WATER MANAGEMENT IN RELATION TO SPLIT APPLICATION OF NITROGEN ON BHINDI

Abelmoschus esculentus (L) Moench

By

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THESIS

Submitted in partial fulfilment of the
requirement for the degree of
MASTER OF SCIENCE IN AGRICULTURE
Faculty of Agriculture
Kerala Agricultural University

Department of Agronomy
COLLEGE OF AGRICULTURE
Vellayani, Trivandrum

1986

Dedicated to the Sacred Memory of
my Beloved Brother Dr. Jaya Kumar,
who Expired on 14-12-1985

DECLARATION

I hereby declare that this thesis entitled "Water management in relation to split application of nitrogen on bhindi (Abelmoschus esculentus (L) Moench)" is 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, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that this thesis entitled "Water management in relation to split application of nitrogen on bhindi (Abelmoschus esculentus (L) Moench)" is a record of research work done by Sri Jayakrishna Kumar, V. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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ACKNOWLEDGEMENTS

I note down herewith humility and pride that I was most furtunate in having done my research work under the able guidance of Dr. G.R. Pillai, Professor of Agronomy, Agronomic Research Station, Chalakudy. I am grateful to him for his sustained interest, candid suggestions, constructive criticism and constant encouragement during the course of my research work and preparation of the thesis.

I am deeply indebted to Dr. V.K. Sashidar, Professor of Agronomy and Shri K.P. Madhavan Nair, Professor of Agronomy, for their expert advice and valuable suggestions and constant encouragement.

I sincerely express my gratitude to Smt.G.Santhakumari, Associate Professor of Agricultural Chemistry and Shri C.S. Gopi, Assistant Professor of Agricultural Chemistry for their valuable suggestions and assistance in providing necessary facilities for chemical analysis. I am also grateful to Dr. M. Abdul Salam, Assistant Professor of Agronomy, Shri Jose Mathew, Assistant Professor of Agronomy and Shri Kuruvila Varghese, Assistant Professor of Agronomy for their helpful suggestions and criticism.

My thanks are also due to the staff of the Agronomic Research Station, Chalakudy and the staff and the students of the Department of Agronomy, for their sincere co-operation and assistance and Kerala Agricultural University for the award of fellowship.

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INTRODUCTION

I. INTRODUCTION

The role of vegetables in human diet as an important source of natural protective food is well known. They are cheap, rich in vitamins and minerals and yield roughly three to four times the food obtained from cereals per unit area per unit time. The requirement of vegetables to meet the nutritional needs of an adult is 200 g d^{-1}. So the provision of vegetables to be made for an adult per day in rice based South Indian and wheat based North Indian diets is 150 g d^{-1} and 180 g d^{-1} respectively. At the rate of 150 g d^{-1}, the quantity of vegetables required for Kerala at present for the adult equivalent of the population will be 13.36 lakh tonnes per annum. However, at the per capita consumption rate of 23 g d^{-1} in the state the annual consumption works out to only 2.06 lakh tonnes (Anon 1983). The existing alarming gap between requirement and consumption of vegetables in the state is still getting widened on account of high rate of increase in population without any corresponding increase in vegetable production. The area under vegetables in Kerala at present is only about 19680 ha (0.65 per cent of the cultivated area) (Anon 1983). Inorder to fill the existing gap of 11.30 lakh tonnes of vegetables in the state, an additional area of 1.08 lakh ha will have to be brought under cultivation. Since there is no scope of increasing the extent of cultivable land in the state, production of vegetables could be enhanced only through intensive multiple cropping practices. Here more emphasis should be given to the efficient use of available water resources in combination with other productive inputs. In Kerala where temperature is not a limiting factor vegetable cultivation throughout the year is possible with adequate and assured irrigation facilities. Therefore summer rice fallows of the state with assured irrigation facilities can be profitably put to vegetable cultivation.

Bhindi (*Abelmoschus esculentus* Moench) is an important warm season vegetable cultivated in most of the tropical countries. The adaptability to a wide range of soil and climatic conditions, the easiness in cultivation, high nutritive value, palatability, suitability for year round production etc. made bhindi a popular vegetable in Kerala. It is rich in proteins and minerals and a good source of Vitamin A, B and C. Being a good source of iodine, bhindi is considered effective against "Goitre".

Cultivation of irrigated bhindi in summer rice fallows has become remunerative and therefore gaining popularity among the farmers of the state, especially in the irrigation commands. Management of water and fertilizer, the two costly inputs is most important in the successful production of summer crops. Agronomic studies conducted in this crop so far, dealt mainly with the fertilizer aspect. Very little attention has been received on the water management of this crop. Sharma and Prasad (1973) reported higher and profitable yields in bhindi by adopting proper water management practices. Appropriate schedule of irrigation for the crop raised in summer rice fallows of the state will have to be worked out for the efficient management of the limited water resources and economic production of the crop. Farmers must also be made aware of the use of various inputs especially fertilizers in combination with irrigation water for optimum crop production. In the package of practices of the Kerala Agricultural University (1982) a fertilizer dose of 250 kg Ammonium Sulphate per hectare in two equal splits (at sowing and one month later) has been recommended besides 50 kg each of super phosphate and Muriate of Potash completely as basal. However, the farmers are applying nitrogen in more number of splits. Studies on the split application of nitrogen to this crop is also scanty.

The present investigation was therefore undertaken to study the effect of water management practices in relation to split application of nitrogen on growth and yield of bhindi with the following objectives.

1) To study the effect of water management practices on growth and yield of bhindi.

2) To compare the efficiency of different split doses of nitrogen on growth and yield of bhindi.

3) To study the interaction between water management practices and split application of nitrogen on growth and yield of bhindi.

4) To determine the uptake of N, P and K at different stages of growth as influenced by water management practices and split application of nitrogen.

5) To work out the moisture extraction pattern, consumptive use and water use efficiency.

6) To work out the economics of production.

REVIEW OF LITERATURE

II. REVIEW OF LITERATURE

Vegetables in general have not received as much attention as that of field crops with respect to their water and nutritional requirements. Research work on water management aspects and split application of nitrogen in bhindi, a popular vegetable of Kerala is also meagre. Attempts have therefore been made to review the important works done in India and abroad on vegetables like tomato, chillies, cucurbits and other related crops.

2.1 Effect of irrigation

2.1.1 Growth characters

Giles and Alexander (1950) pointed out that weekly irrigation in tomato favoured shallow rooting. They also noted that roots penetrated deeper as the frequency of irrigation was widened.

Spencer (1951) in his studies on tomato root distribution under furrow irrigation noted that almost 75 per cent of the roots were found in the top 40 cm layer in plots receiving frequent irrigation.

Hudson and Salter (1953) also obtained the same type of rooting pattern as observed by Giles and Alexander. They noticed that the zone of greatest root development in tomato became progressively deeper in the drier treatments.

Belik (1961) observed that optimum conditions for cucumber development were 80-90 per cent of the full moisture capacity during early growth phase and 60-70 per cent during fruiting stage. He also noticed that irrigation was necessary when the cell sap concentration reached 5.0-6.0 per cent during the first half of the growing period and 7.0-7.5 per cent during fruiting.

Gorbatenko (1962) noticed that root distribution of tomatoes was 85 per cent in the top 125 cm layer of unirrigated soil. With irrigation, he observed 85 per cent of the absorbing roots in the top 30 cm layer of the soil.

Dastane et al. (1963) in their study on tomato in a sandyloam soil of medium fertility noted that the best growth was resulted when the available soil moisture level ranged from 100-50 per cent.

According to Giardini and Pimpini (1971) the highest vegetative growth of aerial parts and roots of capsicum was obtained with irrigation at 0.6 atm (available soil moisture 60 per cent) as compared to irrigation at 0.3, 0.9, 1.5 or 3.2 atm .

Tamaki and Naka (1971) reported that high soil moisture content (85 per cent of field capacity) increased the number of branches, stem length, leaf number and dry weight of various aerial parts in broad beans at later stages of growth.

According to Abdelfattah and Abdel-Salam (1972), the depth of root penetration in brinjal increased as the interval between irrigations was widened. They also reported that roots penetrated deeper when 100 m^3 per feddan was applied than 200 m^3.

From field and green house studies, Cummin and Kretchman (1974) noted that leaf area in cucumber was greatly reduced under water stress.

Escober and Gauman (1974) had grown mexican squash (Cucurbita pepo) hydroponically at low (0.4 atm) and high (2.4 atm) stress. They noticed that leaves of plants under high stress were thicker and smaller containing less water than plants under low water stress.

Hafeez and Cornillon (1976) observed that plant length and leaf area of brinjal were greatest with five irrigations per week and least with one per ten days.

Cascio and Pugila (1978) while investigating the effects of sprinkler, furrow and drip methods of irrigation on the root distribution of tomato to a depth of 100 cm, noticed the highest root density and distribution with furrow irrigation, the lowest with drip irrigation and intermediate with sprinkler irrigation.

Pai and Hukheri (1979) opined that for good growth of vegetables the soil moisture should be maintained at or above

75 per cent of availability in the active root zone.

Gamayun (1980) reported maximum leaf and shoot growth of tomato in plots irrigated throughout the growing season at 80 per cent of field capacity as compared to plots irrigated at 60 or 70 per cent of field capacity.

Chander and Mangal (1983) found that in muskmelon the best growth and cropping were obtained from plots irrigated at 0.9 pan evaporation coefficient (55 mm irrigation water) as compared to plants grown at 0.3, 0.6 or 1.2 pan evaporation coefficients.

In trials with water melon Desai and Patil (1984) obtained good plant growth in relation to plant height, leaf number and dry matter production at IW/CPE of 1.0 as compared to IW/CPE of 0.6, 0.8 or 1.2.

Thomas (1984) found that bittergourd responded well to irrigation. Biometric characters like length of vine, LAI and dry matter production were favourably influenced by frequent irrigation.

2.1.2 Yield and Yield attributes

Vittum *et al*.(1958) reported that irrigation applied to tomato when the available water in the upper 24 inch layer of the soil dropped below 50 per cent significantly increased yield of later stages of growth.

Frohlich and Henkel (1961) observed that yield of cucumber was increased by an average of 16.7 per cent with irrigation before flowering when soil moisture fell to 50 per cent of field capacity and after flowering when it fell to 60-65 per cent of field capacity.

Balasa <u>et</u> <u>al</u>.(1962) reviewing the effect of soil moisture regimes on the production of certain vegetables reported a soil moisture level of 60 per cent of field capacity till fruit set and thereafter of 80 per cent for tomatoes and pepper. Brinjal performed best with soil moisture level kept always above 80 per cent.

Gerard and Cowley (1964) reported that a preplanting irrigation and an irrigation at about flowering time were required for tomato in dry years for higher yields.

Flocker <u>et</u> <u>al</u>. (1965) obtained satisfactory yield of melon by irrigation when the soil moisture tension at 18 inch depth reached 3 bar. They observed that yield increase by irrigation was mainly due to increase in fruit size.

Molnar (1965) found in melons that irrigation advanced flowering and increased the number of female flowers. He also observed a high water requirement at the beginning of fruit growth.

Kartlov and Dimitrov (1970) obtained the highest yield of capsicum at a soil moisture content of 80-90 per cent of field capacity, the range tested being 60 to 90 per cent.

Giardini and Pimpini (1971) in trials with capsicum obtained the highest fruit yield with irrigation when the soil moisture tension reached 0.6 atm (available soil moisture 60 per cent) as compared to irrigation at soil moisture tensions of 0.3, 0.9, 1.5 or 3.2 atm . In trials with Capsicum Abdel-fattah and Abdel-Salam (1972) obtained satisfactory fruit yield by watering it every week as compared to every 2 or 3 weeks. They also observed that yield increase due to irrigation was attributable to increase in number and weight of fruits.

Neil and Zunino (1972) indicated that irrigation upto 80 per cent of maximum evapotranspiration had recorded the maximum yield in melon and was found to be economically feasible. The yield increase due to irrigation was mainly by increase in fruit size and number of fruits.

Aladzajkov et al.(1973) reported higher fruit yield of Capsicum by irrigating the plant when the moisture content of the soil at 30 cm depth fell to 65 per cent of field capacity.

According to Caliandro and Caro (1973), irrigation with 300 m^3 ha^{-1} of water in Capsicum gave the highest yield and fruit weight and hastened maturity.

Deidda and Marras (1973) reported that higher yield was obtained in tomatoes by irrigating them seven to eight days, each time with 450-500 m^3 ha^{-1} of water and the total amount of water applied in the season was 5500-6000 m^3 ha^{-1}.

Muminov (1973) while trying to forecast the time of irrigation by the leaf water content obtained the highest melon yield by irrigating the crop at a leaf water content of 84-86 per cent.

Razvi and Jagirdar (1973) in a series of trials with bhindi obtained the best yields with irrigation given every 11 days as compared to 7 or 15 days. Sharma and Prasad (1973) in a field study with bhindi, found that irrigation applied at a soil moisture suction of 0-0.50 atm at 24 cm depth resulted in more number of pods and higher profit than that applied at lower and higher values of 0-0.25 atm and 0-0.75 atm respectively.

In trials with Cucumber Dimitrov (1974) recorded the highest yield at a soil moisture of 70 per cent of field capacity before picking and 90 per cent during picking. It was noted that yield was 26 per cent higher than that of control when 70 per cent of the field capacity was maintained during the entire growing season.

Umrani and Khot (1974) obtained the highest brinjal yield with irrigation at 45 mm cumulative Pan Evaporation (CPE) as compared to irrigation at every 15, 30, 60 or 75 mm CPE.

Varga (1974) reported that an irrigation with 40 mm of water between flowering and fruit ripening period was necessary for fruit development. However, excessive application of water was found to be deleterious.

Jagoda and Kaniszewski (1975) reported that irrigation appreciably improved the yield of cucumber. The crop was irrigated when the soil moisture content fell to 58 per cent of field capacity at 10-27 mm depth.

Pavlov (1976) obtained the highest yield of cucumber when 70-100 l m^{-2} water was applied during the plant growing phase in 20-32 individual irrigations followed by 480-570 l m^{-2} during fruiting in 92-94 irrigations.

Pellicciari and Sisamondo (1976) in their studies on the effect of irrigation on antichoke yield observed that 400 m^3 ha^{-1} of water applied after 50 mm evaporation and 600m^3 ha^{-1} applied after 10 mm were effective in giving higher yields.

Linsalata and Caro (1977) obtained the highest yield of brinjal with a seasonal total of 3600-4800 m^3 ha^{-1} of irrigation water when applied at the highest frequency, ie. when evapotranspiration between two consecutive irrigations was 20 or 27 mm.

According to Loomis and Crandall (1977) the best irrigation schedule for pickling cucumbers involved the removal of 48 to 64 per cent of the available water from the upper 90 cm of the soil profile between irrigations. They also observed that moderate stress in cucumbers had no significant effect on the grade or number of poorly developed fruits.

Tedeschi and Ruggiero (1977) in a two year experiment with tomatoes reported that irrigation at 45 per cent available soil moisture gave the highest yield and decreased the number of fruits rotted by blossom end.

Motoki and Kurokawa (1977) in trials with melon obtained optimum yields with irrigation applied at pF 2.5 as compared to irrigation at pF 2.0 or 2.7. The yield increase was attributable to increase in fruit size.

Pugila et al. (1977) obtained higher yields of tomato with irrigation at an IW/CPE of 0.7. Rudich et al.(1978) observed that irrigation during the fruit set and fruit development stages of tomato increased yield by 53 t ha^{-1} as compared to unirrigated plants.

Abreu et al. (1978) reported from field trials that in melons the highest average yield was obtained from drip irrigation with two emitters per planting hole applied at 0.7 atm as compared to irrigation with 4 emitters applied at 0.4 atm .

Rudich et al.(1978) from drip irrigation studies in musk melon reported that irrigation given during the fruit development stage had resulted in higher yields.

Singh and Singh (1978) reported higher yields with drip irrigation at 65 per cent of the evaporation from a Class A pan evaporimeter in crops like bottle gourd, round gourd and watermelon in loamy sand soils of hot and arid regions.

Pandey and Singh (1979) in a two year trial with bhindi obtained the highest seed yield with plants irrigated at 60 mm CPE as compared to lower frequencies of irrigation correspon-ding to 80 or 120 mm CPE.

Bar-Yosef et al. (1980) reported that in tomato the highest yield (76 t ha^{-1}) was obtained with the wettest treatment which consists of applying water at the rate of 1.6-2.3 l d^{-1} as compared to 51 and 61 t ha^{-1} obtained with 0.6-1.05 l d^{-1} and 0.9-1.51 l d^{-1}, respectively. They also reported that higher yields due to irrigation was attributable to increase in fruit number and fresh weight.

Henriksen (1980) found that the yields of ridge cucumbers were the highest with irrigation at 75-100 per cent water deficit than without irrigation. Twice as many fruits and upto three times greater weight of fruits per plant were obtained by irrigation.

Palevitch et al.(1980) in drip irrigation studies with Capsicum noted that irrigation during the fruit maturation stage was essential to obtain higher yields. They also reported that application of higher amounts of water did not produce any significant increase in yield.

Studies on scheduling irrigation to bitter gourd and cucumber at the Agronomic Research Station, Chalakudy indi-cated that 3 cm irrigation at IW/CPE ratio of 0.4 was optimum for both the crops in summer rice fallows (Anon 1981a).

Barbieri and Duranti (1981) reported that yields of tomato were increased with the highest irrigation frequency of 40 mm of evapotranspiration as compared to irrigation at 80 or 120 mm of evapotranspiration.

According to Cornillon and Dauple (1981), brinjal receiving daily trickle irrigation produced larger fruits and higher fruit yields than those receiving bi-weekly furrow irrigation. They observed that plants receiving water equivalent to 80 per cent of the potential evapotranspiration yielded better than those receiving less water.

Caixeta _et_ _al_. (1981) reported that in Capsicum frequent irrigation led to the highest seed and fruit yields. They also reported that the largest amount of water (6 mm d^{-1}) led to the highest fruit yield.

Goto _et_ _al_. (1981) obtained the highest fruit yield in forced cucumbers with irrigation applied at soil moisture tension corresponding to pF 2.3 as compared to irrigations at pF 1.7, 2.0 or 2.5.

Kuruppuarachchi and Pain (1981) in their trials with Capsicum, onion and banana found that the yields of all the three crops were markedly reduced by irrigation at 40 or 75 per cent soil moisture depletion as compared to irrigation at 10 per cent soil moisture depletion.

Sadykov and Mikhael (1981) obtained the highest yield of Capsicum when it was irrigated at 70-75 per cent of field capacity.

Ali and Raggal (1982) indicated that higher yield of fruits in tomatoes can be obtained with irrigation at 70 per cent of field capacity as compared to irrigation at 50 per cent of field capacity.

Alves et al. (1982) reported that in tomatoes higher yields were obtained from plots irrigated at 0.9 times the mean Class A pan evaporation compared with irrigation at 0.4, 0.6, 0.8, 1.0 or 1.2 times the mean pan evaporation values. The higher yields were mainly due to increase in the number of marketable fruits.

Trials conducted in ash gourd recorded the highest yield at IW/CPE ratio of 1.0 which was on par with the IW/CPE ratio of 0.7. Both these were significantly superior to the IW/CPE ratio of 0.4 (Anon 1982a). The crop was however raised under shallow water table conditions.

Mangal and Pandita (1982) observed that cauliflower yield rose from 37.5 kg per plot on plots receiving the lowest irrigation level (100 mm CPE) to 56.1 kg per plot on plots receiving the highest irrigation level (44 mm CPE). The yield increase was mainly due to the increase in curd average weight, diameter and leaf weight.

Pandey and Singh (1982) obtained the highest seed yield of bhindi with irrigation at 60 mm CPE as compared to irrigation at 80 and 120 mm CPE.

Smittle and Threadgill (1982) found that the highest yield of marketable fruits was obtained with irrigation at 0.3 bar soil water tension in cucumber.

Vuelwascisneros (1982) in trials with Capsicum obtained the highest marketable yield with plants irrigated at 30 per cent soil moisture before flowering and 40 per cent soil moisture after flowering.

Lin et al. (1983) reported that drip irrigation in tomatoes with moisture levels maintained above 25, 50, 65 and 80 per cent of available water produced 20-40 per cent more marketable yield than monthly furrow irrigation and 80 per cent more than the unirrigated control.

O'Dell (1983) reported that trickle irrigated tomatoes gave upto 40 per cent higher yield even in a relatively wet season. Trickle irrigated capsicum yielded 27 per cent more marketable fruits than unirrigated plants. He observed that average fruit size of both tomatoes and Capsicum were enhanced by irrigation.

Pew and Gardner (1983) in trials with musk melon obtained higher yields, larger fruits and earlier maturity by irrigating the crop when soil moisture tension at 25 cm depth reached 50 or 75 K Pa as compared to 25 K Pa.

