WATER MANAGEMENT PRACTICES FOR BITTER GOURD (*Momordica charantia* L) UNDER DIFFERENT FERTILITY LEVELS

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled "Water management practices for bittergourd (*Momordica charantia* L.) under different fertility levels" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship, or other similar title, of any other University or Society.

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CERTIFICATE

Certified that this thesis entitled "Water management practices for bittergourd (*Momordica charantia* L.) under different fertility levels" is a record of research work done by Sri. C. George Thomas 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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Introduction

INTRODUCTION

Bittergourd (Momordica charantia L.) occupies a prominant position among the vegetables cultivated during the summer season in Kerala. The importance of this vegetable has long been accepted on account of its high nutritive value and unique medicinal properties. It ranks first among the group of cucurbitaceous vegetables with regard to nutritive values of fruits particularly proteins, ascorbic acid, phosphorus, potassium and iron (Choudhary, 1979). The fruit is considered to be a good remedy for diabetes and many skin and liver troubles. It is also reported to possess cooling, stomachic, appetising, carminative, antipyretic, anthelmintic, aphrodisiac and vermifuge properties (Blatter *et al*. 1935; Nadkarni, 1954). The fruit is consumed in many ways. It is relished as a vegetable when tender or pickled. It can also be preserved for use in the off season after slicing and drying. On account of this unique qualities there is a consumer preference for this vegetable.

In a state like Kerala where land resources are limited, utilization of rice fallows for vegetable cultivation has relevence and wider applicability.

Bittergourd has been found to be an eminantly suitable vegetable for cultivation in rice fallows where assured irrigation facility exists. Further it has been found to be more remunerative than other vegetables grown in rice fallows and hence gaining popularity among farmers under intensive multiple cropping practices. Therefore technologies useful in increasing the production and net income per unit area by the cultivation of this crop needs emphasis.

Water and fertilizer are the two costly inputs in vegetable production. Water is, however the most limiting among them during the summer season. It influences the availability and uptake of plant nutrients as well as growth and yield. The full potential of any cultivar of a crop can be exploited only with judicious water and fertilizer management practices. Therefore performance of the crop in relation to water and fertilizers require major attention. However detailed studies have not been undertaken in Kerala or elsewhere on this aspect. Therefore it was felt necessary to find out the optimum and economic irrigation and fertilizer management practices for this crop. In view of the above an experiment was undertaken on bittergourd during the summer season of 1982-83 at the Agronomic Research Station, Chalakudy with the following objectives.

1. To find out the effect of timing and frequency of irrigation and fertility levels on growth and yield.

2. To ascertain the optimum combination of the levels of irrigation and fertilizers.

3. To work out the consumptive use and moisture extraction pattern.

4. To study the effect of irrigation and fertility levels on the content and uptake of nitrogen, phosphorus and potassium.

5. To work out the economics of irrigation and fertilizer application.

Review of Literature

REVIEW OF LITERATURE

Vegetables have not received as much attention as that of field crops with respect to the studies on water or nutritional requirements. Available literature, however emphasized the importance of moist regimes and frequent irrigations where water table is low, and judicious application of manures and fertilizers under normal field conditions. In the case of bittergourd, little specific research has been reported on the water management aspect. Literature on manurial requirements of this crop is also meagre. Attempts have therefore been made to review the important works conducted in India and abroad on cucurbits, a group of vegetables to which bittergourd belongs.

2.1. Effect of Irrigation

2.1.1. Growth and yield

Flocker *et al.* (1965) obtained satisfactory yield of melon by irrigating it when the soil moisture tension at 18 inch depth reached 0.3 bars. They observed that the yield increase due to irrigation was mostly by the increase in fruit size. They also found that frequent heavy irrigations increased the number of cull fruits which was associated with increased vine growth and succulance. Soil moisture stress also had increased the cull fruits but with restricted vine growth.

Molnar (1965) found that in melons irrigation advanced flowering and increased the number of female flowers. He also observed a higher water requirement at the beginning of fruit growth. A reduction in fruit drop of irrigated crops was also reported by him.

Dunkel (1966) used overhead sprinklers to irrigate tomatoes and cucumbers grown at different soil moisture conditions in the upper 10 cm soil. The highest yield in both the crops was obtained when the soil moisture did not drop below 70 per cent of field capacity. A water requirement of 600 - 750 mm was reported for optimal yields. In another study with sprinkler irrigation in cucumber, Borna (1969) showed that irrigation during the entire growing season was more effective than irrigation upto or after cropping started.

While describing the cultivation of bittergourd, Hali (1969) emphasized the necessity of daily irrigation to the crop during summer season in Kerala.

Jassal <u>et al</u>. (1970) reported from a field trial in muskmelon that fruit weight and yield were significantly increased by weekly irrigation as compared with fortnightly ones. Varga (1971) observed a parabolic relationship between yield and soil moisture content in cucumber. He found that the optimum soil moisture content for the crop was 68 - 75 per cent of field capacity.

Neil and Zunino (1972) indicated that irrigation given upto 80 per cent of maximum evaporation which amounts to 60 per cent of the potential evapotranspiration was economically feasible in melons. Average irrigation requirement was found to be 2000 m^3 ha^{-1}. Raising the irrigation rate produced heavier melons with improved flavour and decreased firmness. Pestova and Pestova (1973) by using soil water deficit approach to schedule irrigation in muskmelon observed that the best quality melons were produced with a stable soil water content of 55 per cent which was increased to 65 per cent for the period from full bloom to fruit set.

The time and amount of irrigation can be determined by the leaf water content. Muminov (1973) while trying to forecast the time of irrigation by this method obtained the highest melon yield at a leaf water content of 84 - 86 per cent. Dimitrov (1973) had shown that the most economic irrigation treatment for watermelon was to maintain the soil moisture at 70 - 80 per cent of field capacity over the entire season.

Varga (1973) from the results of 10 years trials in cucumber concluded that the optimum number of irrigation was 3 to 5. He also observed that the 30 to 40 days between flowering and fruit ripening were critical for fruit development and during this period it was necessary to supply the crop with 40 mm water. However, excessive application of water was deleterious. Similar observation was made by Tomitaka (1974) in cucumber. He got the highest plant growth and fruit yield at a medium soil moisture level of pF 2.0.

Escobar and Gausman (1974) had grown mexican squash (Cucurbita pepo) hydroponically at low (0.4 atm) and high (2.4 atm) water stress. Higher water stress was induced by adding an osmoticum (Polyethylene glycol). They noticed that the leaves of the plants under higher stress were thicker and smaller containing less water than the plants under lower water stress. A similar finding was reported by Cummins and Kretchman (1974) in cucumber from field and green house studies. They noted that leaf area and fruit yield were greatly reduced under stress.

From a glass house trial with cucumber Dimitrov (1974) recorded the highest yield when the soil moisture was maintained at 70 per cent of field capacity before picking and 90 per cent during the picking period. On a four year average the yield was 26 per cent higher than that of the control wherein 70 per cent of the field capacity was maintained during the entire growing season.

Jagoda and Kaniszewski (1975) reported from an experiment with two cultivars of cucumber that irrigation appreciably improved the yield and fruit quality. The crop was irrigated when the soil water content fell to 58 per cent of field capacity at 10-27 mm.

Cocucci *et al.* (1976) followed the growth of squash fruit in the field under normal and drought conditions. They observed a peculiar phenomena that under drought conditions fruit growth was normal at night but it become more and more reduced in the day. They also found that the decrease in growth during the day time did not correspond to dehydration of the fruit tissues and it was accompanied by conversion of polysomes to monosomes. Water stress caused a decrease of RNA and protein content in the fruit tissues but did not affect the rate of growth at night. They further opined that under drought conditions fruit growth was controlled by water availability through protein synthesis. Rhodes and Matsuda (1976) in their studies with pea and pumpkin seedlings suggested that growth rate reduction during salt or desiccation induced water stress may be directly proportional to the accompanying reduction in polyribosome level.

Motoki and Kurokawa (1977) applied irrigation to melons at different soil moisture regimes ranging from pF 2.7 to 2.0 and obtained optimum plant growth and yields with irrigation at pF 2.5.

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 in the upper 90 cm of the soil profile between irrigations. They also noted from growth chamber studies that transpiration rate (water consumption per unit leaf area) reached a maximum shortly after the first flower was fully developed. This maximum was then followed by a decline in transpiration rate with a general levelling off during the final five days.

Katyal (1977) recommended frequent irrigations for bittergourd at an interval of 3 to 4 days during dry weather. Even in rainfed crops irrigation is required during dry spells. The recommended practice in Karnataka is to irrigate the summer crop of bittergourd once in 4 - 5 days depending on the soil and weather conditions (Anon. 1978).

Singh and Punjab Singh (1978) reported highest total yield with drip irrigation daily at 68 per cent of the evaporation from a Class A pan in cropse like bottle gourd (Lagenaria siceraria), round gourd (Citrullus vulgaris) and watermelon (Citrullus lanatus) in loamy sand soils of hot arid region. They also observed that yield increase was associated with increased number of fruits per plant and increased fruit weight.

Olitta et al. (1978) obtained the highest yield from drip irrigation at 0.7 atm. with one emitter per four plants and Abreu et al. (1978) with 2 emitters per two plants in melons. Kagohashi et al. (1978) observed that in muskmelon water uptake rose gradually before pollination, increased rapidly after pollination, remained high for about 15 days and then fell to pre-pollination levels.

While noting the water requirement of vegetables, Pai and Mukherji (1979) opined that for good growth of vegetables the soil moisture should be maintained at or above 75 per cent of avilability in the active root zone.

They further explained that water requirement would depend upon the soil and the season in which the crops were grown and suggested 3 to 4 irrigations per month for summer and 2 irrigations per month for rabiata place like New Delhi. In Kharif also, irrigation is required whenever there is dry spell for about 12 to 15 days.

Haynes and Herring (1980) reported that irrigation at 700 m bar using the viaflow system of trickle irrigation produced the highest yield of marketable squash. However, the number of marketable fruits was maximum with irrigation at 300 m bar.

Chernovel (1980) while evaluating cucumber yield in relation to time of irrigation reported that night irrigated plants gave the highest yield followed by evening, morning and midday. Silk (1980) in cantaloups observed that plastochron indices advanced more rapidly with time and final leaf size was greater in wet plants receiving 65 cm water compared to dry plants receiving 21 cm water. Diminished water supply appeared to affect the rate of development, more than the sequence of development events.

Some preliminary studies on scheduling irrigation to bittergourd at the Agronomic Research Station, Chalakkudy, Kerala, indicated that 3 cm irrigation at IW/CPE ratio of 0.4 was optimum for the crop in summer rice fallows (Anon, 1980; Anon, 1981). Both the number of fruits per plant and the mean weight of a single fruit did not differ significantly among the IW/CPE ratios tried. The crop was however raised under shallow ground water table conditions (max.104 cm min. 56 cm in the first year of study and max. 151 cm and min. 44 cm in the second year of study). Similar results were reported with regard to cucumber also.

Another experiment conducted at Chalakudy in summer rice fallows to evaluate drip irrigation in ash gourd recorded the highest yield at IW/CPE ratio of 1.0 followed by 0.7. However, these two treatments were on par and significantly superior (by 25.4 per cent)over 0.4 IW/CPE ratio (Anon, 1982). The levels of irrigation tended to increase the number of fruits per plant upto 0.7 IW/CPE ratio. Though not significant, the weight of single fruit increased with increase in the level of irrigation (ground water table : max. 200 cm; min. 132 cm).

Ortega and Kretchman (1982) subjected cucumber cv. premier plants (pickling cucumber) to water stress effects and reported that vine growth rate and node number were reduced after one week and inhibited after two weeks of stress. Fruit growth rate was severely reduced in water stressed plants.

Smittle and Threadgill (1982) compared two irrigation levels, four nitrogen treatments and three tillage methods in a field trial with cucumber. They found that the highest marketable fruit yield resulted from irrigation at 0.3 bar soil water tension, application of 22.5 kg ha^{-1} nitrogen through irrigation system at 2, 3, 4, 5 and 6 weeks after planting and preparation of the seed bed by mould board plough.

Pew and Gardner (1983) in trials with direct sown muskmelon cv. PMR-45 obtained higher yields, larger fruits, and earlier maturity by irrigating the crop when the soil moisture tension at 25 cm depth reached 50 or 75 K Pa compared with 25 K Pa.

From the above review, it is obvious that irrigation profoundly influences the growth and yield characters of cucurbits.

2.1.2. <u>Nutrient composition and uptake</u>

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

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 nitrogen, phosphorus and potassium decreased with increase in moisture avialability from 25 per cent to 50 per cent and 75 per cent available soil moisture in the soil. An increase in soil moisture increased the total uptake of nitrogen significantly. The uptake of phosphorus and potassium also increased with wetter regimes but did not reach the level of significance.

While evaluating the effects of the soil moisture regimes of 25, 50, 75 and 100 per cent available soil moisture on green gram, Varma and Subha Rao (1975) observed a moisture regime of 50 per cent to be optimum for maximum nitrogen content in plant parts.

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 the fruit tissues of water stressed plants. They further observed that under drought conditions fruit growth is controlled by water availability through protein synthesis.

2.1.3. Consumptive use and water use pattern

Neil and Zunino (1972) found that 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, 1008 m^3 ha^{-1} upto fruit enlargement, 882 m^3 ha^{-1} upto prematurity and 280 m^3 ha^{-1} upto harvest.

Tomitaka (1974) in studies with cucumber observed that the evapotranspiration rate rose to a maximum in late June and fell thereafter and it declined with the soil moisture level.

Konishi (1974) found that the total water consumption by a fruit bearing muskmelon with a final leaf area of about 11000 cm^2 was 90-85 litres. As the plants grow the ratio of total water consumption per plant to pan evaporation increased to a maximum at the netting stage and then declined with ageing. Another finding was that young leaves transpired faster than older leaves and most of the transpiration occured when soil pF was 1.6 - 2.0.

Loomis and Crandall (1977) with studies on cucumber found that the total amount of water used during the later two month period of the crop ranged from 30 to 40 cm over each of the four years of the experiment. It was also observed that the rate of average consumptive use increased during flowering and early fruiting and then levelled off during late harvest. The ratio (Kc) of consumptive use to evaporation from pan evaporimeter (E) increased to a maximum of 1.5, 10 days after first picking and then declined.

2.1.4. Moisture depletion pattern

Cucurbits are with medium or deep root systems that require large amounts of water (Vittum and Flocker, 1967).

Gautam and Dastane (1970) reviewed the soil moisture extraction pattern of different crops under optimum moisture regimes on sandy loam soils at the 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 soil layer in the crops under review. The respective figures were as follows. Wheat - 71 per cent; Berseem - 73 per cent; Potato - 73 per cent; Jowar - 70 per cent; Cowpea - 62 per cent and Onion - 93 per cent.

Belik and Veselovski (1975) observed that under irrigated conditions the main root mass of watermelon was in the 8.5 - 17 cm soil layer.

Zabara (1977) noticed that root distribution of cucumbers at bearing stage was 64.5 per cent at 0 - 10 cm soil depth, 28.5 per cent at 10 - 20 cm depth and 6.2 per cent at 20 - 30 cm depth under irrigated conditions. In unirrigated crop the figures were 53.70 per cent at 0 - 10 cm, 29.0 per cent at 10 - 20 cm and 14.9 per cent at 20 - 30 cm soil depths.

From an investigation to study the water consumption of cucumbers during vegetative and reproductive stages of growth, Loomis and Crandal (1977) showed that cucumbers extracted 50 per cent of the total amount of water consumed from the upper 30 cm of the soil profile, 30 per cent from the next 30 cm and 10 per cent from the next 30 cm. They opined that since very little water was extracted from below 90 cm, the effective rooting depth of cucumbers could be considered to be 90 cm.

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

The moisture extraction pattern of different crops make it clear that since extraction is greater from surface layers, frequency is more important than depth of irrigation for the same delta. Higher frequency with lower depth is preferable to a lower frequency and higher depth consistant with application losses.

2.1.5. Soil fertility status

Mengal and Braunschweig (1972) noted a negative influence of higher pF on potassium diffusion and they recommended the application of higher doses of potash to counter balance this.

According to Sharma and Yadav (1976) the available phosphorus content of the soil, in general, increased with the increase in the level of irrigation.

