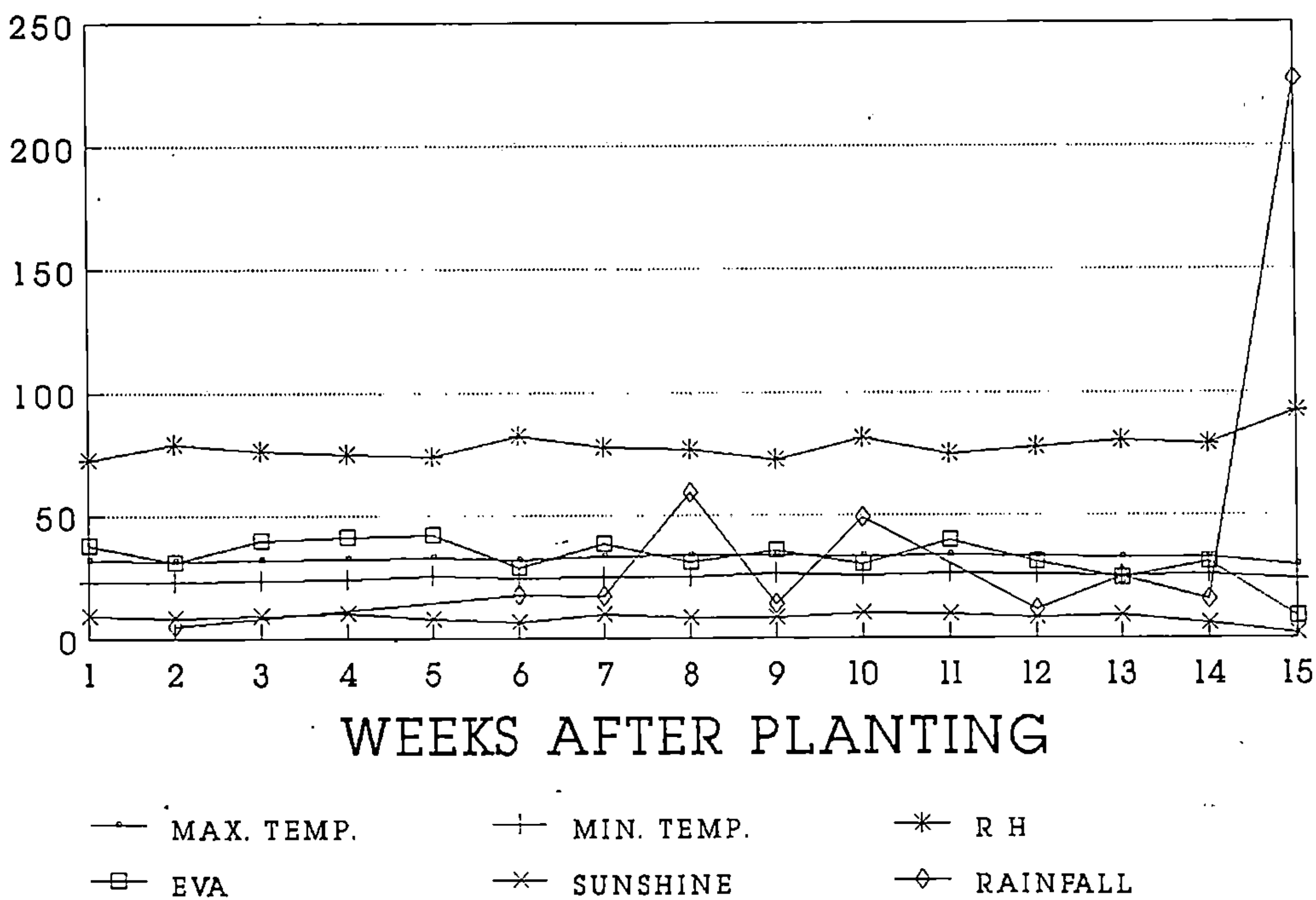


FIG. 2. WEATHER PARAMETERS (II SEASON)



and minimum temperatures are 30.4°C and 24.3°C respectively with a mean relative humidity of 82%. The region receives on an average 6.80 bright sunshine hours a day. The weather conditions that prevailed during the cropping period are presented in Fig.1 and 2 and the relevant meteorological data are furnished in Appendix I and II.

3.1.3 Soil characteristics

The soil was medium in available nitrogen and available phosphorus and low in available potassium. The data on the mechanical, physical and chemical properties of the soil are furnished in Table 1.

3.1.4 Cropping history of the experimental field

The field was left fallow during summer (February - May) of 1989 and was under rice cultivation in subsequent Viruppu (June -September) and Mundakan (October-January) seasons.

3.1.5 Crop variety

The sweet potato variety, Kanjangad, released by Kerala Agricultural University having a duration of 105 days was used for the study. The material was collected from the

Table 1. Soil characteristics of the experimental field

Sl.No.	Properties	Particulars	Content
A	Mechanical composition	Clay	24.70%
		Silt	46.56%
		Fine sand	10.05%
		Coarse sand	18.60%
B	Physical properties	Field capacity	11.26%
		Permanent wilting point	5.17%
		Bulk density	1.34 g/cc
		Maximum water holding capacity	33.35%
C	Chemical composition	Available nitrogen	377.40 kg ha^{-1}
		Available phosphorus	30.32 kg ha^{-1}
		Available potassium	98.25 kg ha^{-1}
		Organic carbon	0.58%
		Cation exchange capacity	5.96 me $100g^{-1}$
		pH(1:2.5 soil water suspension)	4.63

Central Tuber Crops Research Institute, Thiruvananthapuram and was planted in the nursery for multiplication.

3.1.6 Season

The experiment was conducted in the summer for two consecutive years during 1990 and 1991.

3.1.7 Fertilizers

Urea containing 46% nitrogen, superphosphate with 16% P_2O_5 and muriate of potash analysing to 60% K_2O were used for the experiment.

3.1.8 Nursery

The planting material obtained from the Central Tuber Crops Research Institute was multiplied in a well prepared nursery area of 300 m^2. Mounds were raised at a spacing of 75 x 75 cm and five vine cuttings were planted on the centre of each mound. Regular irrigation was provided and the crop was top dressed with urea for better branching and vine growth. Cuttings were collected from the nursery between 45 and 50 days after planting.

3.2 Method

3.2.1 Layout

Layout plan of the field experiment is depicted in Fig.3. The experiment was laid out in a strip plot design replicated thrice with 10 fertilizer combinations and three irrigation schedules. The fertilizer combinations were alloted to the vertical strips and irrigation schedules to the horizontal strips.

3.2.2 Treatments

A Total of 30 treatment combinations, comprising of three irrigation schedules and 10 nutrient levels constituted the treatments.

Irrigation (Horizontal strips)

i_1 - Tuber initiation phase (10-30 DAP) Full CPE+50% CPE (30-100 DAP)

i_2 - Tuber maturity phase (80-100 DAP) Full CPE + 50% CPE (10-80 DAP)

i_3 - Tuber initiation and tuber maturity phase (10-30 and 80-100 DAP) Full CPE + 50% CPE (30-80 DAP)

Nutrient levels: NPK in kg ha^{-1} (Vertical strips)

Fig. 3. LAYOUT PLAN

i1n2k2	i1n1k1	i1n3k3	i1n1k3	i1n3k1	i1n3k3(c)	i1n1k2	i1n3k2	i1n2k1	i1n2k3
i3n2k2	i3n1k1	i3n3k3	i3n1k3	i3n3k1	i3n3k3(c)	i3n1k2	i3n3k2	i3n2k1	i3n2k3
i2n2k2	i2n1k1	i2n3k3	i2n1k3	i2n3k1	i2n3k3(c)	i2n1k2	i2n3k2	i2n2k1	i2n2k3
i2n2k3	i2n3k3	i2n3k2	i2n1k2	i2n2k2	i2n1k1	i2n2k1	i2n3k1	i2n3k3(c)	i2n1k3
i1n2k3	i1n3k3	i1n3k2	i1n1k2	i1n2k2	i1n1k1	i1n2k1	i1n3k1	i1n3k3(c)	i1n1k3
i3n2k3	i3n3k3	i3n3k2	i3n1k2	i3n2k2	i3n1k1	i3n2k1	i3n3k1	i3n3k3(c)	i3n1k3
i2n1k3	i2n1k2	i2n3k3(c)	i2n2k2	i2n1k1	i2n2k3	i2n3k2	i2n3k1	i2n3k3	i2n2k1
i1n1k3	i1n1k2	i1n3k3(c)	i1n2k2	i1n1k1	i1n2k3	i1n3k2	i1n3k1	i1n3k3	i1n2k1
i3n1k3	i3n1k2	i3n3k3(c)	i3n2k2	i3n1k1	i3n2k3	i3n3k2	i3n3k1	i3n3k3	i3n2k1

TREATMENTS

Schedule of irrigation

i1 - Full CPE (10 - 30 DAP) + 50% CPE(30 - 100 DAP)
i2 - Full CPE (80 - 100 DAP) + 50%CPE(10 - 80 DAP)
i3 - Full CPE (10 - 30 & 80 - 100 DAP) + 50% CPE(30 - 80 DAP)

Levels of nitrogen

n1 - 25 kg ha^{-1}
n2 - 50 kg ha^{-1}
n3 - 75 kg ha^{-1}

Levels of potash

k1 - 25 kg ha^{-1}
k2 - 50 kg ha^{-1}
k3 - 75 kg ha^{-1}

Control (c) - FYM 10 t ha^{-1} + NPK 75:50:75 kg ha^{-1}

f_1. 25:50:25 f_2. 25:50:50 f_3. 25:50:75

f_4. 50:50:25 f_5. 50:50:50 f_6. 50:50:75

f_7. 75:50:25 f_8. 75:50:50 f_9. 75:50:75

f_{10}. 75:50:75 + FYM (10 t ha^{-1}) - Control

i. Irrigation schedules : Tuber initiation phase(full CPE), Tuber maturity phase(full CPE), Tuber initiation and tuber maturity phase (full CPE).

ii. Levels of nitrogen : 25, 50 and 75 kg ha^{-1}

iii. Levels of potash : 25, 50 and 75 kg ha^{-1}

Lime @ 500 kg ha^{-1} was applied to all the plots except control plots. All the plots received a uniform dose of P_2O_5 @ 50 kg ha^{-1}.

Treatment combinations

$i_1n_1k_1$	$i_2n_1k_1$	$i_3n_1k_1$
$i_1n_1k_2$	$i_2n_1k_2$	$i_3n_1k_2$
$i_1n_1k_3$	$i_2n_1k_3$	$i_3n_1k_3$
$i_1n_2k_1$	$i_2n_2k_1$	$i_3n_2k_1$
$i_1n_2k_2$	$i_2n_2k_2$	$i_3n_2k_2$
$i_1n_2k_3$	$i_2n_2k_3$	$i_3n_2k_3$
$i_1n_3k_1$	$i_2n_3k_1$	$i_3n_3k_1$
$i_1n_3k_2$	$i_2n_3k_2$	$i_3n_3k_2$

$i_1n_3k_3$ $i_2n_3k_3$ $i_3n_3k_3$

$i_1n_3k_3(c)$ $i_2n_3k_3(c)$ $i_3n_3k_3(C)$

3.2.3 Plot size and spacing

The optimum plot size according to the method of maximum curvature is 24 plants for low land. As plot size did not have any significant effect on CV, any shape can be used (Biradar, 1980).

Plot size (Gross) = 4.2 x 3.6 m

" (Net) = 1.2 x 3.2 m

Spacing = 60 x 20 cm

One row on either side of the boundary and one plant each on the end of each row were left out in each plot as border. Two rows on the right side of the plot leaving the border row were used for destructive sampling and periodic observation of growth. The row adjacent to the destructive sampling rows was also left out as border. Two plants on opposite sides from the destructive sampling rows were carefully uprooted at an interval of 21 days for growth analysis and at 35 days interval for chemical analysis. The neighbouring plants were left as border after each sampling. Growth observations at 21 days interval were taken from 4 plants in the same rows left for destructive sampling.

3.3 Land preparation

The land was ploughed with buffaloes and dug with spades manually during the first and second year respectively. The plots were laid out as per the design of the experiment. The field was properly levelled and ridges were formed at a spacing of 60 cm.

3.4 Planting

Apical portions of sweet potato vines collected from the nursery were uniformly cut into 25 cm length consisting of four to six nodes. Among the different plant portions, such as top, middle and basal, top portion (apical portion) registered comparatively higher yield (Mohankumar and Mandal, 1971). The vines were stored for two days under shade and was sprinkled with water to facilitate quick establishment in the field. Storing the vine cuttings for a period of two days under shaded condition recorded the highest per cent establishment, total and marketable tuber yield (Ravindran and Mohankumar, 1989). Planting was done on top of the ridges at a spacing of 20 cm, keeping two or three nodes buried.

3.5 Gap filling

Gap filling was done on the fifth day with rooted cuttings to secure uniform stand of the crop.

3.6 Application of lime

Lime was applied @ 500 kg ha^{-1} to all the plots except control plots and thoroughly incorporated into the soil a week prior to planting.

3.7 Application of fertilizers

Nitrogen was applied as per treatment with half the quantity as basal and the balance top-dressed after 30 days. The entire quantity of phosphorus and potassium were applied as basal, maintaining the rates of potassium supply as per treatment.

3.8 After cultivation

An interculture followed by earthing up was given on the 30th day after planting along with top dressing of nitrogenous fertilizers.

3.9 Irrigation

The crop was irrigated once in a day for nine days by provided once in four days by sprinkling measured quantity of water using shoulder buckets. Cumulative pan evaporation (CPE) was taken as the standard in fixing the amount of water to be applied during each irrigation.

The quantity of water in litres required to irrigate each plot was calculated from the CPE and the entire quantity was applied uniformly. All the plots received irrigation at 50% CPE during the remaining period of plant growth.

3.10 Plant protection

There was no serious attack of pests or disease during the growth period. As a prophylactic measure, the vines were dipped in 0.05% monocrotophos suspension for 5 to 10 minutes prior to planting for the control of sweet potato weevil and leaf eating caterpillars. One more spray with monocrotophos was given at 45th day to ward off pests infesting sweet potato.

3.11 Harvesting

The crop was harvested at 105 days in the first season and at 104 days after planting in the second season. The border rows were harvested first and the plants in the net area were uprooted carefully for recording the number of tubers, tuber yield and vine yield.

3.12 Biometric observations

3.12.1 Pre-harvest observations

Four plants were tagged at the start of observations and the following characters were recorded and mean values worked out at intervals of 21 days from planting to harvest.

3.12.1.1 Length of vine

The length of the vine was measured in cm from the base to the tip of the longest vine of each plant.

3.12.1.2 Number of branches

The total number of branches present were noted at each observation.

3.12.1.3 Number of leaves

The total number of fully opened leaves were counted from the base to the tip of every branch.

3.12.1.4 Leaf area index (LAI)

The leaf area was calculated by measuring the area of leaves in a leaf area meter. The leaf area index was worked out by the formula suggested by Watson (1947).

$$LAI = \frac{\text{Leaf area of the plant } (cm^2)}{\text{Land area occupied by the plant } (cm^2)}$$

3.12.1.5 Net assimilation rate (NAR)

It is defined as the increase of plant material per unit of assimilatory material per unit time.

It was worked out using the following formula (Williams,1946).

$$NAR = \frac{(W_2 - W_1)(\log_e L_2 - \log_e L_1)}{(t_2 - t_1)(L_2 - L_1)}$$

L_1 and W_1 are respectively the leaf area and dry weight of the plant at time t_1 and L_2 and W_2 are the leaf area and dry weight of the plant at time t_2. This was expressed in g m^{-2} day^{-1}.

3.12.1.6 Crop growth rate (CGR)

Crop growth rate of a unit area of a canopy cover at any instant in time (t) is defined as the increase in weight of plant material per unit of time. This was calculated by the formula

$$CGR = NAR \times LAI \text{ (Watson, 1958)}$$

This was expressed in gm^{-2} day^{-1}.

3.12.1.7 Specific leaf weight (SLW)

Specific leaf weight is the ratio of leaf dry weight to its area and is expressed as mg cm^{-2}.

3.12.2 Post harvest observations

3.12.2.1 Number of tubers $plant^{-1}$

The tubers in the net plot were separated into marketable grade and second grade to arrive at the total, marketable and second grade tubers.

3.12.2.2 Tuber weight

Mean tuber weight was worked out by dividing the fresh tuber weight in the net plot by the total number of tubers and the mean tuber weight is expressed in grams.

3.12.2.3 Length of tuber

The length of five randomly selected tubers of medium size were measured and the mean values recorded in cm.

3.12.2.4 Girth of tuber

Girth was recorded from those tubers which were used for length measurements. Girth was recorded at three places of the tuber, one at the centre and the other two at half way between the centre and both ends of tuber. The average of these three values was taken as the girth of the tuber.

3.12.2.5 Vine yield

The total weight of vines from the net plot was recorded at the time of harvest.

3.12.2.6 Tuber yield

The net plots were harvested by digging out the tubers and the fresh weight of tubers recorded.

3.12.2.7 Utilization index (UI)

Utilization index is the ratio of tuber weight to its shoot weight and is expressed as per cent on fresh weight basis.

$$UI = \frac{\text{Tuber weight}}{\text{Shoot weight}} \times 100$$

3.13 Dry matter production

3.13.1 Dry matter production and partitioning

Sample harvest at 21 days interval from planting were done during both the seasons to study the dry matter production at various growth stages. At each harvest, two plants were carefully uprooted and separated into leaves, shoots, tubers and fibrous roots. Each part was air dried and then oven dried at 80^{0}C to constant weight and the dry weight of various plant parts were recorded to express the dry matter partitioning at various stages of plant growth.

3.13.2 Tuber bulking rate (BR)

It is the rate of increase in tuber weight per unit time and is an important measure of tuber growth. It is expressed in g week^{-1} plant^{-1} (dry weight).

$$BR = \frac{W_2 - W_1}{t_2 - t_1}$$

W_1 and W_2 are the dry weight of tubers at time t_1 and t_2 respectively.

3.13.3 Harvest index (HI)

Harvest index is the ratio of tuber weight to its total biological yield and is expressed as per cent on dry weight basis.

$$HI = \frac{\text{Tuber yield}}{\text{Total biological yield}} \times 100$$

3.14 Quality attributes

3.14.1 Starch content

Starch content of the tuber was estimated by the potassium ferricyanide method (Aminoff *et al.*,1970). The values were expressed as percentage on fresh weight basis.

3.14.2 Sugar content

Sugar content of the tuber was estimated colorimetrically using alkaline copper reagent (Nelson and Somogyi, 1952).

3.15 Chemical analysis

3.15.1 Plant analysis

Nitrogen, phosphorus and potassium contents of vines and tubers were analysed during three stages of plant growth (35 and 70 DAP and at harvest). The plant parts used for dry matter determination were ground separately into fine powder using a Wiley mill for chemical analysis.

3.15.1.1 Nitrogen

Total nitrogen of the plant parts were determined by the modified microkjeldahl method (Jackson, 1967).

3.15.1.2 Phosphorus

The phosphorus content in plants were estimated by the colorimetric method (Jackson, 1967).

3.15.1.3 Potassium

Potassium was determined flame photometrically using a Systronics flame photometer.

3.15.2 Uptake studies

Uptake of nitrogen, phosphorus and potassium at 35 and 70 DAP and at harvest were estimated from the sample plants uprooted and dried for the purpose. The vegetative part (vine) as well as the tuber were analysed separately and the uptake was calculated by multiplying with dry matter.

3.16 Soil analysis

Soil samples were taken before the start of the experiment and after the harvest of crops in both seasons. A representative soil sample of the field obtained by mixing the soil collected from different parts of the field was used for initial analysis. The initial analysis was done for mechanical composition, organic carbon, available nitrogen, available phosphorus, available potassium and CEC. The soil collected after the harvest of each crop was analysed for available nitrogen, phosphorus and potassium.

3.16.1 Analytical methods

The methods followed for the analysis of physical and chemical properties of the soil are given below.

3.16.1.1 Mechanical analysis

The International Pipette method (Piper, 1950) was used for the mechanical analysis of the soil.

3.16.1.2 Soil pH

The pH was determined with the Elico pH meter (Jackson, 1967) in 1:2.5 soil water suspension.

3.16.1.3 Organic carbon

Walkley and Black's net oxidation method, as described by Jackson (1967) was used for the estimation of organic carbon.

3.16.1.4 Available nitrogen

It was estimated by the alkaline permanganate method of Subbiah and Asija (1956).

3.16.1.5 Available phosphorus

Available phosphorus was estimated by Bray's No.1 extract method (Jackson, 1967).

3.16.1.6 Available potassium

Available potassium was extracted by neutral normal ammonium acetate solution and determined by a systronics flame photometer (Jackson, 1967).

3.16.1.7 Cation exchange capacity (CEC)

Cation exchange capacity was estimated by using neutral normal ammonium acetate and potassium chloride method (Piper, 1950).

3.17 Statistical analysis

The experimental data were analysed statistically by applying the technique of analysis of variance for strip plot design (Cochran and Cox, 1965). The standard error of means and the least significant difference at 5% level of significance have been provided wherever the effects of treatments were found significant. Statistical analysis was performed using IBM-PC AT/386 computer installed in the department of Agricultural Statistics, College of Agriculture, Vellayani.

3.18 Economic evaluation

3.18.1 Net return

It is the income obtained or remaining after deducting cost of cultivation from the gross return.

3.18.2 Cost of cultivation

Total expenditure involved in raising a crop, including rental value of land.

3.18.3 Gross return

Total income from the farm, by virtue of sale of entire farm produce.

RESULTS

4. RESULTS

Field experiments were conducted at the Instructional Farm, College of Agriculture, Vellayani to find out a fertilizer application schedule in conjunction with irrigation practice for a catch crop of sweet potato grown in summer rice fallows. The results obtained are presented below.

4.1. Growth and growth attributes

4.1.1 Length of vine

The influence of different treatments on the length of vine recorded at triweekly intervals from planting to harvest is presented in Table 2. Providing moisture stress at certain phases of plant growth profoundly influenced the vine growth. During the first season, i_1 and i_3 irrigation schedules were significantly superior to i_2 at all the stages of observation. However, there was no significant difference among irrigation schedules at 21 DAP in the second season. In all the remaining observations, i_1 and i_3 remained on a par and maintained their superiority over i_2.

Nitrogen remarkably influenced the vine growth in both

Table 2. Effect of treatments on the length of vine (cm)

	1990 Days after planting					1991 Days after planting				
Treatments	21	42	63	84	Harvest	21	42	63	84	Harvest
i_1	23.0	44.7	81.6	120.0	140.5	24.9	55.9	92.9	121.5	140.2
i_2	20.1	36.7	69.0	109.2	128.4	22.7	44.1	67.3	96.6	123.4
i_3	22.5	44.8	81.9	122.7	137.0	24.7	58.7	94.2	121.9	140.2
SE	0.57	1.39	1.73	1.82	2.16	0.92	0.91	1.11	1.38	1.67
CD	2.25	5.45	6.81	7.13	8.49	----	3.59	4.34	5.42	6.57
n_1	18.1	34.8	66.5	103.6	120.6	22.2	45.5	67.7	96.1	117.1
n_2	21.3	42.6	77.2	115.8	136.4	23.2	53.3	88.1	114.9	136.4
n_3	24.8	46.7	86.0	129.1	144.4	26.2	57.6	94.7	124.9	146.2
SE	0.62	0.47	1.21	2.04	4.33	0.53	0.54	0.88	1.43	1.25
CD	1.84	1.41	3.59	6.07	12.87	1.58	1.60	2.62	4.25	3.72
k_1	21.3	41.5	77.1	116.2	135.70	24.10	52.0	82.9	111.7	133.2
k_2	21.2	41.3	77.4	117.2	130.8	23.1	52.2	83.8	112.3	133.7
k_3	21.6	41.2	75.2	115.0	134.9	24.4	52.2	83.8	111.8	132.8
SE	0.62	0.47	1.21	2.04	4.33	0.53	0.54	0.88	1.43	1.25

the seasons. In the first season, except at harvest and in the second season except at 21 DAP, the higher levels of N were significantly superior to the lower levels. At the time of harvest, the effect of N was significant, but n_2 and n_3 remained on a par and registered their superiority over n_1. Similarly, in the second season at 21 DAP, the effect of N was pronounced, where n_3 was superior to n_1 and n_2 and both remained on a par.

Varying levels of potash did not influence the vine length at any stage of growth in both the seasons.

The interaction effect of irrigation x nitrogen(Table 3) was found to be significant at 42 DAP in the first season and at 42, 63 and 84 DAP in the second season. Vine length was maximum in i_1n_3 which remained on a par with i_3n_3 and significantly superior to the rest of the treatment combinations at 42 DAP in the first season. However, in the second season, i_3n_3 recorded significantly superior vine length as compared to all other treatment combinations during the same period. Subsequently, at 63 DAP, i_1n_3 registered its superiority in vine length over other combinations. The superiority of i_1n_3 was maintained at 84 DAP though i_1n_3 was on a par with i_3n_3. The treatment combination, i_2n_1

Table 3. Interaction effect of irrigation and nitrogen on the length of vine (cm)

Stage of growth	Levels of N	Irrigation schedule 1990 i_1	1990 i_2	1990 i_3	1991 i_1	1991 i_2	1991 i_3
21 DAP	n_1	19.0	16.3	18.9	23.0	20.5	23.1
	n_2	22.2	19.9	21.9	24.2	22.9	22.5
	n_3	26.2	22.8	25.3	26.9	24.4	27.3
42 DAP	n_1	36.1	31.1	37.1	47.0	39.5	50.0
	n_2	44.9	37.0	45.9	55.3	45.4	59.1
	n_3	50.5	40.3	49.2	62.1	46.5	64.1
63 DAP	n_1	70.3	58.2	71.1	68.7	58.9	75.4
	n_2	81.8	68.7	81.1	96.8	68.1	99.5
	n_3	90.9	77.1	90.0	107.8	72.8	103.7
84 DAP	n_1	105.2	94.0	111.5	102.5	83.3	102.3
	n_2	119.0	108.7	119.7	120.8	98.9	125.1
	n_3	132.8	121.3	133.0	135.7	105.3	133.7
Harvest	n_1	123.3	112.7	125.9	122.3	106.0	123.1
	n_2	140.0	127.3	141.8	139.1	127.5	142.5
	n_3	154.1	140.9	138.2	154.0	134.1	150.4

		21DAP	42DAP	63DAP	84DAP	Harvest
SE	1990	0.598	0.722	1.371	1.700	5.605
	1991	0.949	0.669	1.330	1.169	1.433
CD	1990	---	2.074	---	---	---
	1991	---	1.921	3.819	3.357	---

registered the lowest vine length at all stages of observation.

4.1.2 Number of branches plant^{-1}

The data on number of branches per plant as influenced by treatments is presented in Table 4. At any stage of observation, scheduling of irrigation did not affect this character appreciably. However with advance in age of the plant, there was a decrease in the number of branches. The maximum number of branches was observed at 63 DAP in both the seasons.

Contrary to the irrigation schedule, different levels of nitrogen markedly influenced the number of branches per plant. During both the seasons, n_3 produced a significantly higher number of branches as compared to n_1 and n_2 though at harvest in the first season, there was no difference between n_3 and n_2. At all stages, n_2 registered its superiority over n_1.

Potassium failed to record significant response at any stage of growth on the number of branches per plant.

The interaction effect of irrigation x nitrogen(Table 5) remained significant at 42 DAP in the first season and at 21

Table 4. Effect of treatments on the number of branches per plant

	1990					1991				
	Days after planting					Days after planting				
Treatments	21	42	63	84	Harvest	21	42	63	84	Harvest
i_1	4.7	10.3	18.4	16.5	14.3	5.1	9.8	18.2	16.8	14.1
i_2	4.7	9.7	17.8	15.2	13.6	4.5	8.9	15.8	14.4	12.3
i_3	4.3	10.8	18.2	15.6	13.8	4.9	10.4	18.7	16.8	14.2
SE	0.22	0.53	0.93	0.51	0.61	0.14	0.51	0.86	0.64	0.56
n_1	4.1	8.4	15.5	13.7	12.1	4.1	7.9	15.0	14.5	12.2
n_2	4.4	10.2	18.2	15.6	13.7	4.8	9.8	17.3	15.8	13.3
n_3	4.9	11.6	20.1	17.5	13.8	5.4	11.3	19.7	17.3	14.7
SE	0.07	0.14	0.25	0.14	0.17	0.08	0.22	0.15	0.17	0.18
CD	0.216	0.405	0.740	0.422	0.507	0.261	0.662	0.456	0.509	0.550
k_1	4.5	10.0	17.9	15.7	13.8	4.8	9.6	17.2	15.9	13.3
k_2	4.5	10.1	18.0	15.6	13.7	4.8	9.7	17.4	15.8	13.4
k_3	4.5	10.1	18.0	15.6	13.7	4.8	9.7	17.5	16.0	13.50
SE	0.07	0.14	0.25	0.14	0.17	0.08	0.22	0.15	0.17	0.18

Table 5. Interaction effect of irrigation and nitrogen on number of branches plant^{-1}

Stage of growth	Levels of N	1990 i_1	1990 i_2	1990 i_3	1991 i_1	1991 i_2	1991 i_3
21 DAP	n_1	4.13	4.34	3.72	4.22	4.03	4.13
	n_2	4.50	4.72	4.03	5.29	4.60	4.69
	n_3	5.05	5.06	4.75	5.65	4.82	5.63
42 DAP	n_1	8.50	8.28	8.34	8.54	7.23	8.09
	n_2	9.99	9.27	11.30	10.00	8.89	10.48
	n_3	11.83	11.11	11.99	11.60	10.22	11.98
63 DAP	n_1	16.04	15.59	14.88	16.00	12.88	16.12
	n_2	18.52	17.70	18.37	17.63	15.54	18.78
	n_3	20.13	19.65	20.57	20.28	18.31	20.68
84 DAP	n_1	14.24	13.40	13.47	15.32	13.33	14.94
	n_2	16.41	15.17	15.32	16.89	13.78	16.81
	n_3	18.33	16.71	17.43	17.88	15.89	18.28
Harvest	n_1	12.58	11.74	12.05	13.00	11.01	12.55
	n_2	14.09	13.58	13.47	13.74	11.87	14.23
	n_3	16.02	15.02	15.17	15.07	13.62	15.51

		21DAP	42DAP	63DAP	84DAP	Harvest
SE	1990	0.144	0.278	0.319	0.270	0.301
	1991	0.132	0.442	0.371	0.249	0.217
CD	1990	---	0.800	---	---	---
	1991	0.379	---	---	0.716	---

and 84 DAP in the second season. The number of branches plant^{-1} was found to be maximum in the treatment combination of i_3n_3 which remained on a par with i_1n_3, i_3n_2 and i_2n_3 at 42 DAP in the first season. In the second season at 21 DAP, i_1n_3 recorded the maximum number of branches which remained on a par with i_3n_3 and i_1n_2. The maximum number of branches was recorded by the treatment combination of i_3n_3 which remained on a par with i_1n_3 and both remained superior to all other combinations.