Udeogalanya and Muoneke (1983) reported that in bhindi the fruit yield in terms of both total number per plant and weight per hectare was increased by irrigation. Irrigation upto 30 l per plant significantly reduced fruit abscission by upto 50 per cent as compared to irrigation with a total of 15 or 60 l of water per plant.

Studies with bittergourd revealed that irrigation scheduled at 60 mm CPE was significantly superior to 40 and 80 mm CPE which in turn were on par with each other (Anon 1984a).

Scheduling irrigation to brinjal indicated at 6 cm irrigation at 75 mm CPE recorded the highest fruit yield which was on par with irrigation at 60 mm CPE. Both these treatments were significantly superior to irrigation at 90 and 105 mm CPE (Anon 1984b).

Acevedo and Massard (1984) in green house trials with tomato seedlings found that water stress during the early stage reduced the yield of first and second clusters, and water stress during the later stage reduced the yield of fourth and fifth clusters. They also reported that all plants recovered from water deficit before fruit development had begun.

Tedeschi and Zerbi (1984) while studying the flowering and fruiting courses of Capsicum showed that total and marketable yields per plant were linearly related to actual evapotranspiration and that yield depended on the number of fruits per plant and the mean fruit weight rather than the number of flowers. Since plants proved very sensitive to even moderate water stress, it was recommended that matric potential should not be allowed to fall below -0.1 M Pa.

Thomas (1984) found that in bitter gourd the yield contributing factors like number of fruits per plant, mean length of fruit and mean weight of fruit were favourably influenced by frequent irrigation. Total fruit yield was also highest in frequently irrigated plot.

From the above review, it is clear that irrigation has a profound influence on growth, yield and yield attributing characters of vegetables including bhindi.

2.1.3 Consumptive use and moisture extraction pattern

Gautam and Dastane (1970) reviewed the soil moisture extraction pattern of different crops under optimum moisture regimes on sandy loam soils at Indian Agricultural Research Institute, New Delhi. They pointed out that more than 60 per cent of the total moisture depletion was from 0-30 cm layer with greater portion of roots in this layer in the crops under review. The respective figures were as follows: Wheat - 71 per cent; Berseem - 73 per cent; Jowar - 70 per cent; Cowpea - 62 per cent; and Onion - 93 per cent.

Neil and Zunino (1972) found that the total water uptake in melon crop was 2730 m^3 ha^{-1}. The water uptake in successive growth stages was 560 m^3 ha^{-1} between germination and fruit set, 1000 m^3 ha^{-1} upto fruit enlargement, 882 m^3 ha^{-1} upto prematurity and 280 m^3 ha^{-1} upto harvest.

Aladzajkov et al.(1973) reported that the water requirement of tomato was in the range of 2700 to 3700 m^3 ha^{-1} per season.

Experiments with Cauliflower at IARI, New Delhi in Sandy loam soils indicated that major amount of soil moisture (90 per cent) was utilised by the crop from the 0-45 cm layer of soil. About 50 per cent of the total extraction was from 0-15 cm soil layer (Sharma and Parashar, 1979).

Thomas (1984) found that consumptive use increased with increase in level of irrigation in the case of bitter gourd.

2.1.4 Nutrient composition and uptake

Nutrient uptake and moisture use are closely related.

Brown et al. (1960) observed that cotton and soybeans increased the absorption of N, P, K and Ca linearly in response to increase in soil moisture level from the wilting point to field capacity.

Tamaki and Naka (1971) from trials with broad bean reported that translocation of nitrogen compounds to seed increased at high soil moisture content (85 per cent of field capacity).

According to Sharma and Prasad (1973) nitrogen uptake by bhindi was higher with irrigation at soil moisture tension of 0-0.5 atm as compared to irrigation at 0-0.25 and 0-0.75 atm, respectively. They reported that irrigation had failed to produce any significant effect on nitrogen content in plant parts.

Singh (1975) studied the effect of different soil moisture regimes along with graded doses of fertilizers on berseem fodder and found that the percentage of N, P and K decreased with increase in moisture availability from 25 per cent to 75 per cent. An increase in soil moisture increased the total uptake of N significantly. The uptake of P and K also increased with wetter regimes, but did not reach the level of significance.

While evaluating the effect of soil moisture regimes of 25, 50 and 100 per cent available moisture on green gram, Varma and Subha Rao (1975) observed that a moisture regime of 50 per cent to be optimum for maximum nitrogen content in plant parts.

While studying the effects of irrigation when soil moisture decreased to 60, 70 or 80 per cent of field capacity Gamayun (1980) observed a moisture regime of 80 per cent of field capacity to be ideal for the maximum uptake of N, P and K by tomato plants.

Patel and Padalia (1980) reported that with increase in sequences of soil moisture stress from 1/3 to 14 bar uptake of N, P, K, Ca, Mg and Fe by different plant parts of groundnut continuously decreased. They also observed that nutrient use efficiency was maximum at 1/3 bar and decreased with increase in soil moisture stress. A single stress of about 10 bar during flowering, pegging or pod development stages significantly decreased the nutrient uptake compared to 1/3 bar.

Balasubramonyan and Yayock (1981) observed that moisture stress during peg and pod development stages in groundnut at 9-13 weeks after sowing lowered the uptake of nitrogen.

2.1.5 Effect of irrigation on quality of fruits

Abdel-Al and Saeed (1975) reported that watering tomato every two weeks resulted in greater percentage of soluble solids, a high titratable acidity and lower pH in fruits as compared to watering every week.

Cocueci *et al*. (1976) followed the growth of squash fruit in the field under normal and drought conditions and found a decrease of RNA and protein content in fruit tissues of water stressed plants. They further observed that under drought conditions the fruit growth was controlled by water availability through protein synthesis.

Galeva *et al*. (1976) in trials with tomato noticed that crude protein, vitamin C and carotene contents of the fruits were the highest with irrigation applied at moderate soil moisture potential values.

Henriksen (1980) observed that irrigation in general improved the crude protein, vitamin C and soluble solid contents of the fruits and reduced the tendency towards spongy fruits in cucumber.

Reviewing the work on tomato, Barbieri and Duranti (1981) concluded that irrigation, in general, reduced the pH, soluble solids, crude protein, sugars, and titratable acidity in the fruit.

Kashi (1981) from his works on cantaloupe reported enhanced soluble solid contents in fruits with irrigation given at intervals of 6 and 8 days as compared to 10, 12 or 14 days.

Khosh-Khui and Azarakhush (1983) in their study on tomato obtained the highest percentage of crude protein and juice soluble solids in fruits with irrigation given at 14 days interval as compared to 7 days interval. Dell'amico and Jerez (1984) observed that tomato fruits from plants irrigated at 70 per cent of maximum retention capacity were significantly more acidic than fruits from plants at 80 or 90 per cent of maximum retention capacity.

Desai and Patel (1984) obtained the best quality fruits of water melon in terms of crude protein, vitamin C, sugar and soluble solids from plants irrigated at IW/CPE of 1.0 as compared to plants irrigated at IW/CPE of 0.6, 0.8 or 1.2.

2.1.6 Soil fertility status

Sharma and Yadav (1976) reported that available phosphorus content of the soil increased with increase in the level of irrigation.

Shanmugasundaram et al. (1979) revealed that, in general, available potassium content was low when irrigation was given frequently whereas the same was markedly high in respect of irrigation at longer intervals.

Muthuvel and Krishnamoorthy (1980) studied the influence of soil moisture regimes, doses of added nitrogen and their interactions on the available phosphorus content of soils. They observed that in general available phosphorus content was affected by moisture regimes. Maximum available phosphorus content was noted in the drier regimes than under wetter regimes. But, with regard to available K content of soil, they reported a non significant effect of soil moisture.

A general trend of increasing available K content left behind in the soil with decreasing frequency of irrigation was noticed at Madurai (Anon, 1981b). Irrigation of IW/CPE of 0.9 with 4 cm water left behind the least amount of available K. But the amount was statistically on par with that of IW/CPE 0.75 with 4 cm irrigation. A negative relationship was suggested between the yield and available K content left behind in soil. As the yield increases the available K content left behind in the soil decreases indicating that more of the available K has been taken up by the crop.

2.2 Split application of nitrogen

2.2.1 Growth and Yield

Peterburgskii (1956) while investigating the effectiveness of applied fertilizers under irrigation observed significant yield increase in irrigated soils when high rates of fertilizers were used. A basal dressing before ploughing, a dressing before sowing and a supplementary top dressing were found to be effective in giving better growth and higher yield.

Yawalker (1962) recommended the application of 40 kg nitrogen per hectare for bhindi with half of it applied one month after sowing and the remaining half one month after the first application for better growth and higher fruit yield.

Matev (1966) in his studies on the time of application of mineral fertilizers to Capsicum obtained the most profitable yield by the early application of a top dressing of 80 kg N ha^{-1}. The response of the plant in terms of growth of aerial parts and yield was highest with a top dressing of 80 kg N ha^{-1}.

Skapski *et al*. (1969) showed that growth, yield and fruit size of certain varieties of tomatoes were increased by the application of organic manure (30-60 t ha^{-1}) given in conjunction with side dressings of 150-200 kg N ha^{-1}.

Chauhan (1972) recommended top dressing of 30-75 kg N ha^{-1} as Ammonium Sulphate between rows before fruiting for better growth in terms of plant height and higher fruit yield in bhindi.

In Cucumber Hammett et al. (1974) obtained higher fruit yield by side dressing of 30 lb of nitrogen per acre at 4-6 leaf stage.

Verma et al. (1974) obtained the highest fruit yield in bhindi with 150 kg N ha^{-1}, applied in the proportion of 3 foliar: 1 soil. Foliar sprays were applied at weekly intervals starting from 25 days after sowing.

Bradley et al. (1975) in a study on cucumbers with nitrogen at 80 lb/acre applied either entirely at preplant or 50 or 20 lb/acre preplant followed by one or two supplementary applications one or two weeks after emergence reported that yields and returns tended to be higher with supplementary applications.

Chuzhova et al. (1975) in their study on the effect of split application of mineral fertilizers on the yield of tomatoes observed that split application of N,P,K increased the fruit size and fruit yield.

Dashkova (1976) from trials with cucumbers using Rodnikoy nutrient solution reported that a double nutrient application at the rate of 3.1 g l^{-1} at the vegetative phase and 3.9 g l^{-1} at the reproductive phase produced the best growth and highest yield.

Smittle (1976) reported increased yield in snap beans by the application of additional nitrogen as top dressing. He also noted the highest yield with nitrogen application to maintain the petiole NO_3N level above 1500 ppm pre blossom and 1000 ppm during fruit development.

According to Katyal (1977), application of 50 t ha^{-1} farm yard manure as a basal dose and a top dressing of Ammonium Sulphate at the rate of 100 kg ha^{-1} soon after flowering was sufficient for a successful crop of bitter gourd.

Voigtander (1978) reported that application of 1-4 side dressings of liquid nitrogenous fertilizer by sprinkler irrigation gave higher yields of lettuce and cabbage.

Batal and Smittle (1981) noticed that yields of Capsicum were improved by frequent irrigation and nitrogen top dressing. The highest marketable yields resulted when sufficient nitrogen was added to maintain soil NO_3N levels between 20 and 30 ppm. They also observed that yield increases were influenced by frequent irrigation only when additional N was applied to maintain a high soil NO_3N level.

From an experiment conducted at Kerala Agricultural University, it was found that application of 250 kg Ammonium Sulphate with half of it applied at the time of sowing and the remaining half one month after sowing gave better growth and higher yield of fruits in bhindi (Anon, 1982b).

Smittle and Threadgill (1982) obtained higher marketable yield of squash by irrigating at 0.3 bar soil moisture tension and applying 22.5 kg N ha^{-1} through irrigation water at 2, 3, 4, 5 and 6 weeks after planting.

Srinivas and Prabhakar (1982) in their trials on the response of Capsicum to nitrogen fertilization found that application of 150 kg N ha^{-1} in three split doses namely at planting and 30 and 60 days after planting gave the highest yield of better quality fruits.

Dod et al. (1983) in a fertilizer trial on Capsicum obtained the highest fruit yield with 100 kg N ha^{-1} in four equal split doses namely at transplanting, 30 days after transplanting, 21 days after the second application and 21 days after the third application. They also reported that dry weight of fruits, yield of fresh fruits and fruit length were increased by split application of nitrogen.

Khosh-Khui and Azarakhush (1983) reported that application of 250 kg ha^{-1} of urea to tomatoes at 125 + 125 kg ha^{-1} in split doses at establishment and just before flowering gave the highest yield of better sized fruits.

2.2.2 Nutrient uptake

Chhonkar and Singh (1963) in their studies on inorganic nutrition of bhindi in sand culture observed that application of nitrogen at 210 ppm in split doses, phosphorus at 237 ppm and potassium at 78 ppm in the nutrient solution had resulted in the optimum ratio of $N:P_2O_5:K_2O$ (4.5:1:5.5) in the plant tissues for best growth.

Leela _et al_. (1975) observed that application of fertilizers (a quarter as foliar spray and the rest being applied to the soil) at the rate of 125 kg N ha^{-1} had produced the highest content of nitrogen in bhindi leaf. They also reported that leaf P content was not affected by the above treatment.

Dashkova (1976) in his studies with cucumbers using Rodnikoy nutrient solution found that a double nutrient application at the rate of 3.1 g l^{-1} at the vegetative phase and 3.9 g l^{-1} at the reproductive phase produced the optimum concentration of N,P,K in leaves and stem.

Smittle (1976) in a fertilizer cum irrigation trial on snap beans noted the highest yield with nitrogen application to maintain the petiole NO_3N level above 1500 ppm pre blossom and 1000 ppm during fruit development.

Batal and Smittle (1981) reported that sufficient nitrogen must be added to maintain soil NO_3N level between 20 and 30 ppm for Capsicum so as to get optimal concentration of nitrogen in plant tissues (2.5 per cent).

Dod et al. (1983) obtained the optimal concentration of N, P and K in Capsicum tissues when nitrogen was applied in four equal splits namely at transplanting, 30 days after transplanting, 21 days after the second application and 21 days after the third application.

2.2.3 Quality of fruits

Dod et al. (1983) obtained the best quality fruits of Capsicum with regard to crude protein and ascorbic acid contents by applying nitrogen in four equal split doses namely at transplanting, 30 days after transplanting, 21 days after the second application and 21 days after the third application.

2.2.4 Soil fertility status

Chuzhova et al. (1975) observed that split application of mineral fertilizers to tomatoes increased the nitrogen and phosphorus content of the soil during the second half of the vegetative phase.

MATERIALS AND METHODS

III. MATERIALS AND METHODS

A field experiment to study the response to water management practices in relation to split application of nitrogen on bhindi was conducted during 1985 in the summer rice fallows of the Agronomic Research Station, Chalakudy. The materials used and methods adopted in the study are briefly described below.

MATERIALS

3.1 General

3.1.1 Location

The experiment was conducted in the farm of the Agronomic Research Station, Chalakudy, Trichur District. The station is situated at 10°20'N latitude, 76°20'E longitude and at an altitude of 3.25 m above the mean sea level.

3.1.2 Soil

The soil of the experimental site was loamy sand in texture with the bulk density ranging from 1.41 to 1.47 g cm^{-3} and slightly acidic in reaction. It was low in organic carbon, available nitrogen and available potassium, but medium in available phosphorus. The important physical and chemical properties of the soil are presented in Table 1.

Table 1: Soil characteristics

a) Physical properties

1. Mechanical composition

Coarse sand	(%)	48.96
Fine sand	(%)	30.65
Silt	(%)	9.16
Clay	(%)	10.79
Textural class		loamy sand

2. Infiltration rate — 6.3 cm h^{-1}

3. Important physical constants of the soil

Particulars	Depth of soil layer (cm)		
	0-30	30-60	60-90
Field capacity (%)	10.40	10.90	11.10
Permanent wilting point (%)	3.80	4.10	4.50
Bulk density (g cm^{-3})	1.45	1.47	1.41

b) Chemical properties

1. Organic carbon (%)	0.36
2. Available nitrogen (kg ha^{-1})	90.68
3. Available phosphorus (kg ha^{-1})	15.00
4. Available potassium (kg ha^{-1})	16.60
5. Soil pH	5.70

3.1.3 Season

The crop was sown during the months of January to March, 1985, which is the regular growing season of vegetables in rice fallows.

3.1.4 Weather conditions

The weekly averages of temperature, evaporation, relative humidity and the weekly totals of rainfall during the cropping period and their averages for the previous three years collected from the meterological observatory attached to the farm are presented in Appendix I and Fig.1. Variations in weather parameters during the crop season from the three year averages have also been worked out.

The weekly averages of maximum temperature ranged between 32.7°C to 36.6°C and the minimum between 20.1°C and 24.9°C. The maximum temperature experienced during the crop season in general was slightly lower than that of the three year average.

The crop did not receive any appreciable amount of rainfall during the cropping period.

The relative humidity during the crop season ranged from 77.6 and 88.3 per cent at 8 AM and 31.0 and 48.9 per cent at 2 PM.

The wind velocity during the crop season ranged from 40.7 km d^{-1} to 95.0 km d^{-1}.

The mean weekly pan evaporation values varied from 2.9 mm to 5.2 mm per day. The rate of evaporation was found to be more during the later stages of crop growth.

3.1.5 Ground water fluctuations

The monthly fluctuations in ground water table of the experimental field are presented in Table 2. Ground water fluctuations were measured with the help of two observation wells in the experimental area.

Table 2: Ground water fluctuations during the crop period

Month	Depth from ground surface (cm)	
	Maximum	Minimum
January 1985	152	130
February 1985	147	145
March 1985	136	86

3.1.6 Crop rotation followed

Rice-Rice-Bhindi

3.1.7 Cultivar used

The cultivar Pusa Savani was used for the study. It is a high yielding variety tolerant to yellow vein mosaic, an aphid transmitted virus disease.

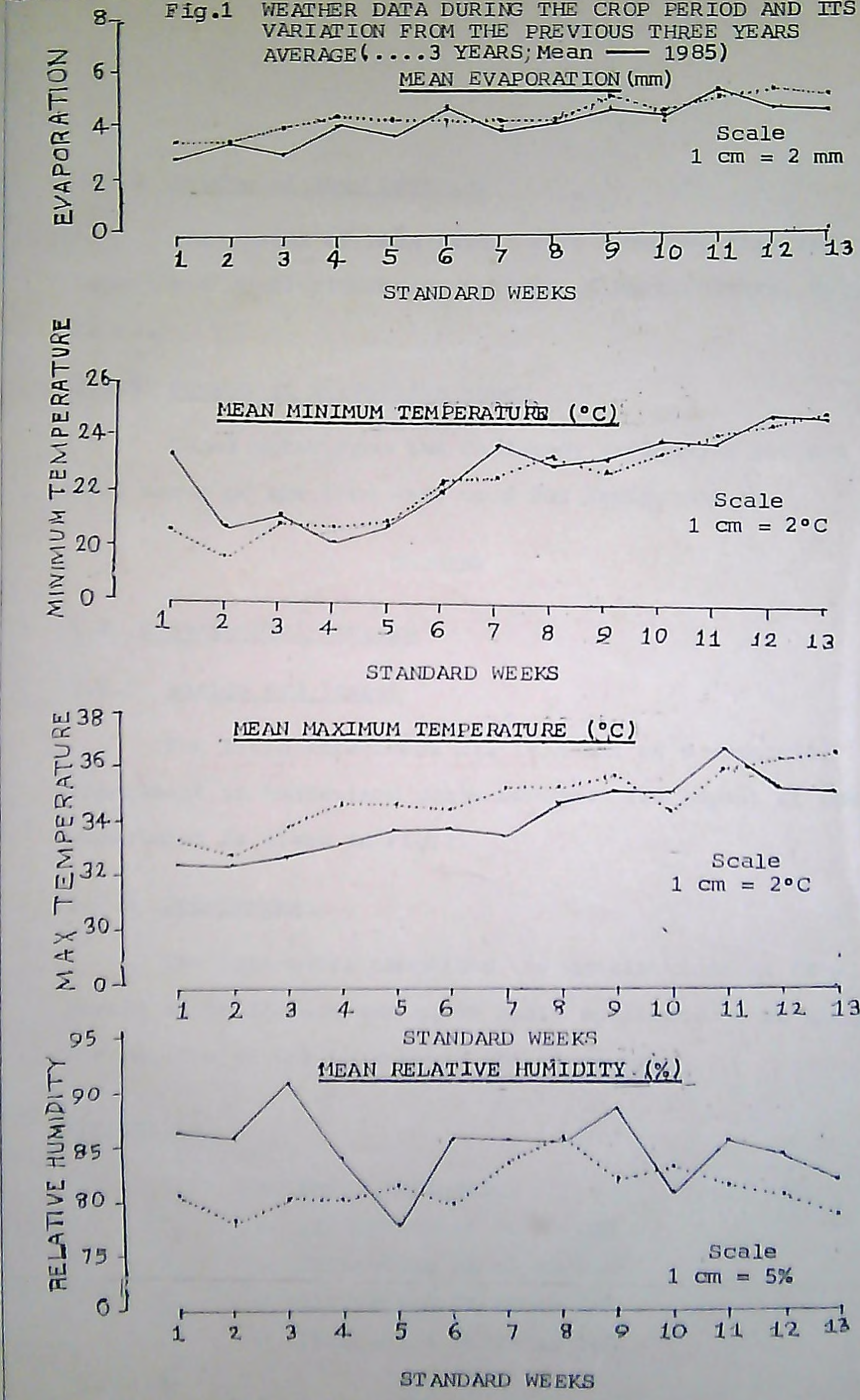


Fig.1 WEATHER DATA DURING THE CROP PERIOD AND ITS VARIATION FROM THE PREVIOUS THREE YEARS AVERAGE(....3 YEARS; Mean —— 1985)

3.1.8 Source of seed material

Pure seeds of Pusa Savani were obtained from the Department of Olericulture, College of Horticulture, Vellanikkara.