Shanmugasundaran *et al*. (1979) revealed that, in general, available potassium content was low when irrigations were 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 the moisture regimes. Maximum available phosphorus content was noticed in the drier regimes than wetter regimes. But, with regard to available K content of soils, Muthuvel and Krishnamoorthy (1981) reported a non-significant influence 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, 1981). Irrigation at IW/CPE 0.9 with 4 cm irrigation 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 left behind in soil decreases indicating that more of available K has been taken up by crop plants resulting in increased yield and decreased available K left behind in soil.

2.2. Effect of Fertilizers

2.2.1. Growth and yield

Flocker *et al.* (1965) observed significant yield increase in cantaloup due to nitrogen fertilization. But, the response over 30 lb N depended on the prior cropping history. Yield response to nitrogen fertilization was mostly by increase in fruit size. Heavier nitrogen fertilization increased cull fruits associated with increased vine growth and succulance.

Dhesi *et al.* (1966) concluded from trials to study the response of bittergourd to NPK fertilization that application of N at 56 kg ha^{-1}, was superior in fruit yield compared to 112 kg ha^{-1}. But, no significant difference between 56 kg ha^{-1} and 112 kg ha^{-1} was noted. They also noticed a beneficial response due to the application of phosphorus on fruit yield which was statistically significant in the second year of study. But they could not observe any beneficial effect due to the application of potassium. They also did not observe any effect of interaction of nutrients. From the results they recommended 56 kg ha^{-1} N and 56 kg ha^{-1} P_2O_5 as the optimum dose of fertilizers for bittergourd.

Rekhi et al. (1968) reported an alteration in the ratio of perfect to staminate flowers in muskmelon by the application of N at 120 or 180 kg ha^{-1}. The ratio was changed to 1 : 20.6 and 1 : 16.6 respectively from 1 : 41.5 in control plants. However soil application of P or K did not register any effect on sex expression.

Padda et al. (1969) in trials with muskmelon obtained most profitable yield by the application of N at 56 kg ha^{-1}. The yields however were greater when double the quantity of N was used. They did not get any significant yield response to P and K. They suggested the application of 36 kg ha^{-1} P_2O_5 and 28 kg ha^{-1} K_2O along with nitrogen as a financially sound dosage.

Bishop et al. (1969) showed that in pickling cucumbers phosphorus was of greater importance in yield response than N or K. They indicated that N and P at approximately 50 and 100 kg ha^{-1} respectively was adequate. They also recommended a K_2O dose of 50 kg ha^{-1} on the basis of studies elsewhere.

Parikh and Chandra (1969) experimented on cucumber with nitrogen levels from 0 to 120 kg ha^{-1} and found that maximum and minimum number of female and male flowers respectively were produced, when nitrogen was applied at 80 kg ha^{-1}. They also noted that higher N rates delayed the appearance of the first female flower.

Jassal et al. (1970) in a fertilizer cum irrigation trial observed significant increase in fruit weight and yield by nitrogen application in muskmelon. Nitrogen and irrigation interaction was significant in respect of fruit weight. Potassium application increased the yield but phosphorus had no significant effect.

Pettiet (1971) compared the effect of factorial combinations of N, P and K on the growth and yield of pickling cucumbers grown for once over machine harvesting. It was observed that P favoured early growth and hastened maturity. Lack of K did not inhibit early growth, but K additions were found to be beneficial to growth and cropping. He obtained the highest yield by the annual application of 50 lb N, 80 lb P and 80 lb K per acre. Application rates greater than 50 lb N and 80 lb K per acre delayed maturity.

Mc Collum and Miller (1971) noticed maximum dry matter production and marketable yield at N, P, K rates of 80, 42 and 80 lb per acre respectively.

Sharma and Shukla (1972) reported a significant increase in yield of pumpkin in both rainy and summer season by increasing N levels. An increase in the level of phosphorus also resulted in an increase in yield. Suggested rates for economic production were N at 103 kg ha^{-1}, P_2O_5 at 106 kg ha^{-1} for the summer crop and N at 96 kg ha^{-1} and P_2O_5 at 88 kg ha^{-1} for the rainy season crop with a constant level of K_2O at 40 kg ha^{-1}.

The number of flowers per plant increased with increase in the rate of nitrogen application in muskmelon (Jassal <u>et al</u>. 1972). The maximum number of female flowers (7.32 per cent) was produced in response to 165 kg ha^{-1} N and 55 kg ha^{-1} P_2O_5.

Wilcox (1973) observed optimum growth and yield of muskmelon when ammonium nitrate was applied preplant at the rate of 80 - 90 kg ha^{-1}. Pandey and Singh (1973) found that nitrogen at 50 or 100 kg ha^{-1} increased pistillate and staminate flowers, fruits as well as yield in bottle gourd. But the female : male flower ratio was unaffected.

Pandey *et al.* (1974) studied the response of muskmelon to foliar and soil application of nitrogen and found that foliar application of nitrogen as urea at 1.5 per cent in three applications, giving a total of 22 kg resulted in the highest number of fruits per plant and yield per hectare as compared with soil application of 50 to 200 kg ha^{-1}. Soil applied N at rates above 50 kg ha^{-1} was not beneficial to yield. They also observed that the treatments had no effect on sex expression or fruit quality.

Ermokhin and Naumenko (1975) established a relationship between yield and soil content of available N, P and K. Accordingly if at the planting time, the soil contained 15 - 25 mg of NO_3-N, 60 - 70 mg of P_2O_5 and 60 mg of K_2O per 100 g of soil the application of mineral fertilizers would be ineffective.

Penny *et al.* (1976 a) observed a markedly poor growth of cucumber in potassium deficient than in full nutrient solution. This was attributed to reduced CO_2 fixation by cotyledons which form the bulk of the photosynthetic surface at this stage of growth and to a much lower level of export of photosynthetic products from the cotyledons. They further pointed out that the magnitude of these effects increased as the seedlings get aged. In another study, Penny et al. (1976 b) reported that seedlings with leaf like photosynthetic cotyledons (Cucumis sativas, Sinapsis alba) had higher growth rates and requirements for external K than hypogeal species (Pisum satium, Vicia faba) or epigeal species with very fleshy cotyledons (Phaseolus vulgaris). From the findings they opined that species with expanding photosynthetic cotyledons utilized their reserve K during cotyledon development and it was not transported to epicotyl and hence an external K supply was essential for development of the photosynthetic system and the roots.

Novotorova (1976) observed a positive correlation between leaf P content and productivity in green house cucumber. Critical P level noted in the third leaf from the apex was 0.30 - 0.35 per cent. She also got highest yields from soils containing 16 mg P_2O_5 per 100 g.

Mahakal et al. (1977) reported the optimum dose of NPK as 75 : 50 : 100 kg ha^{-1} for tinda (Citrullus vulgaris var. fistulosus) from trials on a medium heavy soil. Highest fertilizer dose tried (75 : 100 : 150 kg ha^{-1}) gave only a slight increase in yield.

Cantliffe (1977 a) observed a slight increase of pistillate flowers per plant upto a N dose of 134 kg ha^{-1} in pickling cucumbers grown for once over harvest, when applied as pre-plant. Nitrogen pre-plant application of 67 or 134 kg ha^{-1} resulted in higher yields than no nitrogen fertilization. Cantliffe (1977 b) also reported from petiole analysis for NO_3-N that less than 0.8 per cent or more than 1.5 per cent at harvest usually reflected reduced yields. Optimum yields occurred when leaves contained 4 - 5 per cent total N.

According to Katyal (1977), the application of 50 t ha^{-1} farmyard 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 bittergourd. In Karnataka the recommended practice for bittergourds is to apply 18 t ha^{-1} farmyard manure , 62.5 kg ha^{-1} N and 50 kg ha^{-1} P_2O_5 (Anon. 1978).

Bhosale et al. (1978) from an evaluation of yield performance of watermelon cv. sugar baby reported highest yields with 75 or 100 kg ha^{-1} N, 30 kg ha^{-1} P_2O_5 and 75 or 100 kg ha^{-1} K_2O.

Ogunremi (1978) studied the response of watermelon to N at 0 to 72 kg ha^{-1} in several trials. Increased levels of nitrogen application increased the leaf number and was the highest in plots receiving 72 kg ha^{-1}N. Flowering was found to be delayed by a week with high nitrogen application. Fruit number per unit area and fruit size were highest with N at 48 kg ha^{-1}.

Kano et al. (1978) observed a reduction in leaf chlorophyll content as the N content decreased and with an increase in leaf age in muskmelon.

Randawa et al. (1981) in trials with two cultivars of muskmelon reported best results with regard to plant growth, number of fruits per vine, fruit weight per vine and fruit quality from plots receiving an NPK level at 50 : 375 : 375 kg ha^{-1}.

Rajendran (1981) studied the effect of different doses of NPK on pumpkin. He found that the N, P and K alone produced significant difference in the number of days required for the female flower production, percentage of fruit set, equitorial parameters of fruit and fruit weight. The effects of main factors N, P and K were found to be significant in the case of

LAI at 30 and 60 days after sowing. Total dry matter content at 60th day and at harvest increased with increased levels of N and P. He further noted that the response to nitrogen was quadratic and the economic level was worked out to be 71 kg ha^{-1}. However, the response to P was linear. He recommended a fertilizer schedule consisting of 71 kg ha^{-1} N and 50 kg ha^{-1} P_2O_5 as optimum dose. The response to K_2O was not significant in respect of yield and as such there would be no need for K_2O application in soils of similar type.

Smittle and Threadgill (1982) subjected squash plants to factorial combinations of two irrigation levels, four nitrogen treatments and three tillage methods. They observed higher marketable yield by giving irrigation at 0.3 bar soil water tension, applying 22.5 kg ha^{-1} N through irrigation water at 2, 3, 4, 5 and 6 weeks after planting and preparing the seed bed by mould board plough tillage.

An experiment conducted in Kerala to find the response of different doses of N, P and K showed that 50 kg ha^{-1} N , 25 kg ha^{-1} P_2O_5 and 50 kg ha^{-1} K_2O gave the maximum yield of bittergourd (Anon. 1981).

However, this observation was not consistant in the subsequent years (Anon. 1982).

2.2.2. Chemical composition and Nutrient uptake

Tayal *et al.* (1965) found that application of nitrogen fertilizers increased both nitrogen percentage and the total nitrogen content in different plant parts. It was also observed that the total N absorbed by the plants per unit area increased with N fertilization. Locascio (1967) while experimenting with watermelon observed an increase in tissue phosphorus content due to applied P.

Fiskell and Breland (1967) observed that the leaf K content decreased sharply with increasing yield. Leaf nitrogen content was not significantly affected. Bishop *et al.* (1969) conducted fertiliser trials with pickling cucumbers and noted that the effect of fertilizers on nutrient percentage in laminae and petioles were generally similar and the ratio of the percentage of a given nutrient in the lamina to that in the petioles was relatively constant.

Grozdova (1970) determined the N, P, K contents of cucumber and tomato leaves during different phases of growth. They found that cucumber required higher N dose from the time of flower bud formation until the end of growth. The need for P increased during flower bud formation, decreased slightly during flowering and rose again during cropping. Potassium was readily absorbed during early growth, declined during flower bud formation and then rose again.

Mc Collum and Miller (1971) reported that the total uptake of N, P and K by pickling cucumbers was 90, 12 and 145 lb per acre respectively. They estimated the nutrients removed by the harvested fruits as 40 lb N, 6½lb P and 55 lb K per acre.

Aleksandrova (1971) observed a significant increase in leaf nitrogen content by increasing N rates.

Jassal et al. (1972) reported that the percentages of N and P in the plant tissues were highest after maximum application of the respective nutrients irrespective of irrigation frequency.

Wilcox (1973) determined leaf nitrogen content and related it to yield. Optimum leaf total nitrogen composition in relation to yield was over 4.5 per cent and the optimum petiole nitrate nitrogen composition was over 15000 ppm during plant growth and fruit formation respectively.

Kagohashi et al. (1978) reported the characterisation of nutrient uptake by muskmelon. They observed that the rates of nitrogen uptake by melon plants grown in hydroponic culture rose gradually before pollination, increased rapidly after pollination, remained high for about 15 days and then suddenly fell to pre-pollination levels. Total uptake of NO_3-N was higher during the early stages while that of K was during the later stages of the plant cycle.

Laske (1979) showed from trials with domestic cucumbers planted at the rate of 1.2 plants per m^2 that it removed equivalent of 500 kg ha^{-1} N during the growing season. He noted that when N=1, the removal of N : P_2O_5 : K_2O: Ca 0 : Mg 0 was 1.0 : 0.4 : 2.0 : 1.6 : 0.24.

Tesi et al. (1981) reported that when adequate fertilizers were applied the uptakes of N, P_2O_5 and K_2O in Cucurbita pepo amounted to 170.5, 71.2 and 394.4 kg ha^{-1} respectively. He also observed that nutrient requirements were greatest during the 15 days preceding the first harvest and during the subsequent 15 days.

Rankov and Aleksandrova (1982) observed from trials with three cultivars of gherkin grown for mechanised harvesting that the uptake of K predominated over N, and the uptake of P was the lowest.

2.2.3. Soil fertility status

Soil level of phosphorus and potassium increased linearly with fertilizer application (Downes and Lucas 1966). Bains (1967) also noted similar results. He concluded from glass house experiments on field bean that soil test values for available P and K were affected by the application of the respective fertilizer elements, particularly at higher levels of applied phosphorus and potash due to build up of those nutrients in soil.

Fiskell *et al.* (1970) while experimenting with water melon observed a linear increase of both soil and plant nutrient values at the thinning stage with the percentage of fertilisers added initially.

In trials with cucumber Largskii (1971) indicated that fertilizers increased the reserve of mobile soil nutrients. Sahu and Behera (1972) reported that phosphate manuring of cowpea, groundnut and greengram at 22.4 kg ha^{-1} P_2O_5 resulted in 58, 29 and 26 per cent increases in soil nitrogen content respectively.

Sharma and Yadav (1976) in a field experiment reported that available phosphorus content of soil, in general, increased with the addition of phosphorus.

From pot and field experiments, Muthuvel and Krishnamoorthy (1980) noted that, in general, levels of applied nitrogen had a significant influence on the available phosphorus content of the soil. The lower levels of added nitrogen led to greater available phosphorus content of the soils and the maximum phosphorus was under no nitrogen treatment.

Mani and Ramanathan (1980) conducted a field experiment to study the effect of N and K fertilizers in bhindi crop on available potassium status of soil. The available K content of the soil was not influenced by the application of nitrogen. However, the application of K significantly increased the K content of the soil. A progressive reduction in the available K content of the soil was noticed as the crop growth advanced due to crop uptake.

Jose Mathew (1981) in his experiments with groundnut noted a significant increase in the available potassium content of the soil with the increase in the level of applied potash. Application of 75 kg ha^{-1} K_2O recorded the highest available potassium content in soil. However, in the case of available phosphorus content he could not observe any significant influence by the increased application of phosphorus.

Materials and Methods

MATERIALS AND METHODS

The present investigation to study the response of bittergourd to different water management practices and fertility levels was conducted during the summer season of 1982-83 in rice fallows in a statistically laid out field experiment. The materials used and methods adopted in the study are briefly described below.

3.1. General

3.1.1. Location

The experiment was laid out in the rice fields of the Agronomic Research Station, Chalakudy, Trichur district. The station is situated at 10° 20' N latitude and 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 field was loamy sand in texture with the bulk density ranging from 1.44 - 1.56 g cm^{-3}. The soil was slightly acidic in reaction and non-saline. It was low in organic carbon,

Table 1. Soil characteristics of the experimental area.

a. Physical properties

1. Mechanical composition

Coarse sand (%)	-	47.95
Fine sand (%)	-	30.55
Silt (%)	-	9.20
Clay (%)	-	10.80
Textural class	-	Loamy sand

2. Infiltration rate - 6.3 cm hr^{-1}

3. Important physical constants of the soil

Particulars	Depth of soil layer (cm)			
	0-15	15-30	30-60	60-90
Field capacity (%)	10.8	10.2	10.4	10.4
Moisture percentage at 15 bar	3.6	3.5	3.5	3.5
Bulk density (g cm^{-3})	1.44	1.56	1.49	1.47

b. Chemical properties

1.	Organic carbon (%)	-	0.36
2.	Available nitrogen (Kg ha^{-1})	-	90.53
3.	Available phosphorus (Kg ha^{-1})		13.74
4.	Available potassium (Kg ha^{-1})	-	28.91
5.	Soil reaction (p^{H})	-	5.80
6.	Electrical conductivity (m mhos cm^{-1})		0.36

available nitrogen and available potassium but medium in available phosphorus. The important physical and chemical properties of the soil are depicted in Table-1.