4.1.3 Number of leaves plant^{-1}

The effect of treatments on the number of leaves per plant presented in Table 6 show that irrigation significantly influenced the leaf production at all stages except at the time of harvest in the first season. Both i_1 and i_3 schedules were significantly superior to i_2 schedule of irrigation.

Nitrogen remarkably enhanced the leaf production as the higher levels remained significantly superior to the lower levels. However, only one exception was noticed wherein n_2 and n_3 were on a par at 21 DAP in the first season. Potassium influenced the number of leaves at 63 DAP in the second

Table 6. Effect of treatments on the number of leaves per plant

	1990 Days after planting					1991 Days after planting				
Treatments	21	42	63	84	Harvest	21	42	63	84	Ha
i_1	54.9	129.9	260.7	231.1	191.5	52.9	121.9	249.0	222.2	187.9
i_2	49.4	110.3	234.5	202.6	179.1	44.3	96.2	219.2	194.0	175.9
i_3	59.1	128.3	261.4	228.3	190.1	55.7	122.0	257.4	228.0	195.5
SE	1.32	2.32	4.61	4.23	3.44	1.05	0.83	1.52	2.50	2.35
CD	5.18	9.10	18.10	16.60	---	4.11	3.26	5.97	9.83	9.22
n_1	45.4	103.4	221.4	195.2	167.2	41.4	95.8	215.5	192.9	170.2
n_2	56.2	121.1	247.2	219.1	187.2	49.6	111.1	236.8	211.3	186.0
n_3	59.0	138.2	278.4	240.1	200.6	59.1	126.7	265.4	234.0	198.8
SE	1.57	1.42	1.84	2.28	1.68	0.89	2.96	0.84	1.03	1.36
CD	4.67	4.22	5.48	6.78	4.98	2.65	8.78	2.51	3.05	4.05
k_1	51.9	119.6	246.7	216.6	184.0	48.7	110 .6	237.3	211.6	184.5
k_2	54.8	121.6	250.3	218.4	185.7	49.6	108.0	240.2	213.4	185.6
k_3	53.8	121.5	250.0	219.4	185.2	51.7	115.0	240.2	213.1	184.9
SE	1.57	1.42	1.84	2.28	1.68	0.89	2.96	0.84	1.03	1.36

season where k_2 and k_3 remained on a par and maintained their superiority over k_1. At all other stages, potassium did not play a significant role in modifying the number of leaves.

The influence of irrigation x nitrogen interaction(Table 7) was visible in seven out of ten observations in both the seasons. The treatment combination, i_1n_3 recorded the maximum number of leaves at 42 DAP in the first season which remained on a par with i_3n_3 and both were superior to other combinations. At 63 DAP also the same trend was maintained where both i_1n_3 and i_3n_3 were on a par and registered their superiority over other combinations. However, at 84 DAP a marginal increase over i_1n_3 was recorded by i_3n_3 and both remained on a par.

In the second season, i_3n_3 registered the maximum number of leaves and maintained parity with i_1n_3 and both remained superior to all other combinations at 21 DAP. In the subsequent observation at 63 DAP also i_3n_3 maintained its superiority over all other combinations except i_1n_3 which remained on a par. Both i_1n_3 and i_3n_3 recorded the same number of leaves at 84 DAP and registered their superiority over other combinations. At harvest also, i_3n_3 and i_1n_3 were superior in leaf production. The treatment combination i_2n_1

Table 7. Interaction effect of irrigation and nitrogen on number of leaves $plant^{-1}$

Stage of growth	Levels of N	1990 i_1	1990 i_2	1990 i_3	1991 i_1	1991 i_2	1991 i_3
21 DAP	n_1	44.90	41.50	49.80	41.50	38.80	43.90
	n_2	59.90	50.70	58.10	50.10	44.20	54.40
	n_3	56.30	54.00	66.70	63.80	48.20	65.30
42 DAP	n_1	103.70	98.40	108.00	100.70	81.30	105.50
	n_2	129.00	110.00	124.40	117.10	94.90	121.30
	n_3	149.90	119.20	145.40	141.90	107.50	130.70
63 DAP	n_1	227.20	208.10	228.80	219.20	198.40	228.90
	n_2	254.70	227.50	259.40	240.40	216.10	253.90
	n_3	290.30	258.30	286.50	278.30	236.50	281.40
84 DAP	n_1	206.20	184.20	195.10	195.40	179.30	204.00
	n_2	228.80	200.30	228.30	214.20	194.00	225.70
	n_3	251.10	216.50	252.70	248.70	204.70	248.70
Harvest	n_1	173.20	160.40	167.90	168.50	163.40	178.70
	n_2	191.90	178.80	191.80	185.70	174.30	198.00
	n_3	205.00	191.80	205.00	204.10	186.10	206.30

		21DAP	42DAP	63DAP	84DAP	Harvest
SE	1990	2.56	2.23	1.98	2.60	1.90
	1991	1.12	5.58	2.20	2.13	1.59
CD	1990	---	6.39	5.68	7.45	---
	1991	3.22	---	6.33	6.12	4.58

recorded the lowest number of leaves at all stages of crop growth.

4.2 . Growth analysis

4.2.1 Leaf area index (LAI)

The effect of treatments on LAI presented in Table 8 show that irrigation schedule profoundly influenced the LAI at all stages of observation. Both i_1 and i_3 schedules remained on a par and registered their superiority over i_2 at all stages though there was no significant difference between i_1 and i_2 at harvest in the second season(Fig.4).

Nitrogen substantially improved the LAI at all stages of crop growth. The higher levels of N were significantly superior to the lower levels. In both the seasons, LAI was maximum at 63 DAP and minimum at 21 DAP (Fig.5).

The influence of potassium in modifying the LAI was visible at 63 DAP in the first season and at 63 and 84 DAP in the second season. In all these observations, k_3 was superior to k_2 only at 63 DAP in the first season.

The interaction effect of irrigation x nitrogen(Table 9) was pronounced in three observations in the first season and

Table 8. Effect of treatments on LAI at various stages of growth

	1990 Days after planting					1991 Days after planting				
Treatments	21	42	63	84	Harvest	21	42	63	84	Harvest
i_1	0.64	2.10	6.26	4.59	3.13	0.48	1.73	5.64	4.87	2.87
i_2	0.54	1.50	5.66	3.80	2.87	0.39	1.25	4.80	4.05	2.67
i_3	0.67	2.09	6.28	4.65	3.22	0.50	1.82	5.88	4.94	3.00
SE	0.003	0.033	0.049	0.120	0.054	0.016	0.048	0.052	0.091	0.052
CD	0.012	0.132	0.194	0.471	0.213	0.062	0.189	0.020	0.357	0.204
n_1	0.48	1.40	5.05	3.54	2.60	0.35	1.24	4.59	3.97	2.47
n_2	0.62	1.81	6.06	4.19	3.04	0.44	1.52	5.32	4.51	2.81
n_3	0.71	2.29	6.77	5.02	3.42	0.54	1.91	6.19	5.16	3.15
SE	0.014	0.024	0.031	0.107	0.038	0.009	0.026	0.047	0.030	0.030
CD	0.042	0.072	0.093	0.317	0.113	0.028	0.076	0.141	0.091	0.090
k_1	0.60	1.79	5.82	4.20	2.96	0.43	1.50	5.26	4.47	2.78
k_2	0.61	1.84	5.94	4.31	3.03	0.44	1.56	5.40	4.56	2.82
k_3	0.60	1.87	6.12	4.24	3.07	0.45	1.60	5.43	4.60	2.82
SE	0.014	0.024	0.031	0.107	0.038	0.009	0.026	0.047	0.030	0.030
CD	---	---	0.093	---	---	---	---	0.141	0.091	---

Table 9. Interaction effect of irrigation and nitrogen on LAI

Stage of growth	Levels of N	Irrigation schedule 1990 i_1	i_2	i_3	1991 i_1	i_2	i_3
21 DAP	n_1	0.47	0.43	0.53	0.35	0.33	0.37
	n_2	0.66	0.56	0.65	0.45	0.39	0.49
	n_3	0.75	0.60	0.78	0.58	0.42	0.61
42 DAP	n_1	1.44	1.23	1.53	1.32	1.03	1.37
	n_2	2.02	1.47	1.94	1.63	1.22	1.70
	n_3	2.63	1.70	2.54	2.12	1.42	2.20
63 DAP	n_1	5.20	4.71	5.26	4.69	4.14	4.92
	n_2	6.28	5.65	6.25	5.46	4.75	5.74
	n_3	6.98	6.30	7.03	6.49	5.34	6.74
84 DAP	n_1	3.72	3.27	3.63	4.04	3.63	4.24
	n_2	4.52	3.38	4.66	4.67	4.01	4.85
	n_3	5.25	4.44	5.38	5.63	4.34	5.51
Harvest	n_1	2.66	2.48	2.66	2.44	2.36	2.60
	n_2	3.05	2.80	3.27	2.81	2.61	3.00
	n_3	3.50	3.17	3.59	3.22	2.94	3.29

		21DAP	42DAP	63DAP	84DAP	Harvest
SE	1990	0.011	0.043	0.050	0.154	0.038
	1991	0.010	0.032	0.071	0.085	0.046
CD	1990	0.033	0.125	---	---	0.109
	1991	0.028	0.091	0.205	0.245	---

FIG. 4. EFFECT OF IRRIGATION ON LEAF AREA INDEX

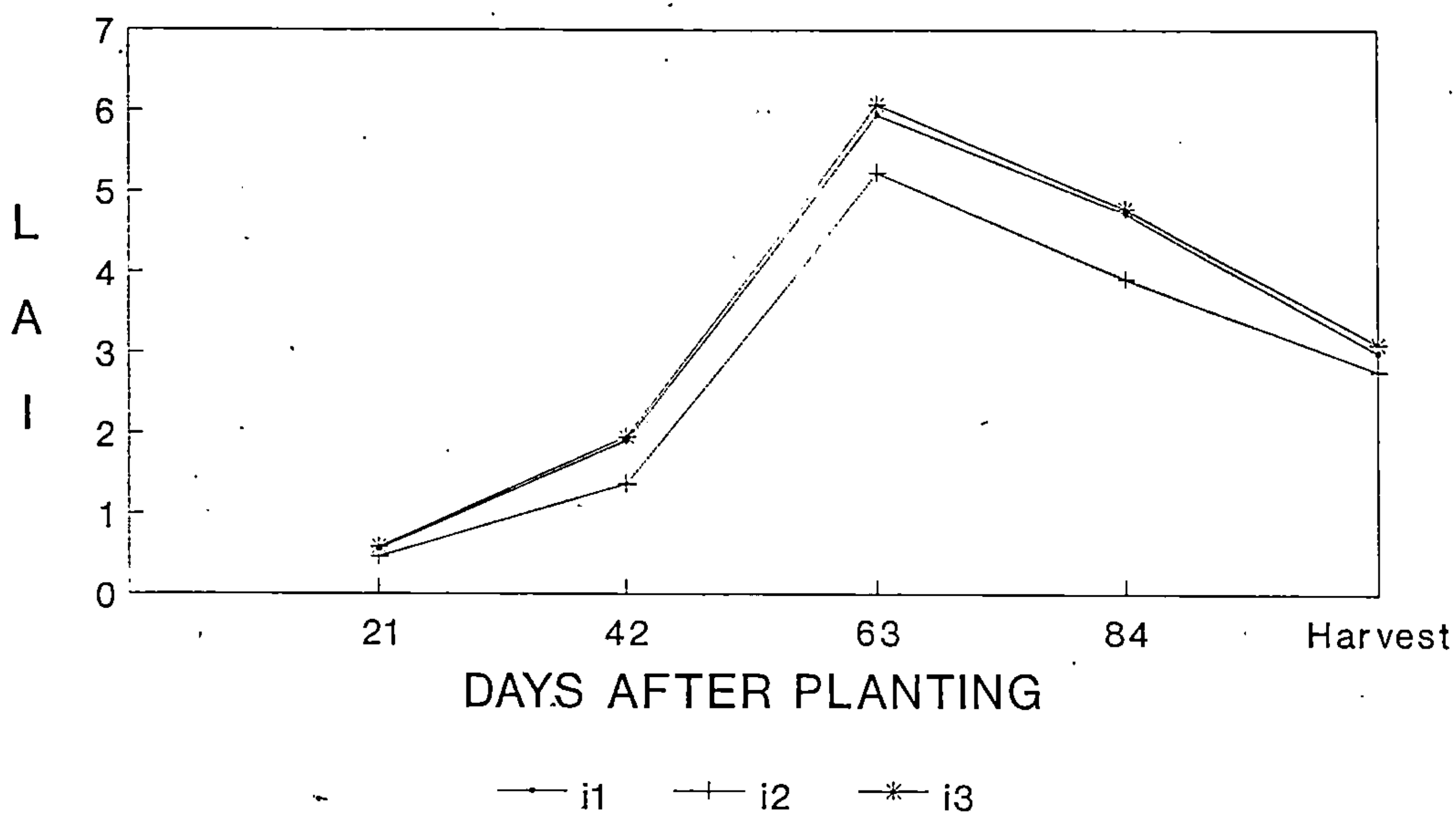
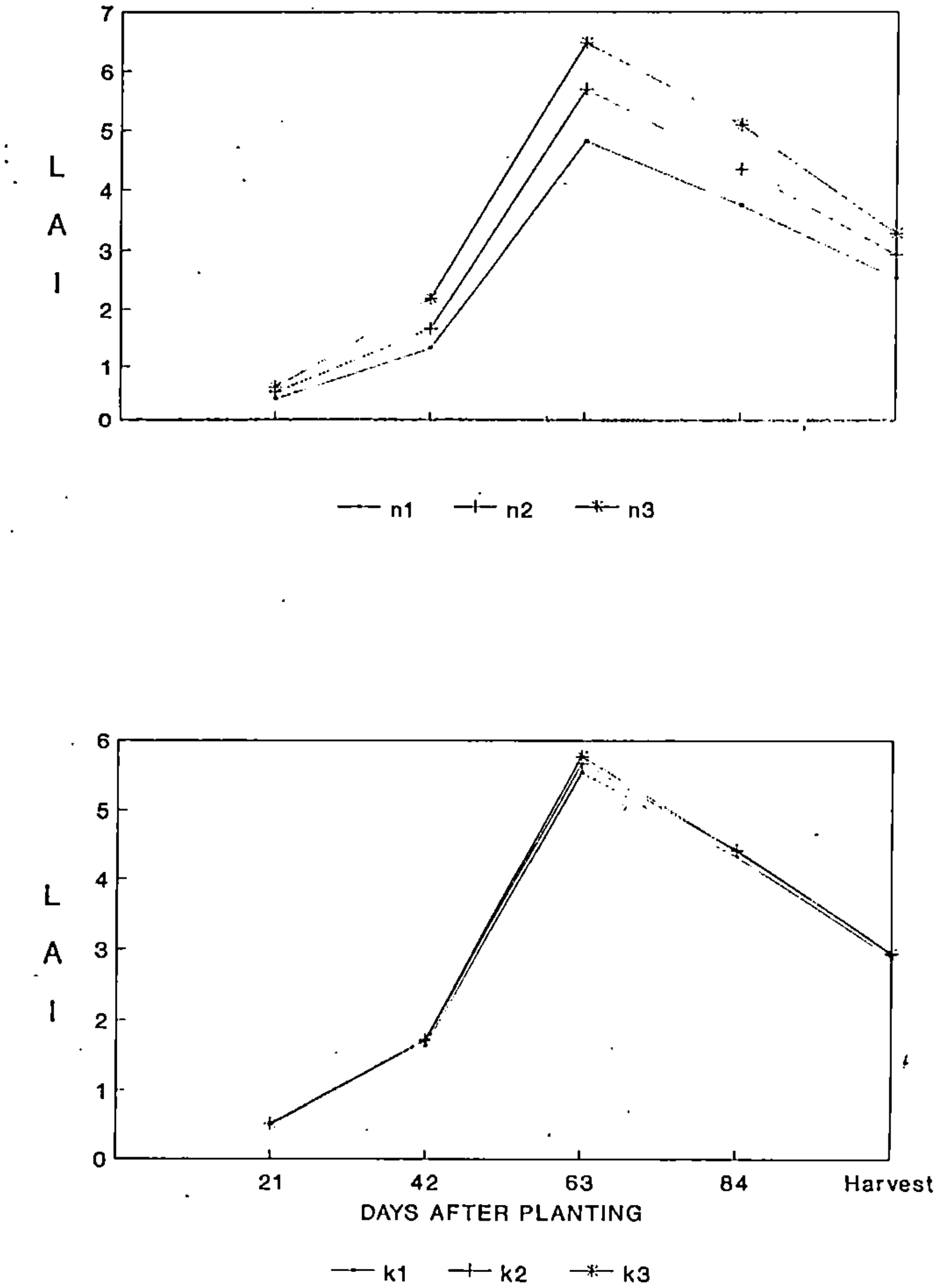


FIG. 5. EFFECT OF NITROGEN AND POTASSIUM ON LEAF AREA INDEX



at four observations in the second season. The leaf area index was maximum in the treatment combination of i_3n_3 which remained on a par with i_1n_3 and both were superior to other combinations at 21 DAP in the first season. At 42 DAP, however i_1n_3 recorded the maximum LAI which remained on a par with i_3n_3. At harvest, i_3n_3 registered the maximum LAI and maintained its superiority over combinations other than i_1n_3 which remained on a par. In all the five observations, i_2n_1 recorded the lowest LAI.

In the second season, the treatment combination i_3n_3 recorded the maximum LAI which remained on a par with i_1n_3 and both were superior to other combinations at 21 DAP. The same trend was maintained where i_3n_3 recorded the maximum and remained on a par with i_1n_3 at 42 DAP. However, at 63 DAP the treatment combination of i_3n_3 was significantly superior to all other combinations in LAI. The treatment combination of i_1n_3 which was second in position, registered the maximum LAI and remained on a par with i_3n_3 at 84 DAP. The LAI was invariably lower in the treatment combination of i_2n_1 at all stages of growth.

4.2.2 Net assimilation rate (NAR)

The NAR observed at four stages of crop growth is presented in Table 10 and illustrated graphically in Fig.6. NAR was found to be significantly higher at i_2 schedule of irrigation between 21 and 42 DAP in both the seasons. However, no significant difference was visible during the remaining stages of observation. In general, i_2 schedule registered marginally higher NAR as against i_1 and i_3 throughout the growth period.

The influence of nitrogen in modifying the NAR was very clear especially in the first season, where n_1 was significantly superior to n_2 and n_3 in the beginning. At the second stage (42-63 DAP), however, n_2 was superior to n_3. In the second season also, almost the same trend was visible where n_1 maintained its superiority over n_2 and n_3. Potassium too played a significant role in altering the NAR at 42-63 and at 63-84 DAP in the first season. In the first observation, k_3 was significantly superior to k_1 while the same was reversed in the second observation.

The interaction effect of irrigation x nitrogen(Table 11) was remarkable in three out of four observations in the first season. NAR did not register any significant variation in the second season. The maximum NAR was recorded by i_1n_1 at 21-42 DAP which remained on a par with i_2n_1 and superior to other combinations. In the second observation (42-63 DAP),

Table 10. Effect of treatments on NAR (g m^{-2} day^{-1})

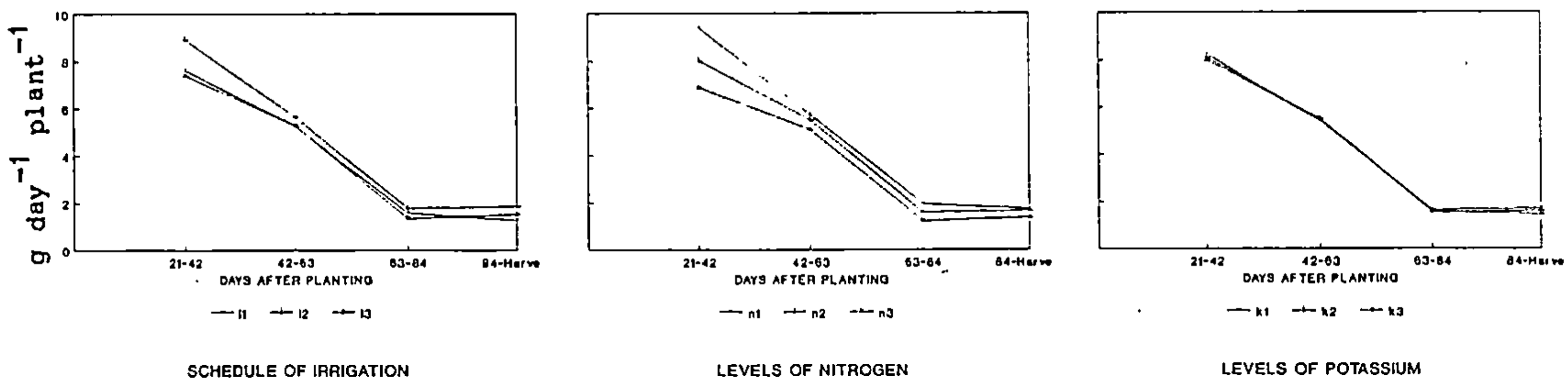
Treatments	1990 Days after planting 21-42	42-63	63-84	84-Harvest	1991 Days after planting 21-42	42-63	63-84	84-Harvest
i_1	6.83	5.05	1.61	1.07	8.41	5.53	1.57	1.48
i_2	8.18	5.25	1.73	1.41	9.68	6.10	1.84	2.34
i_3	6.89	5.04	1.66	1.05	7.91	5.58	0.95	2.01
SE	0.107	0.103	0.073	0.154	0.204	0.186	0.182	0.209
CD	0.485	---	---	---	0.803	---	---	---
n_1	8.55	5.14	2.39	1.38	10.27	6.37	1.50	2.12
n_2	7.37	5.23	1.64	1.34	8.70	5.80	1.54	2.00
n_3	6.35	5.04	1.16	0.90	7.44	5.17	1.31	1.86
SE	0.107	0.042	0.077	0.126	0.189	0.185	0.133	0.219
CD	0.319	0.126	0.231	0.374	0.561	0.549	---	---
k_1	7.58	4.99	1.90	1.29	8.93	5.78	1.44	2.16
k_2	7.43	5.15	1.72	1.15	8.77	5.76	1.35	2.08
k_3	7.26	5.26	1.58	1.19	8.71	5.79	1.57	1.74
SE	0.107	0.042	0.077	0.126	0.189	0.185	0.133	0.219
CD	---	0.126	0.231	---	---	---	---	---

Table 11. Interaction effect of irrigation and nitrogen on NAR ($g\ m^{-2}\ day^{-1}$)

Stage of growth	Levels of N	Irrigation schedule					
		i_1	i_2	i_3	i_1	i_2	i_3
21-42 DAP	n_1	8.97	8.51	8.16	10.11	11.01	9.71
	n_2	6.71	8.41	6.98	8.41	9.67	8.01
	n_3	5.32	7.81	5.90	7.12	8.74	6.46
42-63 DAP	n_1	5.25	5.07	5.10	6.08	7.03	5.98
	n_2	5.10	5.29	5.29	5.55	6.37	5.49
	n_3	4.87	5.36	4.88	5.01	5.14	5.35
63-84 DAP	n_1	2.10	2.89	2.19	1.64	1.62	1.25
	n_2	1.71	1.51	1.70	1.78	1.86	0.98
	n_3	1.25	1.03	1.20	1.39	1.97	0.58
84 DAP-Harvest	n_1	1.22	1.38	1.54	1.67	2.95	1.75
	n_2	1.23	1.70	1.10	1.55	2.12	2.32
	n_3	0.78	1.15	0.77	1.22	2.25	2.11

		21-42DAP	42-63DAP	63-84DAP	84 DAP-Harvest
SE	1990	0.186	0.096	0.140	0.268
	1991	0.267	0.257	0.191	0.325
CD	1990	0.535	0.276	0.402	---
	1991	---	---	---	---

FIG. 6. EFFECT OF TREATMENTS ON NET ASSIMILATION RATE



the treatment combination of i_2n_3 recorded the maximum NAR which remained on a par with i_3n_2, i_2n_2, i_1n_1, i_1n_2 and i_3n_1. At the third observation (63-84 DAP), the treatment combination i_2n_1 registered its superiority over other combinations. NAR was invariably lower in the treatment combinations involving the highest level of N namely n_3.

4.2.3 Crop growth rate (CGR)

The results presented in Table (12) reveal that irrigation schedules played a significant role in enhancing the CGR in the first two observations in both the seasons. Both i_1 and i_3 schedules registered their superiority over i_2 schedule in all the four observations(Fig.7). However, there was no significant difference between i_1 and i_3 schedules. Nitrogen profoundly influenced the CGR in the first season where significant effect was visible in three out of four observations. No significant difference was observed towards harvest. In the first two observations, n_3 was significantly superior to n_2 which in turn was superior to n_1. However, in the subsequent stage, n_1 was found to be superior to both n_2 and n_3. Nitrogen application did not influence the CGR at any stage of observation in the second season.

The effect of potassium was visible between 42-63 DAP in

Table 12. Effect of treatments on the CGR (g m^{-2} day^{-1})

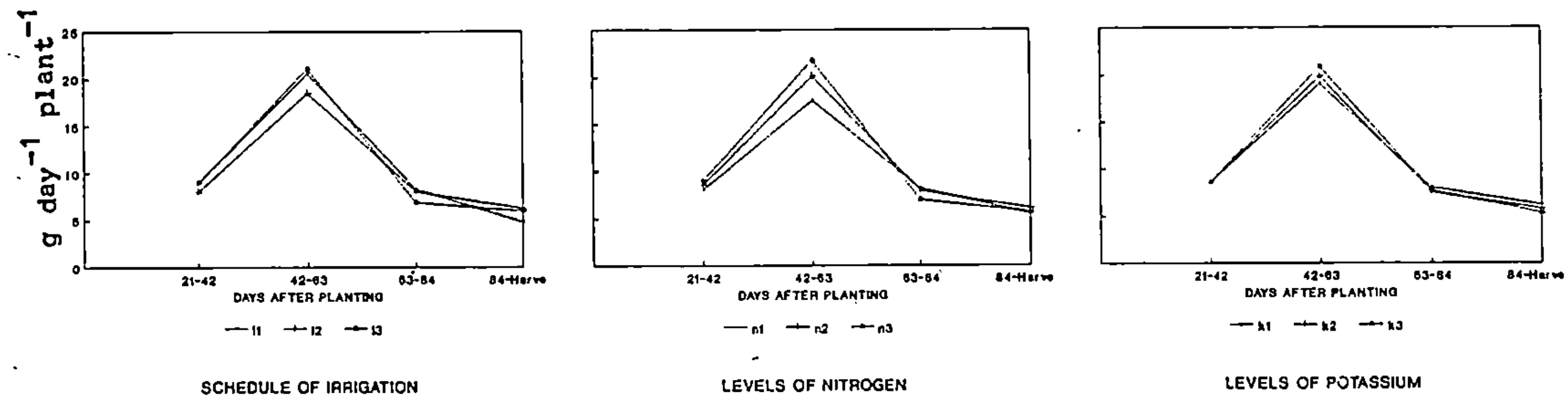
Treatments	1990 Days after planting 21-42	42-63	63-84	84-Harvest	1991 Days after planting 21-42	42-63	63-84	84-Harvest
i_1	8.90	21.06	8.45	4.10	8.96	20.11	8.12	5.56
i_2	8.27	18.85	7.78	4.77	7.81	18.20	8.22	7.73
i_3	9.20	21.01	8.75	3.90	8.84	21.19	4.96	8.00
SE	0.103	0.453	0.331	0.617	0.140	0.569	0.961	0.815
CD	0.405	1.778	---	---	0.549	2.236	---	---
n_1	8.01	16.59	10.16	4.26	8.13	18.46	6.35	6.71
n_2	8.83	20.57	8.53	4.89	8.44	19.71	7.46	7.30
n_3	9.26	22.74	6.86	3.78	8.87	20.81	7.16	7.60
SE	0.105	0.192	0.415	0.472	0.222	0.707	0.631	0.790
CD	0.314	0.571	1.232	---	---	---	---	--
k_1	8.71	18.94	9.12	4.58	8.36	19.25	6.92	7.75
k_2	8.78	19.99	8.47	4.00	8.48	19.75	6.55	7.52
k_3	8.62	20.98	7.97	4.35	8.59	20.81	7.49	6.34
SE	0.105	0.192	0.415	0.472	0.222	0.707	0.631	0.790
CD	---	0.571	---	---	---	---	---	---

Table 13. Interaction effect of irrigation and nitrogen on CGR ($g\ m^{-2}\ day^{-1}$)

Stage of growth	Levels of N	1990 i_1	1990 i_2	1990 i_3	1991 i_1	1991 i_2	1991 i_3
21-42 DAP	n_1	8.57	7.04	8.42	8.45	7.44	8.49
	n_2	9.01	8.50	9.00	8.74	7.78	8.80
	n_3	8.99	9.02	9.11	9.44	8.09	9.07
42-63 DAP	n_1	17.45	15.00	17.33	18.29	18.20	18.88
	n_2	21.21	18.83	21.67	19.66	19.03	20.44
	n_3	23.41	21.46	23.36	21.49	17.41	23.53
63-84 DAP	n_1	9.32	11.49	9.68	7.05	6.29	5.72
	n_2	9.22	7.11	9.27	9.04	8.15	5.17
	n_3	7.63	5.48	7.46	8.39	9.57	3.52
84 DAP-Harvest	n_1	3.90	4.03	4.85	5.32	8.81	5.99
	n_2	4.66	5.67	4.35	5.82	7.00	9.09
	n_3	3.56	4.41	3.37	5.36	8.18	9.27

		21-42DAP	42-63DAP	63-84DAP	84 DAP-Harvest
SE	1990	0.211	0.339	0.712	1.000
	1991	0.314	0.906	0.930	1.217
CD	1990	0.607	---	2.043	---
	1991	---	2.602	---	---

FIG. 7. EFFECT OF TREATMENTS ON CROP GROWTH RATE



the first season whereas no significant effect was noticed over k_2 and k_1 levels.