3.1.9 Source of irrigation water

Canal water from the Chalakudy irrigation project and well water of the farm were used for irrigation.

METHODS

3.2 Experimental details

3.2.1 Design and layout

The field experiment was laid out as a factorial experiment in Randomised Block Design. The layout of the experiment is given in Fig.2.

3.2.2 Treatments

The treatments comprised the combinations of five levels of irrigation and three split applications of nitrogen. The details of the treatments are given below.

Irrigation

I_1 - Daily irrigation
I_2 - Irrigation at 30 mm CPE
I_3 - Irrigation at 45 mm CPE
I_4 - Irrigation at 60 mm CPE
I_5 - Irrigation at 75 mm CPE

Split application of nitrogen

S_1 - ½ nitrogen basal + ½ 30 DAS
S_2 - ½ nitrogen basal + ¼ 30 DAS + ¼ 50 DAS
S_3 - 1/3 nitrogen basal + 1/3 30 DAS + 1/3 50 DAS

The treatment I_1 was standardised after surveying local farmer's practice.

Number of treatment combinations		-	15
Number of replications		-	3
Total number of plots		-	45
Plot size	Gross	-	5.4 x 4.0 m^2
	Net	-	3.0 x 2.8 m^2
Spacing		-	60 x 40 cm
Number of plants per plot		-	
	Gross		90
	Net	-	40

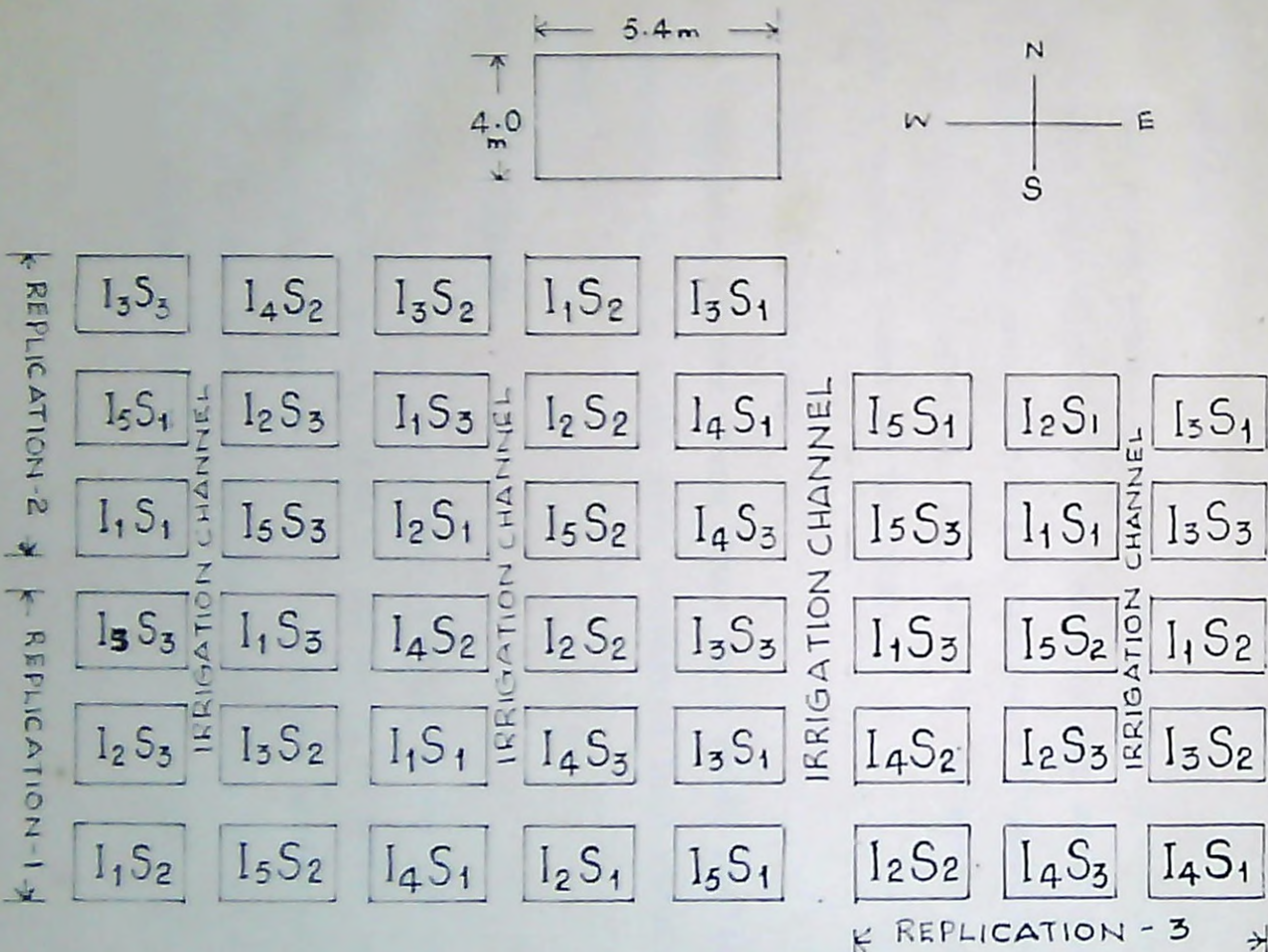
One row was left as border row all round the plot. Two additional rows were left along the width of the plot to facilitate periodical removal of sample plants.

3.3 Field culture

3.3.1 Land preparation

The experimental area was ploughed with a power tiller levelled and laid out into blocks and plots within each block Buffer area of 50 cm width was left all around each plot. Irrigation channels and distributories were also provided to facilitate irrigation to individual plots.

Fig.2 LAYOUT OF THE EXPERIMENT



TREATMENTS

IRRIGATION

I_1 - Irrigation daily

I_2 - Irrigation at 30 mm CPE

I_3 - Irrigation at 45 mm CPE

I_4 - Irrigation at 60 mm CPE

I_5 - Irrigation at 75 mm CPE

SPLIT APPLICATION OF NITROGEN

S_1 - ½ basal + ½ 30 Days After Sowing (DAS)

S_2 - ½ basal + ¼ 30 DAS + ¼ 50 DAS

S_3 - 1/3 basal + 1/3 30 DAS + 1/3 50 DAS

DESIGN

5 x 3 FACTORIAL EXPERIMENT IN R.B.D. WITH 3 REPLICATIONS

3.3.2 Manures and fertilizers

Farm Yard Manure at the rate of 12 t ha^{-1} was applied uniformly to all the plots and mixed well with the top soil. Fertilizers to supply 8 kg P_2O_5 and 30 kg K_2O were also applied through 50 kg each of superphosphate and Muriate of potash respectively as basal and 50 kg N ha^{-1} was supplied through 109 kg of urea in split doses as per treatments.

3.3.3 Sowing

The seeds soaked in water overnight to ensure good germination were dibbled at the rate of two seeds per hole at a depth of 3-5 cm. The seedlings were thinned to one per hole 15 days after sowing. Gap filling was also done to ensure a uniform stand of the crop.

3.3.4 After cultivation

Earthing up was given after each split application of nitrogen and the plots were converted into ridges and furrows.

3.3.5 Irrigation

One pre sowing irrigation was given to the field on the day prior to sowing with 50 mm depth of water and sowing was done on 23rd January, 1985. A common irrigation was also given to all the plots on 6th February with 50 mm depth of water to ensure uniform establishment of seedlings. The differential irrigation according to treatments was started only after 6th February. The evaporation readings from a USWB Class A open pan evaporimeter were recorded daily and whenever the cumulative pan evaporation values attained the treatment values, irrigation was given to the concerned plots with 40 mm depth of water. The irrigation water was measured using a circular orifice plate. Furrow irrigation was practised in all the plots.

In the case of daily irrigation treatment, irrigation was given to alternate furrows alternatively with 70 litres of water per furrow. Daily irrigation was started from 14th February, 1985. The details of irrigation are presented in Table 3a.

3.3.6 Plant protection

Prophylactic spraying of Dimecron was given against the yellow vein mosaic disease twice during the later stages of crop growth. No insect attack was noticed on the crop.

3.3.7 Harvesting

First harvest of the crop was done on 8th March, 1985. Subsequent harvests were made on alternate days uniformly from all the treatments upto 26th March, 1985. A total of 10 harvests were made.

Table 3(a): Details of irrigation

Serial number of irrigation	Treatments				
	Daily	30 mm	45 mm	60 mm	75 mm
	14-2-85 to 23-3-85				
1		14-2-85	17-2-85	21-2-85	25-2-85
2		21-2-85	27-2-85	6-3-85	12-3-85
3		28-2-85	9-3-85	18-3-85	
4		6-3-85	17-3-85		
5		13-3-85			
6		18-3-85			
7		24-3-85			
Total number of irrigations	38	7	4	3	2
Quantity of water applied (mm)	493	280	160	120	80
Pre sowing Irrigation (mm)	50	50	50	50	50
Common Irrigation (mm)	50	50	50	50	50
Rainfall (mm)	0.4	0.4	0.4	0.4	0.4
Total quantity of water applied (mm)	593.4	380.4	260.4	220.4	180.4

Table 3(b): Quality of Irrigation water

	Canal water	Well water
pH	6.4	6.2
EC (millimhos cm^{-1})	0.42	0.50
Carbonate ($meql^{-1}$)	traces	nil
Bicarbonate ($meql^{-1}$)	1.0	0.50
Chloride ($meql^{-1}$)	0.36	0.46

3.4 Biometric observations

3.4.1 Height of the plant

The height of the plant was recorded from the five randomly selected plants at three stages of growth viz., 25th, 40th and 55th day after sowing. The height of the main stem from the ground level to the top most bud leaf was reckoned as the height of the plant. Mean height of the plant was worked out and expressed in cm.

3.4.2 Number of leaves per plant

Simultaneously with observation on the height of plants, number of leaves per plant was also counted and the mean number of leaves per plant worked out.

3.4.3 Leaf Area Index (LAI)

The fully expanded 5th leaf from the top was selected and length of the midrib measured in centimetres. The leaf area was calculated using the formula given by Asif (1977).

$$Y = 115X - 1050$$

where

Y = leaf area in cm^2

X = length of the mid rib in cm

The leaf area was multiplied by the total number of leaves per plant and expressed as leaf area per plant in cm^2. The leaf area was divided by the land area occupied by the plant and expressed as LAI.

3.4.4 Dry matter production per plant

Dry matter production was recorded during three growth stages viz. 25th, 40th and 55th day after sowing. Three plants were uprooted from the destructive row at each stage, carefully without destroying the roots and separated into plant parts. They were put inside a paper cover, sundried for four hours and oven dried at 80 $\pm$ 5°C to a constant weight. The dry weight of the fruits was also recorded to get total dry matter production.

3.4.5 Length of root

Length of main roots of the three plants uprooted for dry matter estimation without damaging the roots was measured mean length worked out and expressed in cm.

3.4.6 Shoot:Root ratio

Under each treatment, Shoot:Root ratio was calculated after recording the length of shoot and root in cm. (Sampath Kumar, 1980).

3.4.7 Number of fruits per plant

The number of fruits harvested from the five observation plants was counted and the average worked out.

3.4.8 Length of fruit

Ten fruits were selected at random from each treatment and their length measured and averages worked out and expressed in cm.

3.4.9 Girth of fruit

The girth of fruits at the centre was measured at the time of recording weight and mean worked out and expressed in cm.

3.4.10 Weight of fruit

Weight of ten fruits selected at random from various harvests was recorded and mean worked out.

3.4.11 Total fruit yield

Weight of fruits from the various harvests was totalled up at the end of the cropping season and the average yield in kilogram per plot worked out and converted into per hectare yield.

3.5.1 Water use efficiency

Field water use efficiency was calculated by dividing the economic crop yield by the total amount of water used in the field (WR).

Field water use efficiency $E_u = Y/WR$

3.6 Moisture studies

3.6.1 Consumptive use

Consumptive use was worked out from the data on soil moisture depletion as suggested by Dastane (1972). Soil samples were collected from 0-30, 30-60 and 60-90 cm depth using a soil augor before and 24 hours after each irrigation and at final harvest. Thermogravimetric method of soil moisture determination was adopted.

Mean daily consumptive use and mean daily evaporation rates were obtained by dividing total consumptive use and total evaporation by total number of days.

3.6.2 Moisture depletion pattern

The average relative soil moisture depletion from each soil layer in the root zone was worked out for each irrigation interval. The potential evapotranspiration values (PET) for the 24 hours after each irrigation extrapolated from the Class A pan evaporation data were added to the depletion in the first layer and total loss from each layer was determined on percentage basis at the end of the cropping period.

3.7 Analytical procedure

3.7.1 Soil analysis

3.7.1.1 Physical properties

a) Particle size distribution

Mechanical analysis of the soil was carried out by Robinson's International Pipette method, after oxidation of organic matter with 6 per cent hydrogen peroxide as described by Piper (1950). Soil was classified into textural group using I.S.S.S. system.

b) Infiltration rate

A double ring infiltrometer was used for determining the infiltration rate as designed by Michael (1978).

c) Bulk density

Bulk density was determined *in situ* by collecting the soil samples using a core sampler.

d) Field capacity

Field capacity was determined by field method as suggested by Colman, (1944).

e) Moisture percentage at 15 bar

Moisture percentage of the soil at an applied pressure of 15 bar in a pressure-membrane apparatus was noted and taken as an index of the permanent wilting percentage (Richards, 1947).

3.7.1.2 Chemical properties

a) Organic carbon

Organic carbon was estimated by Walkley and Black's rapid titration method (Jackson, 1967).

b) Available nitrogen

Available nitrogen in the soil was determined by alkaline permanganate method, described by Subbiah and Asija (1956).

c) Available phosphorus

Available phosphorus in the soil was extracted in

Bray No.1 dilute acid flouride solution (Bray and Kurtz, 1945) and colorimetric determination of phosphorus in the extract by the chlorostannous reduced molybdo phosphoric blue colour method in hydrochloric acid system (Jackson, 1967).

d) Available potassium

The available potassium content of the soil was determined with neutral normal ammonium acetate extract, reading in an EEL flame photometer (Jackson, 1967).

e) Soil reaction

The pH of the soil water suspension (1:2.5 ratio) was determined using a Perkin-Elmer pH meter with glass and calomel electrodes (Jackson, 1967).

3.7.2 Plant analysis

Samples collected for chemical analysis were oven dried at 80 $\pm$ 5°C, ground in Willey Mill and sieved through 60 mesh sieve and used for chemical analysis. The N, P, K contents in the shoots including leaves were determined at three stages of crop growth. Analysis of fruits was carried out with composite samples collected from different harvests.

a) Crude protein content of fruits

Crude protein content of fruits was determined by multiplying the nitrogen content of fruits with a factor 6.25.

3.7.3 Uptake studies

The total uptake of nitrogen, phosphorus and potassium at 25th, 40th and 55th day after sowing was computed from the contents of these nutrients at the respective plant parts and the dry matter production at these stages.

3.7.4 Statistical analysis

Data relating to each character was analysed by applying the analysis of variance technique and significance tested by 'F' test (Snedecor and Cochran, 1967).

RESULTS

IV RESULTS

The observations recorded have been statistically analysed and presented with appropriate interpretations. The economics of various treatments have also been worked out and presented.

1. Growth characters

1.1 Height of plant

The data on mean height of plants recorded at 25th, 40th and 55th day after sowing are presented in Table 4 and the analysis of variance in Appendix II. The data revealed the significant influence of irrigation and split application of nitrogen on plant height at 40th and 55th day after sowing. The interaction between irrigation and split application of nitrogen was not significant.

Daily irrigation resulted in a significantly higher plant height (40.23 and 63.89 cm at 40th and 55th day after sowing respectively) than other irrigation schedules. The plant height decreased (though not always significant) with increase in the interval between irrigation and I_5 (75 mm CPE) recorded the lowest values (23.24 and 36.62 cm) at 40th and 55th day after sowing respectively. The increase in plant height due to I_2 over I_3 and I_3 over I_5 was significant at 40th day. At 55th day I_2 was on par with I_3 and significantly superior to I_4 and I_5 which in turn were on par with each other.

Split application of nitrogen also exerted a significant influence on plant height at 40th and 55th day after sowing. At 40th day the treatment S_1 (½ basal + ½ 30 DAS) was significantly superior to S_3 (1/3 basal + 1/3 30 DAS + 1/3 50 DAS) and statistically on par with S_2 (½ basal + ¼ 30 DAS + ¼ 50 DAS). At 55th day S_1 was significantly superior to S_3 and on par with S_2 which was in turn on par with S_3. Application of nitrogen in two splits showed the superiority over its application in three splits which one third dose as basal with regard to plant height.

1.2 <u>Number of leaves</u>

The mean number of leaves produced per plant at 25th, 40th and 55th day after sowing are presented in Table 5 and the analysis of variance in Appendix III.

Irrigation had a significant influence on leaf production at the later two stages of crop growth (40th and 55th day). The mean number of leaves per plant decreased significantly with increase in each successive interval between irrigation from daily (I_1) to 60 mm CPE (I_4) and beyond that it was not significant.

Split application of nitrogen exerted a significant influence on leaf production only at 40th day after sowing.

Table 4: Mean height of plants (cm) at different stages

	25th day	40th day	55th day
Irrigation			
I_1	13.03	40.23	63.89
I_2	12.60	31.89	48.18
I_3	12.47	27.64	46.31
I_4	12.69	25.85	39.04
I_5	12.48	23.24	36.62
F test	NS	Sig	Sig
Split application of nitrogen			
S_1	12.66	31.74	51.80
S_2	12.66	30.78	45.69
S_3	12.64	26.80	42.93
F test	NS	Sig	Sig
CD 0.05 (I)	-	4.035	8.709
CD 0.05 (S)	-	3.126	6.746

SE of means at 25 DAS: I = ± 0.1568, S = ± 0.1214

S_1 and S_2 were on par with each other and significantly superior to S_3. Application of nitrogen in two or three splits with 50 per cent as basal (S_1 and S_2) was superior to its application in three splits with one third as basal (S_3).

1.3 Leaf Area Index

The leaf area index recorded at 40th day after sowing are presented in Table 6 and the analysis of variance in Appendix IV. The effects due to main factors as well as their interaction were significant.

Irrigation schedules markedly influenced the LAI. The LAI increased with increase in the frequency of irrigation from 75 mm CPE (I_5) to daily irrigation (I_1). The variations in LAI among I_1, I_2, I_3 and I_5 levels were significant and I_4 was on par with I_3 and I_5. The I_1 level of irrigation recorded the maximum LAI of 2.50 as against the least value of 0.79 in I_5.

Split application of nitrogen also significantly influenced the LAI and the variations among S_1, S_2 and S_3 were significant. LAI was the highest with S_1 (1.65) followed by S_2 (1.41) and S_3 (1.19).

The interaction IxS was significant and the treatment combination I_1S_1 recorded the highest LAI (2.90). The lowest LAI was recorded by I_5S_3 (0.74). The pronounced effect of split application of nitrogen was noticed under more frequent

Table 5: Mean number of leaves per plant at different stages

	25th day	40th day	55th day
Irrigation			
I_1	4.47	14.90	19.26
I_2	4.42	12.63	17.70
I_3	4.70	10.56	16.52
I_4	4.39	8.04	13.02
I_5	4.50	8.66	12.06
F test	NS	Sig	Sig
Split application of nitrogen			
S_1	4.42	11.46	16.09
S_2	4.58	11.00	15.87
S_3	4.48	10.42	15.18
F test	NS	Sig	NS
CD 0.05 (I)	-	0.628	1.113
CD 0.05 (S)	-	0.486	-

SE of means at 25 DAS: I = ± 0.1107, S = ± 0.0858

irrigation schedules viz., I_1 and I_2.