3.1.3. Season

The crop was grown during the months of January to April, 1983, coinciding with the summer season, which is the regular growing season for vegetables in rice fallows.

3.1.4. Weather conditions

The weekly averages of temperature, evaporation, wind speed, relative humidity and the weekly totals of rainfall during the crop period and their averages for the previous four years collected from the observatory attached to the farm are presented in Table 2 and Fig.I. Variations in weather parameters during the crop season from the four years averages have also been worked out.

The weekly averages for maximum temperature ranged between 34.71°C and 38.21°C, and the minimum between 20.57°C and 26.00°C. The maximum temperature experienced during the crop season in general was slightly higher than that of the four years averages.

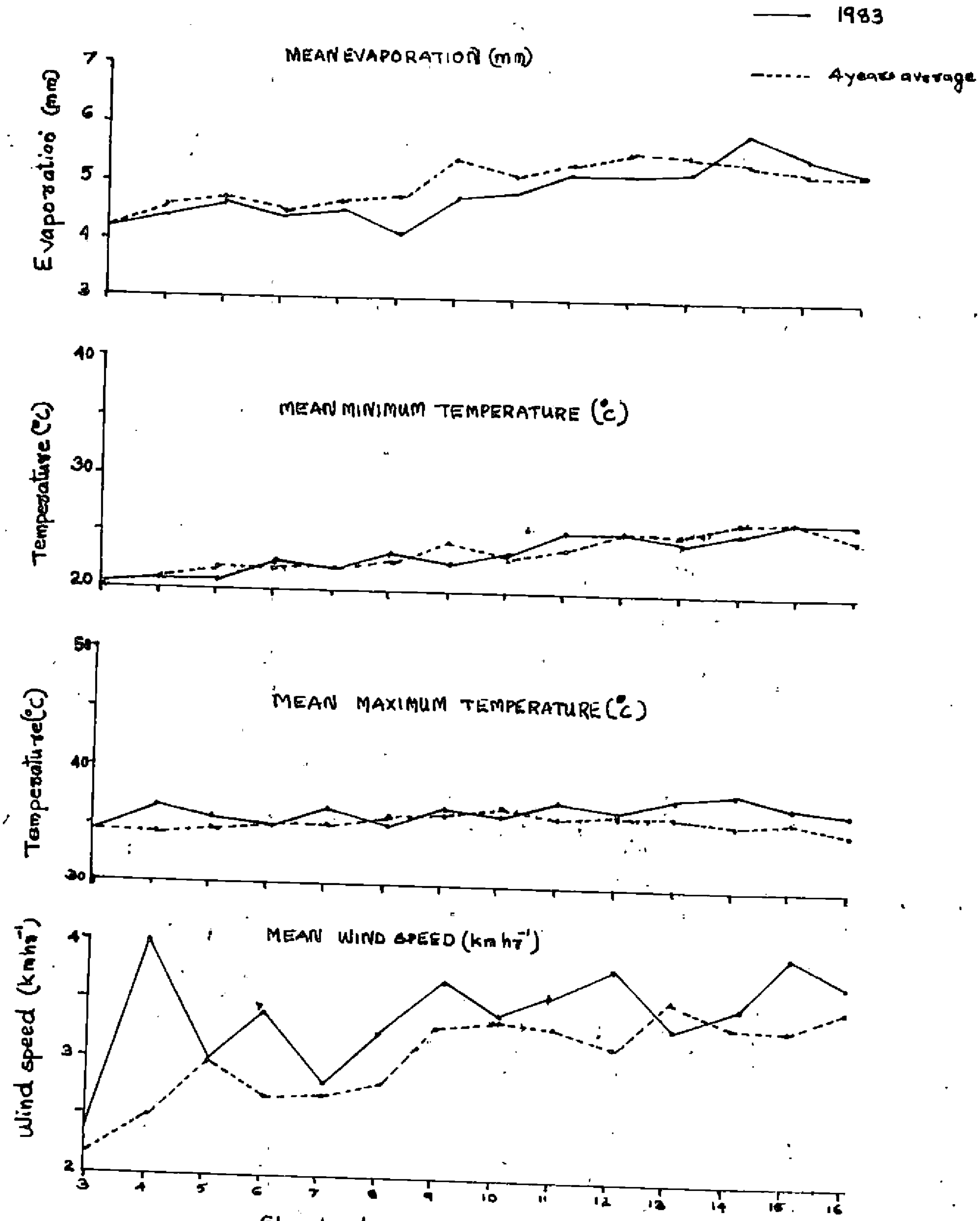


Fig. 1 WEATHER DATA DURING THE CROP SEASON AND THE AVERAGE FOR THE LAST FOUR YEARS

Table 2. Weather data during the crop period and its variation from the last four years (weekly average).

Period	Meteorology week	Evaporation (mm)			Rainfall (mm)*			Wind speed (km hr^{-1})		
		1983	4 years average	Variation	1983	4 years average	Variation	1983	4 years average	Variation
I	3	4.19	4.23	-0.04	-	-	-	2.49	2.21	+0.28
	4	4.38	4.63	-0.25	-	-	-	3.97	2.51	+0.46
	5	4.58	4.66	-0.08	-	-	-	2.97	3.03	-0.06
II	6	4.38	4.54	-0.24	-	-	-	3.40	2.66	+0.74
	7	4.45	4.62	-0.17	-	0.15	-0.15	2.78	2.71	+0.07
	8	4.13	4.71	-0.58	-	0.36	-0.36	3.23	2.76	+0.45
	9	4.66	5.29	-0.63	-	4.00	-4.00	3.70	3.28	+0.42
III	10	4.75	5.09	-0.34	-	-	-	3.39	3.35	+0.04
	11	5.06	5.34	-0.28	-	-	-	3.59	3.30	+0.29
	12	5.14	5.52	-0.38	-	-	-	3.80	3.14	+0.60
	13	5.12	5.41	-0.29	-	7.05	-7.05	3.33	3.53	-0.20
IV	14	5.79	5.31	+0.48	-	6.78	-6.78	3.46	3.36	+0.10
	15	5.35	5.08	+0.27	-	35.05	-35.05	3.95	3.30	+0.65
	16	5.09	5.06	+0.03	-	29.70	-29.70	3.69	3.43	+0.26

*Weekly total

+ Sign shows increase over the average data.

- Sign shows decrease over the average data.

Table 2. (Contd...)

Period	Mateo-rology week	Temperature (°C)						Relative humidity (%)					
		Maximum			Minimum			8 AM			2 PM		
		1983	Four years ave-rage	Varia-tion	1983	Four years ave-rage	Varia-tion	1983	Four years ave-rage	Varia-tion	1983	Four years ave-rage	Varia-tion
I	3	34.71	34.39	+0.32	20.57	20.43	+0.14	74.29	81.09	-6.80	35.57	37.48	-1.91
	4	36.29	34.34	+1.95	20.86	20.68	+0.18	77.79	76.14	+1.65	33.93	35.14	-1.21
	5	35.43	34.32	+1.11	20.79	21.93	-1.14	86.21	78.26	+7.95	38.36	39.45	-1.09
II	6	35.00	35.14	-0.14	22.43	22.14	+0.29	82.43	78.28	+4.15	38.86	40.45	-1.59
	7	36.00	34.79	+1.21	22.14	22.30	-0.16	82.14	79.21	+2.93	32.57	39.41	-6.84
	8	35.07	35.37	-0.30	23.29	22.54	+0.75	83.57	82.59	-0.98	39.36	42.62	-3.26
	9	36.50	35.94	+0.06	22.57	24.09	-1.52	84.00	81.69	+2.31	38.43	46.82	-8.39
III	10	36.07	35.91	+0.16	23.29	22.82	-0.47	82.80	81.36	+1.44	44.71	50.19	-5.48
	11	37.00	36.01	+0.99	24.86	24.25	-0.61	81.57	78.02	+3.55	47.21	40.62	+6.59
	12	36.57	36.09	+0.48	25.07	24.96	+0.11	77.14	79.40	+2.26	44.57	43.03	+1.54
	13	36.86	36.07	+0.79	24.50	25.16	-0.66	73.29	77.71	+4.42	44.43	45.41	-0.98
IV	14	38.21	35.59	+2.62	24.64	26.11	-1.47	78.29	80.69	-2.40	43.14	50.93	-7.79
	15	36.86	35.87	+0.99	26.00	26.27	-0.27	72.57	78.55	-5.48	47.00	53.08	-6.08
	16	36.71	34.86	+1.85	25.79	25.28	+0.51	73.86	79.71	-5.85	48.71	50.59	-1.88

\+ Sign shows increase over the average data.

\- Sign shows decrease over the average data.

The crop did not receive any rainfall during the season.

The relative humidity during the crop season ranged from 72.57 per cent to 86.21 per cent at 8 AM and 32.57 per cent to 48.71 per cent at 2 PM.

The mean weekly pan evaporation values varied from 4.13 mm to 5.79 mm per day. The rate of evaporation was found to be more during the later stages of crop growth.

The mean wind speed was slightly higher during the crop period as compared to the four years mean values. It varied from 2.49 to 3.95 km hr^{-1}.

In general, the crop season was comparatively dry and less favourable for crop growth.

3.1.5. Ground water fluctuations in the experimental area

The monthly fluctuations in ground water table of the experimental field are presented in Table 3. Ground water fluctuations were measured with the help of two observation wells in the experimental area. There was a steady increase in depth to ground water table from January to April.

Table 3. Ground water fluctuations in the experimental area.

Month		Depth from ground surface (cm)	
		Maximum	Minimum
January	1983	172	131
February	1983	186	170
March	1983	Below 200	186
April	1983	Below 200	192

3.1.6. <u>Crop rotation followed</u>

Rice - Rice - Bittergourd.

3.1.7. <u>Cultivar used</u>

The cultivar VK-1 (*Priya*), a pure line selection from Cannanore local having long broad fruits with prominent spines and devoid of ridges was used for the study.

3.1.8. <u>Source of seed materials</u>

The seed materials for the experiment were obtained from the Department of Olericulture, College of Horticulture, Vellanikkara.

3.1.9. Manures and fertilizers

Farm yard manure obtained from the Cattle Breeding Station, Thumburmuzhi was used in the study. Urea (46% N), Super phosphate (16% P_2O_5) and Muriate of potash (60% K_2O) were used as the sources of nitrogen, phosphorus and potassium respectively.

3.1.10. Source of irrigation water

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

3.2. Experimental Details

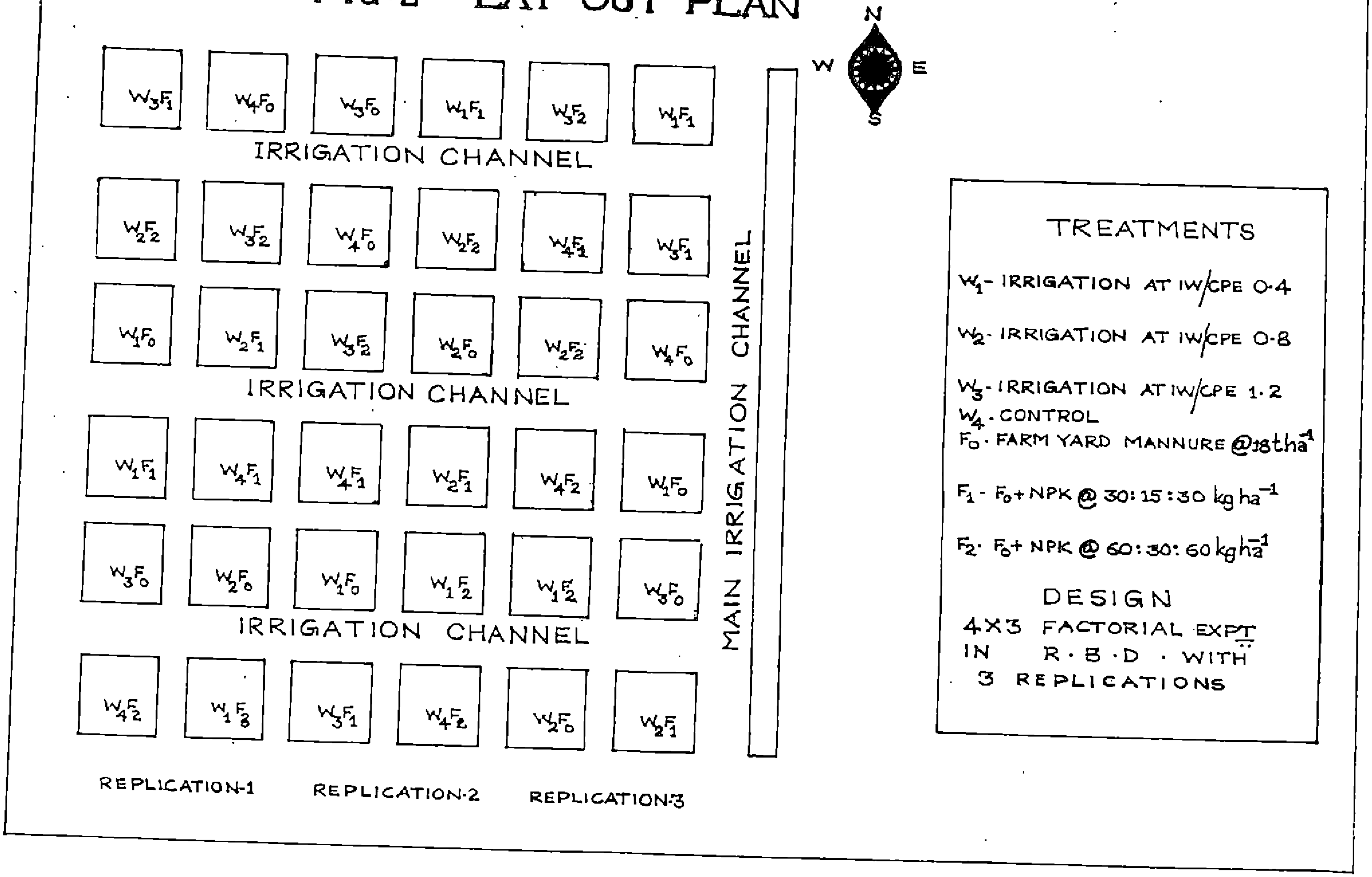
3.2.1. Design and layout

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

3.2.2. Treatments

The treatments included in the study were the different combinations of four levels of irrigation and three levels of fertilizers as given below.

FIG. 2 LAY OUT PLAN



Irrigation:

W_1 - Irrigation at IW/CPE ratio of 0.4

W_2 - Irrigation at IW/CPE ratio of 0.8

W_3 - Irrigation at IW/CPE ratio of 1.2

W_4 - Farmers' practice (Control)

Fertilizers:

F_0 - Farm yard manure @ 18 t ha^{-1}

F_1 - Farm yard manure @ 18 t ha^{-1} + N : P_2O_5 : K_2O @ 30 : 15 : 30 kg ha^{-1}

F_2 - Farm yard manure @ 18 t ha^{-1} + N : P_2O_5 : K_2O @ 60 : 30 : 60 kg ha^{-1}

Number of treatment combinations - 12

The irrigation schedules were based on different ratios between depth of irrigation (IW) and cumulative pan evaporation (CPE) values, a practical way of timing irrigation.

The treatment W_4 was standardised after surveying the local farmers' practice of irrigation in bittergourd.

Depth of irrigation	-	30 mm
Number of replications	-	3
Total number of plots	-	36
Plot size	-	6 m x 4.5 m
Spacing	-	120 cm x 90 cm
Number of plants per plot	-	Gross : 25 Net : 9

One row of plants was left as border row all around the plot.

3.3. Field Culture

3.3.1. Land preparation

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

3.3.2. Manurial application

Farm yard manure at the rate of 18 t ha^{-1} was applied uniformly to all the plots as basal dose in the basins (60 cm diameter and 30 cm depth). The basins were filled to ground level with farm yard manure and top soil. Differential doses of fertilizers were also applied in accordance with the treatments. The entire quantity of P and K was applied basally before dibbling the seeds. Nitrogen was applied in two split doses one at 15 days and the other at 45 days after sowing.