Interaction effect of irrigation x nitrogen(Table 13) was observed in the first season at 21-42 and at 63-84 DAP whereas in the second season significant effect was noticed at 42-63 DAP only. The CGR was maximum in the treatment combination of i_3n_3 which remained on a par with i_2n_3, i_1n_2, i_3n_2 and i_1n_3. CGR was lowest in the treatment combination of i_2n_1. In the subsequent observation at 63-84 DAP, the treatment combination of i_2n_1 recorded the maximum CGR which remained on a par with i_3n_1 and significantly superior to other combinations. CGR was minimum in the treatment combination of i_2n_3.

In the second season, significant superiority of CGR was observed at 42-63 DAP where the combination of i_3n_3 recorded the maximum and maintained its parity with i_1n_3. CGR was lowest in the treatment combination of i_2n_3.

4.2.4 Specific leaf weight(SLW)

The effect of different treatments on the specific leaf weight observed at an interval of 21 days from planting to harvest is presented in Table 14.

Table 14. Effect of treatments on specific leaf weight (mg cm^{-2})

	1990 Days after planting					1991 Days after planting				
Treatments	21	42	63	84	Harvest	21	42	63	84	Harvest
i_1	4.10	3.83	3.42	3.41	3.16	4.31	4.00	3.64	3.60	3.37
i_2	4.29	3.92	3.50	3.44	3.22	4.52	4.18	3.85	3.77	3.54
i_3	4.12	3.86	3.47	3.33	3.09	4.44	4.10	3.73	3.56	3.33
SE	0.030	0.019	0.046	0.036	0.039	0.027	0.027	0.024	0.020	0.012
CD	0.117	---	---	---	---	0.106	0.107	0.093	0.080	0.048
n_1	4.27	4.02	3.59	3.55	3.30	4.51	4.16	3.94	3.82	3.57
n_2	4.16	3.81	3.45	3.37	3.15	4.42	4.10	3.74	3.64	3.41
n_3	4.08	3.78	3.37	3.28	3.05	4.34	4.03	3.59	3.52	3.29
SE	0.025	0.035	1.036	0.033	0.038	0.037	0.041	0.039	0.036	0.034
CD	0.074	0.105	0.107	0.097	0.112	0.109	---	0.115	0.108	0.100
k_1	4.19	3.91	3.45	3.38	3.13	4.41	4.09	3.74	3.65	3.42
k_2	4.20	3.90	3.52	3.44	3.20	4.50	4.13	3.79	3.70	3.47
k_3	4.11	3.80	3.44	3.38	3.17	4.36	4.07	3.73	3.63	3.38
SE	0.025	0.035	0.036	0.033	0.038	0.037	0.041	0.039	0.036	0.034
CD	0.07	---	---	---	---	---	---	---	---	---

Irrigation exerted a significant effect on specific leaf weight especially for the second season at all stages of observation. However, in the first season, significance was observed only at 21 DAP. Specific leaf weight was higher in plots receiving i_2 schedule as compared to i_1 and i_3 schedules.

Nitrogen application profoundly influenced the specific leaf weight in both the seasons. Enhanced rate of application of nitrogen resulted in a decrease in specific leaf weight. The specific leaf weight was higher in n_1 level and lowest in n_3 level. However, during the second season, no significance was observed at 42 DAP.

Potassium played a significant role in modifying the specific leaf weight only at 21 days after planting in the first season. In all other observations, during both the seasons, potassium had no significant effect in improving the specific leaf weight.

The interaction effect of irrigation x nitrogen(Table 15) was significant at 63 and 84 DAP in both the seasons. The treatment combination of i_2n_1 recorded the maximum specific leaf weight throughout the period of plant growth.

Table 15. Interaction effect of irrigation x nitrogen on specific leaf weight (mg cm^{-2})

Stage of growth	Levels of N	1990 i_1	1990 i_2	1990 i_3	1991 i_1	1991 i_2	1991 i_3
21 DAP	n_1	4.23	4.33	4.23	4.39	4.51	4.61
	n_2	4.09	4.21	4.17	4.34	4.51	4.42
	n_3	4.00	4.25	4.00	4.22	4.54	4.26
42 DAP	n_1	4.00	4.10	3.97	4.10	4.14	4.25
	n_2	3.84	3.72	3.89	4.03	4.19	4.07
	n_3	3.71	3.89	3.75	3.89	4.21	3.99
63 DAP	n_1	3.56	3.69	3.53	3.88	3.92	4.02
	n_2	3.51	3.34	3.50	3.75	3.87	3.61
	n_3	3.24	3.45	3.42	3.39	3.78	3.51
84 DAP	n_1	3.56	3.65	3.44	3.80	3.88	3.79
	n_2	3.52	3.28	3.33	3.71	3.74	3.79
	n_3	3.21	3.36	3.26	3.36	3.70	3.49
Harvest	n_1	3.28	3.42	3.20	3.53	3.65	3.55
	n_2	3.27	3.08	3.10	3.45	3.55	3.24
	n_3	3.00	3.14	3.00	3.19	3.43	3.26

		21DAP	42DAP	63DAP	84DAP	Harvest
SE	1990	0.062	0.065	0.065	0.056	0.062
	1991	0.062	0.065	0.072	0.068	0.066
CD	1990	---	---	0.187	0.161	---
	1991	---	---	0.206	0.194	---

Table 16. Interaction effect of irrigation x potassium on specific leaf weight (mg cm^{-2})

Stage of growth	Levels of K	1990 n_1	1990 n_2	1990 n_3	1991 n_1	1991 n_2	1991 n_3
21 DAP	k_1	4.30	4.31	4.19	4.52	4.57	4.43
	k_2	4.06	4.21	4.20	4.29	4.61	4.37
	k_3	4.21	4.09	3.94	4.42	4.32	4.28
42 DAP	k_1	4.07	4.01	3.98	4.18	4.18	4.13
	k_2	3.72	3.91	3.82	4.01	4.21	4.08
	k_3	3.94	3.79	3.61	4.07	4.01	4.01
63 DAP	k_1	3.60	3.58	3.60	3.98	3.93	3.91
	k_2	3.35	3.56	3.44	3.72	3.83	3.68
	k_3	3.40	3.43	3.27	3.53	3.62	3.60
84 DAP	k_1	3.57	3.53	3.56	3.83	3.83	3.81
	k_2	3.29	3.48	3.36	3.59	3.75	3.56
	k_3	3.28	3.33	3.22	3.51	3.52	3.52
Harvest	k_1	3.30	3.28	3.32	3.57	3.63	3.53
	k_2	3.07	3.22	3.16	3.39	3.47	3.38
	k_3	3.02	3.10	3.03	3.31	3.32	3.24

		21DAP	42DAP	63DAP	84DAP	Harvest
SE	1990	0.043	0.061	0.060	0.057	0.065
	1991	0.064	0.072	0.067	0.063	0.058
CD	1990	0.128	0.182	---	---	---
	1991	0.189	---	---	---	---

In general, the specific leaf weight was higher in treatments receiving irrigation at i_2 schedule. The specific leaf weight was considerably lower in treatments receiving nitrogen at the highest level of n_3.

The interaction effect of nitrogen x potassium(Table 16) was also found to be significant at 21 and 42 DAP in the first season and at 21 DAP in the second season. Specific leaf weight was maximum in the treatment combination of n_2k_2 at 21 DAP while n_1k_1 recorded the highest value at 42 DAP in the first season. In the second season, the specific leaf weight was maximum in the combination of n_2k_2. The influence of potassium was more as compared to that of nitrogen in influencing the specific leaf weight as the lower levels of potassium tended to increase the specific leaf weight.

4.3. Dry matter production and partitioning

4.3.1 Dry matter content of leaves

The dry matter content of leaves as affected by irrigation and fertility is presented in Table 17. Irrigation schedules especially in the first season except at 42 DAP significantly influenced the dry matter content of leaves. In all the observations, i_1 and i_3 were significantly superior to i_2. In the second season, leaf dry

Table 17. Effect of treatments on the dry matter content of leaves (g plant^{-1})

Treatments	1990 Days after planting 21	42	63	84	Harvest	1991 Days after planting 21	42	63	84	Harvest
i_1	3.19	6.32	27.42	24.64	18.13	1.82	6.09	27.03	22.48	16.66
i_2	2.93	6.63	24.95	21.70	17.55	1.72	5.61	23.66	20.39	16.60
i_3	3.24	6.64	28.55	25.13	18.43	1.98	6.33	28.27	20.29	17.15
SE	0.033	0.125	0.466	0.525	0.167	0.089	0.157	0.829	0.505	0.357
CD	0.129	---	1.830	2.062	0.656	---	---	3.256	---	---
n_1	2.96	6.30	22.10	22.39	15.81	2.07	5.86	24.36	18.67	15.77
n_2	3.05	6.61	27.00	24.41	18.20	1.77	5.94	25.99	20.88	16.78
n_3	3.24	6.58	28.31	24.41	19.41	1.66	6.12	28.00	22.54	17.76
SE	0.034	0.088	0.298	0.514	0.235	0.076	0.159	0.773	0.641	0.226
CD	0.103	0.261	0.887	1.528	0.699	0.226	---	2.296	1.905	0.672
k_1	2.98	6.43	24.72	23.28	17.45	1.83	6.04	25.42	20.20	17.36
k_2	3.08	6.50	26.27	23.79	17.68	1.78	5.90	26.15	20.18	16.39
k_3	3.20	6.56	28.31	24.14	18.30	1.90	5.98	26.78	21.71	16.56
SE	0.034	0.088	0.298	0.514	0.235	0.076	0.159	0.773	0.641	0.226
CD	0.103	---	0.887	---	---	---	---	---	---	0.672

matter was significant only at 63 DAP where i_1 and i_3 were superior to i_2.

The effect of nitrogen in influencing the dry matter content of leaves was remarkable in both the seasons, though no significance was observed at 42 DAP in the second season. The level of n_3 was superior to n_1, though at times n_3 was on a par with n_2. Contrary to the general superiority of the highest level over the lowest level, n_1 was superior to both n_2 and n_3 at 21 DAP in the second season.

Potassium did influence the leaf dry matter content significantly at 21 and 63 DAP in the first season and at harvest in the second season. The highest level of potassium(k_3) was significantly superior to the lowest level(k_1) in the first season while k_1 was superior to k_3 in the second season. However, potassium failed to have any influence on the leaf dry matter content during all other stages of observation.

The interaction effect of irrigation x nitrogen(Table 18) was significant at 21, 42 and 84 DAP in the first season and at 63 DAP in the second season. Both i_1n_3 and i_3n_3 were significantly superior to i_2n_3 at 21 and 63 DAP while at 42 and 84 DAP, i_2n_1 recorded the lowest dry matter content of

Table 18. Interaction effect of irrigation and nitrogen on dry matter content of leaves (g plant^{-1})

Stage of growth	Levels of N	1990 i_1	1990 i_2	1990 i_3	1991 i_1	1991 i_2	1991 i_3
21 DAP	n_1	2.94	2.95	3.00	2.04	2.08	2.10
	n_2	3.09	2.93	3.14	1.70	1.74	1.87
	n_3	3.40	2.88	3.45	1.74	1.39	1.86
42 DAP	n_1	6.48	5.98	6.43	5.70	5.61	6.27
	n_2	6.54	6.72	6.57	5.87	5.48	6.47
	n_3	6.02	7.03	6.70	6.41	5.70	6.24
63 DAP	n_1	23.40	19.42	23.48	24.27	23.69	25.13
	n_2	27.60	24.95	28.43	26.17	24.42	27.39
	n_3	29.75	28.82	32.05	29.58	23.05	31.38
84 DAP	n_1	22.23	22.18	22.77	19.20	18.00	18.80
	n_2	25.81	21.43	25.99	22.51	20.94	19.19
	n_3	25.73	21.48	26.03	24.67	21.49	21.47
Harvest	n_1	16.17	15.20	16.07	15.29	16.55	15.48
	n_2	18.22	17.64	18.74	16.80	16.35	17.19
	n_3	19.15	19.29	19.79	17.77	17.01	18.50

		21DAP	42DAP	63DAP	84DAP	Harvest
SE	1990	0.059	0.186	0.550	0.728	0.403
	1991	0.110	0.305	1.126	0.897	0.496
CD	1990	0.169	0.534	---	2.091	---
	1991	---	---	3.233	---	---

leaves.

4.32 Dry matter content of shoots

The effect of treatments on the shoot dry matter content is presented in Table 19. Irrigation had a substantial role in influencing the dry matter content of shoot. Out of five observations in the first season, except at 42 DAP, i_1 and i_3 were significantly superior to i_2. In the second season, the observation at 21 DAP and at harvest failed to record any significant difference. However, in the other three observations, irrigation at i_1 and i_3 schedules were significantly superior to i_2.

Nitrogen profoundly influenced the shoot dry matter content especially in the first season. The level n_3 was significantly superior to n_2 and n_3. In all other observations, n_3 produced maximum shoot dry matter and was significantly superior to n_1 at 84 DAP and at harvest.

The effect of potassium was significant at 21 and 84 DAP in the first season. In both observations, k_3 was superior to k_1 while k_2 and k_3 remained on a par. Potassium did not exert any significant effect on shoot dry matter in the second season.

Table 19. Effect of treatments on the dry matter of shoot (g plant^{-1})

	1990 Days after planting					1991 Days after planting				
Treatments	21	42	63	84	Harvest	21	42	63	84	Harvest
i_1	1.74	11.16	22.81	32.84	35.09	0.97	10.60	21.37	30.28	33.05
i_2	1.55	11.46	19.63	29.52	34.17	0.91	9.71	18.45	27.32	32.72
i_3	1.69	11.74	22.43	34.00	35.69	1.05	10.65	22.54	27.23	34.27
SE	0.032	0.186	0.182	0.593	0.263	0.054	0.180	0.681	0.439	0.639
CD	0.126	---	0.713	2.328	1.034	---	0.707	2.673	1.726	---
n_1	1.52	11.09	17.33	30.58	31.23	1.09	10.21	19.90	25.78	31.18
n_2	1.63	11.48	21.72	32.82	35.14	0.97	10.02	19.93	28.03	33.07
n_3	1.78	11.63	24.57	32.67	37.47	0.88	10.48	21.98	29.51	35.28
SE	0.022	0.142	0.271	0.523	0.314	0.037	0.266	0.655	0.974	0.391
CD	0.066	0.423	0.804	1.554	0.933	0.109	---	---	2.896	1.162
k_1	1.60	11.53	20.49	31.76	34.04	1.01	10.24	20.38	26.52	33.40
k_2	1.63	11.49	21.54	32.04	34.67	0.96	10.13	20.52	27.18	33.10
k_3	1.69	11.18	21.60	32.28	35.14	0.96	10.33	20.90	29.61	33.02
SE	0.022	0.142	0.271	0.523	0.314	0.037	0.266	0.655	0.974	0.391
CD	0.066	---	0.804	---	---	---	---	---	---	---

The interaction of irrigation x nitrogen (Table 20) was significant at 42 DAP in the first season and at 63 DAP in the second season. The combinations of i_1 and i_3 with different levels of nitrogen were significantly superior to the combinations involving i_2.

The interaction effect of nitrogen x potassium (Table 21) was also significant at 21 DAP in the first season and at harvest in the second season. In both the seasons, combination of potassium with nitrogen at n_3 level recorded higher shoot dry weight over combinations involving n_1 level.

4.3.3 Dry matter content of fibrous roots

The dry matter content of fibrous roots as observed in both the seasons is presented in Table 22. In the first season, on all observations except at 21 DAP, irrigation had a profound influence on the dry matter content of fibrous roots. Irrigation at i_3 schedule was significantly superior to i_1 in three stages and to i_3 in two stages out of total of four observations. At the above two stages, i_2 was significantly superior to i_1. Significance was noticed in the second season on three stages where i_3 was significantly superior to i_2. However, significant difference was noticed between i_1 and i_2 schedules at one stage only.

Table 20. Interaction effect of irrigation and nitrogen on dry matter content of shoots (g $plant^{-1}$)

Stage of growth	Levels of N	Irrigation schedule 1990 i_1	1990 i_2	1990 i_3	1991 i_1	1991 i_2	1991 i_3
21 DAP	n_1	1.58	1.45	1.52	1.07	1.09	1.10
	n_2	1.67	1.57	1.66	0.96	0.89	1.06
	n_3	1.89	1.63	1.81	0.91	0.77	0.96
42 DAP	n_1	11.53	10.45	11.28	10.08	9.74	10.80
	n_2	11.27	11.65	11.51	10.20	9.40	10.45
	n_3	10.75	12.08	12.07	10.99	9.90	10.54
63 DAP	n_1	18.70	14.85	18.43	19.59	18.84	21.27
	n_2	22.48	19.98	22.72	20.71	18.48	20.60
	n_3	25.80	22.55	25.35	22.82	18.02	25.09
84 DAP	n_1	30.11	30.19	31.45	27.01	24.33	25.99
	n_2	34.69	29.01	34.78	30.73	27.99	25.37
	n_3	33.73	29.29	35.00	31.68	28.60	28.24
Harvest	n_1	31.23	30.51	31.95	30.39	30.85	32.29
	n_2	35.30	34.50	35.63	33.38	32.77	33.05
	n_3	37.44	36.68	38.30	34.80	34.45	36.59

		21DAP	42DAP	63DAP	84DAP	Harvest
SE	1990	0.049	0.295	0.467	1.121	0.559
	1991	0.053	0.483	0.817	1.343	0.847
CD	1990	---	0.847	---	---	---
	1991	---	---	---	2.347	---

Table 21. Interaction effect of nitrogen and potassium on the dry matter of shoots (g plant^{-1})

Stage of growth	Levels of K	Levels of nitrogen 1990 n_1	1990 n_2	1990 n_3	1991 n_1	1991 n_2	1991 n_3
21 DAP	k_1	1.51	1.58	1.71	1.12	1.03	0.87
	k_2	1.55	1.57	1.77	1.10	0.94	0.85
	k3	1.48	1.75	1.85	1.04	0.93	0.92
42 DAP	k_1	11.33	11.47	11.79	10.27	9.93	10.52
	k_2	10.92	11.73	11.82	10.12	9.84	10.42
	k_3	11.01	11.23	11.29	10.23	10.28	10.49
63 DAP	k_1	17.14	20.77	23.57	19.59	20.08	21.48
	k_2	17.45	22.01	25.14	20.18	19.01	22.38
	k_3	17.39	22.40	25.00	19.93	20.70	22.08
84 DAP	k_1	30.43	32.29	32.55	24.71	26.80	28.04
	k_2	30.22	33.10	32.80	25.14	27.38	29.02
	k_3	31.10	33.09	32.67	27.48	29.91	31.45
Harvest	k_1	30.89	34.69	36.54	31.38	32.07	36.77
	k_2	30.87	35.55	37.58	30.62	33.71	34.98
	k_3	31.94	35.19	38.30	31.53	33.42	34.10

		21 DAP	42 DAP	63 DAP	84 DAP	Harvest
SE	1990	0.039	0.246	0.468	1.906	0.544
	1991	0.064	0.460	1.135	1.687	0.678
CD	1990	0.115	---	---	---	---
	1991	---	---	---	---	2.013

Table 22. Dry matter content of fibrous roots (g $plant^{-1}$) as affected by treatments

	1990 Days after planting					1991 Days after planting				
Treatments	21	42	63	84	Harvest	21	42	63	84	Harvest
i_1	1.53	2.93	4.01	4.91	4.89	3.30	2.74	3.48	4.16	4.33
i_2	1.51	2.67	3.46	4.91	5.23	2.94	2.72	3.17	4.23	4.20
i_3	1.52	3.03	4.01	5.12	5.26	3.26	2.86	3.39	4.08	4.55
SE	0.020	0.047	0.040	0.043	0.061	0.026	0.010	0.077	0.068	0.078
CD	---	0.186	0.157	0.168	0.241	0.101	0.040	---	---	0.306
n_1	1.25	2.38	3.30	4.13	4.34	2.46	1.92	2.83	3.18	3.15
n_2	1.48	2.77	3.81	4.98	5.15	3.08	2.81	3.15	4.08	4.19
n_3	1.74	3.27	4.20	5.56	5.65	3.67	3.38	3.84	4.91	5.35
SE	0.018	0.038	0.049	0.037	0.066	0.050	0.058	0.072	0.066	0.100
CD	0.054	0.115	0.147	1.109	0.197	0.150	0.172	0.214	0.197	0.298
k_1	1.47	2.69	3.67	4.77	4.91	2.99	2.61	3.21	3.99	4.10
k_2	1.50	2.81	3.74	4.86	5.03	3.04	2.70	3.25	4.02	4.21
k_3	1.50	2.93	3.90	5.04	5.20	3.18	2.79	3.36	4.16	4.38
SE	0.018	0.038	0.049	0.037	0.066	0.050	0.058	0.072	0.066	0.100
CD	---	0.115	0.147	0.109	0.197	0.150	---	0.214	---	---

The influence of nitrogen in enhancing the dry matter of fibrous roots was remarkable at all the stages of observation. The highest level of n_3 was significantly superior to n_2 and n_1 levels whereas n_2 was superior to n_1 at all stages.

Potassium was also found to register a significant influence in enhancing the dry matter content of fibrous roots. In the first season, except at 21 DAP, k_3 registered significantly higher dry matter of fibrous roots over the level k_1. In the second season, the influence of potassium was visible at 21 and 63 DAP only. In all cases, k_2 registered marginally higher values over k_1.

The interaction effect of irrigation x nitrogen (Table 23) was significant at 63 and 84 DAP in the first season and at 21 DAP in the second season. In all the three stages, i_1n_3 and i_3n_3 registered the highest values whereas the lowest value was recorded by i_2n_1.

4.3.4 Dry matter content of tuber

The dry matter content of tuber recorded at four stages in each season is presented in Table 24. In the first season, all the four observations showed significant

Table 23. Interaction effect of irrigation and nitrogen on dry matter content of fibrous roots (g $plant^{-1}$)

Stage of growth	Levels of N	1990 i_1	1990 i_2	1990 i_3	1991 i_1	1991 i_2	1991 i_3
21 DAP	n_1	1.25	1.23	1.26	2.48	2.41	2.50
	n_2	1.45	1.50	1.49	3.07	3.01	3.18
	n_3	1.77	1.73	1.72	3.99	3.24	3.78
42 DAP	n_1	2.39	2.20	2.55	1.91	1.85	1.99
	n_2	2.84	2.61	2.85	2.78	2.73	2.92
	n_3	3.34	2.99	3.49	3.29	3.35	3.49
63 DAP	n_1	3.39	3.00	3.50	2.91	2.61	2.98
	n_2	3.97	3.50	3.95	3.35	3.07	3.02
	n_3	4.52	3.68	4.41	4.09	3.59	3.85
84 DAP	n_1	4.24	4.03	4.11	3.19	3.18	3.18
	n_2	4.73	5.02	5.20	4.08	4.19	3.98
	n_3	5.44	5.50	5.73	4.93	5.02	4.78
Harvest	n_1	4.21	4.41	4.40	3.03	3.11	3.31
	n_2	4.81	5.39	5.24	4.10	4.03	4.44
	n_3	5.40	5.70	5.87	5.44	5.11	5.49

		21 DAP	42 DAP	63 DAP	84 DAP	Harvest
SE	1990	0.030	0.079	0.060	0.076	0.095
	1991	0.088	0.086	0.088	0.165	0.118
CD	1990	---	---	0.171	0.219	---
	1991	0.254	---	---	---	---

Table 24. Dry matter content of tuber (g plant^{-1}) as affected by treatments

Treatments	1990 Days after planting 42	63	84	Harvest	1991 Days after planting 42	63	84	Harvest
i_1	6.19	20.59	33.47	47.01	5.98	18.85	33.42	49.78
i_2	4.39	18.69	29.97	40.84	5.05	17.71	31.72	49.36
i_3	6.01	20.52	33.12	47.08	5.77	19.32	34.30	49.72
SE	0.153	0.407	0.284	0.871	0.067	0.352	0.452	0.489
CD	0.601	1.598	1.116	3.421-	0.262	----	1.777	---
n_1	4.39	18.33	29.24	45.40	5.32	17.14	32.52	47.04
n_2	5.65	20.25	31.79	46.37	5.65	19.03	33.59	50.12
n_3	6.27	20.94	34.45	43.49	5.75	19.01	33.18	51.31
SE	0.115	0.256	0.280	1.272	0.242	0.341	0.377	0.573
CD	0.343	0.760	0.833	---	---	1.014	---	1.703
k_1	5.41	19.95	31.77	46.28	5.15	17.78	32.62	48.24
k_2	5.50	19.98	31.99	44.14	5.76	18.58	33.53	49.93
k_3	5.40	19.59	31.71	44.53	5.82	18.82	33.14	50.30
SE	0.115	0.256	0.280	1.272	0.242	0.341	0.377	0.573
CD	---	---	---	---	---	---	---	1.703

difference while in the second season, significant difference was observed in two stages only. In all the six observations, i_1 and i_3 schedules were on a par and were significantly superior to i_1. In the other two observations also, i_1 and i_3 were found to register higher dry matter content in tuber.

In the case of nitrogen, out of eight observations in both the seasons, significant influence was noticed in five observations. The n_3 and n_2 levels recorded significantly higher dry matter content as compared to n_1 level in both the seasons. However, the difference between n_3 and n_2 was not significant in all the cases. In certain instances, n_2 registered marginally higher dry matter content of tuber over n_3 level.

The effect of potassium was found to be significant only in one observation, namely at harvest in the second season. The k_3 level had a significantly higher dry matter content in tuber as compared to the level of k_1 while k_2 remained on a par.

4.3.5 Total dry matter production

The total dry matter production as affected by the

Table 25. Total dry matter production (g $plant^{-1}$) in the first season

Treatments	1990 Days after planting 21	42	63	84	Harvest
i_1	6.45	26.60	74.83	95.85	105.11
i_2	5.99	25.15	66.72	86.11	97.79
i_3	6.46	27.42	75.51	97.36	106.46
SE	0.017	0.173	0.775	0.913	0.977
CD	0.066	0.679	3.042	3.585	3.837
n_1	5.73	24.15	61.06	86.34	96.78
n_2	6.17	26.51	72.78	94.01	104.87
n_3	6.76	27.76	79.93	97.10	106.03
SE	0.038	0.182	1.21	0.918	1.314
CD	0.113	0.540	1.225	2.728	3.906
k_1	6.05	26.07	68.84	91.58	102.68
k_2	6.22	26.29	71.52	92.69	101.82
k_3	6.39	26.07	73.40	93.18	103.18
SE	0.038	0.182	0.412	0.918	1.314
CD	0.113	---	1.225	---	---

treatments are presented in Tables 25, 26 and 27. Dry matter production of the plant was very much influenced by scheduling of irrigation except at harvest in the second season. The i_1 and i_3 schedules of irrigation were on a par and significantly superior to i_2 schedule except at 84 DAP in the second season where i_3 and i_2 schedules remained on a par (Fig.8).

Dry matter production was influenced by varying the levels of nitrogen at all stages of observation. The highest level of N, namely n_3 was superior to n_1 level. However, the difference between n_2 and n_3 was not significant at harvest in the first season and at 84 DAP in the second season. Similarly, the differences between n_1 and n_2 were significant at all stages except at 21 DAP in the second season(Fig.9).

The influence of added levels of potassium on the dry matter production was not so marked except at three out of ten observations. At 21 and 63 DAP in the first season and at 84 DAP in the second season, the k_3 level produced higher dry matter as compared to k_1 level. The level k_3 was also significantly superior to k_2 in the first two observations.