1.4 <u>Dry matter production</u>

The dry matter production per plant recorded at 25th, 40th, and 55th day after sowing are presented in Table 7(a) and Fig.3 and the analysis of variance in Appendix V.

Irrigation significantly influenced the dry matter production of 40th and 55th day after sowing. The accumulation at dry matter increased with increase in soil wetness. At 40th day I_1 was significantly superior to I_2 and I_2 to I_3, I_4 and I_5. At 55th day I_1 was on par with I_2 and significantly superior to others. I_3 and I_4 were on par at both the stages and the variation between I_4 and I_5 reached the level of significance at 40th day. The percentage increase in dry matter production due to daily irrigation (I_1) over 75 mm CPE (I_5) was 220.45 and 108.73 at 40th and 55th day respectively.

Split application of nitrogen did not exert any marked influence on dry matter production at 25th and 55th day after sowing. At 40th day however the dry matter production due to S_1 (14.02 g), S_2 (12.11 g) and S_3 (9.60 g) varied significantly among each other.

The IxS interaction at 40th day on dry matter production was significant (Table 7b). The effect on split application of nitrogen was pronounced with daily and 30 mm CPE schedules. I_1S_1 recorded the highest (23.28 g) and I_5S_3 the lowest (4.94 g)

Table 6: Combined effect of irrigation and split application of nitrogen on leaf area index at 40th day

	Irrigation levels					
	I_1	I_2	I_3	I_4	I_5	Mean
Split application of nitrogen						
S_1	2.90	2.21	1.30	1.00	0.83	1.65
S_2	2.45	1.67	1.17	0.98	0.80	1.41
S_3	2.15	1.10	0.98	0.96	0.74	1.19
Mean	2.50	1.66	1.15	0.98	0.79	

CD 0.05 (IxS) = 0.429

CD 0.05 (I) = 0.248

CD 0.05 (S) = 0.192

values of dry matter production respectively.

1.5 Length of root

The mean length of root recorded at 25th, 40th and 55th day after sowing are presented in Table 8(a) and the analysis of variance in Appendix VI.

Irrigation levels exerted significant influence on the root length at 40th and 55th day after sowing. The root length increased with decrease in soil wetness and the variations among the irrigation levels were significant. The root length recorded by daily irrigation was 20.00 cm and 29.38 cm as against 29.28 cm and 39.98 cm by I_5 at 40th and 55th day after sowing respectively.

Split application of nitrogen did not exert any significant influence on root length at any of the growth stages.

The interaction (IxS) was significant only at 55th day after sowing (Table 8b). A significant reduction in root length due to S_3 as compared to S_1 could be noticed under daily irrigation (I_1). I_5S_1 (40.31 cm), I_5S_2 (39.42 cm) and I_5S_3 (40.22 cm) were on par and superior to other treatment combinations. I_5S_1 produced the maximum (40.31 cm) and I_1S_3 the minimum (28.55 cm) values of root length. I_1S_3 was however on par with I_1S_2 (29.15 cm).

Table 7(a): Dry matter production (g/plant) at different stages

	25th day	40th day	55th day
Irrigation			
I_1	4.41	19.74	28.22
I_2	4.32	16.05	25.00
I_3	4.49	8.98	18.43
I_4	4.53	8.60	14.91
I_5	4.32	6.16	13.52
F test	NS	Sig	Sig
Split application of nitrogen			
S_1	4.42	14.02	20.84
S_2	4.41	12.11	20.65
S_3	4.41	9.60	18.59
F test	NS	Sig	NS
CD 0.05 (I)	-	1.165	3.967
CD 0.05 (S)	-	0.902	-

Table 7(b): Combined effect of irrigation and split application of nitrogen on dry matter production (g/plant) at 40th day

	Irrigation levels				
	I_1	I_2	I_3	I_4	I_5
Split application of nitrogen					
S_1	23.28	20.82	9.39	10.11	6.49
S_2	20.28	16.56	8.21	8.44	7.06
S_3	15.67	10.78	9.33	7.28	4.94

CD 0.05 (IxS) = 2.017

SE of means at 25 DAS: I = $\pm$ 0.0715, S = $\pm$ 0.0554

" at 55 DAS: S = $\pm$ 1.0609

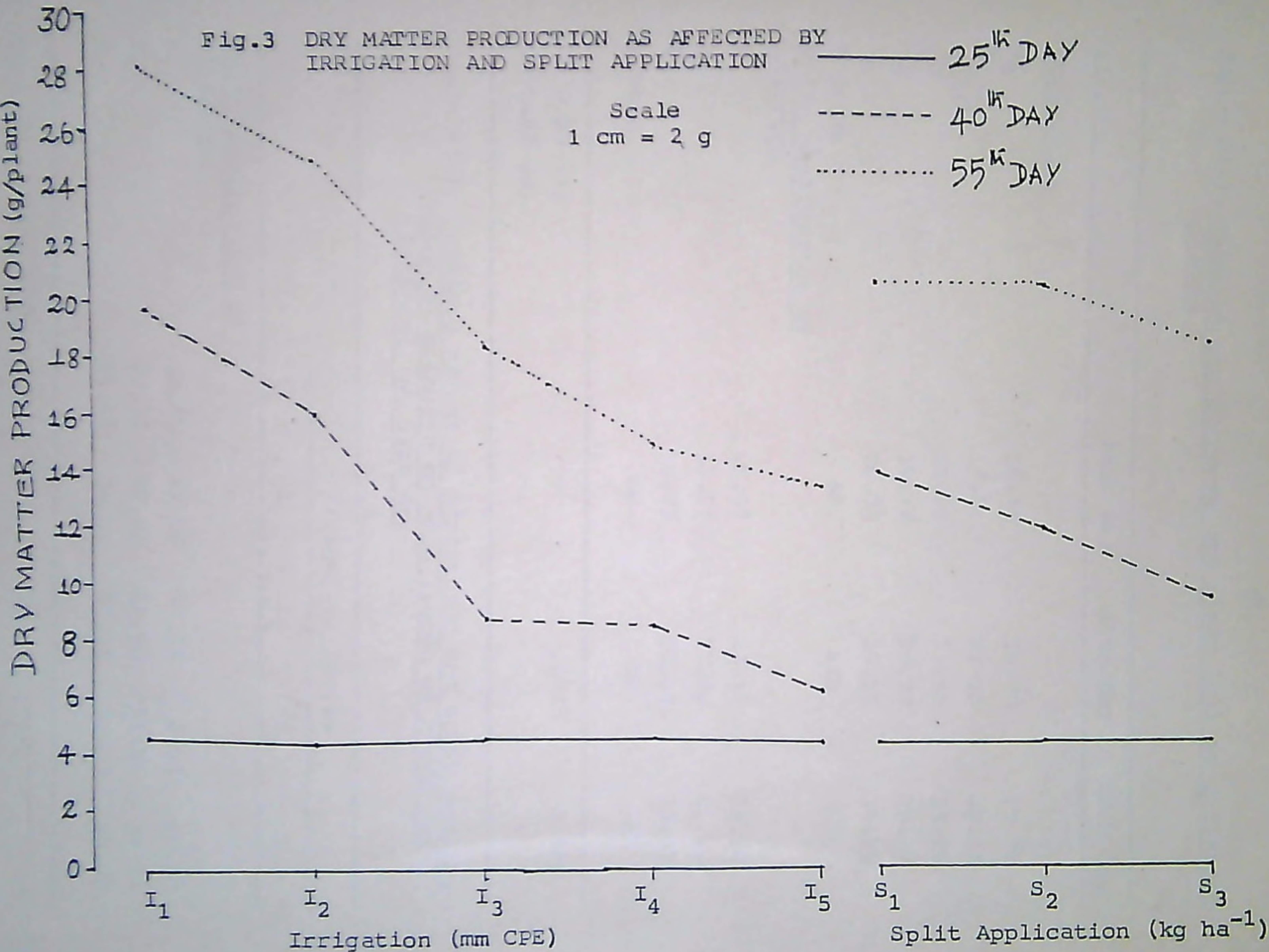


Fig.3 DRY MATTER PRODUCTION AS AFFECTED BY IRRIGATION AND SPLIT APPLICATION
25th DAY
40th DAY
55th DAY
Scale
1 cm = 2 g
DRY MATTER PRODUCTION (g/plant)
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
I1
I2
I3
I4
I5
Irrigation (mm CPE)
S1
S2
S3
Split Application (kg ha-1)

Table 8(a): Mean length of roots per plant (cm) at different stages

	25th day	40th day	55th day
Irrigation			
I_1	16.61	20.00	29.38
I_2	16.56	21.10	30.32
I_3	16.79	23.41	33.25
I_4	16.74	24.77	35.29
I_5	16.72	29.28	39.98
F test	NS	Sig	Sig
Split application of nitrogen			
S_1	16.67	23.12	33.38
S_2	16.67	23.68	33.58
S_3	16.72	23.87	33.97
F test	NS	NS	NS
CD 0.05 (I)	-	1.045	0.865
CD 0.05 (S)	-	-	-

Table 8(b): Combined effect of irrigation and split application of nitrogen on mean length of roots per plant (cm) at 55th day

	Irrigation levels				
	I_1	I_2	I_3	I_4	I_5
Split application of nitrogen					
S_1	30.45	29.56	32.55	34.04	40.31
S_2	29.15	30.41	33.98	34.96	39.42
S_3	28.55	31.00	33.22	36.87	40.22

CD 0.05 (IxS) = 1.498

SE of means at 25 DAS: I = $\pm$ 0.0850, S = $\pm$ 0.0658,

" at 40 DAS: S = $\pm$ 0.2794

" at 55 DAS: S = $\pm$ 0.2312

1.6 Shoot:Root Ratio

The shoot:Root ratio recorded at different stages of growth are presented in Table 9 and the analysis of variance in Appendix VII.

The shoot:root ratios at the later two stages of growth (40th and 55th day) were favourably influenced by irrigation. I_1 recorded the maximum ratio at these two stages (2.012 and 2.175 at 40th and 55th day respectively) and was significantly superior to other schedules. At both the stages I_2 was on par with I_3 which in turn was on par with I_4. I_4 and I_5 were on par with each other. The ratio decreased with decrease in the irrigation frequency and I_5 recorded the least values of 0.794 and 0.916 at 40th and 55th day after sowing respectively.

Split application of nitrogen had a significant influence on shoot:root ratio at 40th day after sowing. S_1 recorded the maximum ratio of 1.373 at 40th day which was on par with S_2 and superior to S_3. The treatment S_3 registered the lowest ratio (1.123 and at 40th day).

The effect due to IxS interaction was not significant.

2. Yield and yield attributes

2.1 Number of fruits

The data on mean number of fruits per plant are presente

Table 9: Shoot:root ratio at different stages

	25th day	40th day	55th day
Irrigation			
I_1	0.784	2.012	2.175
I_2	0.761	1.511	1.589
I_3	0.743	1.199	1.393
I_4	0.758	1.043	1.106
I_5	0.746	0.794	0.916
F test	NS	Sig	Sig
Split application of nitrogen			
S_1	0.759	1.373	1.552
S_2	0.759	1.300	1.361
S_3	0.756	1.123	1.264
	NS	Sig	NS
CD 0.05 (I)	-	0.325	0.453
CD 0.05 (S)	-	0.249	-

SE of means at 25 DAS: I = ± 0.0137, S = ± 0.0106

in Table 10 and Fig.4 and the analysis of variance in Appendix VIII.

Irrigation profoundly influenced the fruit number. I_1 (daily irrigation) produced a significantly higher number of fruits per plant (12.34) than other schedules and it was followed by I_2 (9.30) which was on par with I_3 (9.08). I_4 (6.48) and I_5 (6.55) were on par with each other and inferior to other schedules. Daily irrigation produced nearly double the number of fruits produced by 60 and 75 mm CPE schedules.

Split application of nitrogen also influenced the fruit production. S_1 (9.32) was significantly superior to S_2 (8.35) and S_3 (8.58) and S_2 and S_3 were on par.

The effect due to IxS interaction was not significant.

2.2 Length of fruit

The data on mean length of fruits (Table 10 and Fig. 4) revealed the significant influence of irrigation. Decrease in the moisture stress increased the fruit length. The length of fruits produced by I_1 (14.51 cm) was significantly higher than that of I_2 and I_3 which in turn were on par. The reduction in fruit length at I_4 and I_5 was also significant.

Split application of nitrogen also exerted a significant influence on length of fruits. The length of fruits produced by S_1(12.69 cm) was significantly superior to

S_3 (12.01 cm) and on par with S_2 (12.29 cm). S_2 in turn was on par with S_3.

IxS interaction was not significant.

2.3 Girth of fruit

The data on mean girth of fruits are presented in Table 10 and the analysis of variance in Appendix IX.

Effect of irrigation on fruit girth was significant. Unlike the other fruit characters daily irrigation (I_1) recorded the lowest value of fruit girth (6.23 cm). The maximum girth recorded by I_2 (6.59 cm) was significant over I_1 and a gradual reduction in girth could be noticed with increased moisture stress beyond I_2 (30 mm CPE). I_2, I_3 and I_4 were on par. I_4 was on par with I_5 and I_5 with I_1.

Split application of nitrogen did not exert any discernable variation on girth of fruits.

The effect due to IxS interaction was also not significant.

2.4 Dry weight of fruits

The data on mean weight of ten fruits (g) are presented in Table 11 and Fig. 4 and the analysis of variance in Appendix IX.

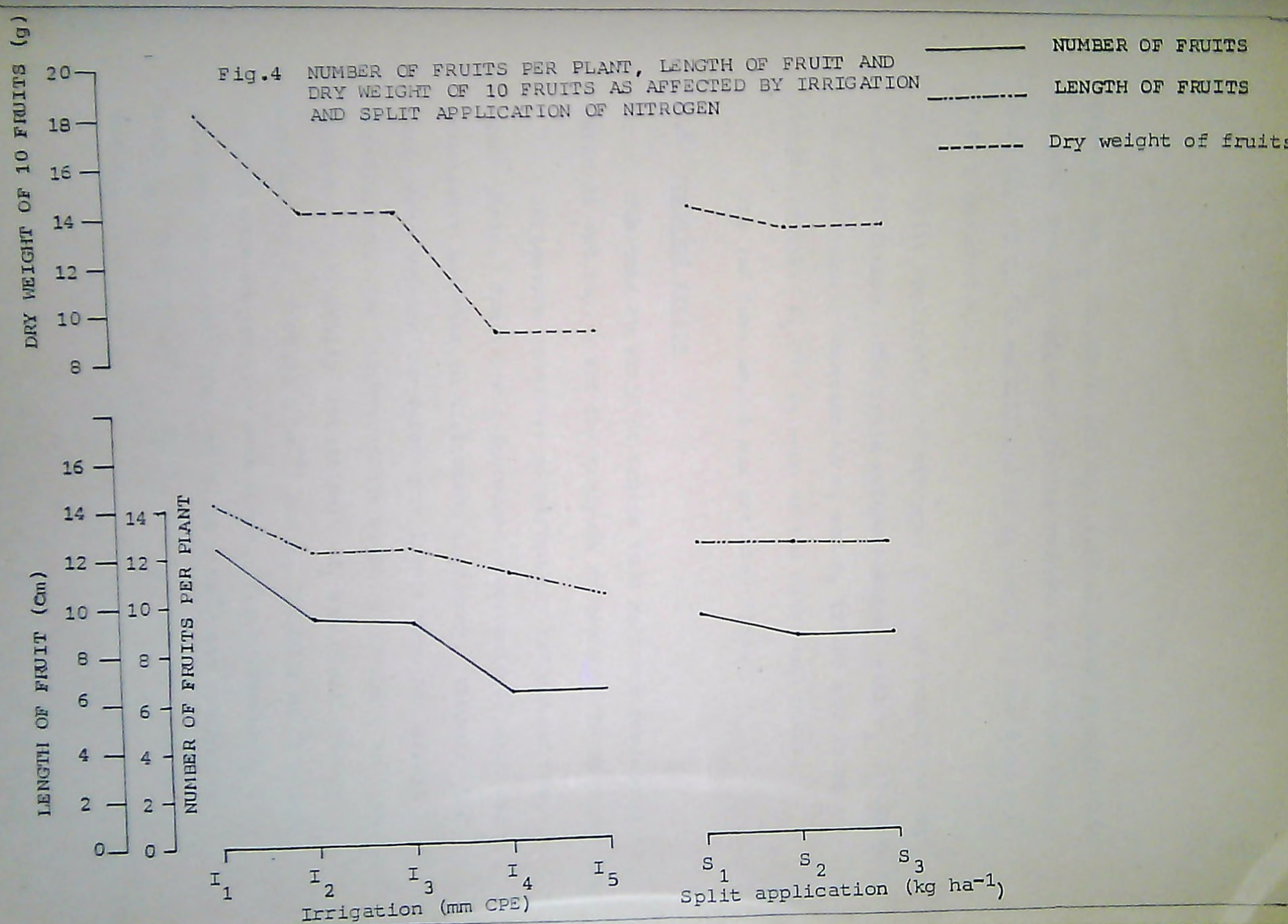
Mean data indicated that daily irrigation recorded the highest dry weight of fruits (18.65 g) which was significantly

Table 10: Mean number of fruits per plant, length of fruits (cm) and girth of fruit (cm)

	Number of fruits	Length of fruit	Girth of fruit
Irrigation			
I_1	12.34	14.51	6.23
I_2	9.30	12.56	6.59
I_3	9.08	12.34	6.52
I_4	6.48	11.72	6.46
I_5	5.55	10.40	6.31
F test	Sig	Sig	Sig
Split application of nitrogen			
S_1	9.32	12.69	6.57
S_2	8.35	12.29	6.52
S_3	8.58	12.01	6.42
F test	Sig	Sig	NS
CD 0.05 (I)	0.707	0.611	0.214
CD 0.05 (S)	0.547	0.474	-

SE of means for girth : S = ± 0.0571

Fig.4 NUMBER OF FRUITS PER PLANT, LENGTH OF FRUIT AND DRY WEIGHT OF 10 FRUITS AS AFFECTED BY IRRIGATION AND SPLIT APPLICATION OF NITROGEN



superior to I_2 (14.69 g) and I_3 (14.68 g) which in turn were on par. The dry weight of fruits reduced at a higher magnitude beyond I_3 (45 mm CPE) and at I_4 and I_5 it was 9.43 and 9.42 g respectively.

Split application of nitrogen also influenced the dry weight of fruits. The fruit weight obtained with S_1 (13.96 g) was significantly superior to S_2 and S_3 (13.09 and 13.08 g respectively). S_2 and S_3 were on par with each other.

The IxS interaction was not significant.

2.5 Yield of fruits

The data on yield of fruits in q ha^{-1} are presented in Table 11 and Fig. 5 and the analysis of variance in Appendix IX.

Irrigation schedules significantly influenced the fruit yield. Fruit yield increased progressively with each successive increase in irrigation frequenty. However, the variations between the successive levels were not always significant. The highest fruit yield of 139.29 q ha^{-1} was recorded by I_1 (daily irrigation). I_1 was significantly superior to I_2 (108.81 q ha^{-1}) and I_3 (97.02 q ha^{-1}) which in turn were on par with each other. The treatment I_5 produced the lowest yield of 72.38 q ha^{-1} and was on par with I_4 (76.67 q ha^{-1}). I_1, I_2 and I_3 were superior to I_4 and I_5.

Split application of nitrogen failed to influence the fruit yield significantly. However, the trend was in favour of S_1 (109.05 q ha^{-1}). The yield obtained due to S_2 and S_3 was 98.93 q ha^{-1} and 94.17 q ha^{-1} respectively.

The effect due to IxS interaction was not significant.

3. Field Water Use Efficiency

The data on field water use efficiency and the analysis of variance are presented in Table 12 and Appendix X respectively.

The data showed the significant influence of irrigation on water use efficiency. The maximum water use efficiency (40.18 kg ha mm^{-1}) was recorded by I_5 and it was on par with I_3 and I_4 (37.32 and 34.84 kg ha mm^{-1}). The above irrigation schedules were significantly superior to I_1 and I_2. I_1 registered the lowest water use efficiency (25.14 kg ha mm^{-1}) followed by I_2 (28.63 kg ha mm^{-1}).

Split application of nitrogen did not have any significant influence on water use efficiency. However, S_1 recorded the maximum water use efficiency (36.87 kg ha mm^{-1}).

The effect due to IxS interaction was not significant.

4. Moisture studies

4.1 Consumptive use

The data on consumptive use are presented in Table 13.