3.3.3. Sowing

Three seeds soaked in water overnight to ensure good germination were dibbled in each basin side by side. The seedlings were thinned to one per basin 15 days after sowing. When the plants started to run, they were individually trained on pandals erected at a height of about 1.8 m.

3.3.4. <u>After cultivation</u>

The crop received two hoeings during the crop period.

3.3.5. <u>Irrigation</u>

The differential irrigations according to treatments were started only from the twentieth day after sowing. A presowing irrigation using two pots (16 l) of water each was given uniformly to all the basins. Thereafter, daily pot watering at the rate of two litre per day per basin was given uniformly to all the plots upto the 20th day. On the 20th day 30 mm irrigation was uniformly given to all the plots receiving irrigation on the basis of IW/CPE ratios. Afterwards, 30 mm irrigation water was applied as and when the respective cumulative pan evaporation values are attained in the various treatments. Accordingly, irrigations were scheduled when the evaporation values from a Class A pan accumulated to 25 mm, 37.5 mm and 75 mm respectively in the case of ratios 1.2, 0.8, and 0.4. Water was let into the plots by measuring with a circular orifice plate of 9 cm diameter.

In the control plot (farmers' practice) from the 20th day onwards pot watering was given at the rate of 4 l/plant/day (half pot) for a month. Later the rate of application was increased to 8 l/plant/day (one pot). The details of irrigation given are presented in Table 4.

3.3.6. <u>Plant protection</u>

During the cropping period prophylactic plant protection measures were taken against the leaf feeding insects and fruit fly according to general recommendations (Anon, 1978). During the later stages of the crop attack of leaf feeding insects were noticed and they were kept under control by spraying systemic insecticides.

3.3.7. <u>Harvesting</u>

First harvest of the crop was done on 18-3-1983. Subsequently, fruits were harvested as and when they were mature. The maturity for vegetable purpose was judged by visual observations. Final harvest of the

Table 4. Details of irrigation given (20th day onwards)

Serial number of irrigation	W_4	W_3	W_2	W_1
1	Daily	#7 February	#7 February	#7 February
2		13 February	15 February	24 February
3		19 February	23 February	12 March
4		24 February	4 March	27 March
5		2 March	12 March	9 April
6		7 March	19 March	
7		12 March	26 March	
8		17 March	2 April	
9		22 March	9 April	
10		27 March	16 April	
11		1 April		
12		5 April		
13		10 April		
14		15 April		
Total number of irrigations		14	10	4
Quantity of water applied (mm)	422*	420	300	150
Pre-treatment irrigation (mm)	52*	52*	52*	52*
Total quantity applied (mm)	474	472	352	202

Common irrigation

* Equivalent water delta

crop was done on 20-4-1983.

3.4. Biometric Observations

3.4.1. Length of vine

The length of vine was recorded from the four randomly selected plants at two growth stages viz. 20th and 35th day of planting. The length of main vine was measured from the base to the growing tip of the vine and the mean length of vine per plant was worked out.

3.4.2. Number of leaves per plant

The total number of leaves on the randomly selected plants was recorded on the 20th and 35th day of planting and mean number per plant worked out.

3.4.3. Dry matter production per plant

Dry matter production was recorded during two growth stages viz. 55th day and at final harvest. One plant from each plot was randomly selected for that purpose at each stage, cut close to the ground and separated into plant parts (leaves, shoots and reproductive parts) and oven dried at 80 $\pm$ 5°C to a constant weight. The dry weight of fruits already harvested from the vines prior to the stage of observation was also added to the above dry weight to get total dry matter production.

3.4.4. Leaf Area Index (LAI)

The LAI was calculated using the punch method in the sample plant used for the estimation of dry matter production at 55th day after sowing. The total leaf area was divided by the land area occupied by the plant and expressed as LAI.

3.4.5. Days for opening of the first male flower

The number of days taken for the first male flower of 50 per cent of plants to open from the date of sowing was recorded.

3.4.6. Days for opening of the first female flower

As in the case of male flower, the number of days taken for the first female flower of 50 per cent plants to open from the date of sowing was noted.

3.4.7. Number of fruits per plant

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

3.4.8. Length of fruit

The length of all the fruits harvested from each observation plant was recorded in centimeter and mean length worked out.

3.4.9. Girth of fruit

The girth at the centre of each fruit of observation plants was recorded and mean girth for a fruit calculated.

3.4.10. Weight per fruit

Weight of all the fruit harvested from each observation plant was recorded and mean weight noted.

3.4.11. Fruit yield per plant and per hectare

Weight of fruits from the various harvests from each observation plant was totalled at the end of the cropping period and the average yield in kilogram per plant was worked out and then converted into per hectare yield.

3.5. Moisture studies

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) including growth (G), transpiration (T), direct evaporation from soil surface (Es) and deep percolation loss (D) and is expressed in Kg ha - mm^{-1}.

$$\text{Field water use efficiency Eu} = Y/(G + T + Es + D) = Y/WR.$$

3.5.2. Consumptive use

Consumptive use was worked out from the data on soil moisture depletion as suggested by Dastane (1972). Soil samples were collected from 0-15, 15-30, 30-60 and 60-90 cm depth using a soil augur before and 24 hours after each irrigation, and at final harvest. Thermo-gravimetric method of soil moisture determination was adopted.

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

3.5.3. Moisture depletion pattern

The average relative soil moisture depletion from each soil layer in the root zone (upto 90 cm depth) was worked out for each irrigation interval. The potential evapotranspiration (PET) values 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 of each layer was determined on percentage basis at the end of the cropping period.

3.6. Analytical Procedures

3.6.1. Soil Analysis

3.6.1.1. Physical properties

a) Particle size distribution

Mechanical analysis of the soil was carried out by the 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 cylinder infiltrometer was utilized for determining the infiltration rate as described by Michael (1978).

c) Bulk density

Bulk density was determined in situ by collecting the soil samples using a core sampler (Bodman, 1942).

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 with sausage casing membrane, was noted and taken as an index of the permanent wilting percentage (Richards, 1947).

3.6.1.2. Chemical properties

a) Organic carbon

Organic carbon was estimated by Walkley and Black's rapid titration method (Jackson, 1958).

b) Available nitrogen

Available nitrogen in the soil was determined by the 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 fluride solution (0.03 N NH_4F and 0.025 N, HCl) - (Bray and Kurtz, 1945) and colorimetric determination of phosphorus in the extract by the chlorostannous reduced molybdophosphoric blue colour method in hydrochloric acid system (Jackson, 1958).

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, 1958).

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, 1958).

f) Electrical conductivity

Electrical conductivity of 1 : 2 soil water extract was determined using a solu bridge (Jackson, 1958).

3.6.2. Plant Analysis

Samples collected for chemical analysis were oven dried at 80° ± 5°C, ground in Willey Mill and Sieved through 60 mesh sieve and used for chemical analysis. The N, P and K contents in the shoots and leaves were determined at two stages of crop growth, viz. 55th day and at final harvest. Analysis of fruit was carried out with composite samples collected from different harvests.

a) Nitrogen content

The total nitrogen content of plant samples was determined by Microkjeldahl method (A.O.A.C., 1960).

b) Phosphorus content

The phosphorus content of the samples was determined using triple acid extract (Jackson, 1958). A Klett-Summerson photoelectric colorimeter was used for reading the colour intensity developed by Vanadomolybdc phosphoric yellow colour method in nitric acid system.

c) Potassium content

The potassium content of samples was determined with triple acid extract, reading in an EEL flame photometer (Jackson, 1958).

3.6.3. Uptake studies

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

3.6.4. Statistical analysis

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

Results

RESULTS

The results of the field experiment conducted to evaluate the response of bittergourd to different water management practices and fertility levels are highlighted in the following pages, after analysing the data statistically.

4.1. Growth Characters

4.1.1. Length of vine

The mean length of vine recorded on the 20th day and 35th day of sowing is presented in Table 5 and their analysis of variance in Appendix I.

Levels of irrigation or fertilizers or their interactions did not influence significantly the length of vine at any of the stages. An increasing trend was however noticed at both stages due to fertilizers and on the 35th day due to irrigation.

4.1.2. Number of leaves produced per plant

Data relating to the mean number of leaves produced per plant at 20th and 35th day of sowing are presented in Table 5 and the respective analysis of variance in Appendix I.

Table 5. Length of vine and number of leaves as affected by irrigation and fertility levels.

Treatments	Length of vine (cm)		Number of leaves	
	20th day	35th day	20th day	35th day
Irrigation levels				
W_1	16.63	84.78	8.30	44.26
W_2	14.70	94.26	8.09	50.39
W_3	17.11	96.52	8.41	51.43
W_4	16.96	99.26	8.09	55.30
SEm ±	0.982	4.147	0.307	2.361
CD (5%)	NS	NS	NS	NS
Fertility levels				
F_0	15.78	87.86	7.75	45.58
F_1	16.28	94.25	8.27	50.68
F_2	17.00	99.00	8.66	55.60
SEm ±	0.841	3.591	0.266	2.045
CD (5%)	NS	NS	NS	5.997
Interaction (W x F)				
SEm ±	1.610	7.183	0.532	4.089
CD (5%)	NS	NS	NS	NS

With regard to leaf production also, the levels of irrigation did not show any significant influence at both the stages. However an increasing trend in the number of leaves produced was noticed at higher levels of irrigation. The leaf production was not affected by fertilizers on the 20th day. But on the 35th day it differed significantly due to fertilizers. The treatment F_2 produced the highest number of leaves per plant, closely followed by F_1 and both were on par. The level F_0 though recorded the least leaf number, was found to be on par with F_1.

The interaction between irrigation and fertilizers failed to evoke any influence on leaf production.

4.1.3. Number of days taken for flowering

Mean number of days taken for 50 per cent flowering is presented in Table 6 and the respective analysis of variance in Appendix I.

It was seen that the variation in the frequency of irrigation had no significant influence on the date of flowering (both male and female flowers). The effect of fertilizers as well as their interaction with irrigation were also found to be non significant. However,

Table 6. Number of days taken for 50 per cent flowering as affected by irrigation and fertility levels.

Treatments	Number of days	
	Male flowers	Female flowers
Irrigation levels		
W_1	36.33	42.78
W_2	35.44	41.56
W_3	35.11	40.89
W_4	34.44	41.22
SEm ±	0.943	0.986
CD (5%)	NS	NS
Fertility levels		
F_0	35.75	42.33
F_1	35.33	42.00
F_2	34.92	40.50
SEm ±	0.817	0.854
CD (5%)	NS	NS
Interaction (W x F)		
SEm ±	1.634	1.708
CD (5%)	NS	NS

there was a trend to hasten flowering at the highest levels of both the factors. The mean number of days taken for 50 per cent flowering ranged between 34 - 36 days, and 40 - 42 days in the case of male and female flowers respectively.

4.1.4. <u>Leaf Area Index</u>

The LAI worked out on the 55th day of sowing is presented in Table 7(a) and the analysis of variance in Appendix I.

The irrigation levels produced significant influence on LAI at this stage. The LAI of treatments W_4 (1.178) and W_3 (1.0441) were found to be significantly superior to W_1 (0.7348). However, W_4 and W_3 were on par with W_2 (0.9866) and W_2 was on par with W_1.

The fertility levels also showed marked influence on LAI. The treatment F_2 recorded the maximum LAI (1.1590) and was significantly superior to F_0 (0.8099). The treatment F_2 was on par with F_1 (0.9887) and F_1 with F_0 (0.8099).

The interaction between the factors did not show any significant influence on LAI.

Table 7(a). Leaf area index and total dry matter production as affected by irrigation and fertility levels.

Treatments	Leaf area index	Total dry matter production (g/plant)	
	55th day	55th day	Final harvest
Irrigation levels			
W_1	0.7348	46.233	159.982
W_2	0.9866	69.722	236.551
W_3	1.0441	71.233	278.746
W_4	1.1780	80.985	311.121
SEm ±	0.0866	6.6755	11.9692
CD (5%)	0.2533	19.5798	35.1066
Fertility levels			
F_0	0.8099	49.683	203.499
F_1	0.9887	64.258	259.220
F_2	1.1590	87.189	277.089
SEm ±	0.0748	5.7812	10.3656
CD (5%)	0.2193	16.9560	30 .4037
Interaction (W x F)			
SEm ±	0.1497	11.5623	20.7312
CD (5%)	NS	NS	60.8060

4.1.5. Dry matter production per plant

The mean dry weight of plants at different growth stages of the crop is presented in Table 7(a) and in Fig.3 and it analysis of variance in Appendix I.

Irrigation exerted marked effect on the dry weight of plants at both stages of growth. W_4 produced the maximum dry weight (80.985 g) which was on par with W_3 (71.233 g) and W_2 (69.722 g) at 55th day after planting. These three levels were significantly superior over W_1 (46.233 g).

With regard to fertility levels F_2 recorded the maximum dry weight (87.189 g) followed by F_1 (64.256 g). The treatments F_1 and F_0 (49.683 g) were on par, far inferior to F_2. The interaction effect due to irrigation and fertilizers on dry matter production was not significant.

At the stage of final harvest also daily irrigated plots (W_4) recorded the maximum dry weight (311.121 g) followed by W_3 (278.746 g). However, both were on par and significantly superior to other treatments. Further W_2 (236.551 g) was found to be significantly superior to W_1 (159.982 g).

Fertility levels also influenced the dry matter production at this stage considerably. F_2 recorded the maximum dry matter production (277.089 g) followed by F_1

Fig. 3 · EFFECT OF IRRIGATION AND FERTILITY LEVELS ON DRY MATTER PRODUCTION

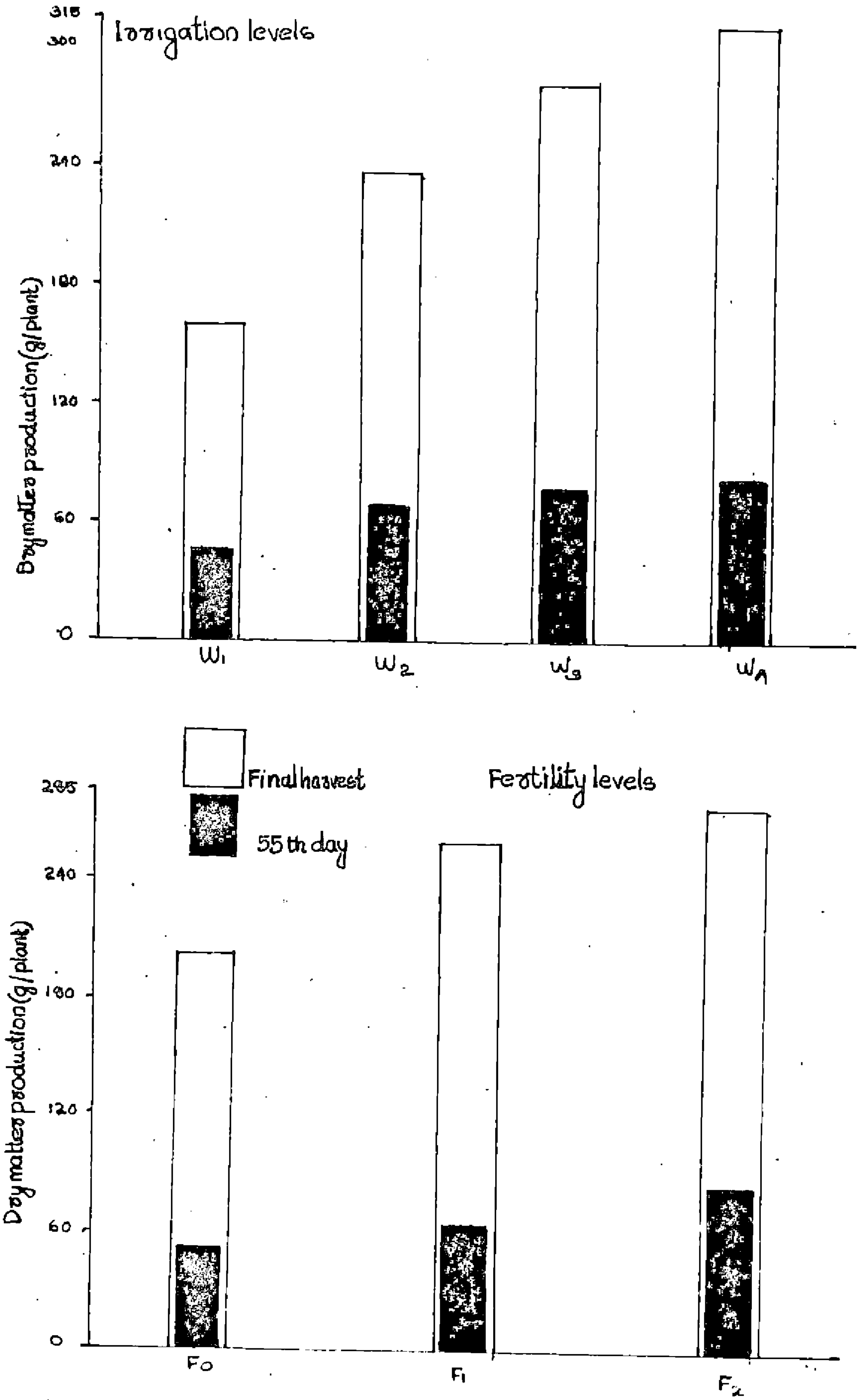


Table 7(b). Interaction of irrigation and fertilizer application on the total dry matter production at final harvest (g)

Treatments	F_0	F_1	F_2	Mean
W_1	126.223	174.313	179.410	159.982
W_2	177.917	243.800	287.937	236.551
W_3	197.517	302.047	336.673	278.746
W_4	312.340	316.686	304.336	311.121
Mean	203.499	259.220	277.09	

SEm ± 20.7312

CD (5%) 60.8060

(259.220 g) and both were on par. These levels were significantly superior to F_0 (203.499 g).