The interaction effect of irrigation x nitrogen(Table 27) was observed on 21, 42 and 84 DAP in the first season and

Table 26. Total dry matter production (g $plant^{-1}$)

in the second season

Treatments	21	42	63	84	Harvest
	Days after planting				
i_1	6.09	26.41	70.73	90.34	103.83
i_2	5.57	23.09	62.98	83.66	102.88
i_3	6.30	25.61	73.52	85.90	105.70
SE	0.119	0.298	1.217	1.272	1.427
CD	0.468	1.170	4.777	4.994	---
n_1	5.62	23.31	64.24	80.15	97.14
n_2	5.82	24.42	68.10	86.58	104.17
n_3	6.21	25.72	72.84	90.14	109.70
SE	0.097	0.350	1.274	1.377	1.033
CD	0.289	1.042	3.787	4.091	3.070
k_1	5.83	24.04	66.79	83.23	103.10
k_2	5.78	24.49	68.51	84.92	103.64
k_3	6.04	25.72	69.87	88.62	104.27
SE	0.097	0.350	1.274	1.377	1.033
CD	---	---	---	4.091	---

Table 27. Interaction effect of irrigation and nitrogen on dry matter production (g plant^{-1})

Stage of growth	Levels of N	Irrigation schedule 1990 i_1	1990 i_2	1990 i_3	1991 i_1	1991 i_2	1991 i_3
21 DAP	n_1	5.77	5.63	5.79	5.59	5.58	5.70
	n_2	6.22	6.01	6.29	5.73	5.64	6.11
	n_3	7.07	6.23	6.98	6.64	5.41	6.60
42 DAP	n_1	25.37	21.89	25.21	23.64	21.97	24.32
	n_2	26.80	25.83	26.90	24.82	23.14	25.29
	n_3	27.14	27.03	29.10	26.94	23.77	26.47
63 DAP	n_1	64.17	54.91	64.10	64.35	61.58	66.78
	n_2	75.09	67.21	76.03	68.94	64.71	70.65
	n_3	81.84	74.59	83.25	75.84	62.21	80.45
84 DAP	n_1	87.33	83.55	88.14	82.09	77.41	80.94
	n_2	97.89	84.90	99.24	90.81	85.22	83.71
	n_3	100.95	88.28	102.07	95.04	86.24	89.14
Harvest	n_1	97.21	92.81	100.33	95.27	99.30	96.85
	n_2	106.59	99.07	108.94	104.61	102.62	105.27
	n_3	109.39	99.30	104.41	110.15	106.62	112.33

		21DAP	42DAP	63DAP	84DAP	Harvest
SE	1990	0.086	0.424	0.642	1.552	2.252
	1991	0.187	0.605	1.705	2.243	2.510
CD	1990	0.248	1.218	---	4.456	---
	1991	0.537	---	4.895	---	---

FIG. 8. EFFECT OF IRRIGATION ON DRY MATTER PARTITIONING

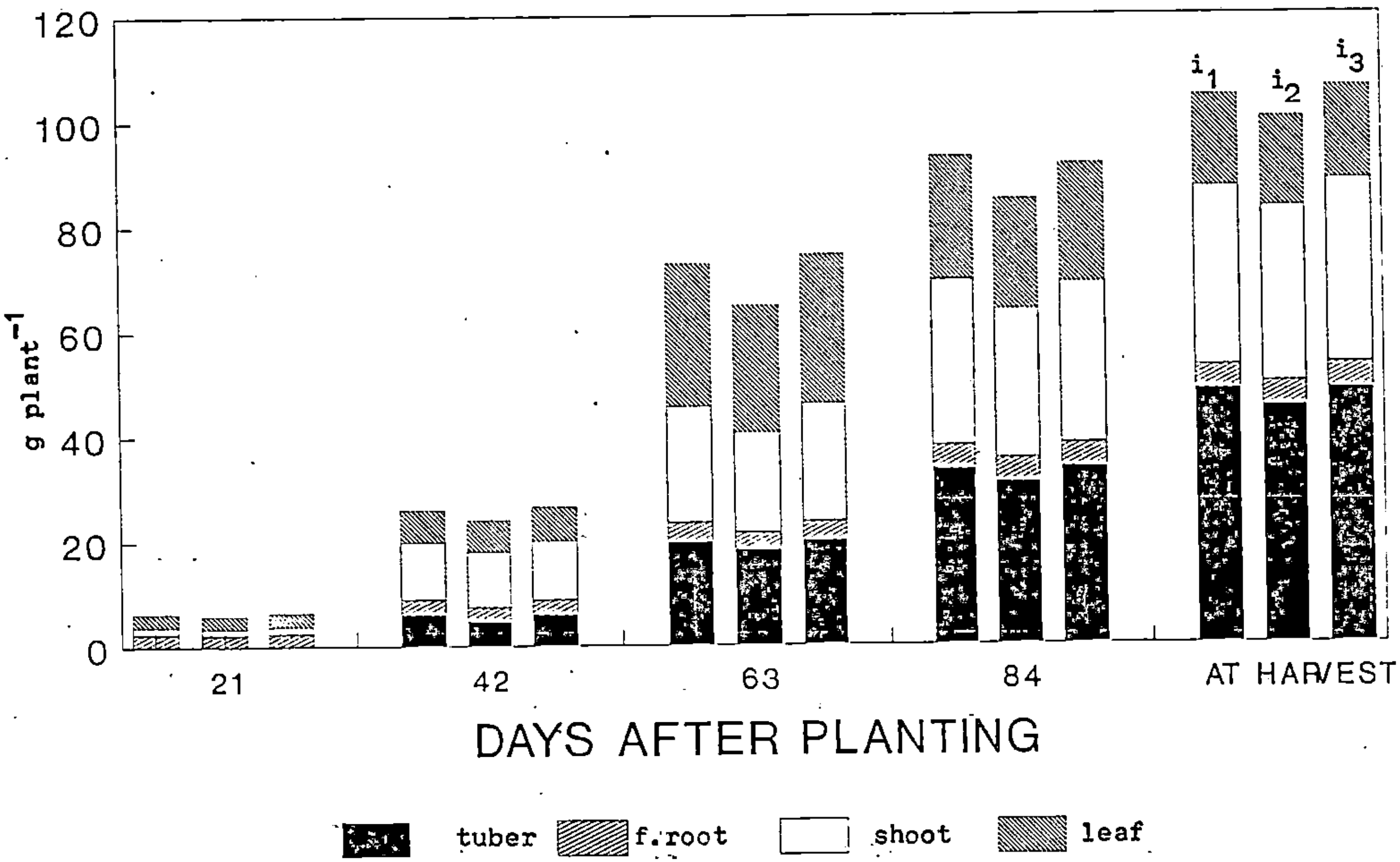
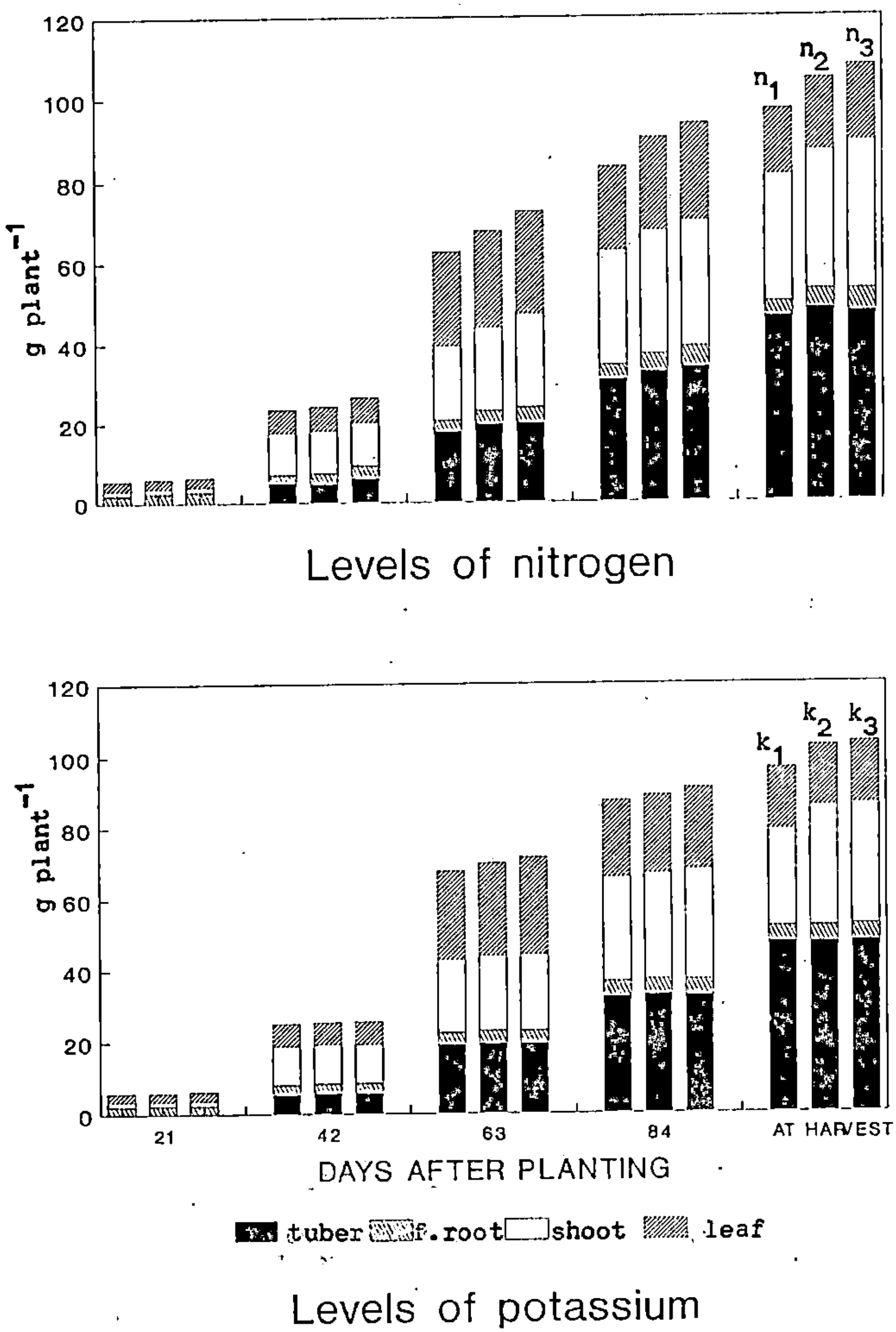


FIG. 9. EFFECT OF NITROGEN AND POTASSIUM ON DRY MATTER PARTITIONING



at 21 and 63 DAP in the second season. Dry matter production was maximum in the treatment combination of i_1n_3 and was on par with i_2n_3 and both remained superior to all other combinations at 21 DAP in the first season. However, at 42 DAP, i_3n_3 was superior to all other treatment combinatons in dry matter production. The treatment combination i_3n_3 maintained its lead over all other treatment combinations at 84 DAP but was on a par with i_1n_3 and i_1n_2.

In the second season at 21 DAP, significant superiority in dry matter production was observed where i_2n_3 recorded the maximum and remained on a par with i_1n_3 and i_3n_2. Significant influence of irrigation and nitrogen was visible at 63 DAP where i_3n_3 recorded the maximum dry matter production which remained on a par with i_1n_3 and significantly superior to all other combinations.

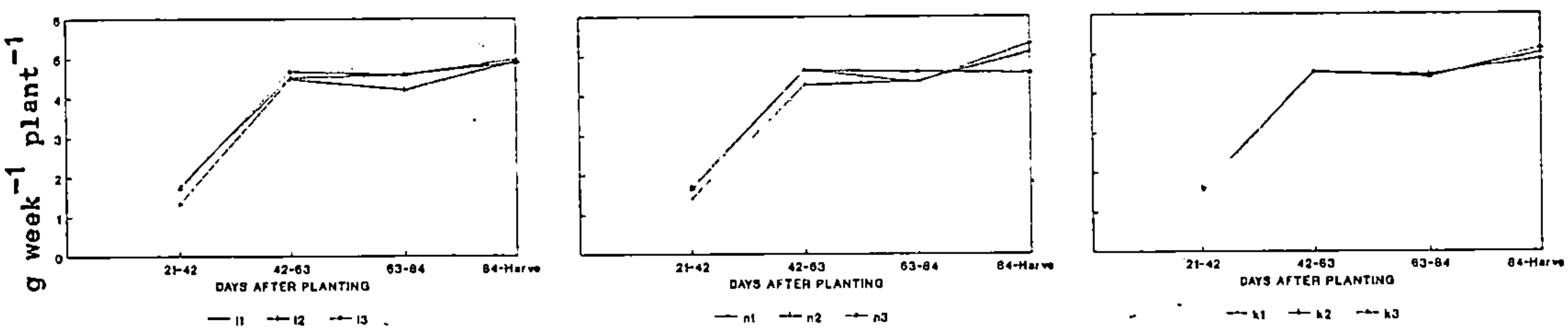
4.3.6 Tuber bulking rate

Tuber bulking rate at different intervals starting from tuber initiation to harvest is presented in Table 28 and Fig.10. Scheduling of irrigation had a significant influence during 21-42 DAP in the first and second seasons and at 63-84 DAP in the second season. In both situations, i_3 was superior to i_2 while i_1 registered its superiority over i_2

Table 28. Tuber bulking rate (g week^{-1} plant^{-1}) as influenced by treatments

Treatments	1990 Days after planting 21-42	42-63	63-84	84-harvest	1991 Days after planting 21-42	42-63	63-84	84-harvest
i_1	1.55	4.80	4.30	4.51	1.99	4.29	4.86	5.45
i_2	0.96	4.76	3.76	3.97	1.68	4.22	4.67	5.88
i_3	1.50	4.83	4.20	4.65	1.92	4.52	4.99	5.14
SE	0.052	0.131	0.181	0.202	0.022	0.106	0.057	0.233
CD	0.203	---	---	---	0.085	---	0.224	---
n_1	1.04	4.65	3.63	5.39	1.77	3.94	5.13	4.83
n_2	1.39	4.86	3.85	5.14	1.88	4.46	4.85	5.51
n_3	1.51	4.89	4.50	3.12	1.92	4.42	4.72	6.04
SE	0.036	0.100	0.1326	0.414	0.080	0.087	0.185	0.247
CD	0.107	---	0.405	1.230	---	0.260	---	0.734
k_1	1.31	4.85	3.94	4.85	1.71	4.21	4.95	5.20
k_2	1.33	4.83	4.00	4.25	1.92	4.27	4.98	5.47
k_3	1.30	4.73	4.04	4.55	1.94	4.33	4.77	5.72
SE	0.036	0.100	0.136	0.414	0.080	0.087	0.185	0.247

FIG. 10. EFFECT OF TREATMENTS ON TUBER BULKING RATE



SCHEDULE OF IRRIGATION

LEVELS OF NITROGEN

LEVELS OF POTASSIUM

during 21-42 DAP.

The influence of N on the bulking rate was revealed during 21-42 DAP, 63-84 DAP and 84 DAP to harvest in the first season and at 42-63 DAP and 84 DAP to harvest in the second season. In all these observations, except during 84 DAP to harvest, n_3 was significantly superior to n_1. However, both n_1 and n_2 registered their superiority over n_3 during this period.

Potassium had no influence in altering the tuber bulking rate at any of the growth stages.

4.4. Yield and yield attributes

4.4.1 Length of tuber

The influence of treatments on the length of tuber presented in Table 29 did not show any effect due to scheduling of irrigation.

Nitrogen exerted a significant influence on the length of tuber. Increasing the level of N from n_1 to n_3 resulted in a steady increase in the length of tuber.

Potassium did not modify the length of tuber to any appreciable extent in both the seasons.

Table 29. Length and girth (cm) of tuber at harvest

	Length		Girth	
Treatments	1990	1991	1990	1991
i_1	16.34	15.94	12.93	12.70
i_2	16.49	15.75	12.95	12.50
i_3	16.45	15.93	12.87	12.76
SE	0.139	0.108	0.257	0.057
n_1	14.78	14.56	12.67	12.36
n_2	16.11	15.62	13.78	13.78
n_3	17.80	17.03	12.36	11.91
SE	0.162	1.144	0.107	0.141
CD	0.483	0.328	0.318	0.419
k_1	16.03	15.65	12.37	12.10
k_2	16.46	15.83	13.10	12.89
k_3	16.19	15.74	13.34	13.07
SE	0.162	0.144	0.107	0.141
CD	---	---	0.318	0.419

4.4.2 Girth of tuber

The girth of tuber presented in Table 29 was not influenced by irrigation schedules to any appreciable extent.

Nitrogen remarkably influenced the girth of tuber wherein the medium level of N namely n_2 (13.78 cm) was significantly superior to n_1 and n_3 levels. The girth of tuber was the lowest at n_3 level.

Potassium significantly altered the girth of tuber, the maximum girth being recorded at k_3 (13.07-13.34 cm) level which was significantly superior to k_1 level.

4.4.3 Total number of tubers

The data on total number of tubers per plant at harvest presented in Tables 30 and 31 and in Fig.11 show that scheduling of irrigation had a significant effect. The maximum number of tubers per plant was produced by i_3 (2.39-2.55) which was significantly superior to i_1 and both i_3 and i_1 being superior to i_2.

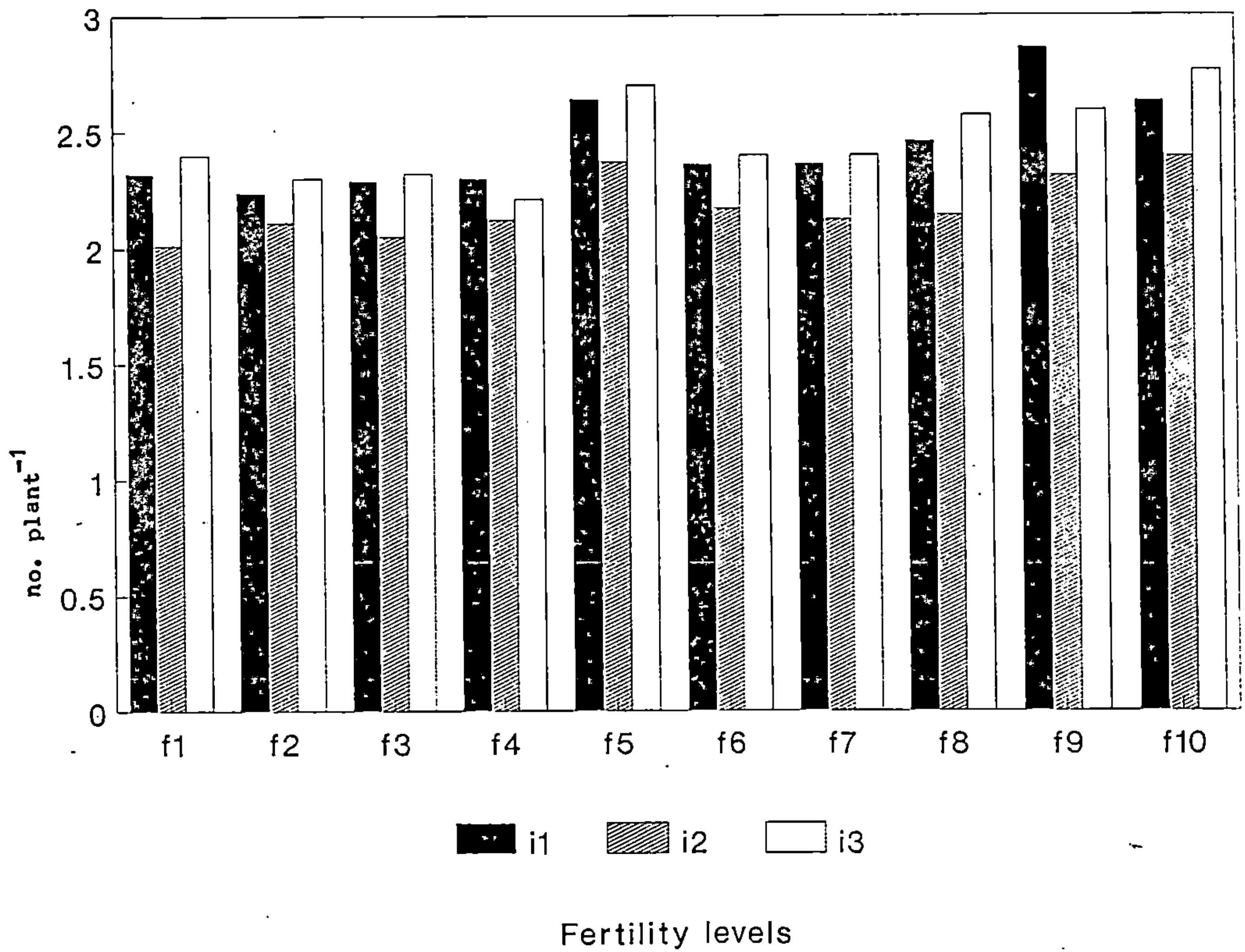
Varying the supply of nitrogen significantly improved the total number of tubers per plant and the maximum was

Table 30. Effect of treatments on the number of tubers plant^{-1}

	Total no.of tubers		No.of marketable tubers	
Treatments	1990	1991	1990	1991
i_1	2.50	2.34	1.66	1.59
i_2	2.26	2.11	1.52	1.44
i_3	2.55	2.39	1.70	1.62
SE	0.006	0.007	0.010	0.014
CD	0.024	0.021	0.040	0.054
n_1	2.29	2.17	1.59	1.52
n_2	2.45	2.29	1.64	1.57
n_3	2.49	2.30	1.62	1.53
SE	0.041	0.031	0.038	0.023
CD	0.123	0.093	---	---
k_1	2.32	2.18	1.56	1.51
k_2	2.48	2.31	1.68	1.60
k_3	2.43	2.25	1.61	1.51
SE	0.041	0.031	0.038	0.023
CD	0.123	0.093	---	0.069

Levels of K	Levels of N					
	1990(total)			1991(total)		
	n_1	n_2	n_3	n_1	n_2	n_3
k_1	2.31	2.26	2.38	2.18	2.16	2.21
k_2	2.28	2.67	2.49	2.15	2.48	2.30
k_3	2.28	2.41	2.60	2.17	2.22	2.38
	SE		CD	SE		CD
	0.072		0.213	0.054		0.161
	Marketable			Marketable		
k_1	1.62	1.51	1.56	1.54	1.48	1.50
k_2	1.58	1.82	1.63	1.52	1.75	1.53
k_3	1.57	1.58	1.66	1.50	1.48	1.55
	SE		CD	SE		CD
	0.066		---	0.040		0.119

FIG. 11. EFFECT OF TREATMENTS ON TOTAL NUMBER OF TUBERS



recorded by n_3 (2.30-2.49) which was on a par with n_2 and both were significantly superior to n_1.

Potassium also influenced the number of tubers per plant and the maximum was noticed at k_2 (2.31-2.48) level which was on a par with k_3 and significantly superior to k_1.

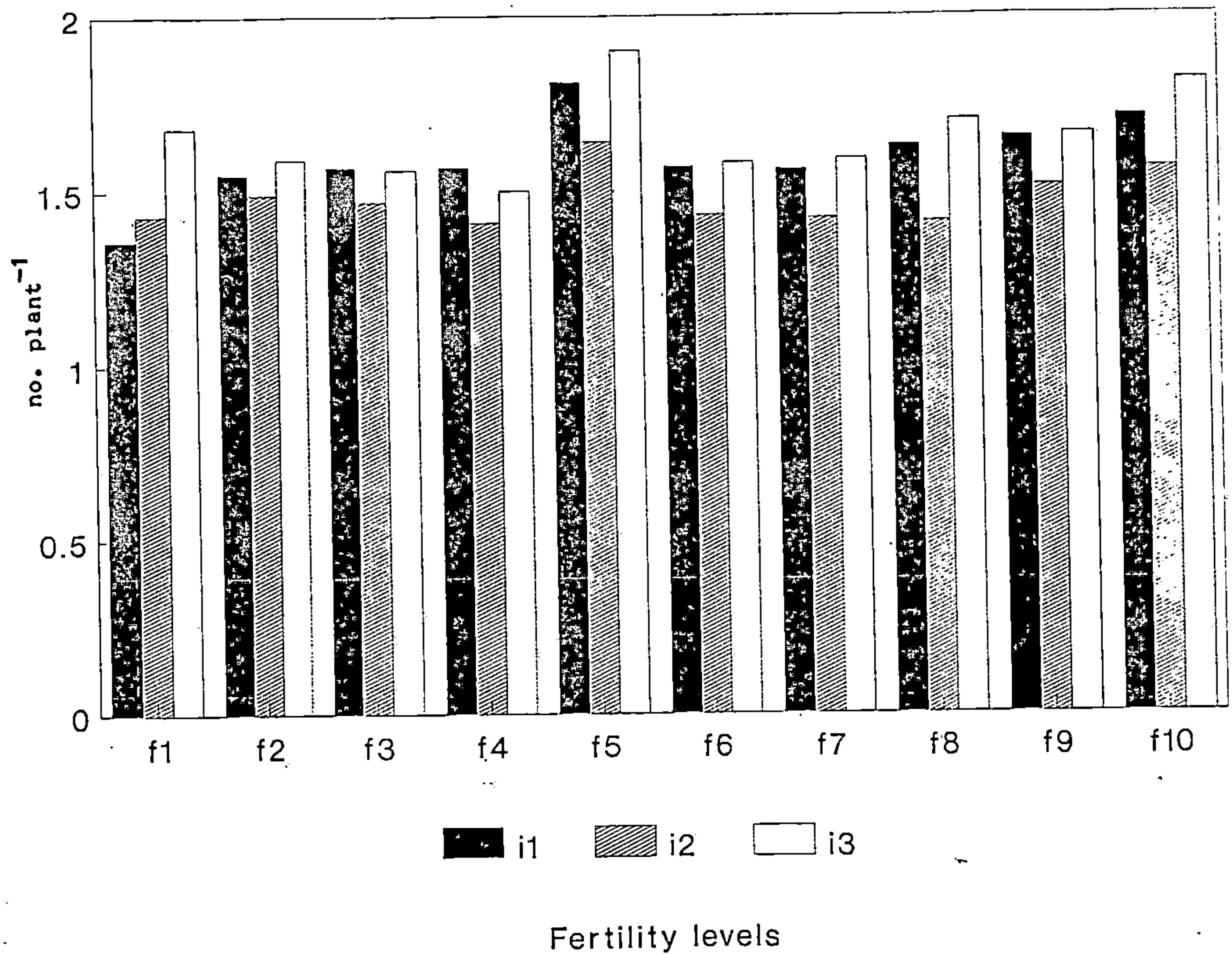
The interaction effect of nitrogen x potassium(Table 31) was significant in both the seasons. When N was combined with K, no significant difference in number of tubers plant^{-1} was observed at k_1 level in the first season. However, the combination of N with k_2 and k_3 registered a significant increase in the number of tubers at n_2k_2 and n_3k_3 but both remained on a par. Further, N in combination with K showed a diminishing return from n_2k_2 to n_2k_3. In the second season, almost the same trend was visible.

Pooled analysis of the data revealed the consistency of main effects and interaction in the case of total number of tubers.

4.4.4 Number of marketable tubers

The data on number of marketable tubers per plant is presented in Table 30 and Fig.12. Irrigation schedules significantly influenced the number of marketable tubers

FIG. 12. EFFECT OF TREATMENTS ON NO. OF MARKETABLE TUBERS



where i_1 and i_3 (1.59-1.70) schedules were significantly superior to i_2 in both the seasons.

Varying the level of nitrogen application did not influence the number of marketable tubers per plant.

In the second season, the influence of potassium was visible in altering the number of marketable tubors per plant where k_2 (1.60-1.68) level registered its superiority over k_3 and k_1.

As regards, the number of marketable tubers, a trend similar to total number of tubers was noticed in the second season, although no significant difference was noticed in the first season.

4.4.5 Mean tuber weight

The data on mean tuber weight presented in Table 32 show significant variation due to scheduling of irrigation in the first season. The i_3 and i_1 (88.60-89.07 g) schedules were significantly superior to i_2 schedule and both remained on a par.

Different levels of nitrogen and potassium had in no way influenced the mean tuber weight.

Table 32. Effect of treatments on mean tuber weight(g)

Treatments	Mean tuber weight 1990	1991
i_1	88.60	86.30
i_2	82.90	82.23
i_3	89.07	84.73
SE	0.919	0.951
CD	3.609	---
n_1	86.30	83.52
n_2	89.18	86.37
n_3	85.26	84.00
SE	1.834	1.612
k_1	86.22	84.67
k_2	87.52	84.59
k_3	87.00	84.63
SE	1.834	1.612

4.4.6 Total tuber yield

Total tuber yield as influenced by treatments are presented in Tables 33, 34 and 35 and in Fig.13. Irrigation schedules remarkably influenced the total tuber yield in both the seasons where i_1 and i_3 (16.79 to 18.90 t ha^{-1}) schedules remained on a par and registered their superiority over i_2 (14.37 to 15.78 t ha^{-1}).

The influence of N in modifying the total tuber yield was revealed in both the seasons. The n_2 level that registered the maximum tuber yield (16.44-18.18 t ha^{-1}) remained on a par with n_3 and both were superior to n_1. Potassium also played a significant role in influencing the total tuber yield in both the seasons. The level k_2, registered the maximum yield (16.28-18.10 t ha^{-1}) and remained on a par with k_3. Both k_2 and k_3 levels were significantly superior to k_1 level.