Table 11: Mean yield of fruits (q ha^{-1}) and dry weight of ten fruits (g)

	Yield of fruits	Dry weight of ten fruits
Irrigation		
I_1	139.29	18.65
I_2	108.81	14.69
I_3	97.02	14.68
I_4	76.67	9.43
I_5	72.38	9.42
F test	Sig	Sig
Split application of nitrogen		
S_1	109.05	13.96
S_2	98.93	13.09
S_3	94.17	13.08
F test	NS	Sig
CD 0.05 (I)	16.39	0.595
CD 0.05 (S)	-	0.461

SE of means : S = $\pm$ 1.7050
for yield

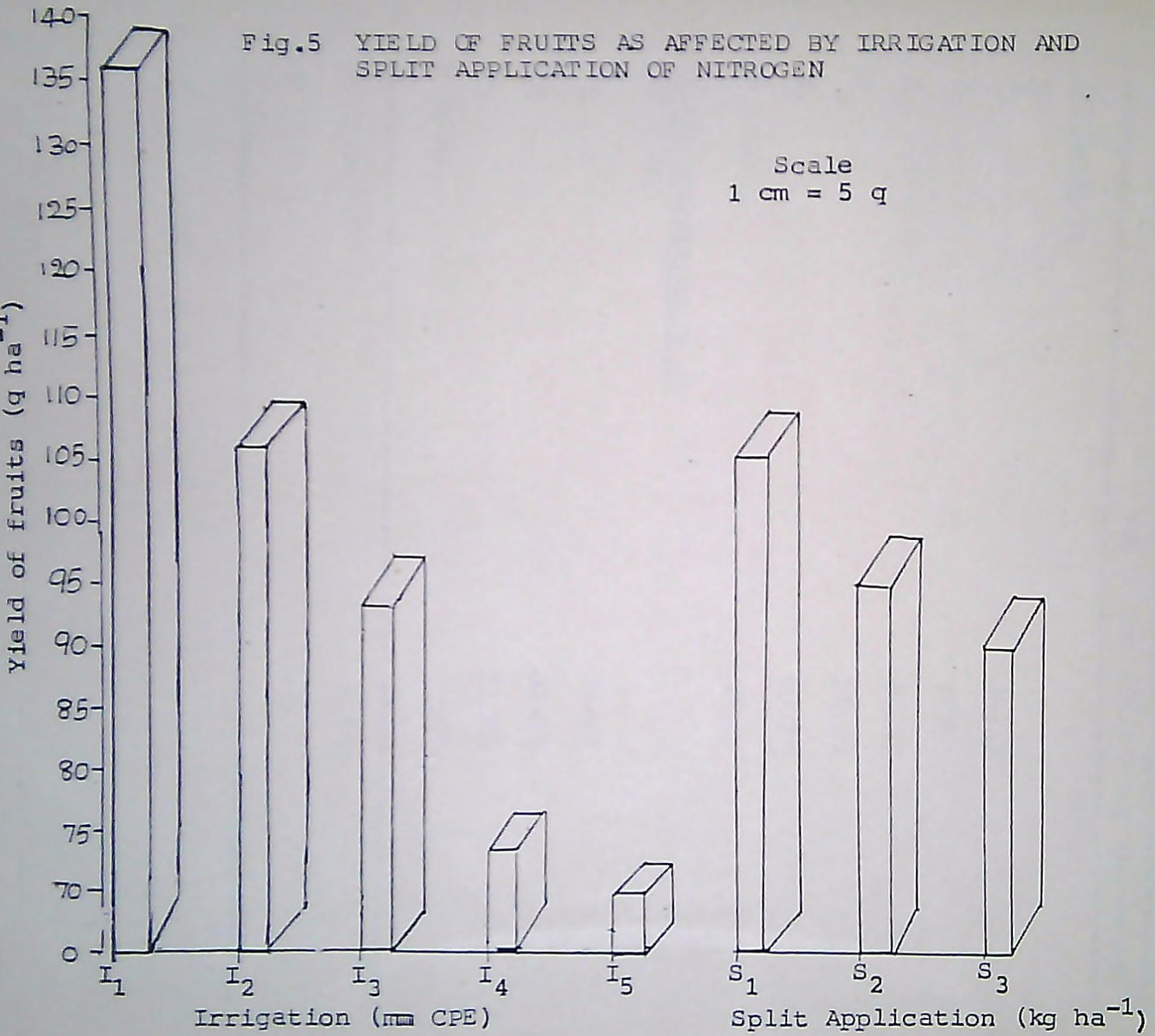


Fig.5 YIELD OF FRUITS AS AFFECTED BY IRRIGATION AND SPLIT APPLICATION OF NITROGEN

Table 12: Water use efficiency as affected by irrigation and split application of nitrogen

	Water use efficiency (kg ha mm^{-1})
Irrigation	
I_1	25.14
I_2	28.63
I_3	37.32
I_4	34.84
I_5	40.18
F test	Sig
Split application of nitrogen	
S_1	36.87
S_2	33.51
S_3	31.55
F test	NS
CD 0.05 (I)	6.194
CD 0.05 (S)	-

SE of means : S = ± 1.6566

The data revealed that consumptive use increased with increase in the frequency of irrigation. The total consumptive use under I_2, I_3, I_4 and I_5 was 229.50 mm, 143.41 mm, 109.08 mm and 80.80 mm respectively. The average daily consumptive use varied from 1.683 mm d^{-1} in I_5 to 4.781 mm d^{-1} in I_2. The ratio ET/EO increased with increase in frequency of irrigation. I_2 recorded the maximum (0.958) and I_5 the minimum (0.337) ratio.

With regard to split application of nitrogen there was no appreciable variation in consumptive use among treatments. The ET/EO ratio also did not vary to a greater extent in different splits of nitrogen.

4.2 Moisture depletion pattern

Moisture depletion pattern from different layers is presented in Table 14 and Fig. 6.

The results revealed that at 0-30 cm soil depth the percentage depletion of moisture decreased with increase in moisture stress. At 30-60 and 60-90 cm depths it increased with moisture stress. On an average 68.53, 22.12 and 9.35 per cent of moisture is extracted from 0-30, 30-60 and 60-90cm soil depth respectively.

There was no appreciable variation in the moisture depletion pattern due to different splits of nitrogen. The percentage depletion under S_1, S_2 and S_3 were 69.58, 69.07

Table 13: Consumptive use and pan evaporation values during the growth period of bhindi

Treatments	Total water applied during the period of irrigation (mm)	Total consumptive use (mm)	Average consumptive use (mm d^{-1}) (ET)	Total CPE (mm)	Average pan evaporation (mm d^{-1}) (EO)	$\frac{ET}{EO}$
Irrigation						
I_2	330.00	229.50	4.781	224.50	4.989	0.958
I_3	210.00	143.41	2.987	224.50	4.989	0.599
I_4	170.00	109.08	2.270	224.50	4.989	0.455
I_5	130.00	80.80	1.683	224.50	4.989	0.337
Split application of nitrogen						
S_1	266.00	140.62	2.929	224.50	4.989	0.587
S_2	266.00	142.33	2.965	224.50	4.989	0.594
S_3	266.00	139.18	2.900	224.50	4.989	0.581

and 68.50 respectively from 0-30 cm layer of soil.

5. Nutrient uptake

5.1 Uptake of nitrogen by plant (excluding fruit)

The data on nitrogen uptake at 25th, 40th and 55th day after sowing are presented in Table 15(a) and Fig. 7 and the analysis of variance in Appendix XI.

Irrigation schedules profoundly influenced the nitrogen uptake at 40th and 55th day after sowing. At 40th day I_1 (20.43 kg ha^{-1}), I_2 (16.75 kg ha^{-1}) and I_3 (9.65 kg ha^{-1}) varied significantly among each other and I_3 was on par with I_4 (9.47 kg ha^{-1}). I_5 showed the least uptake (6.92 kg ha^{-1}). At 55th day I_1 (24.87 kg ha^{-1}) was on par with I_2 (22.45 kg ha^{-1}) and significantly superior to I_3 (16.50 kg ha^{-1}) which was on par with I_4 (13.58 kg ha^{-1}) and I_5 (12.37 kg ha^{-1}).

Split application of nitrogen influenced the nitrogen uptake only at 40th day after sowing. At that stage S_1 (15.35 kg ha^{-1}) recorded the maximum uptake followed by S_2 (12.34 kg ha^{-1}) and S_3 (10.24 kg ha^{-1}).

The effect due to IxS interaction was significant only at 40th day after sowing (Table 15b). I_1S_1 recorded the highest (24.54 kg ha^{-1}) and I_5S_3 the lowest (5.36 kg ha^{-1}) values of nitrogen uptake respectively. The marked variations among split applications could be noticed under frequent irrigation schedules (I_1 and I_2).

Table 14: Soil moisture depletion pattern (per cent) as influenced by irrigation and split application of nitrogen

Treatments	Moisture depletion soil depth (cm)		
	0-30	30-60	60-90
Irrigation			
I_2	71.56	20.63	7.81
I_3	69.83	21.34	8.83
I_4	67.38	22.83	9.79
I_5	65.33	23.68	10.99
Mean	68.53	22.12	9.35
Split application of nitrogen			
S_1	68.56	22.14	9.36
S_2	68.54	22.10	9.38
S_3	68.50	22.12	9.32
Mean	68.53	22.12	9.35

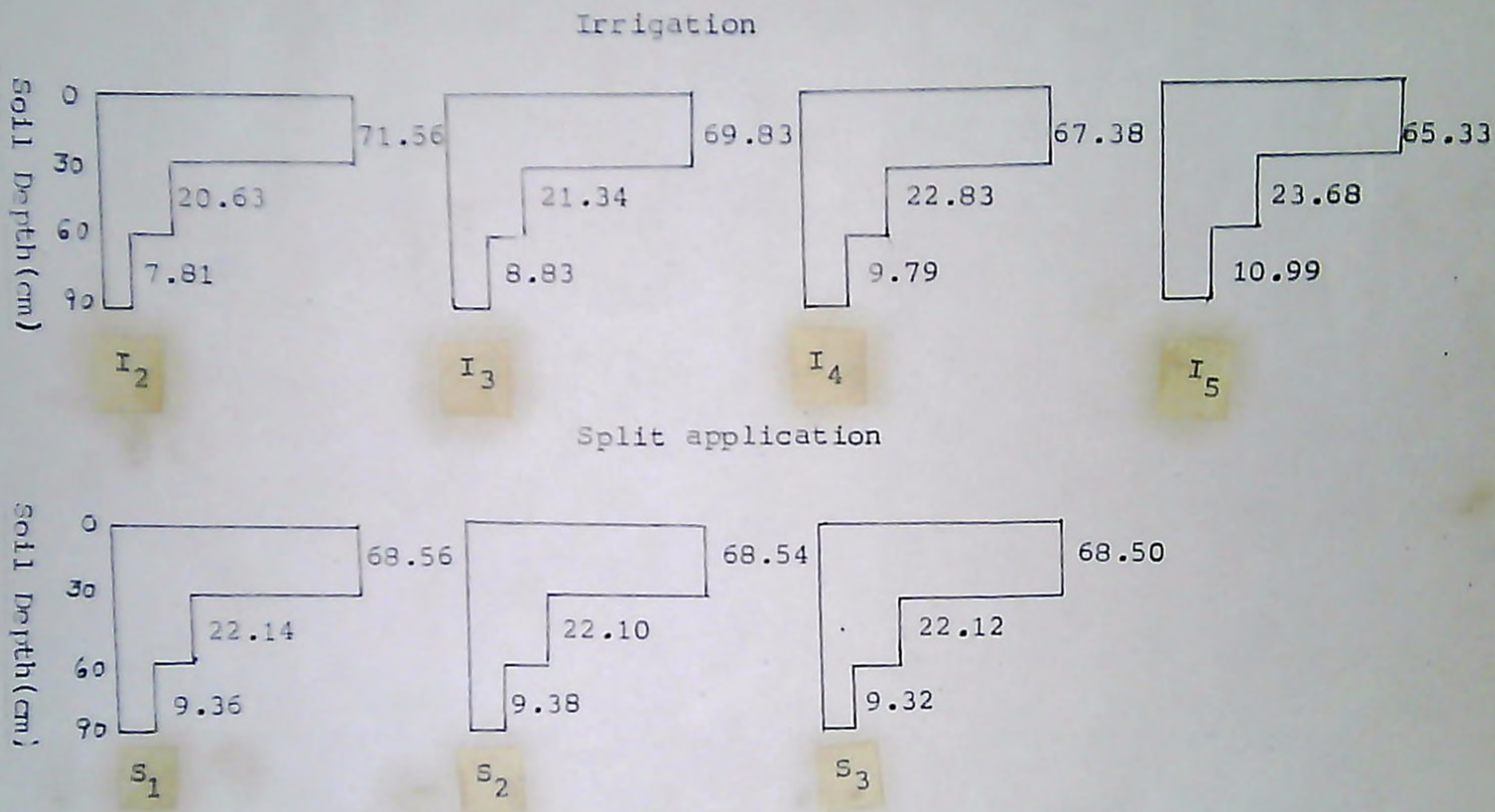
Table 15(a): Uptake of Nitrogen (kg ha^{-1}) at different stages

	25th day	40th day	55th day
Irrigation			
I_1	4.22	20.43	24.87
I_2	4.54	16.75	22.45
I_3	4.54	9.65	16.50
I_4	4.71	9.47	13.58
I_5	4.75	6.92	12.37
F test	NS	Sig	Sig
Split application of nitrogen			
S_1	4.63	15.35	18.77
S_2	4.60	12.34	18.48
S_3	4.56	10.24	16.62
F test	NS	Sig	NS
CD 0.05 (I)	-	1.624	5.468
CD 0.05 (S)	-	1.258	-

Table 15(b): Combined effect of irrigation and split application of nitrogen on uptake of nitrogen by plant at 40th day

	Irrigation levels				
	I_1	I_2	I_3	I_4	I_5
Split application of nitrogen					
S_1	24.54	22.93	10.03	11.90	7.35
S_2	20.43	15.95	8.58	8.70	8.03
S_3	16.32	11.35	10.35	7.81	5.36

Fig.6 Soil Moisture depletion pattern as affected by irrigation & split application of Nitrogen.



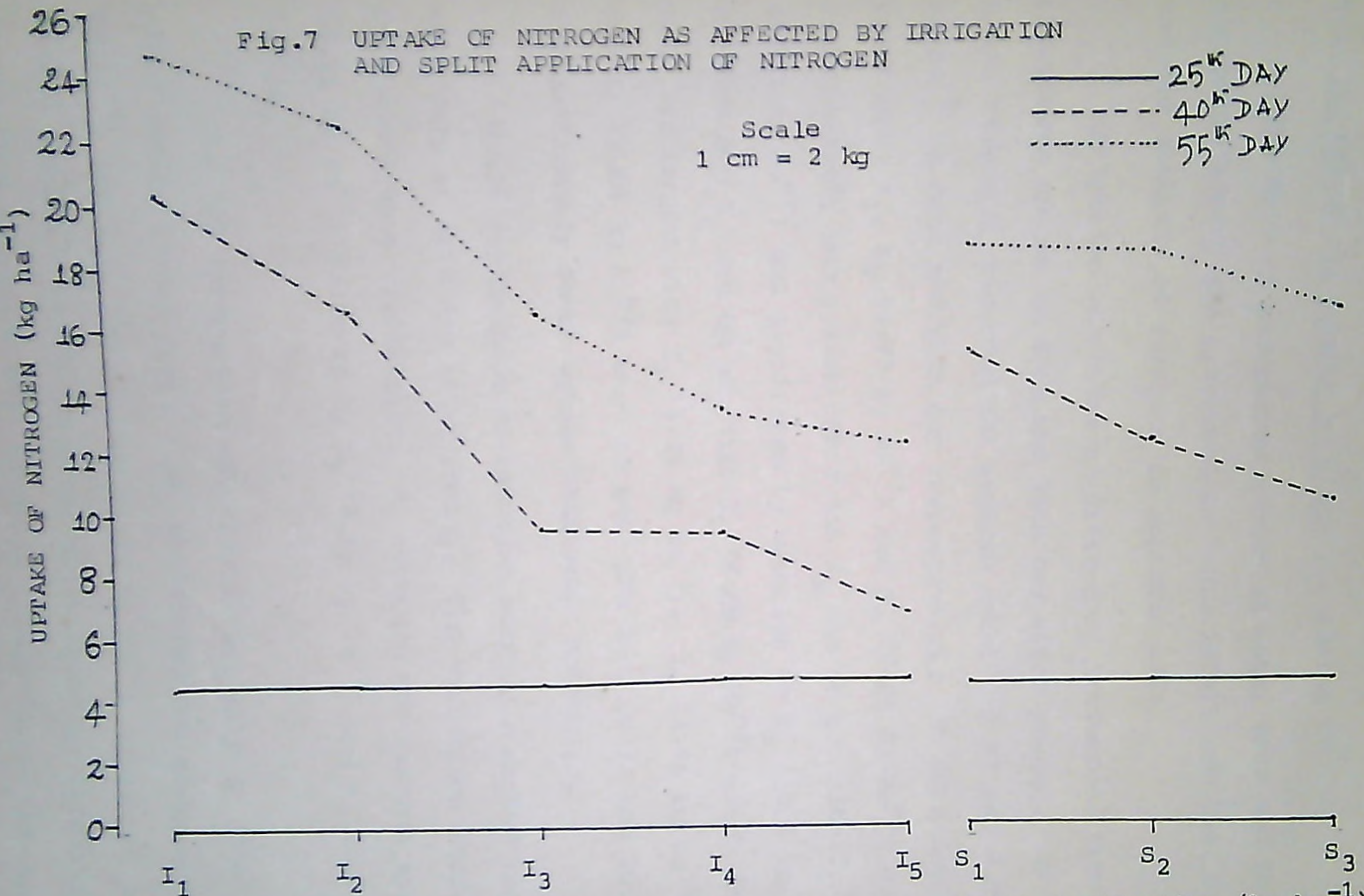


Fig.7 UPTAKE OF NITROGEN AS AFFECTED BY IRRIGATION AND SPLIT APPLICATION OF NITROGEN

5.2 Uptake of phosphorus by plant (excluding fruit)

The data on phosphorus uptake at 25th, 40th and 55th day after sowing are presented in Table 16(a), and Fig. 8 and the analysis of variance in Appendix XII.

Irrigation schedules significantly influenced the phosphorus uptake at 40th and 55th day after sowing. At these stages I_1 recorded the maximum uptake (5.92 and 6.87 kg ha^{-1} at 40th and 55th day respectively). At 40th day the treatments I_1, I_2 (4.83 kg ha^{-1}) and I_3 (2.69 kg ha^{-1}) varied significantly among each other and I_3 was on par with I_4 (2.63 kg ha^{-1}) and significantly superior to I_5 (1.90 kg ha^{-1}). At 55th day I_1 was on par with I_2 (6.08 kg ha^{-1}) which in turn was on par with I_3 (5.10 kg ha^{-1}). I_4 (3.78 kg ha^{-1}) and I_5 (3.54 kg ha^{-1}) were on par with each other and recorded a significantly lower uptake than other schedules.

Split application of nitrogen exerted a marked influence only at 40th day after sowing. The variations among the treatments were significant. S_1 recorded the maximum uptake (4.31 kg ha^{-1}) followed by S_2 (3.55 kg ha^{-1}) and S_3 (2.93 kg ha^{-1}).

The IxS interaction was significant only at 40th day after sowing (Table 16b). I_1S_1 registered the maximum (7.04 kg ha^{-1}) and I_5S_3 the minimum (1.55 kg ha^{-1}) values of phosphorus uptake. Variations among split doses of nitrogen were of a higher magnitude with frequent irrigation schedules (I_1 and I_2).