The interaction due to irrigation and fertilizers was significant on the total dry matter production at final harvest (vide Table 7(b)). The treatment combination W_3F_2 recorded the maximum dry weight (336.673 g) and W_1F_0 the minimum (126.223 g).

4.2. Yield componants and Yield

4.2.1. Number of fruits per plant

The data relating to the mean number of fruits produced per plant are presented in Table 8 and the respective analysis of variance in Appendix II.

The levels of irrigation significantly influenced the number of fruits produced. The treatment W_4 (11.86) was on par with W_3 (10.50) and W_3 with W_2 (9.25). All these treatments were significantly superior to W_1 (7.39).

The levels of fertilizers also substantially influenced the number of fruits produced. F_2 produced the maximum number of fruits (11.04) followed by F_1 (10.02) and both were on par, but significantly superior to F_0 (8.19).

Table 8. Yield components as affected by irrigation and fertility levels.

Treatments	No. of fruits per plant	Mean length of fruits (cm)	Mean girth of fruits (cm)	Mean weight of fruits (g)
Irrigation levels				
W_1	7.39	18.69	11.42	90.998
W_2	9.25	21.24	12.00	103.658
W_3	10.50	20.11	11.82	103.201
W_4	11.86	20.48	11.89	101.306
SEm ±	0.583	0.395	0.160	2.0032
CD (5%)	1.710	1.159	NS	5.8760
Fertility levels				
F_0	8.19	19.41	11.77	96.453
F_1	10.02	20.26	11.71	99.756
F_2	11.04	20.72	11.87	103.163
SEm ±	0.505	0.342	0.139	1.7348
CD (5%)	1.480	1.004	NS	5.0880
Interaction (W x F)				
SEm ±	1.010	0.685	0.278	3.4698
CD (5%)	NS	NS	NS	NS

The interaction effect between the irrigation and fertility levels was not significant.

4.2.2. Mean length of fruits

The data on the mean length of fruits are presented in Table 8 and the respective analysis of variance in Appendix II.

With respect to mean length of fruits, the irrigation levels W_2, W_4 and W_3 were on par and significantly superior to W_1. Fertility levels also influenced the mean length of fruits. The treatment F_2 recorded the maximum length, but was on par with F_1 and significantly superior to F_0. But F_1 and F_0 were on par.

The interaction between irrigation and fertilizers failed to produce any significant influence on length of fruits.

4.2.3. Mean girth of fruits

The mean values of the girth of fruits are shown in Table 8 and the respective analysis of variance in Appendix II.

It can be seen from the table that neither the main effects of irrigation and fertilizers nor their interaction was significant in influencing the mean girth of fruits.

4.2.4. Mean weight of fruits

The data pertaining to mean weight of fruits are presented in Table 8 and the analysis of variance in Appendix II.

The influence of levels of irrigation on mean weight of fruits was significant. The treatments W_2, W_3 and W_4 were on par and significantly superior to W_1. The levels of fertilizers also influenced the weight of individual fruit. The treatment F_2, though significantly superior to F_0, was found to be on par with F_1. The treatments F_1 and F_0 were on par. The interaction effect of the two factors was not significant.

4.2.5. Fruit yield per plant and per hectare

The data regarding fruit yield per plant and per hectare as influenced by levels of irrigation and fertilizers are presented in Table 9 and the analysis of variance in Appendix II. Fruit yield is graphically presented in Fig. 4 also.

The influence of levels of irrigation on the fruit yield was significant. The irrigation schedule

Table 9. Fruit yield as affected by irrigation and fertility levels.

Treatments	Fruit yield	
	Per plant (kg)	Per hectare (kg)
Irrigation levels		
W_1	0.549	5084
W_2	0.895	8286
W_3	0.969	8967
W_4	1.085	10043
SEm ±	0.0412	379.3
CD (5%)	0.1201	1112.0
Fertility levels		
F_0	0.713	6597
F_1	0.901	8343
F_2	1.009	9346
SEm ±	0.0361	328.5
CD (5%)	0.1041	963.0
Interaction (W x F)		
SEm ±	0.0707	656.9
CD (5%)	NS	NS

W_4 (farmers' practice) and W_3 (IW/CPE - 1.2) were statistically on par. The per hectare yields produced by W_4 and W_3 were 10.04 t and 8.97 t respectively. These two schedules were significantly superior to W_1 (IW/CPE - 0.4) which recorded only 5.08 t ha^{-1}. However, (ratio 0.8) was on par with W_3 producing 8.29 t ha^{-1}.

The fertility levels also influenced the fruit production considerably. F_2 (60 : 30 : 60 kg ha^{-1} NPK + 18 t ha^{-1} FYM) produced the maximum yield of 9.35 t ha^{-1} which was obviously superior to other levels. The level F_1 (30 : 15 : 30 kg ha^{-1} NPK + 18 t ha^{-1} FYM) with a production of 8.34 t ha^{-1} was also found to be superior to F_0 (18 t ha^{-1} FYM) which produced only 6.60 t ha^{-1}.

There was no significant interaction due to irrigation and fertilizers on yield.

4.3. Moisture Studies

4.3.1. Field water use efficiency

Field water use efficiency calculated in kilogramme fruits per hectare millimeter water used, is given in Table 10 and graphically shown in Fig. 4. The analysis of variance of the same is given in Appendix II.

EFFECT OF IRRIGATION AND FERTILITY LEVELS ON YIELD AND WATER USE EFFICIENCY

Fig. 4

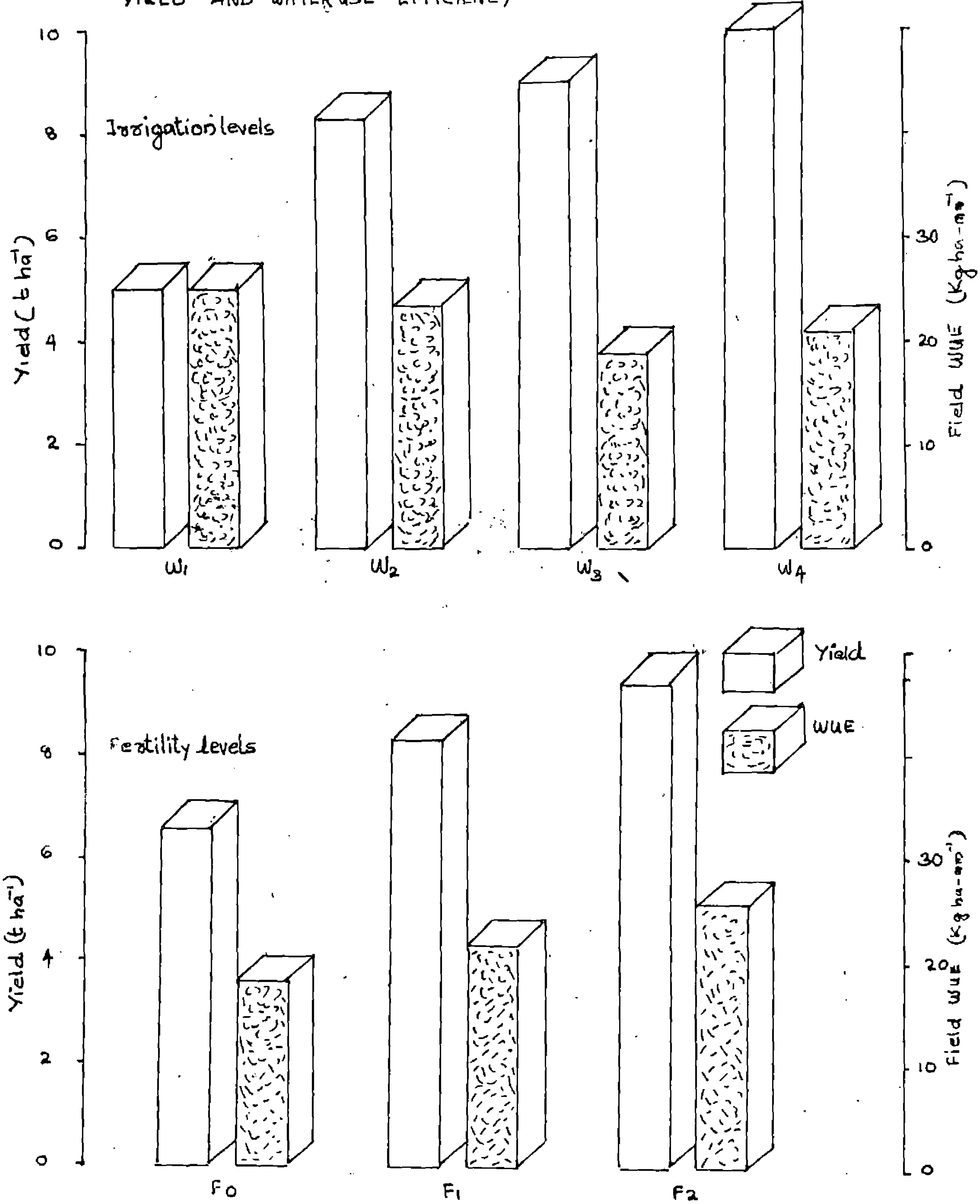


Table 10. Field water use efficiency as affected by irrigation and fertility levels.

Treatments	Total water applied (mm)	Field water use efficiency (kg ha - mm^{-1})
Irrigation levels		
W_1	202	25.17
W_2	352	23.54
W_3	472	19.00
W_4	474	21.189
SEm ±	-	1.074
CD (5%)	-	3.149
Fertility levels		
F_0	375	18.11
F_1	375	22.83
F_2	375	25.74
SEm ±	-	0.930
CD (5%)	-	2.727
Interaction (W x F)		
SEm ±	-	1.860
CD (5%)	-	NS

The treatments W_1 (0.4) and W_2 (0.8) were on par in water use efficiency. Numerically W_1 was the best among the irrigation levels tried with 25.17 kg fruits per ha - mm of water used. The value for W_2 was 23.54 kg ha - mm^{-1}. The treatments W_4 and W_3 were on par and significantly inferior to W_2 and W_1. W_4 and W_3 recorded 21.19 kg ha - mm^{-1} and W_3 19.00 kg ha - mm^{-1} respectively.

Water use efficiency was affected by fertilizer levels also. The treatment F_2 was found to be the most efficient in water utilisation with 25.74 kg ha - mm^{-1}, followed by F_1 (22.83 kg ha - mm^{-1}) and F_0 (18.11 kg ha - mm^{-1}). All these three levels significantly differed with each other.

The interaction effect of water and fertilizer failed to show any influence on water use efficiency.

4.3.2. Consumptive use

Differential irrigation treatments were started in early February (20 days after sowing). Average daily consumptive use and total consumptive use from 20 days after sowing upto the end of the season along with the evaporation data are presented in Table II.

Table 11. Consumptive use and pan evaporation values during the growth period of bittergourd.

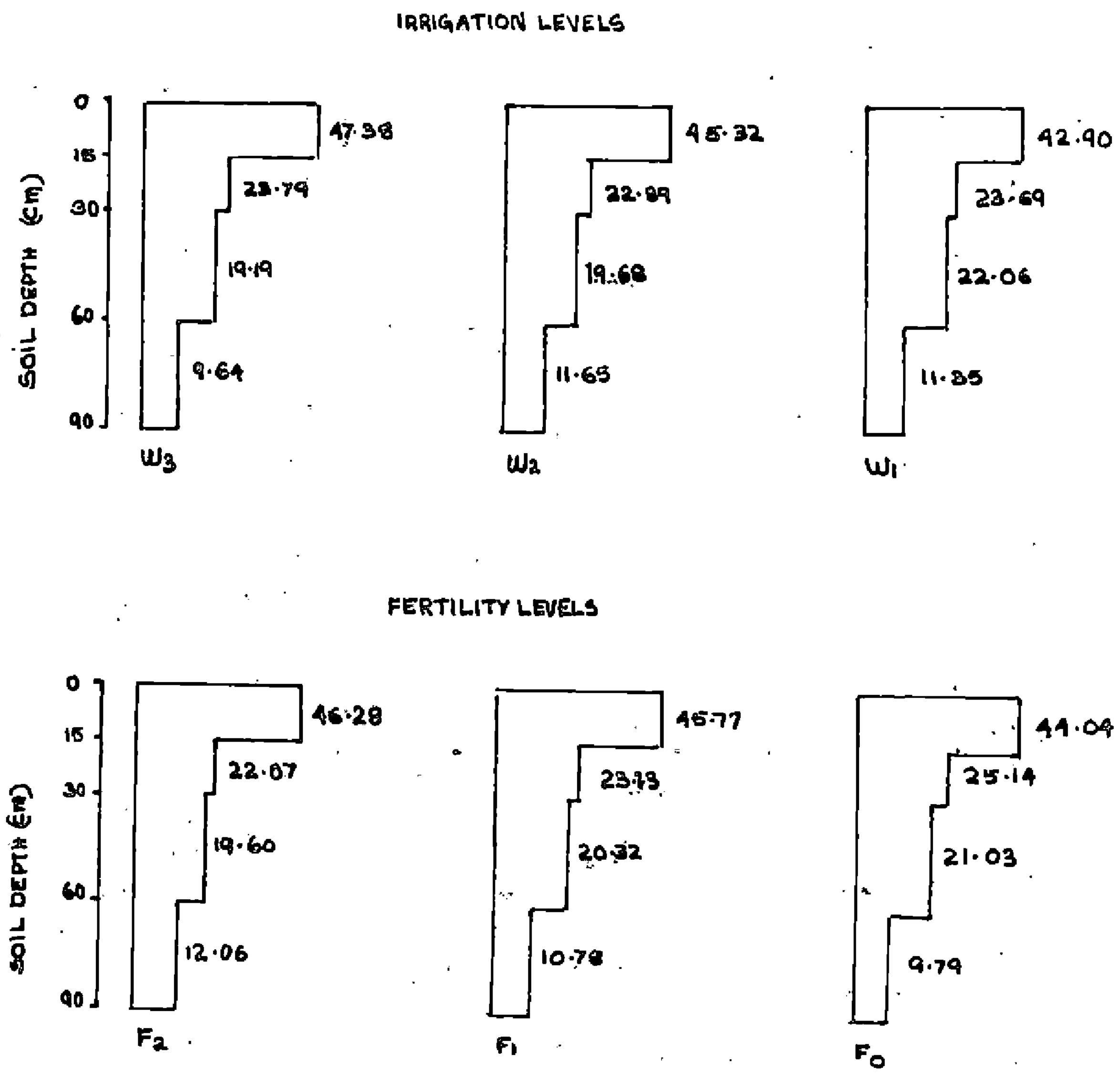
Treatments	Total consumptive use (mm)	Average consumptive use (mm/day)	Total CPE during crop growth period (mm)	Average pan evaporation (mm/day)
Irrigation levels				
W_1	129.15	1.7936	356.33	4.949
W_2	242.08	3.3622	356.33	4.949
W_3	321.78	4.4692	356.33	4.949
Fertility levels				
F_0	225.697	3.1347	356.33	4.949
F_1	233.193	3.2388	356.33	4.949
F_2	234.113	3.2516	356.33	4.949

Total consumptive use was maximum in W_3 (321.78 mm) followed by W_2 (242.08 mm) and W_1 (129.15 mm). In farmers' practice (W_4) as daily irrigation was practiced, consumptive use determination from soil moisture data was not feasible and hence not calculated. There the total water applied was more or less equal to that of W_3 (vide Table 4).