The interaction effects of irrigation x nitrogen and irrigation x potassium (Table 34) on total tuber yield were found significant in the first season. Irrigation at i_3 schedule resulted in the highest total tuber yield with n_2 level which was on a par with i_3n_3 and i_1n_2. But when i_2 was applied, the yield decreased without registering any

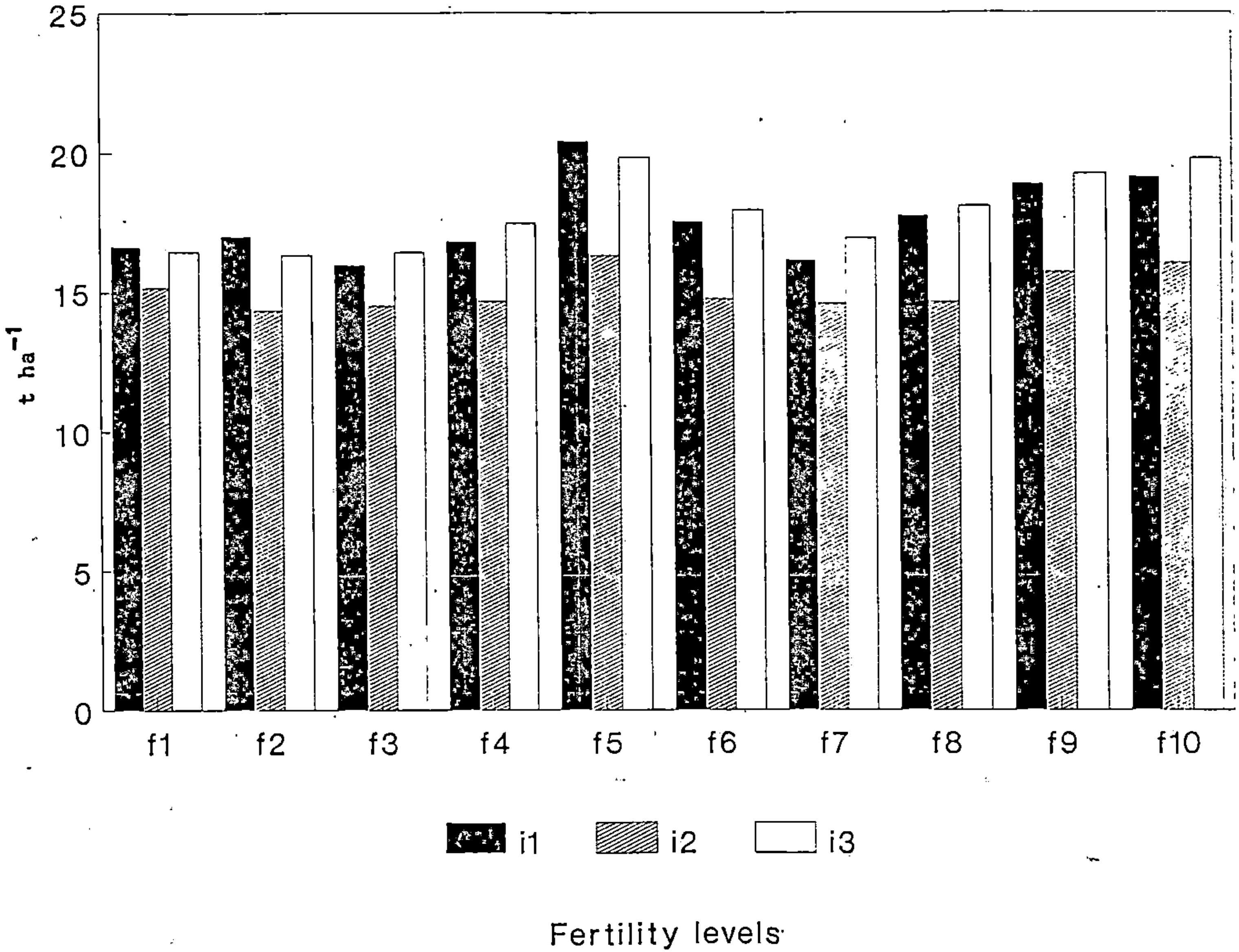
Table 33. Effect of treatments on tuber yield (t ha^{-1})

	Total tuber yield		Marketable tuber yield	
Treatments	1990	1991	1990	1991
i_1	18.48	16.79	17.00	15.40
i_2	15.78	14.37	14.39	13.25
i_3	18.90	16.79	17.42	15.37
SE	0.156	0.171	0.178	0.167
CD	0.614	0.672	0.699	0.654
n_1	16.72	15.03	15.35	13.90
n_2	18.18	16.44	16.78	15.12
n_3	17.72	16.05	16.24	14.69
SE	0.231	0.217	0.182	0.213
CD	0.685	0.644	0.541	0.632
k_1	16.87	15.35	15.40	14.11
k_2	18.10	16.28	16.71	14.99
k_3	17.65	15.91	16.26	14.62
SE	0.231	0.217	0.182	0.213
CD	0.685	0.644	0.541	0.632

Table 34. Interaction effect of I x N and I x K on total tuber yield (t ha^{-1}) in 1990

Irrigation schedule	Levels of N			Levels of K		
	n_1	n_2	n_3	k_1	k_2	k_3
i_1	17.41	19.05	18.37	17.25	19.26	18.32
i_2	15.48	15.92	15.62	15.60	15.80	15.61
i_3	17.27	19.56	19.16	17.75	19.23	19.01
	SE		CD	SE		CD
	0.303		0.870	0.303		0.870

FIG. 13. EFFECT OF TREATMENTS ON TOTAL TUBER YIELD



interaction effect with varying levels of N. As regards irrigation x potassium, the combination of i_1k_2, i_3k_3 and i_3k_2 were on a par in the first season which suggest that both i_1n_2 and i_1k_2 are the best for securing maximum total tuber yield though no such significance was observed in the second season.

The interaction effect of nitrogen x potassium(Table 35) was observed in both the seasons wherein n_2k_2 registered the maximum total tuber yield of 19.87 and 17.82 t ha^{-1} in the first and second seasons respectively. The combination of n_2k_2 remained on a par with the control treatment in both the seasons and was on a par with n_3k_3 in the second season. The lowest yield was recorded by n_1k_3 in both the seasons.

All the factors behaved consistently over the period as their interaction with season was not significant.

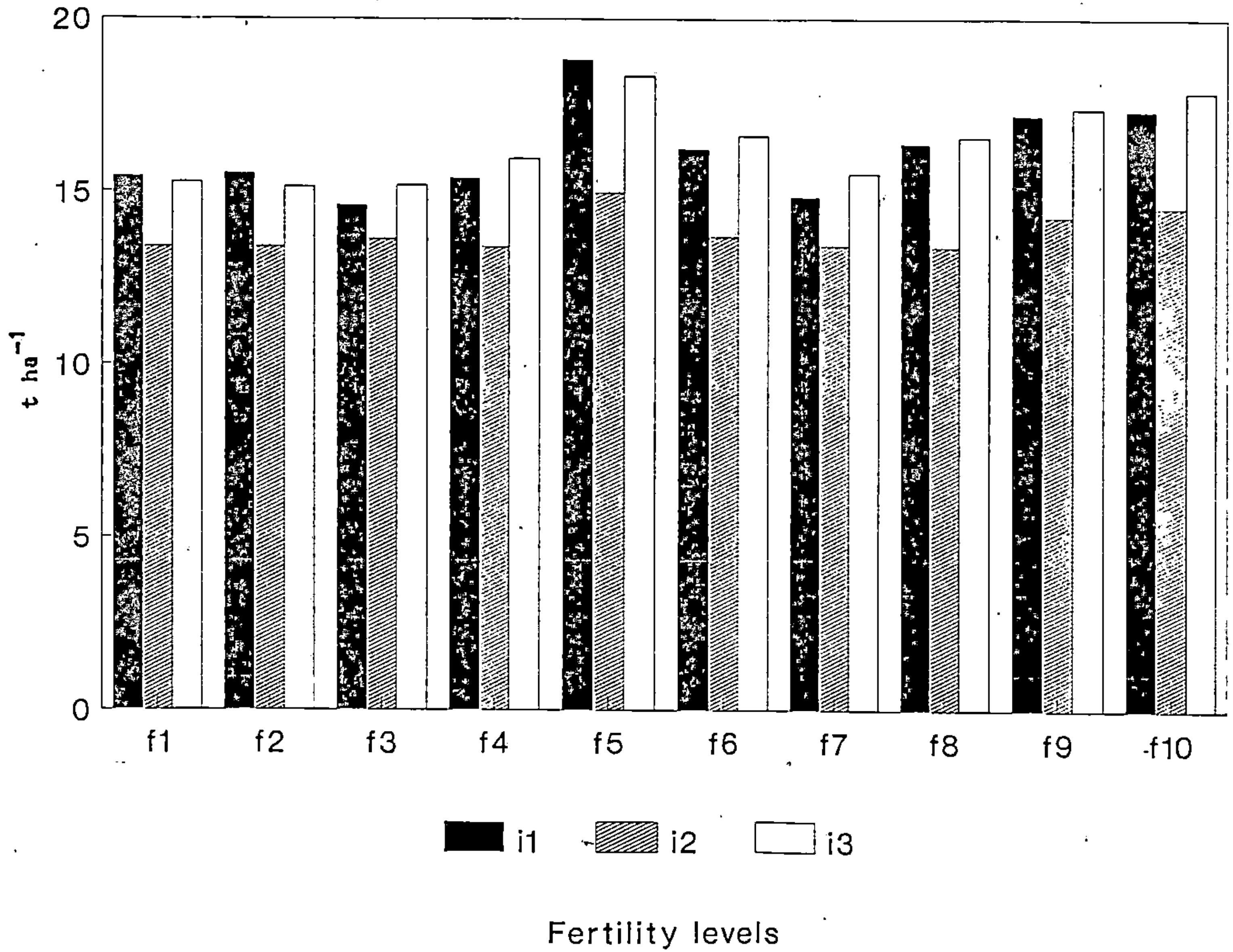
4.4.7 Marketable tuber yield

The data on marketable tuber yield is presented in Table 33 and Fig.14. Irrigation schedule significantly influenced the marketable tuber yield where i_1 and i_3 (15.37-17.42 t ha^{-1}) remained on a par and registered their superiority over i_2 in both the seasons.

Table 35. Interaction effect of nitrogen and potassium on tuber yield (t ha^{-1})

Levels of K	Levels of N					
	1990(total)			1991(total)		
	n_1	n_2	n_3	n_1	n_2	n_3
k_1	16.94	17.05	16.61	15.25	15.62	15.16
k_2	16.67	19.87	17.76	15.12	17.82	15.90
k_3	16.56	17.61	18.78	14.73	15.88	17.11
	SE		CD	SE		CD
	0.399		1.187	0.375		1.115
	1990 (Marketable)			1991 (Marketable)		
k_1	15.27	15.62	15.30	14.14	14.23	13.94
k_2	15.42	18.37	16.35	13.97	16.40	14.58
k_3	15.36	16.34	17.07	13.60	14.72	15.53
	SE		CD	SE		CD
	0.315		0.936	0.368		1.095

FIG. 14. EFFECT OF TREATMENTS ON MARKETABLE TUBER YIELD



Nitrogen application also showed a positive response wherein n_2 was superior (15.12-16.78 t ha^{-1}) to n_1 and remained on a par with n_3. However, increasing the level of N beyond n_2 was not favourable for high yield.

Application of potassium also showed significant response wherein k_2 recorded the highest yield (14.99-16.71) and k_1 the lowest in both the seasons.

As regards the marketable tuber yield, the interaction effect of nitrogen x potassium (Table 35) was pronounced in both the seasons. During the first season, n_2k_2(18.37 t ha^{-1}) recorded significantly higher yield as compared to other combinations and remained on a par with control. However, in the second season both n_2k_2 and n_3k_3 were on a par with control. The marketable tuber yield was lowest in the combination n_1k_1 in the first season and n_1k_3 in the second season.

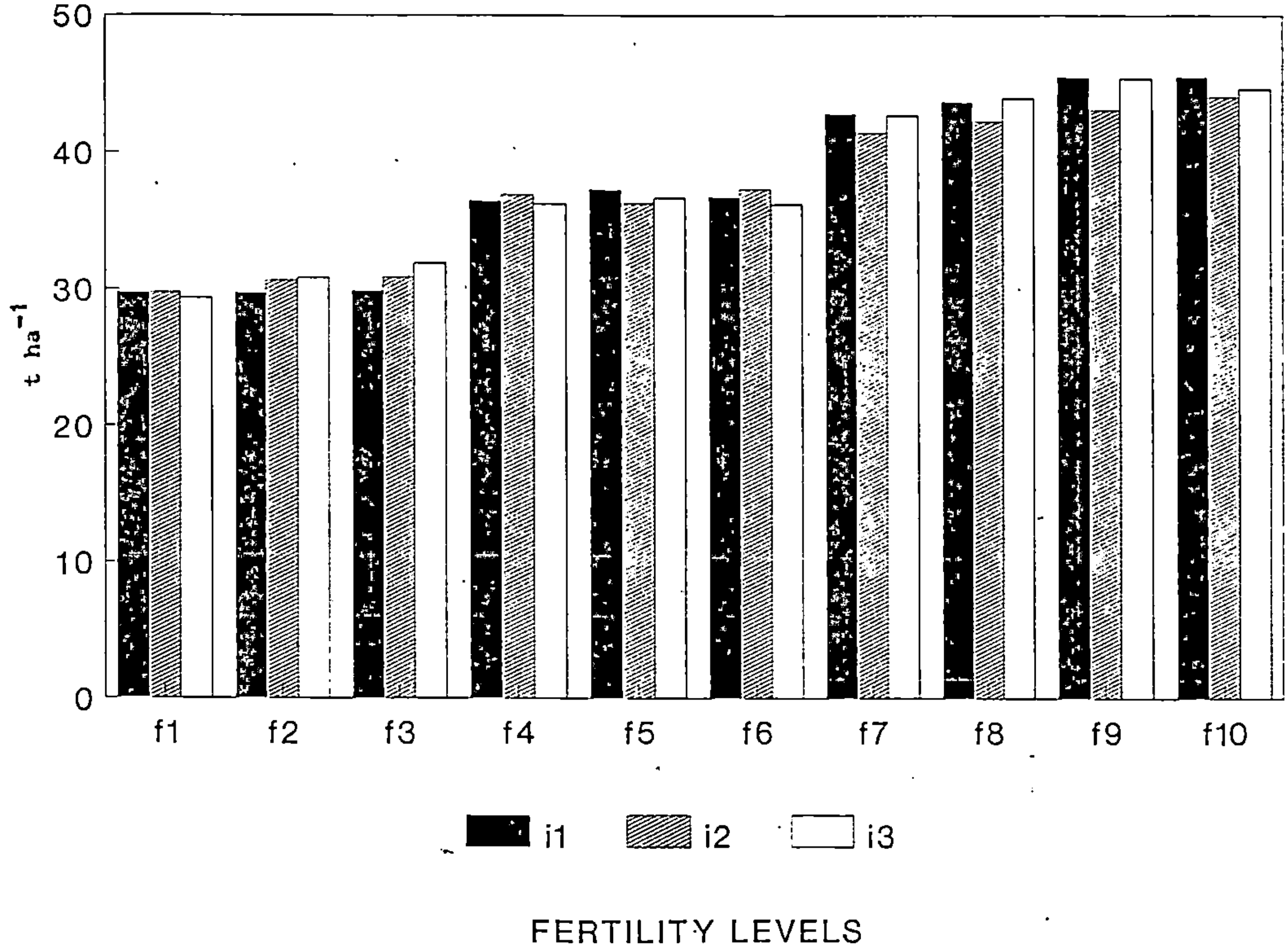
4.4.8 Vine yield

The vine yield recorded by the first and second season crops are presented in Table 36 and in Fig.15. In both the seasons, irrigation schedules failed to record any significant difference in vine yield.

Table 36. Effect of treatments on the vine yield (t ha^{-1})

Treatments	Vine yield 1990	Vine yield 1991
i_1	40.36	34.91
i_2	40.14	34.34
i_3	40.26	35.30
SE	0.244	0.494
n_1	32.36	28.22
n_2	40.17	33.19
n_3	45.79	40.80
SE	0.724	0.511
CD	2.152	1.520
k_1	38.61	33.67
k_2	39.41	34.23
k_3	40.30	34.32
SE	0.724	1.612

FIG. 15. EFFECT OF TREATMENTS ON VINE YIELD



Nitrogen supply profoundly influenced the vine yield in both the seasons. Vine yield was remarkably enhanced by nitrogen application, the maximum being at n_3 (40.80-45.79 t ha^{-1}) and minimum at n_1 level.

Potassium did not influence the vine yield to any appreciable extent. None of the interaction effects were significant with regard to vine yield.

4.4.9 Utilization index (UI)

The utilization index as observed at harvest in both the seasons is presented in Table 37. Irrigation schedules influenced the UI in both the seasons, i_1 and i_3 (46.83-49.57%) remained on a par and retained their superiority over i_2.

Different levels of nitrogen also played a significant role in influencing the UI. Increasing the level of N decreased the UI in both the seasons.

Potassium did not influence the UI in both the seasons.

4.4.10 Harvest index (HI)

The influence of various treatments on the HI is presented in Table 37. Irrigation schedule influenced the HI

Table 37. Utilization index (UI) and Harvest index (HI) as affected by treatments

Treatments	Utilization index 1990	Utilization index 1991	Harvest index 1990	Harvest index 1991
i_1	46.83	49.57	44.72	48.14
i_2	39.50	42.93	41.74	48.00
i_3	48.00	48.42	44.28	47.37
SE	0.581	1.287	0.462	0.466
CD	2.280	5.055	1.815	---
n_1	51.47	53.61	46.75	48.87
n_2	45.46	49.71	44.00	47.85
n_3	38.68	39.41	40.82	47.12
SE	0.997	0.934	0.767	0.293
CD	2.965	2.774	2.280	0.873
k_1	44.18	46.93	44.90	46.74
k_2	46.79	48.77	43.63	48.41
k_3	44.64	47.04	43.04	48.68
SE	0.997	0.934	0.767	0.293
CD	---	---	---	0.873

only in the first season where both i_1 and i_3(44.28-44.72%) remained on a par and were significantly superior to i_2.

Varying the levels of N significantly influenced the HI in both the seasons. The n_1 (46.75-48.87%) level was significantly superior to n_2 and n_3 levels while n_2 was superior to n_3 in the first season only.

Potassium modified the HI in the second season while there was no influence in the first season. The higher levels of K registered their superiority (48.41-48.68%) over the lowest level, however, k_2 and k_3 remained on a par.

4.5. Quality parameters

4.5.1 Cooking quality

Irrigation schedules influenced the cooking quality of the tubers to some extent(Table 38). The tubers were more or less fibrous in plots that received i_1 or i_3 schedules of irrigation while those of i_2 schedule were non-fibrous in nature. No definite trend could be noticed in the taste and texture of the cooked tubers.

As regards nitrogen supply, both n_2 and n_3 levels produced fibrous tubers which were sweet in taste and soft in texture. The plots that received n_1 level produced non-

Table 38. Effect of treatments on the cooking quality of tubers

Treatments	Fibre content	Sweetness	Texture
i_1	Fibrous	Medium sweet	Medium soft
i_2	Non fibrous	Medium sweet	Soft
i_3	Fibrous	Sweet	Soft
n_1	Non fibrous	Medium Sweet	Medium soft
n_2	Fibrous	Sweet	Soft
n_3	Fibrous	Sweet	Soft
k_1	Fibrous	Medium sweet	Medium soft
k_2	Non fibrous	Medium sweet	Medium soft
k_3	Non fibrous	Medium sweet	Medium soft

fibrous tubers with medium taste and texture.

Application of potassium at the highest level(k_3) resulted in the production of non-fibrous tubers. The tubers were medium in taste and texture.

4.5.2 Starch content

Starch content of the tuber presented in Table 39 show no significant variation due to scheduling of irrigation.

There was significant variation in starch content with the application of nitrogen. Starch content was maximum at the medium level of n_2 (19.62-19.64%) which was significantly superior to both n_1 and n_3. However, there was no difference in starch content between n_1 and n_3 levels.

Potassium played a significant role in enhancing the starch content of tuber. The maximum starch content was at k_3 (19.81-19.83%) level and was significantly superior to k_2 and k_1 levels. The level k_2 was significantly superior to k_1.

4.5.3 Sugar content

The sugar content of the tuber presented in Table 39 did not show any variation by scheduling of irrigation.

Table 39. Starch and sugar content of tuber (% on FW basis)

	Starch content		Sugar content	
Treatments	1990	1991	1990	1991
i_1	19.60	19.65	2.94	2.94
i_2	19.27	19.41	2.96	2.95
i_3	19.26	19.44	2.94	2.98
SE	0.166	0.058	0.022	0.011
n_1	19.18	19.34	2.89	2.91
n_2	19.62	19.64	2.96	2.96
n_3	19.27	19.44	2.98	2.98
SE	0.097	0.057	0.021	0.016
CD	0.289	0.171	0.063	0.047
k_1	18.89	19.06	2.85	2.86
k_2	19.38	19.54	2.95	2.96
k_3	19.81	19.82	3.03	3.03
SE	0.097	0.057	0.021	0.016
CD	0.289	0.171	0.063	0.047

Nitrogen application at n_3 (2.98%) level recorded the maximum sugar content and remained on a par with n_2 level. Both n_3 and n_2 levels were significantly superior to n_1 level.

Increased rates of potassium application significantly enhanced the sugar content. Sugar content was maximum when potassium was applied at k_3 (3.03%) level. The level k_3 remained on a par with k_2 in the first season while it was significantly superior to both k_1 and k_2 in the second season. In both the seasons, k_2 was superior to k_1.

4.6. Nutrient uptake

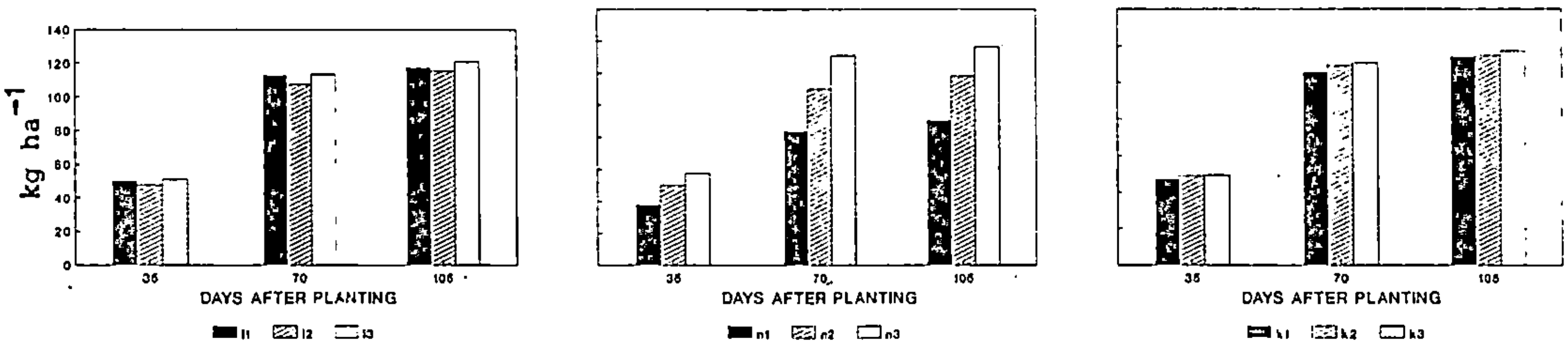
4.6.1 Nitrogen uptake

The total uptake of nitrogen (vines and roots/tubers) as influenced by various treatments is presented in Table 40 and Fig.16. Scheduling of irrigation influenced the total nitrogen uptake especially at harvest in the first season where both i_1 and i_3(123.01-125.28 kg ha^{-1}) maintained their superiority over i_2. In the second season, again i_1 and i_3 were significantly superior to i_2 at 35 and 70 days after planting.

Table 40. Effect of treatments on the uptake of nitrogen(kg ha^{-1})

Treatments	1990 Days after planting 35	70	Harvest	1991 Days after planting 35	70	Harvest
i_1	52.48	112.66	123.01	48.14	113.79	114.05
i_2	50.09	109.43	116.42	44.74	105.59	112.06
i_3	52.31	113.73	125.28	49.34	113.05	116.38
SE	0.859	1.434	1.470	0.889	1.615	1.935
CD	---	---	5.772	3.493	6.339	---
n_1	38.44	83.66	93.81	37.51	84.86	87.98
n_2	52.79	110.71	122.63	47.40	110.20	113.94
n_3	60.41	132.99	138.82	54.35	129.30	134.08
SE	0.615	1.067	2.016	1.177	2.951	1.997
CD	1.826	3.171	5.991	3.497	8.768	5.938
k_1	49.48	104.51	116.43	44.85	107.20	111.84
k_2	50.75	110.52	118.94	47.20	108.01	110.81
k_3	51.41	112.34	120.88	47.20	109.14	113.35
SE	0.615	1.067	2.016	1.177	2.951	1.997
CD	---	3.171	---	---	---	---

FIG. 16. EFFECT OF TREATMENTS ON UPTAKE OF NITROGEN



Schedule of irrigation

Levels of nitrogen

Levels of potassium

The influence of added levels of nitrogen on the uptake of nitrogen was pronounced at all stages of observation. Applying nitrogen at the highest level, namely n_3 registered significantly higher uptake as compared to the lower levels. The level n_2, also maintained its superiority over the lowest level of n_1 throughout the period of observation.

Uptake of nitrogen was significantly influenced by varying the levels of potassium only at 70 DAP in the first season. Potash at the highest level, namely k_3 (112.34 kg ha^{-1}) was on a par with k_2 and both remained superior to k_1. However, in all other stages of observation, no significant superiority was observed, though the highest level recorded the maximum uptake of nitrogen.

4.6.2 Phosphorus uptake

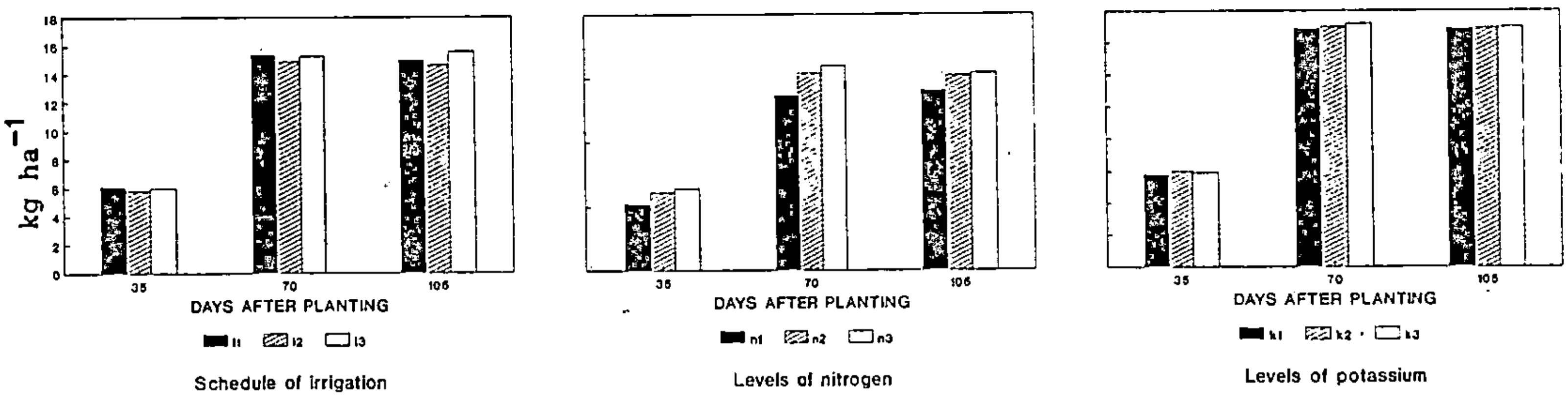
The total uptake of phosphorus by vines and roots/tubers is presented in Table 41 and Fig.17. A significant increase in uptake of phosphorus was observed only at harvest in the first season by scheduling of irrigation. Providing irrigation at i_3(15.84 kg ha^{-1}) and i_1 schedules recorded significantly higher uptake of phosphorus as compared to i_2 schedule.

Nitrogen profoundly influenced the uptake of phosphorus

Table 41. Effect of treatments on the uptake of phosphorus(kg ha^{-1})

	1990 Days after planting			1991 Days after planting		
Treatments	35	70	Harvest	35	70	Harvest
i_1	6.03	15.74	15.50	6.15	15.03	14.42
i_2	5.82	15.08	14.30	5.73	14.76	14.86
i_3	6.16	15.87	15.84	5.91	14.79	15.38
SE	0.092	0.189	0.184	0.103	0.408	0.277
CD	---	---	0.724	---	---	---
n_1	5.02	13.88	14.63	5.43	13.52	13.65
n_2	6.22	15.71	15.38	6.17	15.34	15.57
n_3	6.56	16.74	15.34	6.17	15.34	15.57
SE	0.062	0.190	0.223	0.112	0.412	0.219
CD	0.184	0.563	---	0.324	1.226	0.650
k_1	5.86	15.15	15.08	5.71	14.71	14.71
k_2	5.92	15.61	15.09	6.03	14.45	14.69
k_3	6.02	15.57	15.18	5.85	14.76	14.87
SE	0.062	0.190	0.223	0.112	0.412	0.219

FIG. 17. EFFECT OF TREATMENTS ON UPTAKE OF PHOSPHORUS



at all the stages except at harvest in the first season. The highest level of n_3 registered the maximum uptake of phosphorus, though it maintained parity with n_2 level at certain stages of observation.