Table 16(a): Phosphorus uptake (kg ha^{-1}) at different stages

	25th day	40th day	55th day
Irrigation			
I_1	1.65	5.92	6.87
I_2	1.62	4.83	6.08
I_3	1.71	2.69	5.10
I_4	1.77	2.63	3.78
I_5	1.69	1.90	3.54
F test	NS	Sig	Sig
Split application of nitrogen			
S_1	1.70	4.31	5.47
S_2	1.65	3.55	5.21
S_3	1.72	2.93	4.55
F test	NS	Sig	NS
CD 0.05 (I)	-	0.528	1.477
CD 0.05 (S)	-	0.409	-

Table 16(b): Combined effect of irrigation and split application of nitrogen on uptake of phosphorus by plant at 40th day

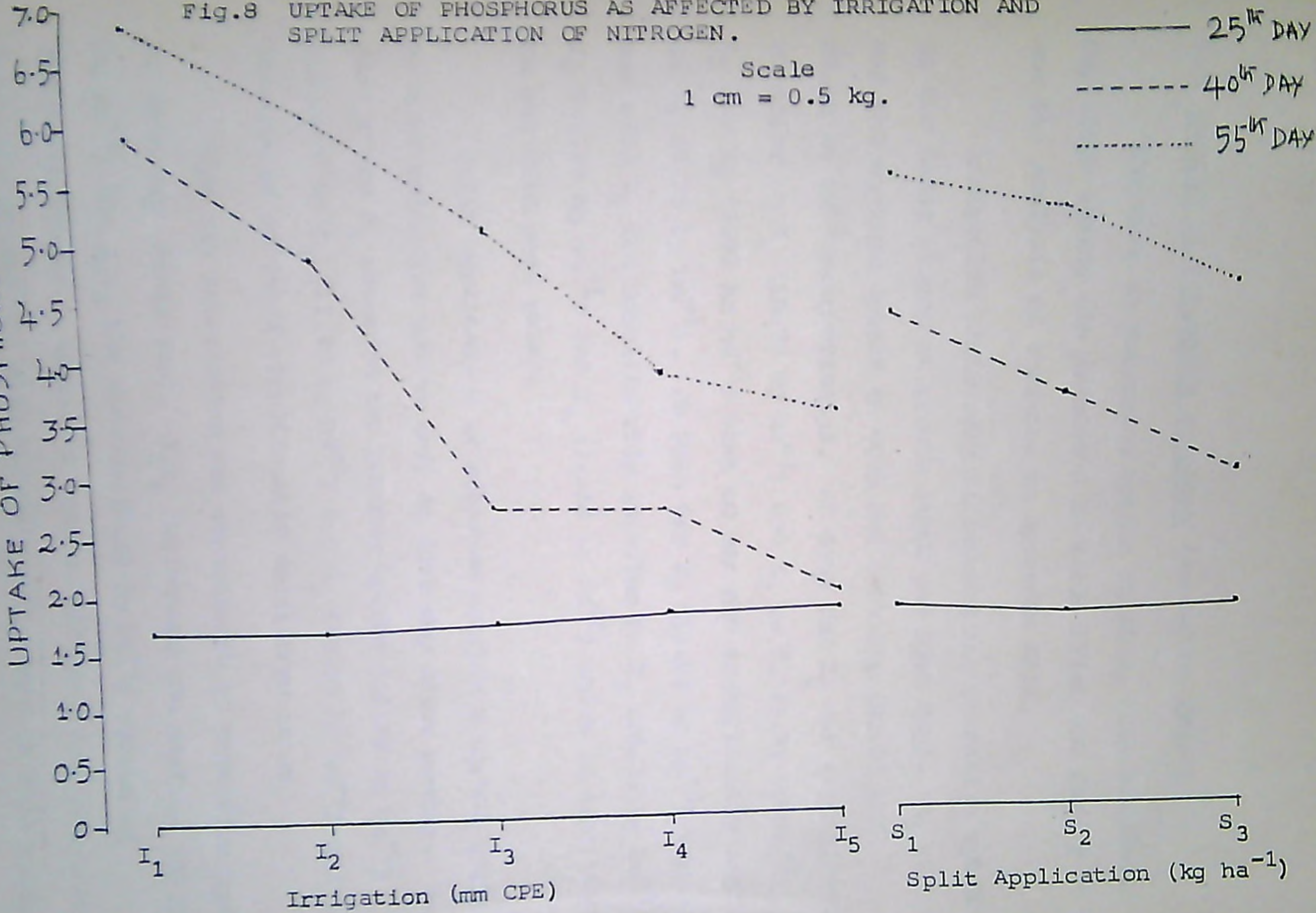
	Irrigation levels				
	I_1	I_2	I_3	I_4	I_5
Split application of nitrogen					
S_1	7.04	6.48	2.82	3.17	2.06
S_2	5.93	4.83	2.40	2.51	2.12
S_3	4.80	3.20	2.85	2.21	1.55

CD 0.05 (IxS) = 0.914

SE of means at 25 DAS: I = ± 0.4395, S = ± 0.3403

" at 55 DAS: S = ± 0.4305

Fig.8 UPTAKE OF PHOSPHORUS AS AFFECTED BY IRRIGATION AND SPLIT APPLICATION OF NITROGEN.



5.3 <u>Uptake of potassium by plant</u> (excluding fruit)

The data on potassium uptake at 25th, 40th and 55th day after sowing are presented in Table 17(a) and Fig. 9 and the analysis of variance in Appendix XIII.

Irrigation profoundly influenced the potassium uptake at the later stages of growth (40th and 55th day). I_1 recorded the maximum uptake at 40th and 55th day (20.80 and 22.08 kg ha^{-1} respectively). At 40th day I_1 was significantly superior to I_2 (16.73 kg ha^{-1}) and I_2 to I_3 (9.91 kg ha^{-1}). I_3 and I_4 (9.92 kg ha^{-1}) were on par and significantly superior to I_5 (6.70 kg ha^{-1}). At 55th day I_2 (19.64 kg ha^{-1}) was on par with I_1 and significantly superior to I_3 (14.16 kg ha^{-1}), I_4 (12.15 kg ha^{-1}) and I_5 (11.62 kg ha^{-1}) which in turn were on par with each other.

Split application of nitrogen exerted a marked influence on potassium uptake only at 40th day after sowing. At this stage S_1 recorded the maximum uptake (14.92 kg ha^{-1}) followed by S_2 (12.70 kg ha^{-1}) and S_3 (10.39 kg ha^{-1}) and the treatments differed significantly among each other.

The IxS interaction was significant on potassium uptake at 40th day (Table 17b). I_1S_1 registered the maximum (24.59 kg ha^{-1}) and I_5S_3 the minimum (5.19 kg ha^{-1}) values of potassium uptake. As in the case of nitrogen and phosphorus, potassium uptake was also markedly influenced by soil wetness and application of nitrogen in two splits.

Table 17(a): Uptake of Potassium (kg ha^{-1}) at different stages

	25th day	40th day	55th day
Irrigation			
I_1	6.38	20.80	22.08
I_2	6.44	16.73	19.64
I_3	6.70	9.91	14.16
I_4	7.00	9.92	12.15
I_5	6.20	6.70	11.62
F test	NS	Sig	Sig
Split application of nitrogen			
S_1	6.70	14.92	15.71
S_2	6.80	12.70	17.14
S_3	6.50	10.39	14.95
F test	NS	Sig	NS
CD 0.05 (I)	-	1.624	4.956
CD 0.05 (S)	-	1.260	-

Table 17(b): Combined effect of irrigation and split application of nitrogen on uptake of potassium by plant at 40th day

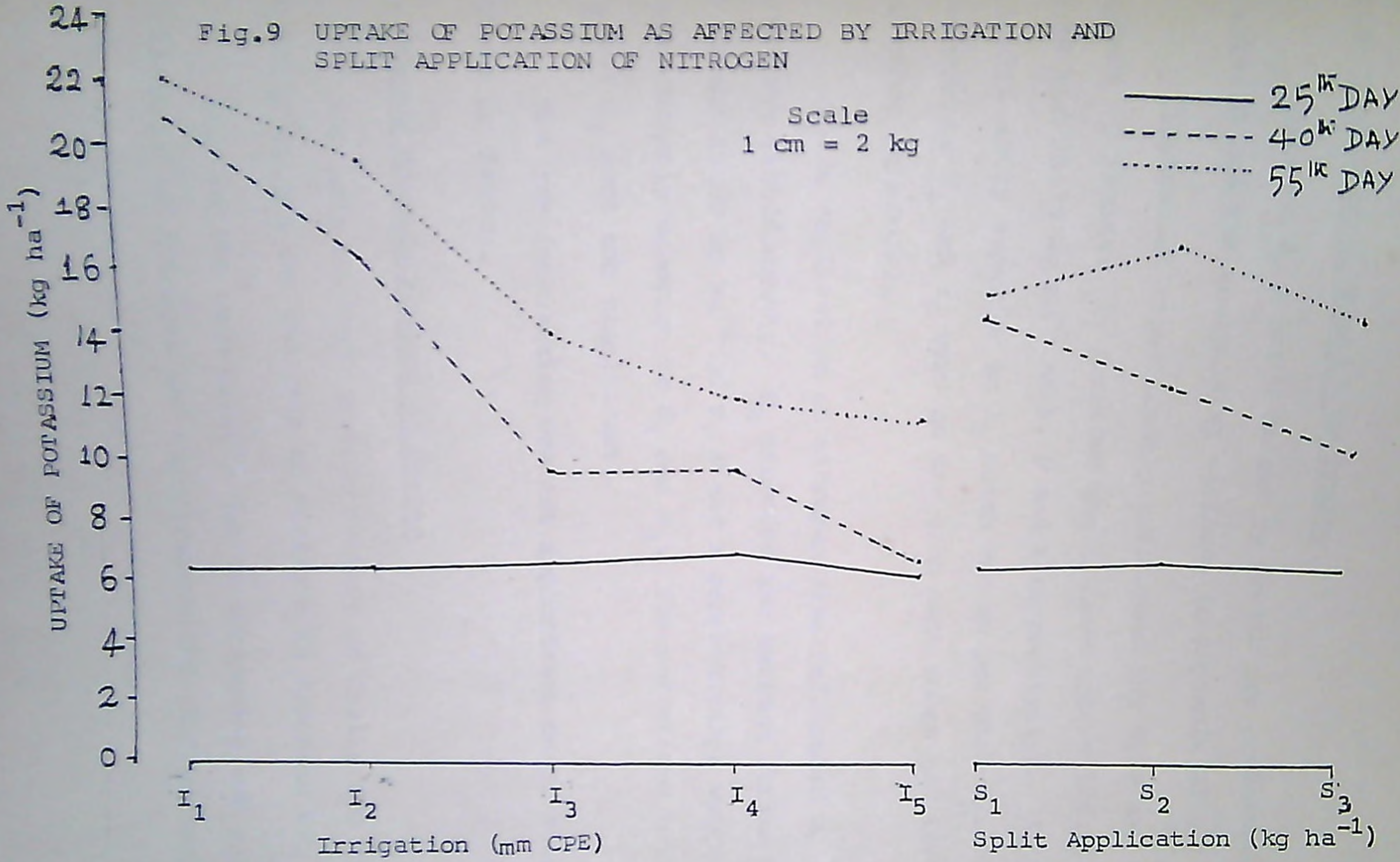
	Irrigation levels				
	I_1	I_2	I_3	I_4	I_5
Split application of nitrogen					
S_1	24.59	22.12	9.92	10.70	7.29
S_2	21.37	16.81	8.66	9.02	7.62
S_3	16.44	11.27	11.14	7.93	5.19

CD 0.05 (IxS) = 2.781

SE of means at 25 DAS: I = ± 0.3930, S = ± 0.3044

" at 55 DAS: S = ± 1.1843

Fig.9 UPTAKE OF POTASSIUM AS AFFECTED BY IRRIGATION AND SPLIT APPLICATION OF NITROGEN



5.4 Uptake of N, P and K by fruits

Data on N, P and K uptake by fruits are presented in Table 18 and the analysis of variance in Appendix XIV.

Irrigation significantly influenced the N, P and K uptake by fruits. I_1 recorded the maximum uptake (24.12, 5.58 and 25.25 kg ha^{-1} of N, P and K respectively). I_1 was significantly superior to I_2 which was on par with I_3. The treatments I_4 and I_5 were on par with each other and inferior to other schedules.

Split application of nitrogen also influenced N, P and K uptake significantly. S_1 recorded the maximum uptake (14.35, 3.42 and 15.50 kg ha^{-1} of N, P and K respectively) which was significantly superior to S_2 and S_3. The variations between S_2 and S_3 were not significant.

The IxS interaction was not significant on N, P and K uptake by fruits.

6. Crude protein content of fruits

The data on crude protein content of fruits are presented in Table 19 and the analysis of variance in Appendix XV.

Neither the main effects due to irrigation and split application of nitrogen nor their interaction influenced the crude protein content of fruits significantly.

Table 18: Uptake of N, P and K (kg ha^{-1}) by fruit

	Uptake of N	Uptake of P	Uptake of K
Irrigation			
I_1	24.12	5.58	25.25
I_2	14.30	3.38	15.46
I_3	14.02	3.21	15.38
I_4	6.55	1.54	5.50
I_5	6.62	1.53	6.33
F test	Sig	Sig	Sig
Split application of nitrogen			
S_1	14.35	3.42	15.50
S_2	12.45	3.00	12.58
S_3	12.57	2.86	12.67
F test	Sig	Sig	Sig
CD 0.05 (I)	2.210	0.429	2.208
CD 0.05 (S)	1.708	0.333	1.708

Table 19: Crude protein content of fruits (per cent)

	Crude protein content
Irrigation	
I_1	16.65
I_2	15.71
I_3	15.79
I_4	16.06
I_5	16.06
F test	NS
Split application of nitrogen	
S_1	15.52
S_2	15.93
S_3	16.12
F test	NS
CD 0.05 (I)	-
CD 0.05 (S)	-

SE of means: I = ± 0.3951, S = ± 0.3060

7. Soil analysis

The mean values of organic carbon, available phosphorus and available potassium content of soil estimated after the completion of the experiment are presented in Table 20 and the analysis of variance in Appendix XVI.

The results revealed that irrigation schedules, split application of nitrogen or their interactions did not exert any significant influence on the above chemical characteristics.

8. Economics of different treatments

Economics of different treatments presented in Table 21 indicated that net profit increased with increase in the frequency of irrigation more or less similar to fruit yield. The highest net profit of Rs.13942 was obtained when irrigation was given daily with 280 litres of water per plot (3.5 l per plant). The increase in net profit due to daily irrigation was Rs.2332, Rs.3860, Rs.6833 and Rs.7396 over 30, 45, 60 and 75 mm irrigation schedules respectively. The net return per rupee invested was maximum in I_2 (1.144), followed by I_3 (1.082), I_1 (1.002), I_4 (0.864) and I_5 (0.826).

Among the split doses of nitrogen the highest net profit was recorded by S_1 (Rs.11606) and it was Rs.1618 and Rs.2332 higher than S_2 and S_3 respectively. S_1 (1.138) recorded the highest net return per rupee invested followed by S_2 (1.020) and S_3 (0.970).

Table 20: Organic carbon (per cent), available phosphorus (kg ha^{-1}) and available potassium content (kg ha^{-1}) of the soil after the experiment

	Organic carbon	Available phosphorus	Available potassium
Irrigation			
I_1	0.343	28.78	19.27
I_2	0.339	28.62	19.50
I_3	0.354	30.02	19.86
I_4	0.313	29.14	19.88
I_5	0.348	29.42	20.04
F test	NS	NS	NS
Split application of nitrogen			
S_1	0.338	29.10	19.48
S_2	0.350	28.94	19.74
S_3	0.331	29.54	19.90
F test	NS	NS	NS
CD 0.05 (I)	-	-	-
CD 0.05 (S)	-	-	-

SE of means for organic carbon: I = $\pm$ 0.0133, S = $\pm$ 0.0103
" for P_2O_5 : I = $\pm$ 0.4821, S = $\pm$ 0.3734
" for K_2O : I = $\pm$ 0.2316, S = $\pm$ 0.1794

Table 21: Cost of production of different treatments

Treatment	Fixed cost Rs. Ps.	Variable cost Rs. Ps.	TCP* (X) Rs. Ps.	Yield kg ha^{-1}	Value (Y) Rs.	Net profit (Y-X) Rs. Ps.	Net return per rupee invested (Y-X/X)
Irrigation							
I_1	4150.85	9764.50	13915.35	13929	27858	13942.65	1.002
I_2	4150.85	6000.50	10151.35	10881	21762	11610.65	1.144
I_3	4150.85	5170.50	9321.35	9702	19404	10082.65	1.082
I_4	4150.85	4073.50	8224.35	7667	15334	7109.65	0.864
I_5	4150.85	3779.50	7929.85	7238	14676	6546.15	0.826
Split application of nitrogen							
S_1	4150.85	6052.50	10203.35	10905	21810	11606.65	1.138
S_2	4150.85	5646.50	9797.35	9893	19786	9988.65	1.020
S_3	4150.85	5408.50	9559.35	9417	18834	9274.65	0.970

Price of 1 kg N = Rs.4.674
" 1 kg P_2O_5 = Rs.5.313
" 1 kg K_2O = Rs.2.00
Price of 1 ton of Farm Yard Manure = Rs.175

1 kg bhindi = Rs.2.00
cost of irrigation = Rs.100 per irrigation
Labour charge : Rs.30 per man
Rs.25 per woman

*TCP - Total Cost of Production.

DISCUSSION

V. DISCUSSION

Results obtained from the investigation to study the response of bhindi to water management in relation to split application of nitrogen presented in the preceding chapter are discussed hereunder.

1. Growth characters

Irrigation schedules significantly influenced the growth characters viz., plant height, number of leaves per plant, leaf area index, dry matter production, length of root and shoot:root ratio (Tables 4 to 9) at 40th and 55th day after sowing. The above growth parameters excepting root length were increased by frequent irrigation schedules and daily irrigation (I_1) recorded the maximum values. The marked influence of irrigation on the growth characters could be noticed within a period of 20 days from the date of application of the treatments (40th day after sowing) ie. the period of active vegetative growth in bhindi. Similar results were reported by Cummin and Kretchman (1974) in cucumber and Acevedo and Massard (1984) in tomato.

Water is the most important limiting factor among the various factors contributing to plant growth. It is a universal solvent and major constituent of protoplasm which is often regarded as the "physiological basis of life". The increased growth of plants is related to increased turgidity of cells with increase in soil moisture availability leading to cell enlargement and cell division - the two vital processes in plant growth. On the contrary, low available soil moisture or water stress adversely affected the above processes and retarded growth (Begg and Turner, 1976). Decrease in plant height in schedules receiving irrigation at wider intervals can be attributed to the adverse effect of water stress. The reduction in the rate of leaf initiation and cell division might have caused the production of lesser number of leaves under water stress. The increase in LAI at flowering stage due to frequent irrigation could be ascribed to the marked increase in leaf area through its favourable influence on leaf size (the number and size of cells) as well as leaf number. Cummin and Kretchman (1974) in cucumber and Thomas (1984) in bittergourd have observed reduction in leaf area due to moisture stress.

Dry matter production at 40th and 55th day was profoundly influenced by irrigation (Tables 7(a) and 7(b) and Fig. 3). However, all the differences between successive levels were not significant. The production of dry matter is influenced more by moisture supply than by nutrients. It is considered to be the most sensitive index for water supply (Black, 1973). Efficient utilisation of nutrients in the frequently irrigated treatments (Tables 15 to 18) has increased the plant growth as evident from the plant height, leaf production, leaf area index (Tables 4 to 6) and thereby dry matter production. Photosynthesis is the basic process for the build up of organic substances and the amount of dry matter production will depend upon the effectiveness of photosynthesis. The leaves are the actual sites of photosynthesis and the photosynthetic efficiency depends on size and thickness of leaves, number of leaves and their life-span. The LAI is the best measure to study the ability of a crop to produce dry matter. Higher dry matter production due to frequent irrigation has been reported by Tamaki and Naka (1971) in broad beans, Hafeez and Cornillon (1976) in brinjal, Desai and Patil (1984) in muskmelon, and Thomas (1984) in bittergourd.

Split application of nitrogen influenced the plant height, number of leaves per plant, LAI and dry matter production significantly (Table 4 to 7). However, the number of leaves and dry matter production were influenced significantly by split application only at 40th day after sowing. All the above growth characters were enhanced by the application of nitrogen in two splits (S_1) followed by three splits (S_2) with 50 per cent of it as basal as compared to three splits (S_3) with one-third nitrogen as basal. Favourable influence of the basal application of a higher proportion of the total nitrogen dose on growth characters has been reported by Bradley (1965) in cucumber, Matev (1966) in Capsicum and Smittle (1976) in snap beans. In the present study the trend of growth characters indicated the importance of the application of nitrogen in two splits with 50 per cent as basal to enhance early vegetative growth. The treatment S_3 receiving only one-third nitrogen as basal has caused a significant reduction in plant height, number of leaves per plant, leaf area index and dry matter production particularly during the active vegetative growth stage. It indicated the inadequacy of the applied basal nitrogen dose in that treatment for optimum growth and production of biomass. For a short duration crop like bhindi, early vigorous growth has to be promoted by judicious application of fertilizers and water since a higher proportion of biomass has to be accumulated during this stage for optimum production. Increased plant height is a function of meristamatic activity which is related to proper nitrogen nutrition. Activation of meristamatic tissues and leaf expansion as a result of adequate nitrogen nutrition will enhance photosynthesis resulting in higher dry matter production (Tanaka et al. 1964).

The combined effect of irrigation and split application of nitrogen was significant on LAI and dry matter production at 40th day (Tables 6 and 7(b) and Fig.3) and the highest values were recorded by I_1S_1 (2.90 and 23.28 g/plant) and the least by I_5S_3 (0.74 and 4.94 g/plant). The effect of interaction on the above growth characters revealed the profound influence of the application of nitrogen in two splits with 50 per cent as basal under frequent irrigation schedules. Increased wetness of the soil due to frequent irrigation increased the availability of plant nutrients as evident from the data on nutrient uptake (Tables 15 to 18) in the present study for better plant growth.