Consumptive use values were slightly higher in plots which received higher levels of fertilizers. The level F_2 recorded the maximum consumptive use (234.11 mm) followed by F_1 (233.19 mm) and F_0 (225.70 mm).

4.3.3. Soil moisture depletion pattern

The average relative soil moisture depletion from different soil layers in the root zone (upto 90 cm depth) was worked out for each drying cycle following irrigation and the relevant data are portrayed in Fig.5. The figure shows that the top 15 cm soil layer accounted for 42 - 48 per cent of the total moisture depleted. The moisture use from the 15 - 30 cm layer was as high as that from the next 30 cm soil layer below. The top 30 cm layer contributed about 66 - 71 per cent of total water use. Moisture depletion decreased rapidly with the soil depth. In comparison



SOIL MOISTURE EXTRACTION PATTERN (%) BY BITTERGOURD AS AFFECTED BY IRRIGATION AND FERTILITY LEVELS. Fig. 5

with wet regimes, dry regimes extracted more soil water from the lower soil layers (30 - 90 cm).

The soil moisture extraction pattern did not vary appreciably due to the different levels of fertilizers tried.

4.4. Chemical Composition of Plant Parts

4.4.1. Nitrogen content

The data on total nitrogen content expressed as percentage on dry weight basis in respect of leaves, vines and fruits are presented in Table 12 and the respective analysis of variance in Appendix III.

a) Leaves

Levels of irrigation failed to produce any significant influence on the percentage of nitrogen at 55th day as well as at final harvest.

However, fertility levels significantly influenced the percentage of nitrogen in leaves. At both the stages, F_2 showed the maximum nitrogen percentage followed by F_1 but both were statistically on par. Though F_0 was much inferior to F_2 statistically, it was on par with F_1.

Table 12. Effect of irrigation and fertility levels on the content of nitrogen in leaves, vines and fruits.

Treatments	Leaves (%)		Vines (%)		Fruits (%)
	55th day	Final harvest	55th day	Final harvest	
Irrigation levels					
W_1	2.774	1.982	2.002	1.133	2.564
W_2	2.814	1.885	1.966	1.262	2.519
W_3	3.025	1.828	2.055	1.243	2.750
W_4	3.170	1.545	2.166	1.238	2.709
SEm ±	0.203	0.187	0.090	0.165	0.083
CD (5%)	NS	NS	NS	NS	NS
Fertility levels					
F_0	2.584	1.486	1.868	1.122	2.393
F_1	2.979	1.844	2.215	1.120	2.639
F_2	3.276	2.099	2.209	1.414	2.876
SEm ±	0.176	0.162	0.078	0.143	0.071
CD (5%)	0.516	0.474	0.229	NS	0.209
Interaction (W x F)					
SEm ±	0.352	0.323	0.156	0.286	0.143
CD (5%)	NS	NS	NS	NS	NS

No interaction effect of irrigation and fertilizers was noted on the nitrogen content of leaves at any of the stages.

b) Vines

Water management practices failed to show any significance in the percentage of nitrogen at both stages of analysis.

The effect of fertilizers was significant only at 55th day. The treatments F_1 and F_2 were on par and significantly superior to F_0.

There was no interaction of irrigation and fertilizers on nitrogen content of vines.

c) Fruits

Irrigation failed to show any significant influence on the nitrogen content of fruits. However, a trend of increasing nitrogen content was noted in wetter treatments.

Application of fertilisers influenced the nitrogen content significantly. The content of nitrogen in fruits increased with increase in the levels of fertilizers and the variation among the treatments was significant. But the interaction effect of both the factors was not significant in producing any difference in nitrogen percentage.

4.4.2. Phosphorus content

The different levels of irrigation or fertility did not produce any significant effect on the phosphorus content of leaves, vines or fruits. The interaction effect also was found to be non-significant on the phosphorus content of different plant parts. The mean values of phosphorus content of leaves, vines, and fruits are given in Table 13 and the respective analysis of variance in Appendix IV.

4.4.3. Potassium content

The data pertaining to potassium content of leaves, vines and fruits at different stages of growth are presented in Table 14 and the abstract of analysis of variance in Appendix V.

a) Leaves

Water management practices significantly influenced the potassium content of leaves at 55th day. The treatment W_4 was significantly superior to other treatments at this stage. Other levels viz. W_1, W_2,

Table 13. Effect of irrigation and fertility levels on the content of phosphorus in leaves, vines and fruits.

Treatments	Leaves (%) 55th day	Leaves (%) Final harvest	Vines (%) 55th day	Vines (%) Final harvest	Fruits (%)
Irrigation levels					
W_1	0.378	0.249	0.378	0.211	0.518
W_2	0.369	0.271	0.396	0.267	0.484
W_3	0.370	0.321	0.411	0.314	0.468
W_4	0.395	0.307	0.438	0.302	0.475
SEm ±	0.018	0.024	0.032	0.028	0.025
CD (5%)	NS	NS	NS	NS	NS
Fertility levels					
F_0	0.391	0.295	0.428	0.263	0.484
F_1	0.371	0.29	0.379	0.291	0.489
F_2	0.372	0.273	0.410	0.267	0.487
SEm ±	0.155	0.021	0.028	0.024	0.022
CD (5%)	NS	NS	NS	NS	NS
Interaction (W x F)					
SEm ±	0.031	0.041	0.056	0.049	0.043
CD (5%)	NS	NS	NS	NS	NS

Table 14. Effect of irrigation and fertility levels on the content of potassium in leaves, vines and fruits.

Treatments	Leaves (%)		Vines (%)		Fruits (%)
	55th day	final harvest	55th day	final harvest	
Irrigation levels					
W_1	2.859	2.403	3.792	1.931	3.876
W_2	2.750	2.583	3.653	2.444	3.444
W_3	2.611	2.583	3.458	2.153	3.472
W_4	3.139	2.569	3.667	2.153	3.792
SEm ±	0.103	0.121	0.177	0.145	0.130
CD (5%)	0.303	NS	NS	NS	NS
Fertility levels					
F_0	2.594	2.177	3.396	1.844	3.510
F_1	2.842	2.729	3.708	2.135	3.708
F_2	3.083	2.698	3.823	2.531	3.719
SEm ±	0.089	0.105	0.153	0.126	0.113
CD (5%)	0.263	0.307	NS	0.369	NS
Interaction (W x F)					
SEm ±	0.179	0.210	0.306	0.252	0.226
CD (5%)	0.263	NS	NS	NS	NS

and W_3 were on par with regard to potassium content. However, in the final harvest there was no appreciable difference in potassium content among the different levels of irrigation.

The fertility levels considerably increased the potassium content of leaves at both stages. The level F_2 recorded the maximum potassium content on the 55th day, which was on par with F_1. However, F_1 was on par with F_0. At final harvest F_1 and F_2 were much superior to F_0 and were on par.

The interaction between water management practices and fertility levels did not reach the level of significance in respect of potassium content at both the stages.

b) Vines

Irrigation had no significant influence on potassium content of vines at both stages. The fertility levels were not significant at 55th day but reached the level of significance at final harvest. At this stage F_2 was much superior to F_1 and F_0. The levels F_1 and F_0 were on par.

No interaction effect of irrigation and fertilizers was noted on potassium content at any of the stages.

c) Fruits

The irrigation treatments or levels of fertilizers failed to show any signifiance in respect of potassium content of fruits. The interaction effect was also not significant.

4.5. Uptake of Major Nutrients

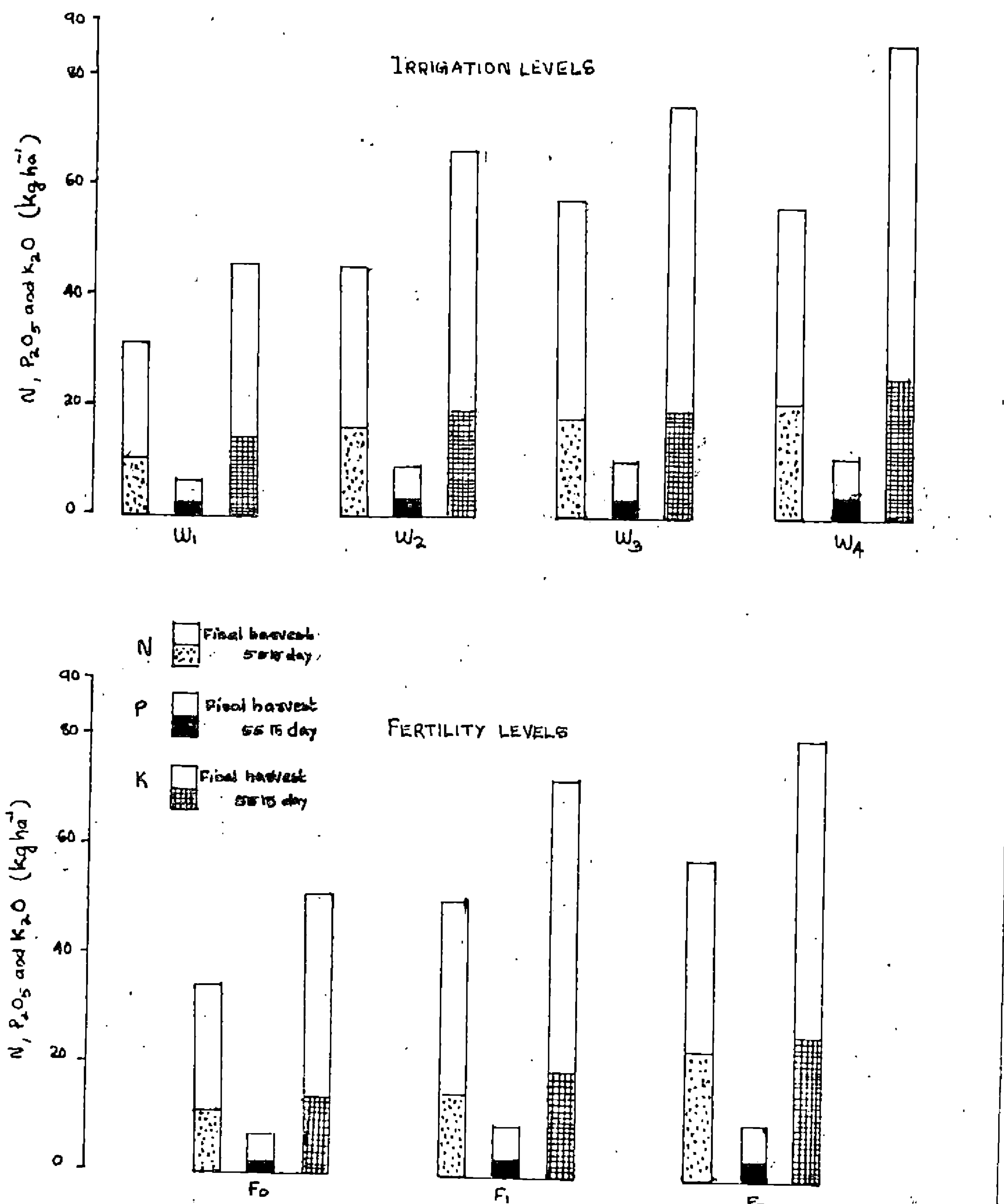
4.5.1. Nitrogen

The mean values of the uptake of nitrogen in kg ha^{-1} at 55th day and at final harvest as influenced by levels of irrigation and fertility are presented in Table 15(a) and Fig.6 and the respective analysis of variance in Appendix VI.

The data revealed that uptake of nitrogen was significantly influenced by the levels of irrigation and fertilizers at both stages. At 55th day the irrigation schedule W_4 recorded the maximum uptake (20.657 kg ha^{-1}) followed by W_3 (18.265 kg ha^{-1}) and W_2 (16.317 kg ha^{-1}). But these three levels were on par and significantly superior to W_1 (10.822 kg ha^{-1}).

The mean data on uptake of nitrogen at final harvest suggested that the treatment W_3 had the maximum uptake (57.607 kg ha^{-1}), closely followed by W_4 (56.132 kg ha^{-1}). Both were statistically on par and

Fig. 6. UPTAKE OF NITROGEN, PHOSPHORUS AND POTASSIUM AS AFFECTED BY IRRIGATION AND FERTILITY LEVELS



significantly superior to other levels viz. W_2 (45.254 kg ha^{-1}) and W_1 (30.986 kg ha^{-1}).

The fertility levels also significantly influenced the uptake of nitrogen. At both stages of study the pattern of uptake was more or less the same. The treatment F_2 showed the maximum uptake followed by F_1 and F_0 and all the three levels varied significantly.

Though the interaction of water management practices and fertility levels on uptake of nitrogen was not significant at 55th day it was significant at final harvest (vide Table 15(b). The treatment combination W_3F_2 showed the maximum uptake (79.675 kg ha^{-1}) and the minimum by W_1F_0 (21.323 kg ha^{-1}).

4.5.2. Phosphorus

The mean data on the uptake of phosphorus at different stages of growth as affected by the levels of irrigation and fertilizers are presented in Table 15(a) and Fig. 6 and the analysis of variance in Appendix VI.

Both irrigation and fertilizer levels markedly influenced the phosphorus uptake at 55th day and at

Table 15(a). Uptake of major nutrients as affected by irrigation and fertility levels.

Treatments	Uptake of Nitrogen (kg ha^{-1})		Uptake of Phosphorus (Kg ha^{-1})		Uptake of Potassium (kg ha^{-1})	
	55th day	Final harvest	55th day	Final harvest	55th day	Final harvest
Irrigation levels						
W_1	10.822	30.986	1.589	5.498	13.757	44.647
W_2	16.317	45.254	2.435	8.067	19.777	66.130
W_3	18.265	57.607	2.529	10.100	19.292	74.544
W_4	20.657	56.132	3.072	10.796	25.335	85.745
SEm ±	1.721	2.557	0.243	0.442	1.847	3.537
CD (5%)	5.047	7.501	0.714	1.296	5.416	10.375
Fertility levels						
F_0	10.588	34.583	1.855	7.210	13.160	50.648
F_1	15.506	50.014	2.238	9.012	18.823	72.054
F_2	23.451	57.886	3.126	9.964	26.638	80.598
SEm ±	1.490	2.215	0.211	0.383	1.599	3.063
CD (5%)	4.371	6.496	0.617	1.122	4.690	8.985
Interaction (W x F)						
SEm ±	2.980	4.429	0.421	0.765	3.198	6.127
CD (5%)	NS	12.991	NS	2.244	NS	NS

final harvest. However, the nature of significance was different. The treatments W_4, W_3 and W_2 were on par statistically, with uptake of 3.072 kg ha^{-1}, 2.529 kg ha^{-1} and 2.435 kg ha^{-1} respectively. All these three levels, were superior to W_1 (1.589 kg ha^{-1}), the least frequently irrigated treatment.

At final harvest, the levels W_4 (10.796 kg ha^{-1}) and W_3 (10.100 kg ha^{-1}) were on par and significantly superior to the other two levels. The level W_2 with an uptake of 8.067 kg ha^{-1} ranked the third place and was much superior to W_1 with an uptake of only 5.498 kg ha^{-1}.

With regard to fertility levels, F_2 with an uptake of 3.126 kg ha^{-1} showed the maximum response at 55th day. It was significantly better to other two levels F_1 and F_0 (2.238 kg ha^{-1} and 1.855 kg ha^{-1}) which were on par. The pattern of uptake of P at final harvest stage was different. Here the levels F_2 (9.964 kg ha^{-1}) and F_1 (9.012 kg ha^{-1}) were on par and significantly superior to F_0 (7.210 kg ha^{-1}).

The interaction of irrigation and fertility levels was found to be significant only at the final harvest stage (vide Table 15(c)). The treatment combination W_3F_2 recorded the maximum uptake (12.305

Table 15(b). Interaction of irrigation and fertilizer application on Nitrogen uptake (kg ha^{-1}) at final harvest.