Potassium did not influence the uptake of phoshorus at any of the growth stages.

4.6.3 Potassium uptake

The total uptake of potassium by vines and roots/tubers are presented in Table 42 and Fig.18. Irrigation schedules did not influence the uptake of potassium except at harvest in the first season where i_3 (177.69 kg ha^{-1}) schedule registered the maximum and remained on a par with i_1. Both i_3 and i_1 schedules registered their superiority over i_2 schedule.

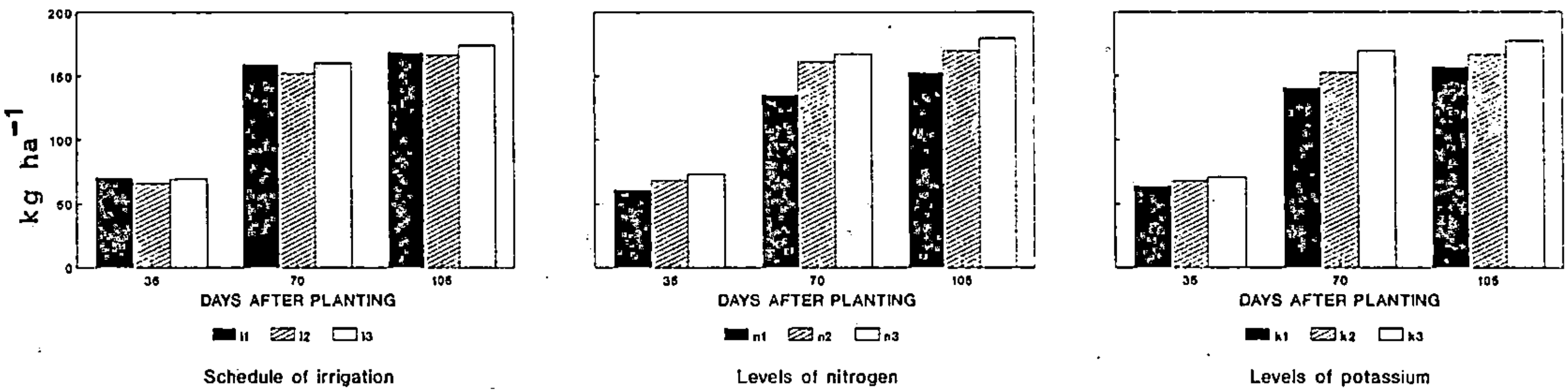
Nitrogen very much influenced the uptake of potassium at all the stages of observation. Applying nitrogen at n_3 level registered significantly higher uptake of potassium as against n_2 and n_1 levels except at 70 DAP in the second season where both n_2 and n_3 remained on a par.

Uptake of potassium also showed a steady increase by enhanced potash application. Potash application at k_3 level

Table 42. Effect of treatments on the uptake of potassium (kg ha^{-1})

	1990 Days after planting			1991 Days after planting		
Treatments	35	70	Harvest	35	70	Harvest
i_1	70.10	159.84	174.89	71.44	159.13	162.28
i_2	65.41	157.69	165.82	66.33	147.16	167.36
i_3	69.80	163.37	177.69	68.53	158.01	170.47
SE	1.055	1.150	1.436	3.838	3.500	4.109
CD	---	---	5.638	---	---	---
n_1	58.22	138.54	156.75	63.72	132.01	149.22
n_2	67.28	159.75	173.11	66.67	162.82	166.32
n_3	74.53	173.31	179.41	72.18	161.04	179.42
SE	0.683	1.848	2.136	2.024	5.984	2.405
CD	2.030	5.490	6.347	6.015	17.782	7.146
k_1	65.70	142.57	156.65	62.74	139.72	158.42
k_2	68.04	158.03	168.65	67.45	147.70	165.11
k_3	69.29	171.00	183.96	72.39	168.44	171.42
SE	0.683	1.848	2.136	2.024	5.984	2.405
CD	2.030	5.490	6.347	6.015	17.782	7.146

FIG. 18. EFFECT OF TREATMENTS ON UPTAKE OF POTASSIUM



registered the maximum uptake and was on a par with k_2 at certain stages. Potassium uptake was the lowest at the k_1 level in all the stages of observation.

4.7. Soil analysis

4.7.1 Available nitrogen content

Available N content of the soil as influenced by scheduling of irrigation was not pronounced at any of the stages of observation as is evidenced from Table 43.

Nitrogen content of the soil, however, showed an improvement after the first crop of sweet potato when the level of nitrogen was increased from n_1 to n_3. There was, however, no improvement in the N status of the soil after the harvest of the second crop of sweet potato.

Application of potassium did not influence the N status of the soil to any appreciable extent.

4.7.2 Available phosphorus

The available phosphorus content of the soil presented in Table 44 did not reveal any significant influence for the irrigation schedule.

Table 43. Available nitrogen content (kg ha^{-1}) of the soil

Treatments	Time of sampling: At harvest of 1^{st} crop	After 1^{st} paddy crop	After 2^{nd} paddy crop	At Harvest of 2^{nd} crop
i_1	367.9	330.6	386.7	366.7
i_2	365.9	327.6	382.3	361.2
i_3	366.7	330.1	381.7	360.7
SE	2.36	2.43	2.29	2.25
n_1	358.5	327.3	388.0	359.8
n_2	366.9	327.8	384.0	362.5
n_3	374.2	330.1	380.5	366.6
SE	2.22	2.33	2.40	2.37
CD	6.61	---	---	---
k_1	368.2	330.2	385.6	367.0
k_2	363.9	325.7	381.9	360.45
k_3	367.4	329.4	385.1	361.5
SE	2.22	2.33	2.40	2.37

Table 44. Available phosphorus content (kg ha^{-1}) of the soil

Treatments	Time of sampling			
	At harvest of 1^{st} crop	After 1^{st} paddy crop	After 2^{nd} paddy crop	At harvest of 2^{nd} crop
i_1	37.3	30.8	37.3	40.8
i_2	37.0	31.0	37.2	40.7
i_3	36.5	30.6	36.6	41.6
SE	0.52	0.77	0.87	1.05
n_1	40.8	34.8	41.2	45.9
n_2	37.8	31.8	37.6	40.7
n_3	33.5	27.3	33.8	37.6
SE	0.98	0.99	1.01	1.01
CD	2.93	2.93	3.00	3.01
k_1	38.3	32.0	38.4	42.1
k_2	37.3	31.4	37.7	41.5
k_3	36.5	30.5	36.5	40.6
SE	0.98	0.99	1.01	1.01

Influence of applied N in modifying the available phosphorus content was visible at any of the stages of observation. Available P content was maximum in plots receiving n_1 level of nitrogen and minimum in plots receiving n_3 level. The P status of the soil was in the middle range when N was applied at n_2 level.

Potassium did not in any way influence the P status of the soil.

4.7.3 Available potassium

The available potassium content of the soil as influenced by treatments is presented in Table 45. Irrigation schedules did not influence the available potassium content of the soil.

Potassium content of the soil showed a clear decline wherever the applied nitrogen was high. The available potassium content of the soil was lowest at n_3 level and highest at n_1 level. The differences between n_1 and n_2 levels were also significant at any stage.

On the contrary, there was a definite improvement in the potassium status of the soil when potassium was applied to

Table 45. Available potassium content (kg ha^{-1}) of the soil

Treatments	Time of sampling: At harvest of 1st crop	After 1st paddy crop	After 2nd paddy crop	At harvest of 2nd crop
i_1	87.4	76.2	99.2	95.2
i_2	93.8	79.1	104.2	99.1
i_3	88.7	76.0	101.3	96.5
SE	1.53	1.27	2.38	2.60
n_1	98.2	83.4	108.3	103.1
n_2	87.4	76.5	101.5	96.2
n_3	82.0	70.7	95.3	91.6
SE	1.56	1.48	1.79	1.66
CD	4.63	4.41	5.31	4.94
k_1	81.2	71.7	98.3	92.7
k_2	88.8	76.8	101.2	96.6
k_3	97.5	82.2	105.6	101.5
SE	1.56	1.48	1.79	1.66
CD	4.63	4.41	5.31	4.94

the soil at higher rates. Application of K at the highest level resulted in a significant improvement in the potassium content of the soil as compared to the lowest level. However, in the last two observations, there was no definite difference between k_1 and k_2 and between k_2 and k_3.

4.8. Water use efficiency

The field water use efficiency calculated in kilogram tuber per hectare - millimetre water used is presented in Table 46. Irrigation schedule profoundly influenced the water use efficiency wherein i_1 and i_3 schedules were on a par and significantly superior to i_2 schedule. In the first season, i_3 schedule recorded 26.63 kg ha^{-1} mm^{-1} while i_1 schedule recorded 26.04 kg ha^{-1} mm^{-1}. In the second season, a reverse trend was noticed where i_1 recorded 26.86 kg ha^{-1} mm^{-1} while it was 26.42 kg ha^{-1} mm^{-1} for i_3 schedule.

Nitrogen profoundly influenced the water use efficiency where n_2 level recorded the maximum and remained on a par with n_3. Both n_2 and n_3 levels were significantly superior to n_1 level.

Potassium also influenced the water use efficiency wherein k_2 level registered the maximum and remained on a par

Table 46. Effect of treatments on water use efficiency (kg ha^{-1} mm^{-1})

Treatments	1990	1991
i_1	26.04	26.86
i_2	24.03	24.74
i_3	26.63	26.42
SE	0.247	0.278
CD	0.969	1.091
n_1	23.95	24.48
n_2	26.30	26.74
n_3	25.64	26.10
SE	0.271	0.351
CD	0.805	1.043
k_1	24.16	24.97
k_2	26.19	26.48
k_3	25.55	25.88
SE	0.271	0.351
CD	0.805	1.043

with k_3 in both the seasons. The k_2 and k_3 were significantly superior to k_1 in the first season whereas in the second season k_2 alone was superior to k_1.

The interaction effect of nitrogen x potassium(Table 47) was pronounced in both the seasons. Water use efficiency was maximum in n_2k_2 and was significantly superior to all other combinations in both the seasons. However, n_2k_2 remained on a par with n_3k_3 in the second season. The lowest water use efficiency was associated with n_1k_1 in the first season and with n_1k_3 in the second season.

Table 47. Interaction effect of nitrogen x potassium on water use efficiency (kg ha^{-1} mm^{-1})

Levels of K	Levels of nitrogen 1990 n_1	n_2	n_3	1991 n_1	n_2	n_3
k_1	23.72	24.69	24.06	24.82	25.41	24.69
k_2	24.13	28.74	25.69	24.62	28.98	25.85
k_3	23.98	25.48	27.17	24.00	25.84	27.82
	SE 0.470	CD 1.395		SE 0.608	CD 1.807	

Table 48. Total quantity of water received (mm)

	1990			1991		
Treatments	Irrigation	Rainfall	Total	Irrigation	Rainfall	Total
i_1	204.1	505.6	709.7	183.5	441.7	625.2
i_2	144.0	505.6	649.6	139.1	441.7	580.8
i_3	204.1	505.6	709.7	193.8	441.7	635.5

DISCUSSION

5. DISCUSSION

The results of the study presented in the previous chapter are discussed in this chapter.

5.1 Length of vine

The data on length of vine recorded at triweekly intervals from planting to harvest (Table 2) revealed that inducing stress by providing irrigation at 1/2 CPE during tuber initiation phase resulted in a reduction in vine length as compared to providing full CPE during the same period.

The metabolic activity of the plant cells is closely related to their water content. Water is essential for the maintenance of proper turgidity that promotes the growth of cells leading to the production of new leaves and shoots. Begg and Turner (1976) stated that any water stress may adversely affect the growth process. Reduction in length of vine in treatments that received irrigation at 1/2 CPE during tuber initiation phase may be due to the moisture stress. Inducing moisture stress during tuber initiation phase (CTCRI, 1985) and throughout the growth period reduced the vine length (Oommen, 1989) of sweet potato.

encourage the elongation of vines through its effect on rapid meristematic activity. A comparison of the data on tuber yield will reveal that there was no advantage by the addition of nitrogen beyond 50 kg ha^{-1}. Application of nitrogen above this level could, thus contribute only to enhanced vegetative growth. Similar increase in the length of vine due to higher levels of nitrogen application had been reported in sweet potato by several workers like Morita (1970), Knavel (1971), Nair (1972), Nair (1987) and Oommen (1989).

Varying the levels of potash did not influence the length of vine at any stage of growth in both the seasons. Differential response to applied potassium had been reported by CTCRI (1979) and Nicholaides et al. (1985). Nair (1987) could not observe any influence on vine length by the application of potash at 50, 75 and 100 kg ha^{-1}. This may probably be due to the lesser influence of potash on the vegetative growth of crops.

The interaction of irrigation x nitrogen was found to be significant at certain stages of plant growth. Application of 75 kg ha^{-1} nitrogen and full CPE during tuber initiation phase recorded significantly higher vine length as compared to 25 kg ha^{-1} N with 1/2 CPE at tuber intiation phase. Such a positive relationship between irrigation and nitrogen is expected as water stress inhibits the proper absorption and utilization of nutrients as a result of mid-day wilting (Bouwkamp, 1989).

5.2 Number of branches $plant^{-1}$

The data on number of branches $plant^{-1}$ as observed at various stages of plant growth was not influenced by scheduling of irrigation (Table 4). In both the seasons, the maximum number of branches $plant^{-1}$ were observed at 63 DAP. There was a reduction in the number of branches as the plants advanced in maturity. The withering of branches leading to a reduction in the number of active branches $plant^{-1}$ is expected as they face severe competition for light which hastens the senescence without further elongation. Bouwkamp (1983) observed that there was a slow increase in vine dry weight that reached a peak at 14-16 weeks after transplanting and then slowly decreased towards harvest.

The number of branches $plant^{-1}$ was very much modified by the amount of applied nitrogen wherein the higher levels resulted in the production of more branches. Hafizuddin and Haque (1979) reported that number of branches $plant^{-1}$ and weight of vines/plot were maximum at 78.52 kg ha^{-1} N and no K.

The increase in the uptake of nitrogen would have led to the proliferation of tissues which in turn might have favoured the production of more number of branches. Vigorous growth of vines as a consequence of increased nitrogen supply was reported by Morita (1970) and Nair (1972) in sweet potato. Wahua and Ordu (1986) also observed an increase in the number of branches by the application of fertilizers.

Potassium application did not influence the number of branches produced per plant at any stage of growth. It seems, potassium does not play a major role in modifying the aerial parts of the plant, rather it helps in the synthesis and translocation of carbohydrates to the developing tubers as reported by Tsuno and Fujise (1964 a).

Just like the length of vine, the interaction of irrigation x nitrogen significantly influenced the number of branches $plant^{-1}$ wherein providing full CPE at tuber initiation and/or tuber maturity phase with 75 kg ha^{-1} was superior to 1/2 CPE at tuber initiation phase with 25 kg ha^{-1} N.

5.3 Number of leaves $plant^{-1}$

The results presented in Table 6 showed significant influence on number of leaves retained $plant^{-1}$ at various stages of plant growth. Providing irrigation at full CPE during tuber initiation and/or tuber maturity phase was superior to providing 1/2 CPE during tuber initiation phase. Avoiding stress during the early part of plant growth may augment the vine elongation and production of more leaves.

The number of leaves $plant^{-1}$ depends primarily on the number of growing points (branches) and the rate of production of new leaves. Sweet potato plants continue to produce new leaves until harvest. Plateauing of number of leaves and leaf area per plant would indicate either a cessation of photosynthate allocation to the canopy or an increase in leaf loss commensurate with the rate of new leaf development (Somda and Kays, 1990).

Increasing the level of nitrogen from 25 kg to 75 kg ha^{-1} resulted in marked improvement in leaf production. The influence of nitrogen in promoting the growth of plants was visible by way of increased leaf area, vine length and number of branches $plant^{-1}$.

Potassium was found to influence the number of leaves produced per plant at 63 DAP in the second season where 75 and 50 kg ha^{-1} registered their superiority over 25 kg ha^{-1}. Leaf area index also showed its peak at 63 DAP and declined towards harvest. However, during the remaining nine out of ten observations, potassium application failed to record any significant improvement in leaf production.

The interaction effect of irrigation x nitrogen was pronounced wherein providing irrigation at full CPE during tuber initiation and/or tuber maturity phase with 75 kg ha^{-1} N was significantly superior to inducing stress during tuber initiation phase with 25 kg ha^{-1} N in promoting the leaf production.

5.4 Leaf area index

The data presented in Table 8 revealed that leaf area index was influenced significantly by scheduling of irrigation. Providing stress during tuber initiation phase registered a significantly lower value as compared to avoiding stress during tuber initiation and/or tuber maturity phase. Supplementing the full amount of water lost through evaporation ensured the proper growth of the plant resulting in more leaf production and a higher leaf area index. Hernandez and Hernandez (1969) and Oommen (1989) also reported increased vegetative growth and higher LAI in plots that received more water.

Nitrogen substantially increased the LAI at all stages of growth, the higher levels being superior to the lower levels. The LAI also showed a peak at 63 DAP while the lowest value was recorded at 21 DAP. The change in leaf area depends, almost entirely on the activity of apical meristems and on the growth and longevity of the leaves they produce. The number of leaves plant^{-1} also showed a peak at 63 DAP and declined thereafter. Haynes et al.(1970) suggested that the leaf area development of sweet potato cultivars was influenced by nitrogen.

According to Russel (1973), as nitrogen supply increases, the extra protein produced allows the plant foliage to grow larger and hence increases the surface area available for photosynthesis. When the concentration of nitrogen in the plant is high, more of the dry matter produced is distributed to the aerial parts increasing the LAI. Tsuno (1981) and Oommen (1989) also reported that there is a linear relationship between nitrogen absorption and LAI.

The leaf area index showed significant variation at 63 DAP in the first season and at 63 and 84 DAP in the second season by varying the levels of potash. However, during the other stages of observation, no significant effect was observed. The beneficial effect of a higher level of potassium on this growth character may be through its indirect influence in enhancing the availability of nitrogen to plants. According to Tsuno and Fujise (1964 a), potassium helps to increase the photosynthetic activity by maintaining an optimum leaf area index and promotes the translocation of carbohydrates to the developing tubers. Bourke (1985) and Oommen (1989) also reported an increase in leaf area index of sweet potato by the application of potassium.

Interaction effect of irrigation x nitrogen was pronounced at two stages in the first season and at four stages in the second season indicating that both irrigation and nitrogen help in building up of leaf area. Irrigation at full CPE during tuber initiation and/or tuber maturity phase with 75 kg ha^{-1} nitrogen was always superior to inducing stress at tuber initiation phase and supplementing with 25 kg ha^{-1} N. Since both irrigation and nitrogen exerted significant influence in enhancing the LAI, naturally the interaction effect will be positive and significant.

5.5 Net assimilation rate (NAR)

The net assimilation rate expressed in g m^{-2} day^{-1} on Table 10 showed that inducing stress during tuber initiation phase was helpful in increasing the NAR in the early stages of plant growth. However, no such trend was noticed when the stress was imposed in the later stages of plant growth.

The influence of lower levels of nitrogen (25 kg ha^{-1}) in increasing the NAR was visible in both the seasons, particularly in the early stages of plant growth. However, the medium level (50 kg ha^{-1}) also showed its supremacy over the highest level of 75 kg ha^{-1} in later stages.

There is a linear relationship between nitrogen absorption and leaf area index. But a linear decline in the NAR with rise in LAI was reported by Watson (1958). This is because of the shading effect imparted by the upper leaves resulting in a reduction in the photosynthetic activity. Tsuno (1981) reported that in several kinds of plants, NAR was proportionately related to the logarithm of light intensity and also pointed out that the relative light intensity inside the plant community showed an exponential decline with increase in LAI. He further stated that, when the LAI is more than 1 in sweet potato, the light interception declines because of mutual shading of leaves even if the plants are capable of attaining the maximum net assimilation rate. The NAR gradually decreases with an increase in leaf area index.

The influence of potassium in altering the NAR was visible only in the first season where the highest level of 75 kg ha^{-1} potash registered its superiority over the lowest level of 25 kg ha^{-1} between 42 and 63 DAP. As the carbohydrate content in the blade is inversely proportional to the K content in the blade, K content and speed of photosynthesis are in direct proportion to each other. Fujise and Tsuno (1969) suggested that potassium contributes to high photosynthetic activity of leaves.

The interaction effect of irrigation x nitrogen was significant in many instances wherein imposing stress during tuber initiation phase combined with lowest level of nitrogen registered its superiority as the LAI was low. Avoiding stress during tuber initiation and/or tuber maturity phase and providing nitrogen at 75 kg ha^{-1} resulted in high LAI leading to low NAR. Chowdhury and Ravi (1990) reported an irregular trend in NAR of sweet potato throughout the growth period.

5.6 Crop growth rate (CGR)

The results presented in Table 12 revealed, that irrigation schedules played a significant role in enhancing the CGR till 63 DAP in both the seasons though no definite trend was visible in later stages of plant growth. Providing stress free conditions during tuber initiation and/or tuber maturity phase maintained high CGR as against inducing stress during tuber initiation phase. Bouwkamp (1989) attributed the low sink efficiency as a consequence of mid-day wilting resulting from moisture shortages that led to low rate of photosynthesis and assimilate translocation to the developing tubers.

The influence of nitrogen in modifying the CGR was visible in the first season whereas no clear cut trend was noticed in the second season. The higher levels of N maintained their superiority till 63 DAP whereas the lowest level registered higher values at later stages of growth. This may be attributed to the excessive vegetative growth resulting from high N and final show down of CGR due to mutual shading. As discussed earlier, there is a linear relationship between nitrogen levels and LAI which lead to a corresponding drop in NAR. Since CGR is the product of LAI and NAR, both have to remain at an optimum level through a judicious supply of nitrogen. Therefore, it may be argued that nitrogen application should not be too high, rather it should be moderate to achieve the desired CGR.

Potassium showed a trend of higher CGR by the application of 75 kg ha^{-1} potash. The lack of response to applied potassium in modifying the LAI and NAR may be the reason for the absence of significant variation in CGR.

The interaction effect of irrigation x nitrogen was significant in modifying the CGR in the early stages of plant growth. CGR was maximum in plots that received 75 kg ha^{-1} N and full CPE of irrigation during tuber initiation and/or tuber maturity phase. Thus, the combined effect of irrigation and nitrogen is evident in enhancing the CGR leading to high dry matter production from unit area. In Japan, Tsuno and Fujise (1963) observed crop growth rates of 120 g m^{-2} $week^{-1}$. A slightly higher crop growth rate of 150 g m^{-2} $week^{-1}$ in the experiments of Yoshida <u>et al</u>.(1970) in Japan, was recorded at 10 to 14 weeks after planting. In a similiar measurement, Enyi (1977) in Papua New Guinea reported the maximum growth rate of the highest yielding variety as 163 g m^{-2} $week^{-1}$. In the present investigation, the highest CGR recorded was 159 g m^{-2} $week^{-1}$.

5.7 Specific leaf weight

The specific leaf weight as observed at triweekly intervals starting from 21 DAP till harvest showed a steady decline as the crop approached maturity. The specific leaf weight was maximum (4.5 mg cm^{-2}) at 21 DAP whereas it was 3.1 mg cm^{-2} at harvest. It may be expected that the photosynthates processed in the leaves are translocated to the developing tubers and do not get accumulated at the source as long as an effective sink is available. Bhagsari (1981) reported a range in specific leaf weight of sweet potato from 3.0 to 4.4 mg cm^{-2}. Irrigation schedules exerted a prominent role in modifying the specific leaf weight only in the second season. Specific leaf weight was significantly higher in plots experiencing moisture stress during tuber initiation phase as compared to providing full CPE during tuber initiation phase and/or tuber maturity phase.

Application of increased doses of nitrogen reduced the specific leaf weight. The specific leaf weight was maximum in plots receiving nitrogen at 25 kg ha^{-1} and lowest in plots receiving nitrogen at 75 kg ha^{-1}. Increased rates of nitrogen supply promotes the enlargement of leaf area without regard to its weight. Moreover, when nitrogen is supplied in excess quantity, it helps in the production of succulent vegetative matter. Knavel (1971) stated that excess leaf area index had an unfavourable effect on dry matter production resulting from intense shading.

The effect of potassium in modifying the specific leaf weight was observed only at 21 DAP in the first season. In general, the lack of response to applied K on specific leaf weight may be attributed to the inconsistent influence of potassium on LAI and leaf dry matter.

5.8 Dry matter of leaves

Irrigation schedules influenced the dry matter content of leaves especially in the first season where inducing water stress during tuber initiation phase recorded significantly lower dry matter production as compared to providing full CPE during tuber initiation and/or tuber maturity phase. Though, in the second season, significant superiority was observed only at 63 DAP, inducing moisture stress during tuber initiation phase continued to record lower values.

An increase in vine length and leaf production would have contributed to an increased LAI which in turn was responsible for high dry matter production. Dry matter distribution in leaves showed a rapid accumulation between 42 and 63 DAP and a gradual decline towards harvest. The LAI was also found to be maximum at 63 DAP which coincided with the high dry matter production of leaves. Senescence of leaves and leaf shedding during the later stages might be responsible for the reduction in dry matter accumulation (Mukhopadhyay et al., 1993).

Increasing the level of applied nitrogen from 25 kg to 75 kg ha^{-1} showed a progressive increase in leaf dry matter production except in the early stages of plant growth. When the nitrogen concentration in the plant is high, more of the dry matter produced is distributed to the aerial parts (Tsuno, 1981) and this trend continued throughout the growth period. Wahua and Ordu (1986) in their studies observed that fertilizer application increased leaf area that led to an increase in leaf dry matter.

The influence of potassium in modifying the dry matter of leaves was visible at 21 and 63 DAP in the first season and at harvest in the second season. Potash at 75 kg ha^{-1} was superior to 25 kg ha^{-1} in the first season whereas a reverse trend was observed in the second season. Such a fluctuating influence of potassium on the leaf dry matter is apparent as a consequence of varied influence on LAI.

Mukhopadhyay et al.(1993) also observed a marginal increase in leaf dry matter production by the application of 75 kg over 100 kg ha^{-1} of potash.

The interaction effect of irrigation x potassium was also significant at certain stages in both the seasons. While no definite trend could be noticed, dry matter content of leaves was minimum in plots induced with water stress during tuber initiation phase coupled with application of 25 kg potash.

5.9 Shoot dry matter

The dry matter of shoot was modified significantly by the irrigation schedules as shown in Table 19. Providing full CPE at tuber initiation and/or tuber maturity phase resulted in a significant improvement in shoot dry matter as compared to inducing moisture stress during tuber initiation phase. An increase in shoot dry matter was attained through an increase in vine length (Table 2) and number of branches $plant^{-1}$ (Table 4) as explained earlier.

The influence of nitrogen in enhancing the shoot dry matter was clearly visible in the first season, though not much influence was noticed in the second season. Application of nitrogen at 75 kg was significantly superior to 25 kg ha^{-1}. An increase in length of vine coupled with the production of more branches resulted in a significant improvement in the dry matter of shoots. The decrease in tuber dry matter production by an increased N supply leads to the logical conclusion that excessive nitrogen application promotes vine growth at the expense of tuber development. Liberal application of nitrogen resulted in heavy vine growth which led to low yield and poor quality tubers (Samuels, 1967). Knavel (1971) could notice a highly significant correlation between nitrogen application and vine dry matter.

Potassium played a significant role in enhancing the shoot dry matter production at 21 and 84 DAP in the first season but no difference was noticed in the second season. In both these observations, 75 kg ha^{-1} was superior to 25 kg ha^{-1} while 75 kg and 50 kg remained on a par. As k_3 and k_2 levels of potash remained on a par it is probable that 50 kg ha^{-1} is sufficient to produce enough vegetative growth for optimum tuber production. The dry matter of shoots attained the maximum towards harvest. This may be due to the continued absorption of potassium and the uninterrupted growth of vines. Mukhopadhyay *et al*. (1993) reported increased shoot dry matter in sweet potato with advance in age.

The interaction effect of irrigation x nitrogen as well as nitrogen x potassium were significant at certain stages of observation. The combination of different levels of nitrogen with irrigation at full CPE during tuber initiation and/or tuber maturity phase and the combination 75 kg ha^{-1} N with different levels of potash were the superior combinations.

5.10 Dry matter of fibrous roots

The fibrous root production was significantly enhanced by scheduling of irrigation in both the seasons, wherein providing full CPE during tuber initiation and/or tuber maturity phase maintained its superiority over inducing stress during tuber initiation phase. The high amount of dry matter observed in the above treatment could be attributed to the fairly high supply of water which promoted the growth of fibrous roots.

The influence of nitrogen in modifying the dry matter of fibrous roots was visible at all the stages of observation wherein higher levels registered their superiority over lower levels. Applying 75 kg ha^{-1} produced significantly higher dry matter of fibrous roots as compared to 50 kg ha^{-1} which in turn was superior to 25 kg ha^{-1}. Enhanced rate of application of nitrogen leads to an increased uptake of nitrogen. This is made possible by an effective root system that proliferates into the soil. Tsuno and Fujise (1968) reported an increase in dry weight of rootlets by the application of nitrogen in sweet potato.

Potassium application also favoured the formation of more fibrous roots. As compared to the lowest level of 25 kg ha^{-1}, the highest level of 75 kg ha^{-1} was superior interms of fibrous root production. Even though, the difference between 50 and 75 kg ha^{-1} was not significant in all the situations, in many instances the superiority of the highest level was visible.