A significant increase in root length could be noticed with increase in the interval between irrigation from 40th day onwards (Table 9a). Giles and Alexander (1950) stated that shallow rooting in tomato was favoured by weekly irrigation and roots penetrated deeper as the frequency of irrigation was widened. Similar rooting pattern was observed by Hudson and Salter (1953) in tomato, Abdelfattah and Abdel-Salam (1972) in brinjal and Cascio and Pugila (1978) in tomato. The root length was not however influenced by split application of nitrogen to an appreciable extent. Black (1973) has clearly demonstrated that a decrease in available soil moisture results in increased root production and total root length. Thus plants themselves play an important role in influencing the availability of soil water through their capability to extend roots downward into moist soil.

The interaction between irrigation and split application of nitrogen was significant on root length at 55th day (Table 8b). Here the significant favourable influence of the application of nitrogen in two equal splits (S_1) could be seen under daily irrigation.

Contrary to root length, the shoot:root ratio decreased with increase in soil dryness (Table 9). It indicates that the magnitude of decrease in plant height was proportionately higher than that of the increase in root length at higher moisture stress. Similar results were reported by Giardini and Pimpini (1971) in Capsicum, Tamaki and Naka (1971) in broad beans, Gibbon (1973) and Hafeez and Cornillon (1976) in brinjal and Gamayun (1980) in tomato.

With regard to split application of nitrogen S_1 followed by S_2 recorded higher ratios due to increase in plant height in these treatments without any appreciable variation on root length. Skapsi et al. (1969) in tomato reported that plant height contributed to an increase in shoot:root ratio at lesser number of splits of nitrogen.

2. Yield components

The yield components viz., number of fruits per plant as well as length, girth and dry weight of fruits (Tables 10 and 11 and Fig. 4) were favourably influenced by soil wetness.

All the above characters except the fruit girth were profoundly influenced by daily irrigation. The effect of daily irrigation on fruit girth was also positive and significant. Molnar (1965) in melons, Abdelfattah and Abdel Salam (1972) in Capsicum, Razvi and Jagirdar (1973) and Udeogalanya and Muoneke (1983) in bhindi have reported higher number of fruits at lower soil moisture tensions. According to Kaufmann (1972) water deficit induces retardation of floral primordia development, flower production, fruit set and induces flower and fruit abscission leading to decrease in fruit production. Increase in fruit length due to frequent irrigation could be attributed to continuing cell division, progressive initiation of tissues, and on the differentiation and enlargement of cells (Fischer, 1973). The results are in conformity with the findings of O'Dell (1983) in Capsicum and Thomas (1984) in bittergourd. Favourable influence of irrigation on dry weight of fruits could be attributed to increase in length and girth of fruits. Daily irrigation recorded a 97.98 per cent increase in dry weight of fruits compared to 75 mm CPE schedule. The results pertaining to fruit weight corroborate with the findings of El-Nadi (1970) in beans, Henriksen (1980) in cucumbers, Cornillon and Dauple (1981) in brinjal and Udeogalanya and Muoneke (1983) in bhindi. Increased availability and absorption of plant nutrients under frequent irrigation resulted in better plant growth and translocation of photosynthates to fruits (Arnon, 1975) and the fruit weight was increased.

Split application of nitrogen influenced the number of fruits per plant as well as length and dry weight of fruits (Tables 10 and 11). The treatment S_1 was significantly superior to other splits with regard to the number of fruits per plant and dry weight of fruits the two important yield components. The increase in fruit number obtained with S_1 in the present study is in agreement with that of Chauhan (1972) in bhindi, Bradley et al. (1975) in cucumbers, Katyal (1977) in bittergourd and Srinivas and Prabhakar (1982) in Capsicum. But in the case of length of fruits S_1 and S_2 were on par and significantly superior to S_3. The higher length of fruits due to S_1 is in conformity with the findings of Hammett et al. (1974) and Batal and Smittle (1981) in cucumber and Capsicum respectively. The results in general indicated the superiority of S_1 ie., the application of nitrogen in two equal splits as compared to more number of splits as in S_2 and S_3. Such an effect of the application of nitrogen can be attributed to the increased availability of nutrients needed for early vigorous growth as evident from the growth characters (Tables 4 to 9) and improvement in photosynthetic rate of the crop. Flocker et al. (1965) reported higher girth of fruits in melons due to application of nitrogen in lesser number of splits. Hammett et al. (1974) in cucumber and Dod et al. (1983) in Capsicum noticed higher dry weight of fruits due to the application of the total nitrogen dose in lesser number of splits.

3. Fruit yield

Irrigation schedules influenced the fruit yield significantly (Table 11 and Fig.5). The effect of split application of nitrogen and interaction between irrigation and split application did not reach the level of significance. The lowest yield of 72.38 q ha^{-1} and the highest yield of 139.29 q ha^{-1} were recorded by 75 mm CPE and daily irrigation schedules respectively. The daily irrigation (I_1) recorded a yield increase of 28.01, 43.57, 81.67 and 92.44 per cent over I_2, I_3, I_4 and I_5 respectively. The marked influence of daily irrigation on the yield components viz., number of fruits per plant, and length and dry weight of fruits resulted in higher fruit yield. The results are in agreement with the findings of Vittum (1958) in tomato, Flocker et al. (1965) in melon, Razvi and Jagirdar (1973) and Sharma and Prasad (1973) in bhindi, Pugila et al. (1977) in tomato, Henriksen (1980) in cucumber, Udeogalanya and Muoneke (1983) in bhindi and Thomas (1984) in bittergourd. Higher fruit yield under frequent irrigation schedules are accompanied by a more or less corresponding increase in the yield components viz., number of fruits per plant and length, girth and dry weight of fruits. Fruit yield is the ultimate manifestation of the combined effect of the yield attributes. Soil wetness increases fruit number by promoting floral primordia development, number of flowers produced and higher fruit set. Fruit weight and size enhanced by higher rate of photosynthesis and increased translocation of photosynthates to the fruits (Kaufmann,1974). Though not significant the trend in fruit yield due to split application of nitrogen was in favour of S_1 receiving 50 per cent nitrogen as basal and the remaining 50 per cent 30 days after sowing. This is in agreement with the findings of Lanchow Wing and Rajkomar (1982) in bhindi.

4. Field water use efficiency

The results indicated that field water use efficiency was higher with less frequent irrigation schedules (Table 12). Water use efficiency is likely to increase with decrease in soil moisture supply until it reaches the minimum critical level because the plants may try to economise water loss in the range from minimum critical to optimum soil moisture level. Water above the optimum level may be lost in the form of excessive evaporation, excessive transpiration or even as deep percolation. These findings are in agreement with the reports of Singh and Singh (1979) and Sharma and Parashar (1979). The highest water use efficiency was recorded by I_5 (75 mm CPE) which was on par with I_3 and I_4 and the lowest by I_1 (daily irrigation) which was on par with I_2 (irrigation at 30 mm CPE).

Neither the split application of nitrogen nor its interaction with irrigation had any marked effect on water use efficiency.

5. Moisture studies

The results indicate a more or less linear increase in total consumptive use with increase in the frequency of irrigation (Table 13). Frequent wetting of the soil surface and root zone resulted in a higher evapotranspiration loss. The maximum consumptive use was recorded by I_2 (irrigation at 30 mm CPE), which produced the maximum dry matter. Under low frequency irrigation schedules, the moisture depletion pattern showed an increasing trend towards deeper layers of soil as compared to I_2. The non availability of water in the surface layers might have caused the root to penetrate deeper resulting in higher moisture extraction from deeper layers of soil. Black (1973) has pointed out that root grows and forages deeper into the soil in search of water when the moisture supply is not adequate in the surface. This is in conformity with the findings of Giles and Alexander (1950) and Hudson and Salter (1953) in tomato, Abdel-Salan (1972) in brinjal and Cascio and Pugila (1978) in tomato. In general the upper 0-30 cm layer of soil contributed on an average 68.53 per cent of the total moisture extraction.

With regard to split application of nitrogen, there was no appreciable variation among treatments.

6. Uptake of nutrients

Uptake of nitrogen, phosphorus and potassium by the plant at 40th and 55th day as well as by the fruits were affected significantly by irrigation (Tables 15 to 18 and Fig. 7 to 9). The uptake of these nutrients increased with increase in irrigation frequency. Such an increase in nutrient uptake with frequent irrigation can be attributed to a more or less similar increase in drymatter production without any perceptible variation in nutrient content. The results are in agreement with the findings of Brown et al. (1960) in cotton, Tamaki and Naka (1971) in broad bean, Sharma and Prasad (1973) in bhindi, Singh (1975) in berseem fodder, Cocucci et al. (1976) in squash and Patel and Padalia (1980) in groundnut. Tanaka et al. (1964) pointed out that nutrient absorption by the plant is controlled by nutrient availability in the soil, nutrient absorption power of the soil and the rate of increase in dry matter. Wetness of the soil rendered the nutrients more available and stimulated growth. The concentration and availability of various elements in the soil for plant growth depends upon the soil solution phase which is controlled by the amount of soil water. So the availability of water is of great significance to the plants need for and ability to absorb nutrients and the soils ability to supply them (Black, 1973).

Split application of nitrogen influenced the uptake of N, P and K by the plant on the 40th day and by the fruit. The non significant effect of split application on the uptake of these nutrients at 25th and 55th day can be ascribed to the similar trend obtained in dry matter production (Tables 15 to 18). The results are in conformity with the findings of Smittle (1976) in snapbeans and Batel and Smittle (1981) in Capsicum.

The effect of interaction due to irrigation and split application of nitrogen on N, P and K uptake was significant at 40th day. I_1S_1 recorded the maximum uptake (24.54, 7.04 and 24.59 kg ha^{-1} of N, P and K respectively) followed by I_2S_1 (22.93, 6.48 and 22.12 kg ha^{-1} of N, P and K respectively). The trend indicated the marked influence of frequent irrigation in increasing the uptake of major nutrients under S_1 and S_2 (50 per cent of N applied as basal, compared to S_3 receiving only one-third N as basal).

7. Crude protein content of fruits

The data revealed the non significant effect of irrigation, split application of nitrogen and their interaction on crude protein content of fruits (Table 19). The non significant effect of the treatments on nitrogen content of fruits caused a similar effect on crude protein content. This is in conformity with the findings of Sharma and Prasad (1973) and Lanchow Wing and Rajkomar (1982) in bhindi.

8. Soil analysis

The results indicate that organic carbon and available P_2O_5 and K_2O content in the soil after the experiment was not influenced significantly by irrigation schedules, split application of nitrogen or their interaction (Table 20). Soil being a reservoir of nutrients, it is likely that small addition or removal of nutrients to and from the soil may not cause any appreciable variation in its available nutrient content.

9. Economics of different treatments

The results indicate an increase in net profit with increase in the frequency of irrigation (Table 21) and the daily irrigation recorded the highest net profit. The increase in net profit due to daily irrigation was Rs.2332, Rs.3860, Rs.6833 and Rs.7396 over 30, 45, 60 and 75 mm irrigation schedules respectively. However, the net return per rupee invested was the maximum in I_2 (30 mm CPE) as compared to 1.002 in I_1 (daily irrigation). Therefore it is more remunerative to adopt daily irrigation under conditions of ample supply of water. However, in command areas where rotational supply of water is being practised, 30 mm CPE schedule (the second best treatment) can be suitably adopted. It involves 7 irrigations at an interval of 6 to 7 days with a saving of 213 mm of water as compared to daily irrigation.

Among the split doses of nitrogen, the highest net profit of Rs.11606 was recorded by S_1 (½ basal + ½ 30 DAS) and it was Rs.1618 and Rs.2332 higher than S_2 and S_3 respectively. The highest net return per rupee invested was also recorded by S_1 (1.138).

SUMMARY

VI. SUMMARY

A field experiment was conducted in the summer rice fallows of the Agronomic Research Station, Chalakudy during 1985 (January to March) to study the response of water management in relation to split application of nitrogen on bhindi. The soil of the experimental field was sandy loam in texture with a bulk density ranging from 1.41 to 1.47 g cm^{-3}, slightly acidic in reaction, low in available nitrogen and potassium and medium in available phosphorus. The weather was almost normal without any appreciable amount of rainfall during the period of crop growth. The test variety was Pusa Savani. The treatments comprising combinations of five levels of irrigation (daily irrigation and irrigation at 30, 45, 60 and 75 mm CPE values) and three split applications of nitrogen (½ basal + ½ 30 DAS; ½ basal + ¼ 30 DAS + ¼ 50 DAS; 1/3 basal + 1/3 30 DAS + 1/3 50 DAS) were laid out as a 5x3 factorial experiment in randomised block design with three replications. The results of the experiment are summarised below.

1. Daily irrigation (I_1) and application of nitrogen in two equal split doses (S_1) significantly increased plant height at 40th and 55th day after sowing.

2. The number of leaves per plant was favourably influenced by irrigation at 40th and 55th day and split application of nitrogen at 40th day.

3. The leaf area index noted at 40th day was enhanced by frequent irrigation and application of nitrogen in two equal splits.

4. The dry matter production per plant on 40th and 55th day increased progressively with increase in the level of irrigation and daily irrigation recorded the maximum values. The effect due to application of nitrogen in two equal splits (S_1) was positive and significant only at 40th day. The interaction effect due to irrigation and split application of nitrogen on dry matter production indicated the pronounced effect of two split doses of nitrogen under daily and 30 mm CPE irrigation schedules.

5. Root length was substantially increased by irrigation at wider intervals. The effect due to split application of nitrogen was not significant. The interaction effect due to irrigation and split application of nitrogen showed a reduction in root length due to three splits as compared to two splits only under daily irrigation.

6. Shoot:root ratio was favourably influenced by frequent irrigation schedules and application of nitrogen in two equal split doses.

7. The mean number of fruits produced per plant rose with increase in the frequency of irrigation and application of nitrogen in two splits. Daily irrigation produced nearly

double the number of fruits produced by 60 mm and 75 mm schedules.

8. Frequent irrigation and application of nitrogen in two equal splits enhanced the mean length of fruits.

9. Girth of fruits was influenced by irrigation and 30 mm CPE schedule registered in maximum girth.

10. Dry weight of fruits was substantially increased by soil wetness and daily irrigation (I_1) recorded the highest value. It was also enhanced by application of nitrogen in two equal split doses (S_1).

11. Irrigation enhanced the yield of fruits significantly. The fruit yield increased progressively with decrease in the interval between irrigation. The highest fruit yield of 139.29 q ha^{-1} was produced by daily irrigation (I_1) and it was 28.01, 43.57, 81.67 and 92.44 per cent more than 30 (I_2), 45 (I_3), 60 (I_4) and 75 (I_5) mm CPE schedules respectively. Neither the effect due to split application of nitrogen nor its interaction with irrigation influenced fruit yield significantly.

12. Field water use efficiency was highest in 75 mm CPE (I_5) and lowest in daily irrigation (I_1). Split application of nitrogen did not affect the water use efficiency significantly.

13. The total consumptive use among the treatments scheduled on the basis of CPE values increased more or less linearly with increase in irrigation frequency from 75 mm to 30 mm CPE. Under low frequency irrigation schedules the moisture depletion showed an increasing trend towards deeper soil layers. Split application of nitrogen did not influence consumptive use to an appreciable extent. On an average bhindi extracted 68.53 per cent of the total moisture from the top 30 cm soil layer.

14. Uptake of N, P and K recorded at 40th and 55th day was significantly increased by frequent irrigation schedules. The favourable significant effect due to split application of nitrogen was observed only at 40th day. The interaction effect (IxS) was significant on uptake at 40th day and the marked influence of split application of nitrogen was observed under frequent irrigation schedules (I_1 and I_2).

15. Neither the main effects due to irrigation and split application of nitrogen nor their interaction produced any significant variation in the crude protein content of fruits.

16. The organic carbon and available phosphorus and potassium content in the soil after the experiment did not vary significantly either due to irrigation or split application of nitrogen.

17. Economics of different treatments indicated that the net profit increased with increase in the frequency of irrigation and the daily irrigation (I_1) registered the highest net profit of Rs.13942 per hectare,with a net return of 1.002 per rupee invested. It was Rs.2332, Rs.3860, Rs.6833, and Rs.7396 higher than 30 mm, 45 mm, 60 mm and 75 mm CPE schedules respectively. The highest net return per rupee invested was recorded by 30 mm CPE schedule (I_2) followed by 45 mm CPE (I_3). Thus in command areas where rotational supply of water is practised, it is remunerative to adopt irrigation scheduled at 30 mm CPE (approximately 6-7 days). Among the split doses of nitrogen, the highest net profit of Rs.11606 was recorded by two equal splits (S_1).

The overall trend of the results suggest that daily irrigation (I_1) can be profitably adopted in places where water is available in plenty. But in places where water is not available in plenty, it is profitable to adopt irrigation at 30 mm CPE. It is also observed that application of nitrogen in two equal splits (S_1) is most profitable in the cultivation of bhindi in summer rice fallows.

REFERENCES

REFERENCES

Abdel-Al, Z.E., and A. Saeed (1975). The effects of plant population, irrigation frequency and cultivars on yield and canning qualities of tomato fruits grown under hot tropical conditions. Acta Horticultare 49: 193-208.

*Abdelfattah, M.A., and A.S. Abdel-Salam (1972). The response of egg plant to irrigation treatments. Beitrage Zur Tropischen Und Subtropischen Landwirtschaft Und Tropenveterinarmedizin. 10(3): 239-246.

*Abdel-Salam A.S. (1972). Yield and quality traits of two brinjal varieties under different irrigation regimes. Acta Horticultura. 100: 173-180.

*Abreu, T.A.DE, A.F.L.Olitta, and D.A.B. Marchetti (1978). Comparison of two irrigation methods (furrow and drip) on melons in the San Francisco Valley. Pesquisa Agropecuaria Brasileira. 13(3): 35-45.

*Acevedo, H.E., and V.C. Massard (1984). Effect of water deficit at two stages of development of tomato (Lycopersicon esculentum Mill) Phyton, Argentina 44 (2): 151-166.

*Aladzajkov, L., M. Cirkova, and H. Hristonanov (1973). Results of irrigation trials with tomatoes and capsicum in the strumica region. Poledelstvo i Gradinarstvo 25: 93-102.

Ali, T., and Raggal (1982). Effect of irrigation regime on the productivity of processing tomatoes. Horticultura. 25: 29-32.

*Alves, E.M., S. Bernardo and J.F. Silva (1982). Effect of different water levels on the productivity of three tomato cultivars using drip irrigation. Revista ceres. 29 (162): 145-154.

Anonymous (1981a). Annual Report 1980-81. Co-ordinated project for research on water management (ICAR), Chalakudy Centre.

Anonymous (1981b). Annual Report 1980-81. Co-ordinated project for research on water management (ICAR), Madurai Centre.

Anonymous (1982a). Annual Report 1981-82. Co-ordinated project for research on water management (ICAR), Chalakudy Centre.

Anonymous (1982b). Package of practices recommendations. Kerala Agricultural University, Mannuthy.

Anonymous (1983). Seminar on KAU 2000 A.D Background papers, Kerala Agricultural University, Mannuthy.

Anonymous (1984a). Annual Report 1984-85. Co-ordinated project for research on water management (ICAR), Mahatma Phule Agricultural University, Ahmednagar.

Anonymous (1984b). Annual Report 1984-85. Co-ordinated project for research on water management (ICAR), Mahatma Phule Agricultural University, Ahmednagar.

A.O.A.C. (1960). Official and Tentative Methods of Analysis 9th edition. Association of Official Agricultural Chemists, Washington D.C.

Arnon, I. (1975). Physiological principles of dryland crop production. In '*Physiological aspects of dryland farming*'. (Ed. U.S. Gupta). Oxford and IBH Publishing Co., New Delhi, Bombay, Calcutta. pp.3-145.

Asif, M.I. (1977). Estimation of leaf area in Okra. (*Abelmoschus esculentus* (L) Moench) *Tropical Agriculture*. **54**(2): 192.

*Balasa, M. (1962). Studies on the influence of various soil water regimes on the yield of some vegetable species. *Lucr. Sti. Inst. agron.* **6**: 301-307.

Balasubramanian, V., and J.Y. Yayock (1981). Effect of gypsum and moisture stress on growth and pod filling of groundnut (*Arachis hypogea*). *Plant and soil*. **62**(2): 209-219.

*Barbieri, G., and A. Duranti (1981). Two years of research on the irrigation of processing tomatoes in the Sele river plan. *Irrigazione*. **28**(2): 11-32.

Bar-Yosef, B., C. Stammers, and B. Sagiv (1980). Growth of trickle irrigated tomatoes as related to rooting volume and uptake of nitrogen and water. *Agronomy Journal*. **72**(5): 815-822.

Batal, K.M., and D.A. Smittle (1981). Response of bell pepper to irrigation, nitrogen and plant population. *Journal of the American Society for Horticultural Science*. **106**(3): 254-262.

Begg, J.E., and N.C. Turner (1976). Crop water deficits. *Adv. Agron*. **28**: 161-207.