Treatments	F_0	F_1	F_2	Mean
W_1	21.323	32.008	39.626	30.986
W_2	31.786	49.236	54.740	45.254
W_3	34.312	56.834	79.675	57.607
W_4	50.912	59.978	57.505	56.132
Mean	34.583	50.014	57.886	
SEm ±	4.429			
CD (5%)	12.991			

Table 15(c). Interaction of irrigation and fertilizer application on Phosphorus uptake (kg ha^{-1}) at final harvest.

Treatments	F_0	F_1	F_2	Mean
W_1	4.091	5.648	8.121	5.498
W_2	6.248	8.601	9.351	8.067
W_3	7.031	10.963	12.305	10.100
W_4	11.471	10.836	10.081	10.796
Mean	7.21	9.012	9.964	
SEm ±	0.765			
CD (5%)	2.244			

kg ha^{-1}) and the least in W_1F_0 (4.091 kg ha^{-1}).

4.5.3. Potassium

The data pertaining to the uptake of potassium at different stages of growth are presented in Table 15(a) and Fig.6 and the abstract of analysis of variance in Appendix VI.

The main effects of irrigation and fertilizers were significant at both stages. The treatment W_4 showed the maximum uptake of 25.335 kg ha^{-1} at 55th day, which was significantly superior to other levels. The treatments W_2 with an uptake of 19.777 kg ha^{-1}) and W_3 with 19.292 kg ha^{-1} were on par and significantly superior over W_1 (13.757 kg ha^{-1}).

The same pattern of significance was noted at the final harvest also with respect to irrigation schedules. W_4 with a potassium uptake of 85.745 kg ha^{-1} was superior to W_3 (74.544 kg ha^{-1}) and W_2 (66.130 kg ha^{-1}) which were on par. W_1 with an uptake of 30.986 kg ha^{-1} was significantly inferior to all other levels.

There was a progressive increase in the uptake of potassium with increase in fertility levels. At

55th day all the three levels differed significantly among each other (13.160 g, 18.823 g and 26.638 g at F_0, F_1 and F_2 levels respectively). At final harvest also F_2 continued to be superior (80.598 g) but was on par with F_1 (72.054 g). Both were significantly better than F_0 (50.648 g).

The irrigation and fertilizer interaction failed to show any effect on the uptake of potassium at both stages.

4.6. Soil Fertility Status

4.6.1. Organic carbon

The mean values of organic carbon content of the soil as affected by levels of water management and fertilizers are presented in Table 16 and the respective analysis of variance in Appendix VII.

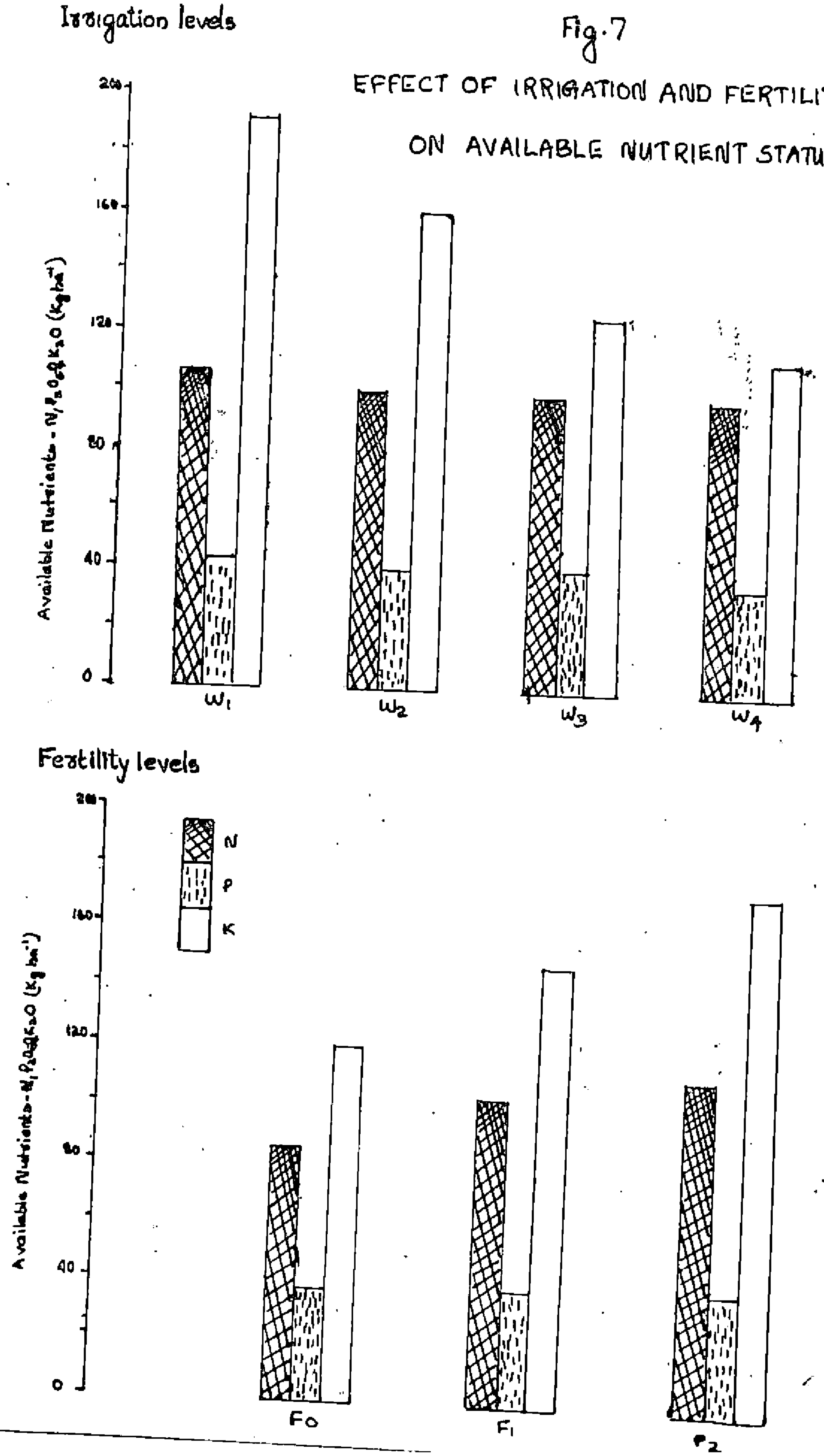
It was seen that the organic carbon status of soil was unaffected neither by the main effects (irrigation and fertilizers) nor by their interactions.

4.6.2. Available nitrogen

The levels of irrigation did not influence the build up of available nitrogen in the soil significantly.

Fig. 7

EFFECT OF IRRIGATION AND FERTILITY LEVELS ON AVAILABLE NUTRIENT STATUS OF SOIL



However, a clear trend of showing higher residual available nitrogen content in least irrigated plots could be seen (vide Table 16, Fig. 7 and Appendix VII).

The available nitrogen status of soil was considerably affected by fertilization. The level F_2 showed maximum available nitrogen with 112.24 kg ha^{-1}, followed by F_1 (104.07 kg ha^{-1}) and both were on par. These two levels were significantly superior to F_0 which recorded only 87.03 kg ha^{-1}.

The interaction of irrigation and fertility levels was not significant.

4.6.3. Available phosphorus content

The mean values are presented in Table 16 and Fig. 7 and the analysis of variance in Appendix VII.

The main effects of irrigation and fertilizers or their interaction were not effective in producing any significant effect on the available phosphorus content of soil. However, a decreasing trend in available phosphorus content could be observed as the irrigation levels increased. On the contrary, an increasing trend was noticed in the case of fertilizers by increasing their levels.

Table 16. Soil chemical properties as affected by irrigation and fertility levels.

Treatments	Organic carbon (%)	Available N ($kg\ ha^{-1}$)	Available P_2O_5 ($kg\ ha^{-1}$)	Available K_2O ($kg\ ha^{-1}$)
Irrigation levels				
W_1	0.452	106.13	42.362	195.948
W_2	0.444	100.49	39.570	158.472
W_3	0.428	100.18	39.057	125.279
W_4	0.443	97.69	35.498	111.361
SEm ±	0.017	4.747	2.349	8.233
CD (5%)	NS	NS	NS	24.147
Fertility levels				
F_0	0.433	87.03	38.457	119.656
F_1	0.449	104.07	38.934	147.765
F_2	0.443	112.27	39.973	175.874
SEm ±	0.015	4.111	2.034	7.130
CD (5%)	NS	12.059	NS	20.912
Interaction (W x F)				
SEm ±	0.029	8.223	4.068	14.259
CD (5%)	NS	NS	NS	NS

4.6.4. Available potassium content

It was observed that irrigation and fertility levels significantly influenced the available potassium build up of the soil (vide Table 16, Fig. 7 and Appendix VII). With regard to irrigation levels, W_1 the least frequently irrigated treatment recorded the maximum available potassium (195.99 kg ha^{-1}). It was significantly superior to W_2 (158.47 kg ha^{-1}) which again showed superiority over other levels. The treatment W_4 (111.36 kg ha^{-1}) recorded the least and was on par with W_3 (125.28 kg ha^{-1}).

Application of higher doses of fertilizers significantly increased the available potassium content of the soil. The level F_2 recorded the highest build up of available potassium (175.87 kg ha^{-1}) followed by F_1 and F_0 (147.77 and 119.66 kg ha^{-1}). All these three levels differed significantly among each other.

The interaction between the two factors viz. irrigation and fertility levels, had no pronounced effect in the build up of available potassium in soil.

Discussion

DISCUSSION

The results of the investigation carried out to study the influence of different water management practices and fertility levels on bittergourd raised in summer rice fallows, given in the preceding chapter are briefly discussed below.

5.1. Crop Growth

Water management treatments did not exert significant influence on the growth parameters viz. the length of vine and number of leaves recorded on the 20th and 35th day of sowing (Table 5). However higher levels of irrigation showed a favourable trend in the production of longer vines and more number of leaves on the 35th day. lack of any such response on the observations recorded on the 20th day could be attributed to the uniform irrigations received by the crop upto 20th day. Water deficit is likely to affect the two vital processes of growth viz. cell division and cell enlargement and according to Begg and Turnor (1976) cell enlargement is more affected, resulting in poor growth. The general belief is that growth is suspended during moisture stress and resumed upon its elimination (Arnon, 1975). The favourable influence of higher levels of irrigation noticed within a period of 15 days after the differential treatments could thus be attributed to stimulation of metabolic activities. Frequent irrigations markedly increased the leaf area index (LAI) and dry matter production (Table 7(a)). Variation in total leaf area may result from changes in leaf number or in leaf size. Leaf number depends on the number of growing points, the length of time during which leaves are produced, the rate of leaf production during the period and the length of life of leaves. Leaf size is determined by the number and size of the cells of which the leaf is built and is influenced by light, moisture regimes and the supply of nutrients (Arnon, 1975). A steep decline in LAI was reported by several workers in crops when leaf water potential decreased to a few bars. This indicates that modest changes in evaporative condition or the soil water supply will have a considerable influence on leaf growth. Low leaf water potential also causes the loss of existing area (Arnon, 1975; Begg and Turner, 1976). Escobar and Gausman (1974) in mexican squash and Cummins and Kretchman (1974) in cucumber also reported reduction in leaf area due to moisture stress.

As evident from Table 7(a) and Fig. 3 the dry matter production at both the stages increased with increase in soil wetness. Photosynthesis is the basic process for the build up of organic substances by the plants, whereby sunlight provides the energy required for reducing Co_2 to sugar as the end product of the process. This sugar serves as the building material for all the other organic components of the plant. The amount of dry matter production will, therefore depend on the effectiveness of photosynthesis of the crop and furthermore on plants whose vital activities are functioning efficiently (Arnon,1975). The leaves of a plant are the main organ of photosynthesis and LAI is the best measure of the capacity of a crop for producing dry matter. Lower photosynthetic efficiency which was evident from low LAI in less frequently irrigated plots might be a major reason for the poor growth and low dry matter production in those treatments.

Higher levels of fertilizers favourably influenced the length of vine, number of leaves, LAI and dry matter production, though it did not reach the level of significance in certain cases. This shows the efficient utilization of the applied nutrients for plant growth and in the production of biomass. Besides nitrogen, the importance of adequate supply of phosphorus and potassium for the healthy and vigorous growth of crops like bittergourd has been reported by Bishop et al. (1969), Pettiet (1971), Penny et al. (1976), Ogunremi (1978), and Rajendran (1981).

The interaction between irrigation and fertilizers on total dry matter production at final harvest showed the marked influence of daily irrigation (W_4) under the lowest level of fertilizers(F_0) tried (Table 7(b)). In the present study maximum dry matter production was obtained under W_3F_2 combination. All the fertiliser levels combined with W_4 (W_4F_0, W_4F_1 and W_4F_2) were however, on par with W_3F_2. The results thus indicated that the response due to fertilizer application was not evident under daily irrigation (W_4) whereas it was evident in the other water management treatments.

5.2. Yield Components

Characters contributing to fruit yield viz. number of fruits per plant, mean length of fruit and mean weight of fruit were improved substantially with increased soil wetness (Table 8). However, the mean girth did not vary significantly among the treatments. The effect of irrigation was more pronounced on fruit number than on other yield attributes. The treatments daily irrigation and irrigation at IW/CPE = 1.2 did not vary significantly with regard to yield attributes. Favourable influence of moist regime on yield attributes has been reported by Flocker et al. (1965) and Neiland Zunino (1972) in melons, Ortega and Kretchman (1982) in pickling cucumbers, Singh and Punjab Singh (1978) in bottle gourd, round gourd and watermelon. Kaufman (1972) stated that water defecit generally induced changes like retardation of floral primordia development, reduction in the number of flowers produced and fruitset, flower and fruit abscission etc., and all of these may lead to the decrease in the number of fruits produced. Frequent irrigations might have increased the availability and supply of plant nutrients resulting in better growth and translocation of photosynthates to fruits and fruit weight increased. The period of fruit enlargement in the reproductive cycle of a plant is very critical during which considerable amounts of nutrient reserves are transported into the fruit. Water defecit if any developed during this period may cause marked reduction in the size of fruits (Kaufman, 1972). An increase in the length of fruit without any marked variation in girth explains the increased mean fruit weight at higher levels of irrigation.

Further, in fruits and vegetables, the fresh weight often continues to increase evenafter the increase in dry weight has ceased (Begg and Turner, 1976). Since the size and weight of fruit at this stage depend on plant water potential to a greater extent, water deficit will have a strong influence on fruit size and fruit weight than the dry weight.

Fertiliser application increased significantly the number of fruits per plant, mean length of fruits and mean weight of fruits. However variation between F_1 and F_2 levels was not significant. As in the case of irrigation the mean girth of fruit was not affected by fertility levels. The favourable influence of fertilizer application on these characters can be ascribed to the increased availability and uptake of plant nutrients required for the production of flowers and the growth and development of fruits. Jassal et al.

(1972) in muskmelon, Pandey and Singh (1973) in bottlegourd and Ogunremi (1978) in watermelon also reported higher fruit number per plant with increased application of nitrogen. Agarwala and Sharma (1976) stated that the size and quality of fruit was poor and it matures early when nitrogen supply was a limiting factor. Phosphorus and potash are found to be essential for early growth of cucumbers (Bishop et al., 1969; Pettiet, 1971 ; Penny et al. 1976). Favourable early growth will have its bearing on number of flowers and number of fruits per plant. Besides the higher levels of fertilisers might have created on optimum balance of nutrients and contributed to production of a greater quantity of photosynthates which were translocated to developing fruits, thus influencing the size and weight of fruit.

5.3. Fruit Yield

The fruit yield increased with increase in the wetness of the soil and the maximum yield was recorded by the treatment W_4 (daily irrigation) and it was not significantly different from W_3 (IW/CPE = 1.2). However the treatment W_3 and W_2 (IW/CPE = 0.8) were on par and W_2 was significantly inferior to W_4 (Table 9 and Fig. 4).

The treatment W_4 brought about 97 per cent and 21 per cent increase in fruit yield over W_1 and W_2 respectively. Beneficial effect of irrigation was more pronounced when the soil moisture level was increased from W_1 to W_2 level (65%). Above W_2 level the response due to irrigation was reduced. A significant reduction in fruit yield at less frequent irrigation treatments may be attributed to the reduction in leaf area and dry matter production due to the multiple adverse effects of water stress like reduced rate of photosynthesis, translocation of photosynthates and disturbance of nitrogen metabolism on plant growth (Kramer, 1969).