The interaction effect of irrigation x nitrogen was pronounced at 63 and 84 DAP in the first season and at 21 DAP in the second season. Providing full CPE during tuber initiation and/or tuber maturity phase coupled with the highest level of 75 kg ha^{-1} N was superior to that of inducing moisture stress during tuber initiation phase supplemented with 25 kg ha^{-1} N. Thus, root growth could be enhanced by increasing the supply of water and nitrogen.

5.11 Tuber dry matter

The dry matter production of tubers showed remarkable improvement by scheduling of irrigation especially in the first season. In the second season, however no significant variation in dry matter of tuber was observed at 63 DAP and at harvest. Under all situations, providing full CPE at tuber initiation and/or tuber maturity phase was far superior to providing stress during tuber initiation phase. Indira and Kabeerathumma (1988) observed that the tuber yield was considerably reduced when stress was imposed during tuber initiation phase (10-30 DAP) in the lysimeter studies. Bouwkamp (1989) stated that the increased storage root dry weight was associated with the percentage of water in the vines near full turgor.

On a close examination of the data on the number of tubers plant^{-1}, it can be noted that providing stress during tuber initiation phase resulted in significant reduction in number of tubers plant $^{-1}$. Since the number of tubers directly influence the sink capacity, any reduction in the number of tubers may decide on the dry matter production of tuber. Bhagsari (1990) from his study on source-sink relationship observed that the yield of many genotypes was limited by the lack of storage root sinks and the traslocation of photosynthates to the storage roots.

The dry matter production of tubers showed that, except at harvest in the first season, the levels of nitrogen played a significant role in altering the dry matter where 75 kg ha^{-1} registered its superiority over 25 kg ha^{-1} though it remained on a par with 50 kg ha^{-1}. In the second season, significant difference was observed only at two stages i.e., at 63 DAP and at harvest wherein 50 and 75 kg ha^{-1} remained on a par and superior to 25 kg ha^{-1}. The maintenance of an optimum leaf area at higher levels of nitrogen in the earlier stages of tuber development would have produced more photosynthates that resulted in the production of high dry matter in tubers. At the highest level of nitrogen, the uptake of nitrogen was also maximum and this would have led to an excessive top growth. In an overgrowing community, the average active period of the leaf is short and result in inefficient production. This is one of the probable reasons for maintaining the same level of dry matter under 50 kg and 75 kg ha^{-1} of nitrogen supply. Oommen (1989) also failed to observe any significant improvement in the dry matter of tuber by applying nitrogen at 100 kg ha^{-1} over that of 75 kg ha^{-1}.

Potassium failed to record any significant improvement in tuber dry matter production except at harvest in the second season where 75 kg ha^{-1} was superior to 25 kg ha^{-1}. The dry matter content of tuber was reduced in the experiment of Constantin et al. (1974) as the level of potash was increased from 0-140 kg ha^{-1}. Nair (1987) did not notice any influence of potassium on the dry matter production of sweet potato. Mukhopadhyay *et al*. (1993) reported a decrease in tuber dry matter by the addition of potash @100 kg ha^{-1} either as basal or split dose.

5.12 Total dry matter production

Dry matter production of the plant was very much influenced by the irrigation schedules except at harvest in the second season. Supplementing full CPE at tuber initiation and/or tuber maturity phase were far superior to inducing moisture stress during tuber initiation phase. Tuber initiation phase could be considered as a critical stage of growth in sweet potato (Indira and Kabeerathumma, 1988). Oommen (1989) also reported that the maximum dry matter production was in plots that received IW/CPE ratio of 1. Increased absorption of nutrients and a favourable sink formation consequent on stress free condition could have resulted in more dry matter production.

Application of nitrogen favourably influenced the dry matter production at all stages of growth. Nitrogen at the highest level of 75 kg ha^{-1} registered its superiority over the lowest level of 25 kg ha^{-1}. The level of 50 kg ha^{-1} maintained its superiority over the level of 25 kg ha^{-1} except at 21 DAP in the second season. Except at harvest, in the first season and at 70 DAP in the second season, 75 kg ha^{-1} maintained its superiority over

50 kg ha^{-1}. This would have resulted in a significant improvement in the leaf, shoot and fibrous root dry matter production which in turn influenced the total dry matter production. When the concentration of nitrogen is high in the plant, more of the dry matter produced is distributed to the aerial parts throughout the growth period. At the highest level of nitrogen, the uptake of nitrogen was also maximum and that might have led to an excessive top growth.

The increase in LAI above an optimum at the highest level of N would have led to mutual shading of the canopy thereby parasitising on the assimilates intended for storage root enlargement. One of the reasons for a decrease in tuber yield at the highest level of N supply may be attributed to this phenomenon. Such a reduction in tuber dry matter at the highest level of nitrogen is in conformity with the findings of Samuels (1967), Tsuno (1981) and Oommen (1989).

Significant improvement in the dry matter production of the plant was not seen by the different levels of potassium. However, at two stages in the first season and at one stage in the second season, the highest level of 75 kg ha^{-1} registered its superiority over the lowest level of 25 kg ha^{-1}. Again, the significant superiority of the highest level over the middle level was apparent in the first season. The lack of steady response to added potassium may be attributed to its fluctuating influence on leaf and shoot dry matter production.

The interaction effect of irrigation x nitrogen was noticed at 21, 42 and 84 DAP in the first season and at 21 and 63 DAP in the second season. Under all the situations, providing full CPE at tuber initiation and/or tuber maturity phase supplemented with 75 kg ha^{-1} was superior to inducing stress during tuber initiation phase and supplementing with 25 kg ha^{-1} N. Irrigation and nitrogen play a significant role in modifying the plant growth leading to an increased dry matter production.

5.13 Tuber bulking rate

The tuber bulking rate which is an expression of the dry weight gain of the tuber showed that inducing stress during tuber initiation phase had an adverse effect particularly during the early part of tuber development. The poor tuber yield recorded in this irrigation schedule may be attributed to the LAI and insufficient sink for the storage of sufficient assimilates in the developing tubers. Bouwkamp (1989) stated that increased storage root dry weight was associated with the percentage of water in the vines at full turgor. Oommen (1989) observed an increase in tuber bulking rate at IW/CPE ratio of 0.75 as compared to the ratio of 0.50 throughout the growth phase.

The influence of nitrogen in modifying the tuber bulking rate was apparent between 21-42, 63-84 and 84 DAP and harvest in the first season and between 42-63 DAP, 84 DAP and harvest in the second season. The highest level of nitrogen at 75 kg ha^{-1} was significantly superior to 25 kg ha^{-1} except between 84 DAP and harvest. In two observations, 75 kg ha^{-1} was significantly superior to 50 kg ha^{-1} while in one instance 50 kg ha^{-1} was significantly superior to 75 kg ha^{-1}. Thus, it may be noted that the nitrogen dose of 75 kg and 50 kg were exerting an overlapping influence on tuber bulking rate. Oommen (1989) reported that though the tuber bulking rate was the highest at 100 kg ha^{-1} N, it was on a par with 75 kg ha^{-1} in one season while a reverse trend was noticed in the other season.

Potassium application could not modify the tuber bulking rate at any stage of crop growth.

5.14 Length of tuber

The length of tuber failed to be influenced by irrigation schedules. This is probably due to the phasic stress imposed during tuber initiation phase (10-30 DAP) and the uniform supply of water upto 80 DAP. Tuber development begins 30 days after planting and hence, it goes without saying that the irrigation schedules imposed may not have any effect in influencing the length of tuber.

Nitrogen played a significant role in influencing the length of tuber and steady increase was noticed by enhanced supply of nitrogen from 25 kg to 75 kg ha^{-1}. An increase in length of tuber with an increase in the levels of nitrogen was noticed by Oommen (1989) when the moisture supply was adequate to maintain proper growth of the plant.

Potassium did not modify the length of tuber to any appreciable extent in both the seasons. The influence of potassium is more or less related to the girth of tuber by way of increased translocation of assimilates to the developing tubers.

5.15 Girth of tuber

The girth of tuber was not influenced by scheduling of irrigation. The tuber initiation phase which falls between 10 and 30 days after planting decides on the number of tubers to be produced plant^{-1}. The flow of assimilates to the developing tubers starts after tuber intiation where there is no variation in moisture supply. Oommen (1989) could not notice any influence of irrigation on the girth of tuber.

Nitrogen supply influenced the girth of tuber wherein application of 50 kg ha $^{-1}$ recorded significantly higher girth as compared to the application of 75 kg and 25 kg ha $^{-1}$. The girth was the lowest when the nitrogen level was the highest. Nair (1972) reported a decrease in girth of tuber with increase in supply of nitrogen from 50 to 100 kg ha $^{-1}$. Similar were the observations made by Nambiar _et al_. (1976) and Kim (1984) who reported a reduction in root development with increased supply of nitrogen. Oommen (1989) reported a decrease in girth of tuber when the level of nitrogen was increased from 50 to 100 kg ha^{-1}. It may be noted that almost a reverse trend was noticed in the case of length of tuber with increasing supply of nitrogen.

The influence of potassium was significant wherein application of 75 kg ha $^{-1}$ recorded the maximum girth and remained superior to the lowest level of 25 kg ha $^{-1}$ potash. The absence of significant superiority over 50 kg ha $^{-1}$ may be attributed to the fact that in summer the leaching loss will be minimum. The positive role of potassium on tuber development of sweet potato was highlighted by several workers like Fujise and Tsuno (1962) and Wang (1975). Hahn and Hozyo(1984) reported that potassium is needed for rapid cambial activity in the tuber in which starch is stored.

The interaction effect of nitrogen x potassiumn was significant wherein 50:50 and 50:75 remained on a par and registered their superiority over other combinations. The combination, 50:25 resulted in the production of thin tubers in both the seasons. An N:K ratio of 1:1 or 1:1.5 favoured a better source activity and sink efficiency as compared to the ratio of 1:0.5.

5.16 Mean tuber weight

The mean tuber weight was found to be modified by the irrigation schedules considerably. Providing full CPE during tuber initiation and/or tuber maturity phase significantly enhanced the mean tuber weight as compared to inducing stress during tuber initiation phase. Oommen (1989) reported that the mean tuber weight was minimum in plots receiving irrigation at IW/CPE ratios of 0.25. An analysis of the tuber bulking rate also revealed that the bulking rate was maximum when full CPE was provided at tuber initiation phase as compared to moisture stress induced during the same period.

Varying the levels of nitrogen and potash did not in any way influence the mean tuber weight. The weight of tuber is governed by the length and girth of tuber. It has been observed that increased levels of nitrogen modified the length of tuber positively resulting in a decrease in girth of tuber. The influence of potassium is felt more on the girth of tuber. Such a negative relationship between length and girth of tuber has contributed to the non-significance of tuber weight by varying the levels of nitrogen and potash.

5.17 Total number of tubers

The total number of tubers which include both marketable and second grade tubers was significantly higher in plots receiving irrigation at full CPE during tuber initiation and/or tuber maturity phase. The tuber initiation commences at 8 days after planting and extends upto 20 days from planting (Indira and Kurien, 1977). Indira and Kabeerathumma (1988) further studied the influence of irrigation in lysimeters and stated that the period between 10 and 30 DAP is critical as regards irrigation to sweet potato is concerned. Thus, it is evident that any stress imposed during the tuber initiation phase will adversely affect the number of tubers plant^{-1} which act as sink.

Varying the supply of nitrogen significantly influenced the number of tubers wherein both 75 kg and 50 kg were on a par and significantly superior to 25 kg ha^{-1}. Mandal et al. (1971) and Nambiar et al.(1976) observed an increase in number of tubers by the application of higher doses of nitrogen. Tsuno (1981), Nawale and Salvi (1984), Bourke (1985) and Oommen (1989) also observed an increase in number of tubers consequent on increase in supply of nitrogen.

Potassium application also influenced the number of tubers plant^{-1} and the maximum was noticed at 50 kg ha^{-1}, which was on a par with 75 kg ha^{-1} and significantly superior to 25 kg ha^{-1}. Knavel (1971) reported that the number of tubers plant^{-1} was influenced more by potassium than by nitrogen.

The interaction effect of nitrogen x potassium was also significant in both the seasons indicating that both nitrogen and potassium favour the production of more number of tubers plant^{-1}.

5.18 Number of marketable tubers

The number of marketable grade tubers plant^{-1} showed a significant improvement when irrigation was given at full CPE during tuber initiation and/or tuber maturity phase. As already discussed, tuber initiation would have been unfavourably affected when moisture stress was imposed during tuber initiation phase (Indira and Kabeerathumma, 1988).

Varying the supply of nitrogen did not influence the number of marketable tubers plant^{-1}. Nitrogen is expected to influence the sink capacity by influencing the total number of tubers plant^{-1} but need not necessarily be the grade of tuber. Knavel (1971) observed that the nitrogen content of the medium greatly influenced the size of tubers while the number of tubers plant^{-1} remained unaffected.

The influence of potassium in altering the number of marketable tubers plant^{-1} was visible in the second season where the medium level of 50 kg ha^{-1} was superior to 75 and

25 kg ha^{-1}. As already discussed, potassium is necessary for the translocation of assimilates and its accumulation in tubers. Hammett et al.(1984) found that the marketable tuber yield were higher in plots receiving higher rates of potassium application.

The interaction effect of nitrogen x potassium was significant in the second season where 50 : 50 was on a par with 75 : 75 and significantly superior to other combinations. Thus, it may lead to the logical conclusion that to get more marketable grade tubers, nitrogen and potash application should be balanced and moderate.

5.19 Total tuber yield

The total tuber yield as influenced by scheduling of irrigation remained significant wherein providing full CPE at tuber initiation and/or tuber maturity phase was superior to inducing stress during tuber intiation phase. Irrigation had a marked influence on the total number of tubers produced $plant^{-1}$ (Table 26). As the number of tubers $plant^{-1}$ is a deciding factor on tuber yield, it may be expected that the tuber yield will be significantly enhanced by an increase in the number of tubers $plant^{-1}$. Pushkaran et al.(1978) reported that the tuber yield was positively correlated with the number of tubers plant^{-1}. The stress imposed during tuber initiation phase may have reduced the number of tubers plant^{-1} as the turgidity of the leaves were adversely affected for the free movement of assimilates.

Varying the supply of nitrogen from 25 to 50 kg ha^{-1} significantly enhanced the total tuber yield. Applying 50 kg ha^{-1} recorded the maximum tuber yield followed by the application of 75 kg ha^{-1} and both remained significantly superior to 25 kg ha^{-1}. Nandpuri *et al*. (1971) reported an increase in tuber yield of sweet potato when the dose of nitrogen was increased from 28 to 56 kg ha^{-1}. However, when the nitrogen level was increased to 84 kg ha^{-1} there was a slight increase in vegetative growth with a corresponding reduction in tuber yield. The excess leaf production at the highest level of nitrogen might have led to poor light reception and lower photosynthetic activity leading to reduced tuber yields at 75 kg ha^{-1}.

Significant yield increase as a consequence of nitrogen fertilization was observed by Mac Donald (1963) who also reported a decrease in tuber yield by excessive nitrogen application. Nair (1972) observed that sweet potato failed to produce increased tuber yields over the application of 50 kg ha^{-1} in a fertilizer trial involving three levels of nitrogen ranging from 50 to 100 kg ha^{-1}. Jana (1982) reported that added nitrogen may reduce the tuber yield of sweet potato by increasing the vine yield. Prasad (1989) obtained maximum tuber yield in sweet potato by applying nitrogen at 50 kg ha^{-1}.

Potassium also played a significant role in influencing the total tuber yield in both the seasons. The level of 50 kg ha^{-1} registered the maximum and remained on a par with 75 kg ha^{-1} maintaining their superiority over 25 kg ha^{-1}.

Potassium is known to be essential for the synthesis and translocation of carbohydrates to the underground roots which is considered to be one of the most important physiological activities of root crops. Potassium significantly affects the activity of starch synthetase (Murata and Akazawa, 1968) so that an early application of potassium to increase the activity of the enzyme in the tuberous roots will often result in higher tuber yield.

The beneficial effect of potassium nutrition in enhancing the tuber yield of sweet potato was reported by workers such as Fujise and Tsuno (1962) and Villareal (1982). Bourke (1984) opined that potassium influenced the tuber yield through an increased diversion of dry matter to the tubers.

The interaction effect of nitrogen x potassium was found to be significant in both the seasons whereas irrigation x nitrogen and irrigation x potassium were significant in the first season only. Application of nitrogen and potash both at 50 kg ha^{-1} remained on a par with 75 : 75 and 75 : 50 and retained their superiority over other combinations. Hence, applications of nitrogen and potash at 50 kg ha^{-1} may be considered optimum for sweet potato grown as a catch crop in rice fallows during the summer season. Nair and Vimala (1990) suggested an NPK dose of 50:37.5:50 to realise economic retuns from sweet potato. Applying full CPE at tuber initiation and/or tuber maturity phase with 50 kg ha^{-1} of nitrogen or potash was superior to applying 1/2 CPE during tuber initiation phase with 25 kg ha^{-1} nitrogen or potash. Therefore, it may be concluded that providing full CPE during tuber initiation and/or tuber maturity phase with 50 kg ha^{-1} each of nitrogen and potash are optimum for sweet potato in a rice based cropping system.

5.20 Marketable tuber yield

The results presented in Table 29 showed significant variation in marketable tuber yield in both the seasons by scheduling of irrigation. Inducing moisture stress during tuber initiation phase resulted in significant reduction in marketable tuber yield. Providing full CPE at tuber initiation and/or tuber maturity phase recorded significantly higher tuber yield and both were on a par.

In a survey conducted in 26 countries, Lin et al. (1983) came to the conclusion that drought is the most important abiotic factor that depressed the tuber yield. Varughese et al.(1987) and Oommen (1989) also obtained highest yields in sweet potato by the application of irrigation water at IW/CPE ratio of 1.2 and 0.75 respectively.

Moisture stress induced during tuber initiation phase resulted in significant reduction in the number of marketable grade tubers thereby resulting in lower tuber yield. Indira and Kabeerathumma (1988) in their lysimeter studies reported a significant reduction in tuber yield as a consequence of water stress induced during tuber initiation phase. Bouwkamp (1989) stated that reduced mid-day wilting increased tuber yield in high yielding genotypes due to an increase in net photosynthesis and partitioning of assimilates to the storage roots. Thompson et al. (1992) observed an increase in marketable tuber yield until a total water application of 76%

of pan evaporation was reached.

Application of nitrogen at 50 kg ha^{-1} recorded significantly superior yield as compared to 25 kg ha^{-1} and remained on a par with 75 kg ha^{-1}. The total tuber yield as well as marketable tuber yield were the highest at 50 kg ha^{-1} which reveal that sweet potato responds favourably to moderate supply of nitrogen at 50 kg ha^{-1} particularly in summer rice fallows.

The yield of sweet potato depends more on the extent of assimilate translocation and accumulation in the roots. Assimiliation, in turn depends on the extent of assimilating surface. The influence of nitrogen in increasing the assimilate surface (leaf area) of plant is well known. Increase in leaf area with increase in nitrogen level was observed in this study also. The vegetative characters like length of vine, number of branches $plant^{-1}$ and number of leaves $plant^{-1}$ were significantly increased by the highest level of nitrogen (75 kg ha^{-1}). The excessive vegetative growth as a result of nitrogen application beyond a certain level might have caused a reduction in tuber yield. Morita (1970), Nair (1972), Jana (1982), Kim (1984) and Oommen (1989) have also reported that high rates of nitrogen application resulted in luxuriant vegetative growth at the expense of tuber yield.

Application of potash showed significant response wherein 50 kg ha^{-1} recorded the highest yield and the lowest yield by 25 kg ha^{-1}. However, increasing the dose of potash above 50 kg ha^{-1} did not result in a significant increase in tuber yield. The girth of tuber was found to be maximum at the highest level of potassium. Hammett <u>et al</u>.(1984) found that the marketable tuber yields were higher at higher rates of potassium application. Bao <u>et al</u>.(1985) observed that potassium fertilizer was very effective in increasing the yield of sweet potato by increasing both the number of tubers and the ratio of large/small tubers. Potassium influenced the tuber yield through an increased diversion of dry matter to the tubers (Bourke, 1985).

The interaction of nitrogen x potassium was visible in both the seasons. Both 75:50 and 50:50 remained on a par and were significantly superior to 25:25. Fujise and Tsuno (1962) observed that combined application of nitrogen and potassium resulted in considerable increase in yield of sweet potato. Nair (1987) and Varughese <u>et al</u>. (1987) reported that a fertilizer dose above 50 kg ha^{-1} of nitrogen and potash failed to record any appreciable increase in tuber yield. Therefore, it may be concluded that applying irrigation water at full CPE during tuber initiation phase and nitrogen and potash at 50 kg ha^{-1} each is beneficial to get optimum yield of marketable grade sweet potatoes.

5.21 Vine yield

The data on vine yield presented in Table 32 did not show any significant variation due to scheduling of irrigation. Providing full CPE at tuber initiation (10-30 DAP) and/or tuber maturity phase (80-100 DAP) did not bring about any significant difference in top growth at harvest. Since all the plots were receiving an uniform supply of water between 30 and 80 DAP, restricting the supply of water at the early and late stages of plant growth may not have any significant effect on the vegetative growth.

Application of nitrogen remarkably increased the vine yield in both the seasons. Vine yield was highest at 75 kg ha^{-1} nitrogen and lowest at 25 kg ha^{-1}. The vine yield is determined by the length of vine, number of branches and number of leaves $plant^{-1}$ which were all significantly enhanced by nitrogen supply in the present study. Similar increase in vine yield due to higher dose of nitrogen application had been reported by Samuels (1967), Morita

(1970), Knavel (1971) and Nair (1972). Feliciano and Lopez (1976), Tsuno (1981) and Oommen (1989) also reported that higher rates of nitrogen tended to increase top growth in sweet potato.

Potassium did not influence the vine yield to any appreciable extent. It was observed that vine length and number of branches plant^{-1} were not modified by varying the levels of potassium and except at 63 DAP the number of leaves plant^{-1} was also not influenced by potassium nutrition. Potassium plays an important role in improving the photosynthetic activity and translocation of carbohydrates to the developing tubers rather than accumulating carbohydrates in the aerial parts.

5.22 Utilization index

The utilization index or tuber efficiency observed during both the seasons were significantly influenced by scheduling of irrigation. Providing full CPE during tuber initiation and/or tuber maturity phase recorded significantly superior UI as compared to inducing stress during tuber initiation phase. The tuber yield was significantly influenced by scheduling of irrigation whereas the vine yield did not show any effect. Therefore, it has to be expected that the utilization index will also follow the same pattern as that of tuber yield as it is root:shoot ratio on fresh weight basis (Obigbesan, 1973).

Varying the supply of nitrogen significantly influenced the UI in both the seasons. The UI was the highest in 25 kg and lowest in 75 kg ha^{-1}. As already discussed, increasing the level of nitrogen resulted in excessive growth of vines without a corresponding increase in tuber yield leading to low UI.

Potassium supply failed to modify the UI to any appreciable extent in both the seasons.

The interaction effect of nitrogen x potassium was also found to be significant wherein the combination of 25:25 recorded the highest UI and the lowest by 75:25. A high proportion of nitrogen as compared to a low level of potassium favoured the growth of aerial parts leading to low tuber efficiency.

5.23 Harvest index

The harvest index presented in Table 33 show significant superiority of treatments that were receiving irrigation at full CPE during tuber initiation and/or tuber maturity phase in the first season. However, no significant superiority in harvest index could be noticed in the second season. It may be noted that the tuber yield, in general, was better in the first season as compared to the second season as a consequence of favourable rains received towards harvest.

Nitrogen supply significantly influenced the harvest index in both the seasons. Application of nitrogen at 25 kg ha^{-1} recorded significantly higher harvest index as compared to that of 50 kg and 75 kg ha^{-1}. Though, there was no significant difference between 50 kg and 75 kg ha^{-1} in the second season, 50 kg ha^{-1} was significantly superior to 75 kg ha^{-1} in the first season. This is attributed to the excessive vegetative growth as a result of increased nitrogen supply. Tsuno and Fujise(1968) concluded that to secure high yields of tuber, nitrogen application should be moderate in order to regulate the growth of tops at the expense of tuber development. Jana (1982) also reported a decrease in tuber yield with a corresponding increase in vine yield by the application of heavy doses of nitrogen. Bhagsari and Ashley (1990) reported that the harvest index of the genotypes varied from 43 to 77% in the first season while it ranged from 31 to 75% in the second season.

Potassium supply influenced the harvest index in the second season though there was no effect in the first season. The highest level of 75 kg ha^{-1} recorded significantly higher harvest index as compared to the lowest level of 25 kg ha^{-1}. However, there was no significant difference between 50 kg and 75 kg ha^{-1}. Potassium is essential for the synthesis and translocation of carbohydrates from the tops to the roots. Tsuno (1981) reported that dry weight of tuber in plots receiving high potassium was 20 percent higher than that of control plots while the dry weight of tops showed no difference which indicated that higher levels of potassium promoted only tuber growth.

5.24 Cooking quality

The tubers contained more dietary fibre in plots that received irrigation at full CPE during tuber initiation and/or tuber maturity phase. However, as regards taste and texture, no definite trend could be noticed. Thompson et al. (1992) reported that sensory evaluation for appearance, flavour, texture and preference of cooked flesh reached their highest values near the irrigation amount giving maximum yield.

As regards nitrogen supply, application of nitrogen at

50 and 75 kg ha^{-1} produced more dietary fibre in tubers which were sweet in taste and soft in texture. The plots that received nitrogen at 25 kg ha^{-1} produced non-fibrous tubers with medium taste and texture. Bradbury (1989) reported an increase in dietary fibre content after cooking owing to the formation of some starch which was resistant to enzymatic action.

Application of potassium at 75 kg ha^{-1} resulted in the production of non-fibrous tubers which were medium in taste and texture.

5.25 Starch content

Starch content of the tuber observed at harvest showed no significant variation due to scheduling of irrigation. In both the seasons, the starch content ranged from 19.26 to 19.65% on fresh weight basis. The quantity of water applied during a major part of the plant growth period (30-80 DAP) remained same in all the treatments. The variation imposed between 80 and 100 days also gets vitiated by the frequent rains received during the tuber maturity phase. Hence there is no drastic difference in the quantity of water applied after 30 days of planting. As tuber development and tuber maturity phases fall in this period, it is expected that there is a constant supply of assimilates to the developing tubers. As starch is the main component in the assimilates, it leads to the logical conclusion that the starch content remains almost same under various irrigation schedules.

Nitrogen application significantly influenced the starch content in both the seasons. Application of nitrogen at the rate of 50 kg ha^{-1} was superior to 25 and 75 kg ha^{-1} and both remained on a par. Tsuno and Fujise (1968) reported that for producing tubers of high starch content, nitrogen application should be moderate in order to prevent excessive development of tops at the expense of tuber growth. Increase in starch content of tuber by nitrogen nutrition had been reported by several workers like Mandal et al.(1971), Bartolini (1982), Oommen (1989) and Mishra et al.(1992).

The starch content of tuber was significantly influenced by potassium wherein the highest level of 75 kg ha^{-1} was significantly superior to the medium level of 50 kg and lowest level of 25 kg ha^{-1}. The beneficial effect of potassium on this quality trait can be attributed to the well known role of potassium in the carbohydrate synthesis and metabolism. Fujise and Tsuno (1962) reported that higher potassium dose might have increased the potassium level in the leaves which in turn might have accelerated the photosynthetic activity of leaves resulting in high starch accumulation in roots. Ashokan and Nair (1984), Sharafuddin and Voican (1984) and Oommen (1989) observed that higher doses of potassium significantly increased the starch content of sweet potato tuber. High K and top dressing with K promoted translocation of photosynthates to the tubers (Xie *et al*., 1989). Patil *et al*.(1990) reported an increase in protein, starch and reducing sugars in sweet potato by K nutrition.

The interaction effect of nitrogen x potassium was significant in the second season where 50:50 recorded the maximum starch content and the lowest by 25:25.

5.26 Sugar content

The sugar content of the tuber was not modified by scheduling of irrigation as in the case of starch content. The reasons for the lack of response to irrigation in modifying the starch content of tuber is also applicable to that of sugar content.

Nitrogen supply significantly influenced the sugar content wherein 75 kg ha^{-1} recorded the maximum and remained on a par with 50 kg ha^{-1} and both retained their superiority over 25 kg ha^{-1}. Mishra et al.(1990) observed an increase in sucrose content of tuber by the enhanced supply of nitrogen from 40 to 120 kg ha^{-1}.

Increased rates of potassium application significantly enhanced the sugar content wherein the highest level of 75 kg ha^{-1} recorded the maximum in both the seasons. It remained on a par with 50 kg ha^{-1} in the first season but maintained the superiority in the second season. The lowest level of 25 kg ha^{-1} recorded the lowest sugar content in tuber. Nair et al.(1976a) reported a significant increase in sugar content by enhanced rate of K application. Bao et al.(1985) on an analysis of 392 experiments came to the conclusion that potassium fertilizer improved the starch and sugar content of sweet potato. Patil et al.(1990) reported an increase in reducing sugars by the enhanced application of nitrogen and potash.

5.27 Nitrogen uptake

The uptake of nitrogen by vines and tubers were observed at an interval of 35 days from planting. Irrigation schedules influenced the uptake of nitrogen by vines at the time of harvest in the first season and at 70 DAP in the second season. Nitrogen uptake by tubers was significantly influenced by irrigation schedules in the first season but without any effect on the second season. Inducing stress during tuber initiation phase had an unfavourable effect on nitrogen uptake as compared to providing full CPE during tuber initiation and/or tuber maturity phase.