*Belik, V.F (1961). The growth and development of cucumbers and the cell sap concentration of leaves at different soil moisture levels. Fiziol. Rast. 8: 497-500.

Black, C.A. (1973). Soil Plant Relationship. 2nd Edition Wiley Eastern Pvt. Ltd., New Delhi. pp.111.

*Bradley, G.A., E.C. Baker, and D.R. Motes (1975). Cultural studies on once over harvested pickling cucumbers. Arkansas Farm Research. 24(2).

Bray, R.H., and L.T. Kurtz (1945). Determining total organic and available forms of phosphate in soils. Soil Sci. 39: 39-45.

*Brown, D.A., C.A. Place, and J.V. Pettiet (1960). The effect of soil moisture upon cation exchange in soils and nutrient uptake by plants. Trans. 7th Int. Congr. Soil Sci. 3: 433-439.

*Caixeta, T.J., V.W.D. Casali, S. Bernardo, and L.M. Oliveira (1981). Effect of quantity of water and frequency of trickle irrigation on sweet pepper. Revista Ceres. 28(155): 52-59.

*Caliandro, A., and A. DE. Caro (1973). The effect of different seasonal rates of irrigation on papper (Capsicum annuum). Annali della Facotta di Agraria dell Universita di Bari. 26(2): 625-651.

*Cascio, B.LO, and S. DEL Pugila (1978). Effects of three methods of irrigation on tomato root density and distribution. Revista di Agronomia. 12(½): 85-88.

Chander, A., and J.L. Mangal (1983). Studies on nitrogen fertilization under various soil moisture regimes on growth, flowering and fruiting behaviour of muskmelon. Punjab Horticultural Journal. 23 (½): 105-110.

Chauhan, D.V.S. (1972). Vegetable Production in India 2nd edition. Ram Prasad and Sons, India, Agra, pp.277.

Chhonkar, V.S., and S.N. Singh (1963). Studies on inorganic nutrition of bhindi in sand culture. Indian Journal of Horticulture. 20(1): 51-58.

* Chuzhova, A.P., E.P. Bukin, L.YA Arbuzova, and E.V. Osipova (1975). The effect of split application of mineral fertilizers on agrochemical soil properties and on physiological characteristics and yield of tomatoes. Agrokhimiya.1: 110-113.

Cocucci, S., M. Cocucci, and C.P. Treccani (1976). Effect of water deficit on the growth of squash fruit. Physiologiya plantarum. 36(4): 379-382.

Colman, E.A. (1944). The dependence of field capacity upon depth of wetting of soils. Soil Sci. 58: 43-50.

Cornillon, P., and P. Dauple (1981). Influence of irrigation rhythm and water supply on growth, water status and yield of egg plant. (Solanum melongena). Plant and soil. 59(3): 365-379.

* Cummins, T.L., and D.W. Kretchman (1974). Moisture stress in relation to growth and development of pickling cucumber. Out door Vegetables Crops research - 1974, Research Summary. Ohio Agricultural Research and Development Centre, 1975 No.81: 23-24.

*Dashkova, N.P. (1976). Cucumber nutrition on artificial substrate. Khimiya V Selskom Khozyaistve 14(2): 40-43.

Dastane, N.G., G.N. Kulkarni, and E.C. Cheriyan (1963) Effects of different moisture regimes and nitrogen levels on quality of tomato. Indian Journal of Agronomy. 8: 405-408.

Dastane, N.G. (1972). A practical manual for water use research in agriculture. 2nd edition. Navabharat Prakashan, 702, Poona.2. p.120.

*Deidda, M., G.F. Marras (1973). The determination of irrigation frequency and volume of irrigation water for tomatoes for canning in relation to soil moisture content. Studi Sassaresi III 21(2): 793-804.

*Dellamico, and E. Jerez (1984). Influence of soil moisture on the growth and development of tomato cv. Campbell 28. Cultivos Tropicales. 4(3): 577-586.

Desai, J.B., and V.K. Patil (1984). Effects of sowing dates and irrigation on growth, yield and quality of watermelon. Journal of Maharastra Agricultural Universities. 9(1): 34-37.

*Dimitrov, Z. (1974). Greenhouse cucumber irrigation. Blgarski plodove Zelenchutsii konservi. 1: 20-22.

Dod, V.N., A.T. Joshi, P.B. Kale, and L.V. Kulwal (1983). Effect of different levels of nitrogen in split doses on yield and quality of red ripe chilli. (Capsicum annuum; Linn) cv. G-3. In Proceedings of National Seminar on Production Technology of Tomato and Chillies., Coimbatore, India, Tamilnadu Agricultural University, 1983, 152-153. Punjabrao Krishi Vidyapeeth, Akola, Maharastra, India.

El-Nadi, A.H. (1970). Water relations of beans. Expl. Agric. 6: 107-111.

Escober, D.E., and H.W. Gausman (1974). Water stress reduces light reflectance of squash leaves. J. Rio Grande Valley Hort. Soc. 28: 57-63.

Fischer, R.A. (1973). Plant Responses to climatic factor. pp.233-241, UNESCO, Paris.

Flocker, W.J., J.C. Lingole, and R.M. Davis (1965). Influence of irrigation and nitrogen fertilization on yield, quality and size of cantaloupes. Proc. am. soc. hort. sci. 86: 424-432.

Frohlich, H., and A. Henkal (1961). The use of supplementary irrigation for outdoor cucumbers. Arch. Gartenb. 9: 538-551.

*Galeva, V., R. Dilkova, and T. Fien (1976). Effect of irrigation at different soil moisture potentials on the quality of tomatoes. Pochvoznanie i Agrokhimiya. 11(5): 12-22

*Ganayun, I.M. (1980). Development, growth and productivity of mid season tomato in relation to irrigation regimes. Selskokhozyaistuennaya Biologiya. 15(1): 141-142.

Gautam, O.P., and N.G. Dastane (1970). Agronomic practices and water use patterns for higher crop yields. In 'New Vistas in Crop Yields', Indian Council of Agricultural Research, New Delhi, pp.148-200.

Gerard, C.J., and W.R. Cowley (1964). The influruence of irrigation and spacing treatments on the production of Rio Grande valley tomatoes. J. Rio Grande Valley Hort. Soc. 18: 82-90.

Giardini, L., and F. Pimpini (1971). Growth, productivity and evapotranspiration in Capsicum as a function of soil moisture content at the time of irrigation. Rivista di Agronomia. 5(2/3): 99-114.

Gibbon, D. (1973). The production of egg plant (Solanum melongena) under surface and subsurface systems of irrigation in Tanzania. J. Hort. Sci. 48(3): 217-221.

Giles, J.E., and D. MCE Alexander (1950). Frequency of irrigation for tomato plants. J. Aust. Inst. Agric. Sci. 16: 95-100.

*Gorbatenko, E.M. (1962). Development of root system of tomatoes under various irrigation regimes. Vestu S-Kh Nauki No.9, pp.43-45.

*Goto, Y., H. Ichikawa, Y. Araki, and A. Shibata (1981). Studies on the variation of soil water suction at the beginning of irrigation and the irrigation requirement of some vegetables under greenhouse conditions. Bulletin of the Vegetable and Ornamental Crops Research Station. No.9, pp.133-141.

Hafeez, A.T.A., and P. Cornillon (1976). Effects of irrigation rhythm on growth, fruit set, yield and quality of egg plant. (Solanum melongena) in South France. Plant and Soil. 45(1): 213-225.

*Hammett, H.L., Albritton, R.C., Brock, W.A., Crockett, S.P. and Waggoner, B.E. (1974). Production of cucumber for pickles. Bulletin, Mississippi Agricultural and Forestry Experiment Station, No.801: 14.

*Henriksen, K. (1980). Irrigation of ridge cucumbers. Tidsskrift for Planteavl 84(6): 479-490.

Hudson, J.P., and P.J. Salter (1953). Effects of different water regimes on the growth of tomatoes under the glass. Nature. 171: 480-481.

Jackson, M.L. (1967). Soil Chemical analysis. Prentice-Hall Inc. Englewood Cliffs. N.J. USA. reprint (1973) by Prentice-Hall of India (Pvt) Ltd., New Delhi, pp.498.

*Jagoda, J., and S.L. Kaniszewski (1975). The effectiveness of irrigation and mineral fertilization during cultivation of 2 cucumber cultivars. Biuletyn Warzywniczy. 18: 47-61.

*Kartalov, P., and Z. Dimitrov (1970). Water regime of pepper grown in hot beds. "V. Kolarov" Plovdiv, 19(2):89-95.

Kashi, A. (1981). Effect of interval and method of irrigation on some quantitative and qualitative characteristics of semsuri cantaloupe of baramin (Cucumis melo var. reticulatus). Indian J. Agric. Sci. 12(¼): 1-12.

Katyal, S.L. (1977). Vegetable growing in India IBH Publishing Co., New Delhi, Bombay, Calcutta, pp.253.

Kaufman, M.R. (1972). Plant responses and control of water balance-water deficit and reproductive growth. In 'water deficit and plant growth'. Vol.III (Ed. T.T. Kozlowski) Academic Press, New York. pp.91-124.

*Khosh-Khui, M., and H. Azarakhush (1983). Influence of irrigation interval, nitrogen fertilization and plant spacing on tomato fruit yield and quality. Iran Agricultural Research. 2(1): 39-50.

Kuruppuarachi, D.S.P., and A.N. Pain (1981). Effect of soil moisture depletion on yield and water use efficiency of chillies, onions and bananas on the latisols of the north-west dry zone. Tropical Agriculturist. 137: 109-121.

Lanchow Wing, K.F., and I. Rajkomar (1982). Effects of planting density and split application of nitrogen on Okra (Abelmoschus esculentus (L) Moench). Revue Agricole et Sucriere de Ille Maunce. 6(1): 9-14.

*Leela, D., Ravel, P., and Shukla, V. (1975). Effects of foliar and soil application of nitrogen and phosphorus on the yield and chemical composition of Abelmoschus esculentus. Geobios. 2(2/3): 56-59.

Lin, S.S.M., J.N. Hubbell, S.C.S. Tsou, and R.W.E. Splittstoesse (1983). Drip irrigation and tomato yield under tropical conditions. Hort. Sci. 18(4): 460-461.

*Linsalata, A.D., and A.DE Caro (1977). The effect of seasonal volume of irrigation water on the yield of egg plant (Solanum melongena). Quadevnide "La Ricerca Scientifica" 9: 149-159.

Loomis, E.L., and P.C. Crandall (1977). Water consumption of cucumbers during vegetative and reproductive stages of growth. J. Amer. Soc. Hort. Sci. 102(2): 124-127.

Mangal, J.L., and M.L. Pandita (1982). Effect of irrigation intensities and nitrogen levels on growth and yield of cauliflower. (Brassica oleracea var botrytis) Variety Hissar-1. Haryana Agricultural University Journal of Research. 12(3): 413-417.

*Matev, T. (1966). The time of application of mineral fertilizers to early pepper crop. Grad lozas, Nauke. 3: 715-722.

Michael, A.M. (1978). Irrigation - Theory and Practice Vikas Publishing House Pvt. Ltd., New Delhi, Bombay, Bangalore, Calcutta, Kanpur. p.801.

*Molnar, E. (1965). Irrigation of melons. Novenytermeles 14: 203-214.

*Motoki, M., and H. Kurokawa (1977). The effect of irrigating at different soil moisture levels on melons growing on coarse volcanic ash soil of komagadake. Bulletin of Hokkaido Perfectural Agricultural Experiment Stations. No.37: 50-67.

*Muminov, T.G. (1973). Forecasting the times of melon irrigation by means of leaf water content. Nauchnye Trudy Nil Ovoschche-Balchchevy-Kh Kutar i Karo Felya. No.10: 62-74.

Muthuvel, P., and K.K. Krishnamoorthy (1980). Influence of soil moisture and added nitrogen on P availability. Madras Agric. Journal. 67(4): 242-247.

Muthuvel, P., and K.K. Krishnamoorthy (1981). Influence of soil moisture regimes and N levels on the availability of potassium in soils. Madras Agric. J. 68(6): 355-359.

*Neil, P., and J.P. Zunino (1972). Water requirements of melons and methods of irrigation. Pepinierstes Horticulteurs Maraichers.123: 45-54.

*O'Dell, C. (1983). Trickle did the trick. American Vegetable Grower. 31(4): 56.

Pai, A.A., and S.B. Mukheri (ed.) (1979). Manuel on irrigation water management. Ministry of Agriculture and Irrigation, Department of Agriculture, Krishi Bhavan, New Delhi. pp.3-26.

*Palevitch, D., G. Gera, M. Shaked, A. Levy, and M.B. Yehuda (1980). Irrigation of Paprika (Capsicum annuum) plants. Hassadeh.60(8): 1535-1543.

Pandey, U.C., and I.J. Singh (1979) Effect of varying moisture regimes, levels of nitrogen and spacing on quality and chemical composition of seeds of Okra. (Abelmoschus esculentus (L) Moench) Haryana Agricultural University Journal of Research. 12(3): 450-455.

Patel, C.L., and M.R. Padalia (1980). Nutrient accumulation and nutrient use efficiency under different sequences of soil water potential. Legime Research. 3(1): 45-50.

*Pavlov, F.I (1976). Irrigation regime for cucumbers under heated plastic greenhouses. Timiryazeva.216: 128-132.

*Pellicciari, M DEG, and P. Sismondo (1976). The effect and method of irrigation, its frequency and the volume of water applied on globe artichoke yield. Edizioni Minerva Medica. 535-552.

*Peterburgskii, A.V., K. Asarov, and P.M. Smirnov (1956). The effectiveness of fertilizers in the south-eastern regions of the USSR under irrigation. Izr timirya zev S-Kh Akad. No.2: 23-36.

Pew, W.D., and B.R. Gardner (1983). Effects of irrigation practices on vine growth, Yield and quality of muskmelon. Journal of the American Society for Horticultural Science. 108(1): 134-137.

Piper, C.S. (1950). Soil and Plant analysis. University of Adelaide, Australia. p.368.

* Pugila, S. DEL, B. Cascio, and V. Lombardo (1977). Irrigation of tomatoes for processing. La Ricerca Scientifica No.99: 139-148.

Razvi, I.A., and S.A.P. Jagirdar (1973). Effect of irrigation interval, spacings and planting methods on the yield of lady's finger. Agriculture, Pakistan. 24(2): 151-157.

Richards, L.A. (1947). Pressure membrane apparatus - Construction and Use. Agr. Engin. 28: 451-454.

Rudich, J., G. Elasser, and Y. Shafi (1978). Optimal growth stages for the application of drip irrigation to muskmelon and watermelon. Journal of Hort. Sci. 53(1): 11-15.

* Sadykov, I.M., and Mikhael ZH-YU (1981). Irrigation regime in direct sown capsicums. Trudy Kuban S-Kh In-t No.197: 114-118.

Salter, P.J. (1960). Effects of different soil moisture conditions during the seedling stage on the growth and yield of early summer cauliflowers. J. Hort. Sci. 35: 239-248.

Sampathkumar, S. (1980). Studies on the effect of different types of soil and water on the growth and development of bhindi. M.Sc. Thesis submitted to Tamilnadu Agricultural University 1980.

Shanmughasundaram, V., P. Jayapal, T.S. Govindan and Madhava Rao (1979). Irrigation study on TMV-7 groundnut (Arachis hypogea L) Farm Sci. 6(5):10-14.

Sharma, R.P., and N.G. Dastane (1968). Estimation of evapotranspiration from evaporation data. In Irrigation Theory and Practice. Vikas Publishing House Pvt. Ltd., New Delhi, Bombay, Bangalore, Calcutta, Kanpur. p.520.

Sharma, J.P., and R. Prasad (1973). Yield of pods, crude protein content and nitrogen uptake by Okra. (Abelmoschus esculentus) as affected by nitrogen and water management. Garten bauwissenchaft. 38(2): 163-169.

Sharma, B.M., and J.S.P. Yadav (1976). Availability of phosphorus to gram as influenced by phosphate fertilization and irrigation regime. Indian J. Agric. Sci. 46(5): 205-210.

Sharma, R.P. and K.P. Parashar (1979). Effect of different water supplies, levels of nitrogen and phosphorus on consumptive use of water and moisture extraction pattern by cauliflower (Var. Snow ball-16). Indian J. Agron. 24(3): 315-321

Singh, S.P. (1975). Effect of soil moisture regimes, nitrogen and phosphorus on N, P, K and Ca uptake by berseem fodder. Indian J. Agron. 20: 337-340.

Singh, S.D., and Punjab Singh (1978). Values of drip irrigation compared with conventional irrigation for vegetable production in hot arid climate. Agron. J. 70(b): 945-947.

Singh, U.B., and R.M. Singh (1979). Consumptive use and its relationship with climatological parameters as influenced by moisture management, nitrogen and phosphorus application in Safflower. Indian J. Agron. 20: 337-340.

Skapski, H., K. Viscardi, and J. Jagada (1969). Effect of sprinkling irrigation and mineral and organic fertilizing on yields of certain tomato varieties. Biul. Warzyw. 9: 121-136.

Smittle, D.A. (1976). Response of snap beans to irrigation, nitrogen fertilization and plant population. J. Amer. Soc. Hort. Sci. 101(1): 37-40.

Smittle, D.A. and E.D. Threadgill (1982). Response of squash to irrigation, nitrogen fertilization and tillage systems. J. Amer. Soc. Hort. Sci. 107(3): 437-440.

Snedecor, G.W., and Cochran, W.G. (1967). Statistical Methods. 6th edition. Oxford and IBH Publishing Co., Calcutta. pp.593.

*Spencer, K. (1951). Tomato root distribution under furrow irrigation. Aust. J. Agric. Res. 2: 118-125.

Srinivas, K., and B.S. Prabhakar (1982). Response of Capsicum to nitrogen fertilization. Vegetable Science. 9(2): 71-74.

Subbiah, B.V. and G.L. Asija (1956). A rapid procedure for the estimation of available nitrogen in soils. Current Sci. 25(8): 259-260.

Tamaki, K., and J. Naka (1971). Effect of soil moisture on growth and chemical composition of various parts of broad bean. Technical Bulletin. Faculty of Agriculture, Kagawa University, 22(2): 73-82. Japan.

Tanaka, A., S.A. Navasero, C.V. Garcia, G.T. Parao and E. Remirez (1964). Growth habit of the rice plant in the tropics and its effect on nitrogen response. Int. Rice Res. Inst. Tech. Bull. 3: 1-80.

*Tedeschi, P., and C. Ruggiero (1977). The irrigation of tomatoes for peeling in the sele plain. La Ricerca Scientifica. No.99: 179-183.

*Tedeschi, P. and Zerbi, G. (1984). Flowering and fruiting courses of sweet pepper (Capsicum annuum) plants grown in lysimeters with relation to different water regimes. Rivista ceres 68(4): 323-329.

Thomas, G.C. (1984). Water management practices for bitter-gourd (Mamordica charantia. L) under different fertility levels. M.Sc. Thesis submitted to Kerala Agricultural University, 1984.

*Udeogalanya, A.C.C., and C.O. Muoneke (1983). Effect of irrigation levels and pruning heights on the yield of Okras (Hibiscus esculentus) in south-eastern Nivera. Beitrage Zur Tropischen Landwirtschaft und Verterinarmedizin. 21(4): 437-443.

Umrani, N.K., and B.D. Khot (1974). Pan evaporation as an index for scheduling irrigation in brinjal (Solanum melongena L.) Research Journal of Mahatma Phule Agricultural University. 5(2): 73-76.

Varga, G.V. (1974). Irrigation of cucumber in relation to variety and weather. Agartudomanyi Egyetem Kozlemenyei. 191-200.

Varma, A.K., and N.S. Subha Rao (1975). Effect of different levels of soil moisture on growth, yield and some physiological aspects of nodulation in greengram. Indian J. Agric. Sci. 45(1): 11-16.

Verma, J.P., S.V.S. Rathore, and C.S. Kushwaha (1974). Effect of level and method of application of nitrogen through urea on the performance of Okra (Abelmoschus esculentus (L) Moench). Progressive Horticulture (1974) 5(4): 77-80.

Vittum, M.T., W.T. Tapley, and N.H. Peck (1958). Response of tomato varieties to irrigation and fertility level. Bull. NY St agric. Exp. Stat. 782, 1958, pp.78.

Voigtander, A. (1978): Effect of sprinkler irrigation on the yield of lettuce and cabbage. Pochvoznanie i Agrokhimiya 10(3): 49-55.

Vuelwascisneros, M.A. (1982). Effect of different levels of available moisture on Pepper (Capsicum annuum) Yields. Proceedings of the Tropical Region, American Society for Horticultural Science. 25: 399-405.

Yawalker, K.S. (1962). Manuring of Okra. In Commercial fertilizers in India. Agri. Horticultural Publishing House, Nagpur.

* Original not seen.