An analysis of the dry matter distribution indicates that both the leaf and shoot dry matter were significantly higher in plots receiving full CPE during tuber initiation and/or tuber maturity phase as compared to inducing stress during tuber initiation phase. The data on fibrous root dry matter and tuber dry matter also followed the same trend. All these might have influenced the N uptake. The influence of added levels of nitrogen by vines and tubers showed significant difference at all stages of observation. The highest dose of nitrogen at 75 kg ha^{-1} recorded the maximum uptake at all stages of observation and the lowest at 25 kg ha^{-1}.

Over the stages, there was a conspicuous decline in nitrogen uptake by vines, especially between 70 DAP and at harvest. One of the probable reasons responsible for this decrease in nitrogen uptake is the senescence of leaves and leaf fall as seen from the dry matter. Translocation of a significant portion of nitrogen stored in vines to the developing tubers might have occurred which is evident from the more or less linear increase in nitrogen uptake by tubers over the stages. However, absorption of nitrogen from soil continued at a fairly fast rate till harvest as is evident from the steady increase in total nitrogen uptake.

The uptake of nitrogen by varying the supply of potassium from 25 to 75 kg ha^{-1} did not show any significant difference except at 70 DAP where 75 kg was superior to 25 kg ha^{-1}. Though, potassium varies the dry matter content of leaves, shoots and fibrous roots at certain stages, the significant superiority did not follow a particular trend. Uptake of nitrogen by vines and tubers almost followed the same trend by applying varying levels of potassium.

5.28 Phosphorus uptake

The uptake of phosphorus by vegetative parts showed significant improvement by scheduling of irrigation only at harvest in the first season. However, as regards the uptake of phosphorus by the tubers, irrigation schedules exerted a significant improvement especially in the first season. Providing full CPE at tuber initiation and/or tuber maturity phase was superior to inducing stress during tuber initiation phase. The general lack of response in the second season may be due to a considerable build up of soil phosphorus besides its uniform application to all plots. However, quantity of uptake of phosphorus was rather very low as compared to the uptake of nitrogen and potassium.

Varying the supply of nitrogen significantly influenced the uptake of phosphorus by plants in both the seasons. In the case of tuber of the plant, except at harvest in the first season and at 70 DAP in the second season, nitrogen supply significantly influenced the phosphorus uptake. This may be due to the synergestic effect of nitrogen on phosphorus. Application of nitrogen at the highest level of 75 kg ha^{-1} resulted in significantly higher uptake of phosphorus as compared to the lower levels of 50 and 25 kg ha^{-1}.

The uptake of phosphorus was not influenced by varying the levels of potassium either by vines or tubers. at any stage of observation. The effect of potassium on the dry matter production of tuber, shoot and leaf was not stable as seen earlier which might have led to a non-significant uptake of phosphorus.

5.29 Potassium uptake

The uptake of potassium by vines was not significantly altered by irrigation schedules at any stage of crop growth. However, the uptake of potassium by tubers was influenced by scheduling of irrigation except at harvest in the second season. In the first season, providing full CPE at tuber initiation and/or tuber maturity phase recorded significantly higher uptake as compared to stress induced during tuber initiation phase. In the second season, providing full CPE during tuber initiation phase was superior to the above two. Enough soil moisture that permits the uninterrupted growth of fibrous roots help in the effective absorpiton of potassium. The results presented in Table 19 clearly indicate that providing full CPE at tuber initiation and/or tuber maturity phase resulted in a significant improvement in the dry matter production of fibrous roots which might have contributed to higher K uptake.

The effect of nitrogen in influencing the potassium uptake was marked at any stage in the case of vines. Nitrogen at 75 kg ha^{-1} was significantly superior to both 50 kg and 25 kg ha^{-1} except at 70 DAP in the second season where 75 kg and 50 kg remained on a par. Under all the situations, the dose of 50 kg was superior to 25 kg ha^{-1}. Potassium uptake by tubers was influenced by nitrogen supply at 35 and 70 DAP in the first season and at harvest in the second season. In all the three observations, the higher levels were significantly superior to the lower levels.

Potassium uptake by vines and tubers was also influenced by varying the levels of potassium. The potassium uptake by vines showed significant superiority at 70 DAP and at harvest in the first season and at 35 and 70 DAP in the second season. Under all the situations, application of 75 kg ha^{-1} was significantly superior to 25 kg ha^{-1}. Potassium uptake by tubers was significantly improved at 70 DAP and at harvest in the first season and at 35 DAP and at harvest in the second season. Application of potash at 75 kg ha^{-1} was significantly superior to 25 kg ha^{-1}. Sekhon and Singh (1982) reported that tuber crops removed substantial amounts of potash from the soil. Hammett et al.(1984) obtained a positive response in root potassium content to increased rates of potassium application.

5.30 Available nitrogen content

Available nitrogen content of the soil was not influenced by scheduling of irrigation. The amount of water applied to the soil particularly during tuber initiation phase was equal to the amount evaporated from an open water surface. This means that the amount of water applied is less than that required to meet the evapotranspirational requirement of the crop. Moreover, irrigation is provided once in four days and as such the quantity of water applied per irrigation was not enough to encourage leaching loss. The difference in the removal of nitrogen in the early stage of development (10-30 DAP) with a LAI of less than unity may get compensated in the remaining period of plant growth.

An improvement in nitrogen status of the soil was noticed after the harvest of the first season crop. Application of nitrogen at the highest level maintained a significantly higher nitrogen content in the soil. However, a depletion in available nitrogen content of the soil was noticed by the application of nitrogen at 25 kg ha^{-1}. Rajendran et al. (1971) observed an increase in the available nitrogen content of soil by the application of 100 kg ha^{-1} nitrogen to cassava. Oommen (1989) reported an increase in available nitrogen content of the soil by the application of nitrogen at 100 kg ha^{-1} to sweet potato. However, no increase in available nitrogen content of soil was observed after the second season crop.

Applying different doses of potassium had in no way influenced the available nitrogen content of the soil. A perusal of the data on the effect of different levels of potassium on the uptake of nitrogen indicate that potassium had no influence. Since the crop removal is not significantly altered, it is to be expected that there may not be much variation in the available nitrogen status of the soil.

5.31 Available phosphorus

The available phosphorus content of the soil did not show any significant variation due to the imposition of different irrigation schedules. The uptake of phosphorus by vines and tubers were rather low and did not follow a specific pattern. Since the uptake is very low, the available phosphorus content of the soil may not show much variation to reach the level of significance.

Varying the levels of nitrogen from 25 to 75 kg ha^{-1} influenced the available phosphorus content of the soil. The available phosphorus content was highest in plots receiving 25 kg ha^{-1} nitrogen and the lowest in plots receiving 75 kg nitrogen. A perusal of the data on uptake of phosphorus will clearly reveal that the uptake was the highest in plots receiving nitrogen at 75 kg ha^{-1}. This in turn has reduced the soil status of phosphorus in plots receiving the highest dose of nitrogen.

Applying different doses of potash did not in any way influence the available phosphorus content of the soil. It may be noted that varying the levels of potassium could not influence the uptake of phosphorus to any appreciable extent. The lack of significant variation in the amount of phosphorus removed by the plant under different levels of potash would have resulted in almost uniform status of available phosphorus in the soil. Nair and Mohankumar (1978) reported an increase in available phosphorus status of the soil after applying lime for sweet potato. Since all the plots other than the control plots received 500 kg ha^{-1} lime prior to planting, the available phosphorus content of the soil after the harvest of sweet potato would be definitely higher than the initial status. Further, as the uptake is low, a build up of phosphorus is expected.

5.32 Available potassium

The available potassium content of the soil did not indicate any definite trend as regards scheduling of irrigation. However, inducing stress during tuber initiation phase has a marginally higher soil potassium content. This may be due to the low uptake of potassium in this particular treatment. Oommen (1989) also observed a reduction in available potassium content of the soil when the IW/CPE ratio was increased from 0.25 to 1.00 on sweet potato.

Applying nitrogen at different levels significantly influenced the available potassium content of the soil. The highest values were recorded in plots receiving nitrogen at 25 kg ha^{-1} and the lowest in 75 kg ha^{-1} plots. Plots that received nitrogen at the lowest level had resulted in significantly lower uptake as compared to plots receiving higher levels of nitrogen. The available potassium status of the soil was high in plots that recorded a low uptake of potassium.

The available potassium content of the soil showed a definite improvement by increasing the levels of potassium application. Available potassium content of the soil was high in plots that received the highest level of potassium. This would have happened due to the proportionately lower uptake of potassium as compared to its availability under high levels of potassium supply. Mohankumar <u>et al</u>. (1971), Rajendran <u>et al</u>. (1972) and Oommen (1989) have reported increase in available potassium content of the soil by the application of higher levels of potassium.

5.33 Field water use efficiency

Field water use efficiency presented in Tables 46 and 47 revealed that in both the seasons, maximum values were recorded by applying full CPE at tuber initiation and/or tuber maturity phase. Applying full CPE at tuber initiation and tuber maturity phases recorded the maximum value of 26.63 kg ha^{-1} mm^{-1} in the first season while applying full CPE during tuber initiation phase recorded the maximum in the second season. The amount of water received by the above two schedules were same in the first season and slightly different in the second season because of the rains received during the later phase of plant growth. However, inducing stress during tuber initiation phase registered the lowest water use efficiency though the amount of water applied was less. This clearly indicates that tuber initiation phase is critical as regards irrigation.

Application of nitrogen at 50 kg ha^{-1} recorded significantly higher water use efficiency as compared to 25 kg ha^{-1} though it remained on a par with 75 kg ha^{-1}. It may be noted that the tuber yield was highest at 50 kg ha^{-1} N.

Potassium applied at 50 kg ha^{-1} recorded the maximum water use efficiency which remained on a par with 75 kg ha^{-1} in both the seasons. However, there was no significant difference between 25 kg and 75 kg ha^{-1} in the second season. Therefore, it may be concluded that potash application may be restricted to 50 kg ha^{-1} for attaining high water use efficiency.

Interaction effect of nitrogen x potassium was pronounced in both the seasons where the combination of 50 kg each of N and K resulted in the maximum water use efficiency in both the seasons. Thus, the application of nitrogen and potash at 50 kg ha^{-1} each result in high water use efficiency.

5.34 Economics of sweet potato cultivation

The economic analysis presented in Table 49 brings out the net income perhectare obtained by growing sweet potato as a catch crop in summer rice fallows. The main effects of irrigation schedules, nitrogen levels, potash levels and the interaction effects of irrigation x nitrogen and nitrogen potassium are also presented.

Irrigating sweet potato at full CPE during tuber initiation and/or tuber maturity phase resulted in significantly superior net returns as against providing 1/2

Table 49. Net income (Rs. ha^{-1})

Treatments	Net income (Rs ha^{-1})	Interaction (Irri x Nitrogen)	Net income (Rs ha^{-1})	Interaction (Nitrogen x Potassium)	Net income (Rs. ha^{-1})
i_1	11139	i_1n_1	10031	n_1k_1	9448
i_2	8071	i_1n_2	12350	n_1k_2	9372
i_3	11230	i_1n_3	11219	n_1k_3	8992
SE	293	i_2n_1	7951	n_2k_1	9639
CD	814	i_2n_2	8639	n_2k_2	13275
n_1	9271	i_2n_3	8028	n_2k_3	10440
n_2	11118	i_3n_1	9831	n_3k_1	9048
n_3	10254	i_3n_2	12365	n_3k_2	10254
SE	264	i_3n_3	11514	n_3k_3	11459
CD	862	SE	293	Package	9542
k_1	9379	CD	842	SE	458
k_2	10967	---	---	CD	1493
k_3	10297	---	---	---	---
SE	264	---	---	---	---
CD	862	---	---	---	---

CPE during tuber initiation phase. The difference in net return is to the tune of Rs. 3068/- to Rs. 3129/- per hectare.

Application of nitrogen at 50 kg ha^{-1} recorded the maximum net return which maintained the superiority over the levels of 75 kg ha^{-1} and 25 kg ha^{-1}. Thus, the amount of nitrogen may be restricted to 50 kg ha^{-1} for realising economic returns from sweet potato.

Potassium supply at different levels also exerted significant variation in net income. The maximum net income was from plots receiving potash at 50 kg ha^{-1} followed by the application of 75 kg ha^{-1}. Both the above levels were significantly superior to the lowest level of 25 kg ha^{-1}. Thus, the application of potash at 50 kg ha^{-1} is sufficient to realise economic returns from sweet potato grown as a catch crop in summer rice fallows.

The interaction effect of irrigation x nitrogen and nitrogen x potassium were also found to be significant. Providing irrigation at full CPE during tuber initiation and/or tuber maturity phase with 50 kg ha^{-1} N was on a par with providing full CPE at tuber initiation phase and tuber maturity phase with 75 kg ha^{-1} and was significantly superior to others in terms of net income.

As regards the application of nitrogen and potash, applying 50 kg ha^{-1} each was significantly superior to all other combinations. Though, the recommended package yielded almost identical tuber yields as compared to the NK combination of 50:50, the net returns realised was for less because of the high cost of FYM. It may, thus be argued, that for realising the maximum net returns, without impairing the productivity of the soil, sweet potato may be grown as a catch crop in summer rice fallows by applying 50 kg ha^{-1} each of nitrogen and potash with 500 kg ha^{-1} lime. FYM may be avoided altogether and supplemented with an appropriate quantity of phosphorus which will not lead to its build up in the soil.

5.35 Benefit-cost analysis

The benefit-cost analysis presented in Table 50 show that irrigating at full CPE during tuber initiation and/or tuber maturity phase resulted in more benefit as compared to providing 1/2 CPE during tuber initiation phase.

As regards, the supply of nitrogen, applying nitrogen at 50 kg ha^{-1} was more beneficial as compared to the level of 75 kg and 25 kg ha^{-1}. Potassium supply at moderate level i.e.,50 kg ha^{-1} potash benefited more as against the level of 75 kg

Table 50. Benefit-cost analysis

Treatments	Benefit-cost ratio	Interaction (Irrigation x nitrogen)	Benefit-cost ratio	Interaction (Nitrogen x potassium)	Benefit-cost rati
i_1	1.85	i_1n_1	1.78	n_1k_1	1.74
i_2	1.64	i_1n_2	1.95	n_1k_2	1.74
i_3	1.84	i_1n_3	1.86	n_1k_3	1.70
SE	0.017	i_2n_1	1.65	n_2k_1	1.75
CD	0.066	i_2n_2	1.69	n_2k_2	2.03
n_1	1.73	i_2n_3	1.63	n_2k_3	1.81
n_2	1.86	i_3n_1	1.76	n_3k_1	1.70
n_3	1.79	i_3n_2	1.94	n_3k_2	1.78
SE	0.020	i_3n_3	1.87	n_3k_3	1.88
CD	0.066	SE	0.022	Package	1.62
k_1	1.73	CD	0.064	SE	0.035
k_2	1.85	---	---	CD	0.114
k_3	1.80	---	---	---	---
SE	0.020	---	---	---	---
CD	0.066	---	---	---	---

and 25 kg ha^{-1}.

The interaction effect of irrigation x nitrogen and nitrogen x potassium were also significantly altered. Supplying irrigation water at full CPE during tuber initiation and/or tuber maturity phase with nitrogen at 50 kg ha^{-1} was superior to other combinations. Applying nitrogen and potash at 50 kg ha^{-1} each resulted in the highest benefit cost ratio of 2.03.

SUMMARY

6. SUMMARY

The salient findings are summarised below.

Length of vine

Providing irrigation at full CPE during tuber initiation phase resulted in a significant improvement in vine length. The length of vine was profoundly influenced by enhanced rate of nitrogen application.

Number of branches plant^{-1}

Nitrogen application at higher rates resulted in the production of more branches plant^{-1}. Irrigation schedules and potash levels failed to record any influence.

Number of leaves plant^{-1}

Supplementing with full CPE of irrigation water during tuber initiation phase produced more leaves plant^{-1} as compared to providing 1/2 CPE during the same period. Increased rates of nitrogen supply favoured the production of more leaves plant^{-1} whereas potassium did not exert a steady influence.

Leaf area index

The LAI was maximum in plots that received irrigation at full CPE during tuber initiation phase. N substantially influenced LAI, higher levels being significantly superior to lower levels. Higher levels of potassium also influenced the LAI favourably.

NAR and CGR

The NAR was highest in plots irrigated with 1/2 CPE during tuber initiation phase. Both NAR and CGR were high in the early stage of growth and decreased towards harvest. Increased rates of N supply decreased the NAR whereas no definite trend could be observed on CGR. Higher levels of potassium had a favourable influence on NAR and CGR.

Specific leaf weight

Specific leaf weight was significantly higher in plots receiving irrigation at 1/2 CPE during tuber initiation phase. Enhanced supply of nitrogen reduced the specific leaf weight while potassium had no definite influence.

Dry matter production

The dry matter content of leaves, shoot, tuber and fibrous roots were significantly enhanced by providing full CPE during tuber initiation phase. Increasing the level of N also influenced the dry matter partitioning wherein higher levels resulted in the production of more dry matter in aerial parts. Nitrogen application at 50 kg ha^{-1} resulted in similar dry matter production as compared to 75 kg ha^{-1} N. Increased rates of K application favoured the production of more dry matter in leaves, shoots and fibrous roots in one season.

Tuber bulking rate

Tuber bulking rate showed a positive trend under irrigation at full CPE during tuber initiation phase. Nitrogen levels at 50 and 75 kg ha^{-1} had an overlapping influence on tuber bulking rate and both remained superior to 25 kg ha^{-1}.

Length and girth of tuber

The length and girth of tuber failed to be influenced by irrigation schedules. An increase in length and a corresponding decrease in girth were noticed at enhanced rate of nitrogen supply. The girth of tuber was maximum at 75 kg ha^{-1} potash while potassium did not exert any influence on the length of tuber.

Mean tuber weight

Providing irrigation at full CPE during tuber initiation phase was superior to 1/2 CPE in influencing the mean tuber weight. Varying the levels of N and K did not influence the mean tuber weight.

Number of tubers $plant^{-1}$

The number of tubers $plant^{-1}$ showed a significant improvement by providing irrigation at full CPE during tuber initiation phase. Increased rates of N supply influenced the total number of tubers $plant^{-1}$ whereas no effect was noticed on the number of marketable tubers. Application of potassium at medium level i.e., 50 kg ha^{-1} promoted the production of more tubers.

Tuber yield

Tuber yield was significantly influenced by irrigation wherein providing full CPE during tuber initiation phase produced superior yield of total and marketable grade tubers. Tuber yield was maximum at the nitrogen dose of 50 kg ha^{-1}.

Application of potash at 50 kg ha^{-1} also resulted in the production of maximum tuber yield.

Vine yield

Irrigation schedules had no influence on vine yield at harvest. However, N influenced the vine yield wherein application of 75 kg ha^{-1} resulted in significantly higher yield and the lowest by 25 kg N.

Harvest index and utilization index

Irrigation at full CPE during tuber initiation phase resulted in significantly high HI and UI. Application of N at 25 kg ha^{-1} resulted in high HI and UI. Though, potassium did not influence the UI, HI was significantly higher when potash was applied @75 kg ha^{-1} in the second season.

Starch and sugar contents

The starch and sugar contents of the tuber were not modified by irrigation schedules. Starch and sugar contents were significantly higher when N was applied @ 50 and 75 kg ha^{-1} respectively and lowest at 25 kg ha^{-1}. Applying potassium at 75 kg ha^{-1} resulted in highest starch and sugar content of tubers.

Cooking quality

Cooked tubers contained more dietary fibre that were irrigated at full CPE during tuber initation phase. As regards N supply, a dose of 50 or 75 kg ha^{-1} produced tubers that were sweet in taste and soft in texture. Application of potassium at 75 kg ha^{-1} produced non-fibrous tubers.

Uptake of nitrogen

The uptake of N was influenced by irrigation schedules where the vines and tubers showed a progressive increase in uptake under full CPE provided during tuber initiation phase. Over the stages, there was a conspicuous decline in uptake of N by vines whereas an increase in the uptake by tubers which suggest that considerable N is translocated to the developing tubers and a significant increase in the total uptake of nitrogen as a result of enhanced nitrogen supply.

Uptake of phosphorous

Irrigation schedules did not influence the uptake of P by vines and tubers. However, application of N at the highest level resulted in maximum uptake of P by vines and tubers. Potassium had no influence on P uptake.

Uptake of potassium

Potassium uptake by vines was not influenced by irrigation whereas applying full CPE during tuber initiation phase accumulated more K in tubers. Nitrogen application at the highest level i.e., at 75 kg ha^{-1} resulted in the maximum uptake of K. Applying potash at 50 or 75 kg ha^{-1} resulted in maximum uptake of K by vines and tubers as compared to 25 kg ha^{-1}.

Available nitrogen content

Irrigation schedule in any way, did not influence the available N content of the soil. Application of N at higher levels maintained a favourably higher N status in the soil after the harvest of first crop, though no definite trend could be visible after the second crop. Potassium application did not influence the N content of the soil.

Available phosphorus content

The available P content of the soil did not show any variation due to scheduling of irrigation. However, varying the N supply influenced the available P content where the maximum was in plots receiving N at 25 kg ha^{-1}. Applying potash at different levels had no influence on available P content of the soil. However, a build up of P as compared to the initial status was seen in all plots.

Available potassium content

Scheduling of irrigation did not modify the available K content. Nitrogen supply modified the available K content wherein plots that received 25 kg ha^{-1} recorded the highest and the lowest by plots that received 75 kg ha^{-1} N. Available K was highest in plots that received the highest dose of potash.

Irrigating at full CPE during tuber initiation phase and restricting the supply of water at later stages of crop growth increased the tuber yield and net returns from sweet potato grown as a catch crop in summer rice fallows. Nitrogen and potash may be applied @ 50kg ha^{-1} each along with an appropriate quantity of phosphorus which will not lead to its build up in soil. Farm yard manure may be avoided altogether and supplemented with lime @ 500kg ha^{-1} to improve the efficiency of applied nutrients.

Abbreviations: ASI, Agricultural Situation in India; CIP, International Potato Centre; CTCRI, Central Tuber Crops Research Institute; DAP, Days After Planting; FAO, Food and Agriculture Organisation.

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APPENDIX

Appendix I Weather parameters during the first season (1990)

Weeks after planting	Period	Temperature (°C) Max.	Min.	R.H(%)	Sunshine (hrs)	Evaporation (mm)	Rainfall (mm)
1	8.3.90-14.3.90	33.2	24.6	63.5	9.3	46.2	-
2	15.3.90-21.3.90	32.7	23.6	64.3	8.5	38.5	-
3	22.3.90-28.3.90	33.0	24.8	69.8	10.1	40.6	-
4	29.3.90-4.4.90	33.7	25.2	63.1	10.5	46.2	-
5	5.4.90-11.4.90	33.5	25.0	66.6	8.1	41.3	12.4
6	12.4.90-18.4.90	32.9	25.9	73.9	6.1	39.9	5.2
7	19.4.90-25.4.90	33.4	26.1	65.7	10.5	45.5	-
8	26.4.90-2.5.90	33.7	25.5	73.1	8.9	44.1	15.4
9	3.5.90-9.5.90	32.5	25.1	74.3	6.8	41.3	29.5
10	10.5.90-16.5.90	32.1	24.6	79.2	6.4	33.6	19.0
11	17.5.90-23.5.90	30.6	23.3	84.3	2.9	29.4	229.9
12	24.5.90-30.5.90	29.9	23.9	89.7	5.7	28.0	53.0
13	31.5.90-6.6.90	29.5	24.0	83.9	3.6	22.4	56.9
14	7.6.90-13.6.90	29.8	23.4	84.6	5.0	28.7	49.7
15	14.6.90-20.6.90	30.0	25.0	87.8	8.3	30.1	34.6

Appendix II Weather parameters during the second season (1991)

Weeks after planting	Period	Temperature (°C) Max.	Temperature (°C) Min.	R.H(%)	Sunshine (hrs)	Evaporation (mm)	Rainfall (mm)
1	22.2.91-28.2.91	32.0	23.1	72.4	9.4	37.8	-
2	1.3.91-7.3.91	31.6	23.3	79.1	8.5	30.8	5.2
3	8.3.91-14.3.91	31.9	23.8	76.5	9.3	39.9	-
4	15.3.91-21.3.91	32.5	23.9	74.8	10.2	41.3	-
5	22.3.91-28.3.91	32.9	25.4	74.1	7.8	42.0	-
6	29.3.91-4.4.91	32.0	24.7	82.1	6.6	28.7	17.6
7	5.4.91-11.4.91	33.4	25.0	77.8	9.6	38.5	17.0
8	12.4.91-18.4.91	33.7	25.1	76.6	8.3	30.8	59.4
9	19.4.91-25.4.91	33.7	26.5	72.5	8.6	35.7	13.8
10	26.4.91-2.5.91	33.3	25.6	81.4	10.0	30.1	49.2
11	3.5.91-9.5.91	33.8	26.2	75.0	9.8	39.9	-
12	10.5.91-16.5.91	33.5	26.1	77.8	8.4	30.8	11.8
13	17.5.91-23.5.91	32.8	25.6	80.5	9.4	24.5	24.8
14	24.5.91-30.5.91	32.8	25.9	78.9	6.3	30.8	16.0
15	31.5.91-5.6.91	29.6	24.1	92.6	1.8	9.0	226.9

ABSTRACT

ABSTRACT

A field experiment on sweet potato was laid out in the rice field fallowed during summer season at the Instructional Farm, College of Agriculture, Vellayani. The study was intended to work out the irrigation schedule and fertilizer practice for sweet potato grown as a catch crop during the summer season of 1990 and 1991. The experiment was designed to economise the use of irrigation water as well as fertilizers by inducing phasic stress at certain phases of plant growth which are considered critical for sweet potato.

The field experiment was laid out in a strip plot design replicated thrice with irrigation in horizontal strips and fertility levels in vertical strips. Irrigation water at full CPE was given during tuber initiation phase (10-30 DAP), full CPE at tuber maturity phase (80-100 DAP) and full CPE at tuber initiation and tuber maturity phases. The crop received irrigation at 1/2 CPE during the rest of the period of plant growth. Nitrogen and potassium were applied @ 25, 50 and 75 kg ha^{-1} and a uniform dose of P_2O_5 @ 50 kg ha^{-1} and lime @ 500 kg ha^{-1} were applied. A control plot that received NPK @ 75:50:75 kg ha^{-1} and FYM @ 10 t ha^{-1} was maintained for treatment comparison.

Growth characters were recorded at an interval of 21 days from planting and it was observed that providing irrigation at full CPE during tuber initiation phase resulted in significant increase in vine length and number of leaves plant^{-1}. Enhanced rate of application of nitrogen promoted the growth of vines, number of branches plant^{-1} and number of leaves produced plant^{-1}. Potassium did not exert any influence on these growth characters.

Growth analysis studies showed that the LAI was maximum in plots that received irrigation at full CPE during tuber initiation phase. Nitrogen substantially influenced the LAI, higher levels being significantly superior to the lower levels. Higher levels of potassium also influenced the LAI. The NAR and specific leaf weight were the highest in plots that received irrigation at 1/2 CPE during tuber initiation phase. Both NAR and CGR were high in the early stage of plant growth and decreased towards harvest. Increased rates of nitrogen supply decreased the NAR and specific leaf weight whereas no definite trend could be observed on CGR. Higher levels of potassium had a favourable influence on NAR and CGR.

The dry matter of leaves, shoots, fibrous roots and tubers were significantly enhanced by providing full CPE during tuber initiation phase. Increasing the level of nitrogen, influenced the dry matter in the aerial parts. The influence of K on dry matter production was not consistent. Tuber bulking rate showed a positive trend under irrigation at full CPE during tuber initiation phase. Nitrogen levels at 50 and 75 kg ha^{-1} had an overlapping influence on tuber bulking rate and both remained superior to 25 kg ha^{-1}.

Scheduling of irrigation did not exert any influence on the length and girth of tuber. However, an increase in the length and a corresponding decrease in the girth were noticed at enhanced rates of nitrogen supply. The number of tubers $plant^{-1}$ showed a significant improvement by providing irrigation at full CPE during tuber initiation phase. The total number of tubers $plant^{-1}$ was increased by high rates of N, but did not influence the number of marketable tubers. Application of K at 50 kg ha^{-1} promoted the production of more tubers. Tuber yield was significantly influenced by irrigation wherein providing full CPE during tuber initiation phase resulted in superior yield of both total and marketable tubers. Tuber yield was maximum at 50 kg ha^{-1} each of nitrogen and potash. Vine yield was significantly enhanced by higher rates of applied nitrogen.

The harvest index and utilization index were enhanced by the application of irrigation water at full CPE during tuber initiation phase. Application of N at 25 kg ha^{-1} resulted in the production of high starch content whereas the sugar content was increased upto the highest level of 75 kg ha^{-1}.

The uptake of nitrogen by vines and tubers showed a progressive increase while the uptake of potassium showed an increase by applying full CPE during tuber initiation phase. Application of higher levels of nitrogen invariably promoted the uptake of N, P and K by the plant. Application of potash at 50 or 75 kg ha^{-1} also resulted in higher uptake of potassium.

The fertility status of the soil did not show a positive trend by scheduling of irrigation. The plots that received the lowest dose of nitrogen, invariably recorded the highest level of available phosphorus. Available potassium content was also high in plots that received higher rates of potash.

Irrigation at full CPE during tuber initiation and/or tuber maturity phase recorded significantly higher water use efficiency and net returns as compared to inducing stress during tuber initiation phase. Nitrogen and potash both at 50 kg ha^{-1} recorded the maximum water use efficiency and net returns from sweet potato cultivation.