The observed increase in yield with increase in soil wetness is attributed to a more or less similar trend in yield attributes like size and fresh weight of fruit and number of fruits per plant. This is to be expected since fruit yield is the ultimate manifestation of the cumulative effect of these characters. The fruit development depends primarily on the conditions prevailing during the period of fruit enlargement when considerable amount of water and carbohydrates are transported into the developing fruit (Kaufman, 1972).

It is to be noted that uptake of major nutrients and plant growth as evidenced by dry matter production are closely related to the amount of water transpired particularly under high evaporative demand conditions (Ghildyal, 1971). Increased transpiration under high evaporative demand and favourable moist conditions of the soil increases the rate of uptake of nutrients as a result of mass transfer of ions through the transpirational stream. An increase in the rate of uptake of N, P and K observed in the present study (Table 15(a))might have contributed to better growth and yield of fruit. Here, emphasis should also be given to the availability and uptake of various other nutrients from the moist surface soil due to frequent shallow irrigations as well the favourable microclimate inside the crop canopy. In short the reduction in yield at lower levels of irrigation is due to the adverse effect of stress on the physiology of growth, reproduction and fruit development.

Application of fertilizers gave an appreciable increase in fruit yield. The percentage increase with F_1 and F_2 levels over F_0 was 26 per cent and 42 per cent respectively. Increased supply of plant nutrients to the soil in general leads to increased uptake of these nutrients which holds good in the present investigation also. Such a phenomenon has resulted in better growth and yield of the crop showing the inter-relation between yield and nutrient uptake. The importance of major nutrients on the synthesis of amino acids, proteins and other metabolic products needs little explanation (Tisdale and Nelson, 1975; Agarwala and Sharma, 1976).

5.4. Moisture Studies

The results revealed that the field water use efficiency increased with decrease in the level of irrigation (Table 10; Fig. 4). Water use efficiency is likely to increase with decrease in soil moisture supply untill it reaches the minimum critical level because plants may actively try to economise water loss in the range from minimum critical to optimum moisture level. However, total production from a unit area decreases as the available soil moisture falls below the optimum (Singh and Sinha, 1977). Water above the optimum moisture level may be lost in the form of excessive evaporation, excessive transpiration or even as deep percolation. These findings coroborate reports of Stansbery and Lorey (1965), Singh and Singh (1979) and Sharma and Parashar (1978).

Application of fertilizers increased the water use efficiency due to increased yield with the same quantity of water applied. This is in agreement with the findings of Sharma and Parashar (1979) and Prasad and Singh (1979).

The consumptive use increased with increase in the level of irrigation. Frequent moisture supply created more favourable conditions for higher evapotranspiration. Similar claims have been advanced by Prasad and Singh (1979), Sharma and Parashar (1979) and Muktar Singh *et al.* (1971).

A slightly higher rate of consumptive use could be noticed at higher levels of fertilizers. Increased growth of roots and foliage at higher levels of fertilizers might have resulted in increased rate of transpiration. Progressive increase of consumptive use by the application of nitrogen was reported earlier in cheena by Prasad and Singh (1979). Favourable influence of nitrogen and phosphorus were also reported by Sharma and Parashar (1979) in cauliflower.

Maximum depletion of soil water was observed from the top 0-15 cm soil layer irrespective of the treatment and then gradually decreased with the increase in soil depth (Fig.5). The high soil moisture depletion observed from the upper 15 cm layer might probably be due to the fact that, besides transpiration, lossess due to evaporation from the soil surface were considerable. The moisture use from 15 - 30 cm layer was as high as that from the next 30 cm soil layer below. Moisture depletion decreased rapidly with the soil depth. It clearly suggests that the activity of bittergourd roots is maximum in the 0 - 60 cm soil layer. Gardner (1968) also reported that root mass and their activity were important for soil moisture extraction. Similar observations were also reported by Muktar Singh *et al.* (1971) in potato, Sharma and Parashar (1979) in cauliflower and Loomis and Crandall (1981) in cucumber.

5.5. Chemical composition of plant parts

The nitrogen and phosphorus contents of plant parts viz., leaves, vines and fruits, were not affected by water management practices during any of the growth stages (Table 12 and 13). However the leaves on the 55th day recorded a significantly higher value of potassium content which was not visible at the final harvest stage which may probably be due to the dilution effect on account of increased production of dry matter. An interesting trend in the nitrogen content of leaves also could be noticed. On the 55th day the nitrogen content in leaves increased with increase in the level of irrigation. But at the final harvest stage a reverse trend could be noticed which evidently supports the view that nitrogen absorbed upto flowering accumulates in leaves and subsequently transported to fruits. In general there was a tendency to show a higher content of nitrogen and phosphorus in more frequently irrigated treatments which might be due to the increased absorption of these elements in wet regimes. The soil moisture controls the concentration and availability of various elements in the soil for plant growth. So availability of water is of great significance to the plants to absorb nutrients and soil to supply them (Tisdale and Nelson, 1975; Agarvala and Sharma, 1976).

Fertilizer application exhibited a significant increase in nitrogen content of plant parts with higher levels of fertilizers at all stages of growth except in vines at the final harvest stage (Table 12) wherein the trend was almost similar. The phosphorus content was not markedly influenced by fertilizer application.(Table 13). The potassium content, however, showed an increasing trend due to fertilizer application in all the plant parts at both stages which was significant in leaves at both stages and vines at the final harvest stage (Table 14). Increased percentages of nitrogen and potassium in plant denote the increased availability due to their application. Better absorption of these nutrients might also have been caused by the better growth and activity of roots. Tesi et al. (1981) reported similar results in *Cucurbita pepo*. Lack of significant increase in nitrogen content due to fertilizer application may be due to the dilution effect as well as the translocation of this nutrient to reproductive parts. The non-significant variation in phosphorus content at different stages of growth shows that the availability of this nutrient due to fertilizer application was only enough to maintain its content more or less at the same level in plant parts at various stages of growth.

5.6. Uptake of Nutrients

Higher levels of irrigation and fertilizers resulted a marked increase in nitrogen, phosphorus and potassium uptake at both the growth stages in various plant parts (Table 15(a); Fig.6). These results are in agreement with that of Brown et al. (1960); Singh (1975); Balakumaran (1981) and Jose Mathew (1981) in different crops. The increase in uptake of these nutrients was mainly due to the dry matter production (Table 7(a)). A stimulated growth under higher levels of irrigation and fertilizer application might have resulted in better proliferation of root system and increased intake efficiency of the plants. Increased availability of plant nutrients due to treatments and consequent increase in growth and mineral absorption also have to be considered in explaining the present trend.

The interaction between irrigation and fertility levels on the uptake of N and P was more or less similar to that of the interaction obtained in dry matter production (Table 7(b)) at final harvest stage. Such a trend can only be expected since the content of the nutrients did not vary significantly among the treatments and the nutrient uptake was computed from the dry matter yields.

In general the uptake of plant nutrients at any stage of growth is mainly related to dry matter production. According to Tanaka et al. (1964) the nutrient availability is controlled by factors like nutrient availability in the soil, nutrient absorption power of roots, and the rate of increase in dry matter. Higher levels of irrigation produced favourable conditions and promoted root growth and rendered nutrients, more available. Increased uptake of nutrients due to fertilizer application can be ascribed to direct manurial effect and increased tapping of nutrients from the soil on account of increased growth and vigour of roots.

5.7. Soil fertility status

The soil chemical properties determined after the harvest of the experiment showed a significant decline in available potassium content with increase in soil wetness. On the other hand at higher levels of fertilizer application an appreciable increase in available nitrogen and potassium content could be noticed. (Table 16). The higher status of available nitrogen and available potassium at higher levels of fertilizers may be due to the direct effect of applied fertilizers over a uniform dose of farmyard manure. A significant reduction in the available potassium content due to irrigation can be attributed to a proportionately higher rate of uptake and removal of potassium from the soil at higher levels of these factors. Such a trend in potassium content of the soil can only be expected in the soil which is low in potassium status. There appears to be a negative relationship between yield and available K left behind. A similar observation has been reported from Madurai (Anon, 1981). The results are in conformity with that of Shanmughasundaram et al. (1979).

5.8. Economics of irrigation and fertilizer application

The abstract of economic analysis of the results is presented in Table 17. Among the irrigation schedules, W_3 (IW/CPE = 1.2) recorded the maximum net profit of Rs.10017.50/ha with a net return of Rs. 0.808 per rupee invested. It was followed by the treatment W_2 (IW/CPE = 0.8) with a net profit of Rs.8715.00 and a net return of Rs.0.726 per rupee invested. The treatment W_4 ranked the third place (net profit = Rs.5707.50; net return per rupee investment = 0.294)

Table 17. Economics of irrigation and fertilizer application

Treatments	Cost of production excluding the treatment (Rs)	Additional cost of the treatment (Rs)	Total cost of production Y (Rs)	Fruit yield (Kg)	Value X (Rs)	Net profit (Rs) X - Y	Net return per rupee invested (Rs) $\frac{X-Y}{Y}$
Irrigation levels							
W_1	11000	400	11400	5084	12710.0	1310.0	0.115
W_2	11000	1000	12000	8286	20715.0	8715.0	0.726
W_3	11000	1400	12400	8967	22417.5	10017.5	0.808
W_4	11000	8400	19400	10043	25107.5	5707.5	0.294
Fertility levels							
F_0	10820	2700	13520	6597	16492.5	2972.5	0.220
F_1	10820	2980	13800	8343	20857.5	7057.5	0.511
F_2	10820	3260	14080	9346	23365.0	9285.0	0.659

Price of 1 ton farmyard manure	=	Rs. 150.000
1 kg nitrogen (N)	=	Rs. 4.674
1 kg phosphorus (P_2O_5)	=	Rs. 5.313
1 kg potassium (K_2O)	=	Rs. 2.000
1 kg bittergourd	=	Rs. 2.500
Cost of one irrigation	=	Rs. 100.000

followed by W_1 (net profit = Rs. 1316.00; net return per rupee invested = Rs. 0.115).

Economic analysis of the results thus revealed that scheduling irrigation at IW/CPE = 1.2 is the best irrigation practice for bittergourd for maximum net profit as well as for higher net return per rupee invested. The same treatment was on par with W_4 (daily irrigation) in fruit yield with more or less the same amount of water used (Table 4). Although the daily irrigation treatment (W_4) recorded a slightly higher fruit yield than W_3, the higher amount of labour involved in the daily irrigation increased the cost of production of that treatment, thereby reducing the net profit and the net return per rupee invested. The treatment W_2 (IW/CPE = 0.8) having the fruit yield on par with W_3 was found to be the next economic treatment. The same treatment received only 10 irrigations as against 14 irrigations in W_3 and the former was significantly superior in water use efficiency than W_3. Hence under limited supply of water, irrigation at IW/CPE = 0.8 can be advocated.

Fertilizer application markedly influenced the economics of production. The net profit as well as net return per rupee invested increased with increase in fertilizer dose. However, the magnitude of increase in these values was higher when F_0 was increased to F_1 level. The treatments F_0, F_1 and F_2 resulted in net profit of Rs.2972.50, 7057.50, 9285.00 and net return per rupee invested of Rs.0.220, 0.511 and 0.659 respectively. The treatment F_2 (NPK at 60 : 30 : 60 kg ha^{-1} + FYM at 18 t ha^{-1}) however, proved to be the most economic one.

Summary

SUMMARY

An experiment was conducted at the Agronomic Research Station, Chalakudy, during the period from January 1983 to April 1983 to study the response of bittergourd to different water management practices and fertility levels in summer rice fallows. The treatments consisted of four levels of irrigation viz. irrigation at IW/CPE ratios of 1.2, 0.8 and 0.4 and the farmers' practice (control) and three fertility levels viz. Farmyard manure (FYM) 18 t ha^{-1}, FYM 18 t + NPK 30 : 15 : 30 kg ha^{-1} and FYM 18 t + NPK 60 : 30 : 60 kg ha^{-1}. The experiment was laid out as a 4 x 3 factorial experiment in randomized block design with three replications. The results of the experiment are summarised below.

1. Higher levels of irrigation or fertilizers did not influence significantly the length of vine at earlier stages of growth.

2. The number of leaves per plant was also not significantly affected by irrigation at earlier stages of growth. However, the effect due to fertilizer application was significant on leaf production on the 35th day.

3. Neither the irrigation nor the fertility levels did influence flowering duration significantly.

4. The Leaf Area Index noted on the 55th day was favourably influenced by the higher levels of irrigation and fertilizers.

5. The dry matter production per plant on the 55th day and at final harvest progressively increased with increase in the level of irrigation and fertilizers. The interaction effect due to irrigation and fertilizers (W x F) was also significant on dry matter production at final harvest.

6. The mean number of fruits produced per plant rose with increase in the level of irrigation and fertilizers.

7. Frequent irrigations and higher fertility levels markedly enhanced the mean length of fruit.

8. There was no discernible variation due to irrigation or fertilizers on the mean girth of fruit.

9. Higher levels of irrigation and fertilizers increased the mean weight of fruit.

10. Effect of irrigation and fertilizers on fruit yield was positive and significant. The higher fruit yields of 10.04 t ha^{-1} and 8.97 t ha^{-1} were produced by the 'farmer's practice' and IW/CPE ratio 1.2 respectively. The highest fertilizer level tried ie. FYM 18 t + NPK 60 : 30 : 60 kg ha^{-1} produced the maximum fruit yield of 9.35 t ha^{-1}.

11. Field water use efficiency was highest in the IW/CPE ratios 0.4 and 0.8 with a fruit yield of 25.17 and 23.54 kg $ha\text{-}mm^{-1}$ respectively. Among the fertility levels, FYM 18 t + 60 : 30 : 60 kg ha^{-1} recorded the maximum water use efficiency.

12. Total consumptive use was maximum in IW/CPE = 1.2 when compared to other ratios. Consumptive use values were slightly higher in plots receiving higher levels of fertilizers.

13. Soil moisture depletion pattern showed that bittergourd extracted 66 - 71 per cent of the total moisture from the top 30 cm soil layer. In comparison with wet regimes dry regimes depleted more soil moisture from the lower soil layers. However, the soil moisture depletion pattern did not vary

appreciably due to the different levels of fertilizers tried.

14. Levels of irrigation did not produce any significant influence on the content of nitrogen in plant parts viz. leaves, vines and fruits. However fertility levels significantly increased the percentage of nitrogen in plant parts at all stages of growth except in vines at the final harvest stage wherein the trend was almost similar.

15. The different levels of irrigation or fertilizers did not produce any significant effect on the phosphorus content of leaves, vines and fruits.

16. Irrigation practices significantly influenced the potassium content of leaves at 55th day and the daily irrigated plots showed the maximum potassium content. The fertility levels markedly increased the potassium content of leaves at 55th day and at final harvest. The effect due to fertility levels in vines was significant only at final harvest and the highest fertilizer level showed the maximum potassium content. But potassium content of fruits was not affected by fertilizer application.

17. Nitrogen uptake by the crop at 55th day and at final harvest was significantly increased by higher

levels of irrigation and fertilizers. The interaction between the two factors (W x F) was also significant at final harvest.

18. Phosphorus uptake by the crop at 55th day and at final harvest was also significantly increased by higher levels of irrigation and fertilizers. The interaction W x F was also significant at final harvest.

19. Potassium uptake of the crop at the two stages viz. 55th day and final harvest was significantly enhanced by higher levels of irrigation and fertilizers.

20. The organic carbon content of the soil determined after the experiment was not affected by irrigation as well as fertilizer application.

21. The levels of irrigation did not influence the build up of available nitrogen in the soil significantly. However, the available nitrogen status was considerably improved by fertilizers.

22. There was no influence on the available phosphorus content of the soil due to irrigation or fertilizers.

23. The available potassium content in the soil after the experiment was found to be significantly influenced by both irrigation and fertilizer levels. The least frequently irrigated treatments showed the maximum build up of available potassium. At higher levels of fertilizers, the status of available potassium was high.

24. Among the irrigation schedules IW/CPE = 1.2 recorded the maximum net profit of Rs.10017.50/ha with a net return of Rs.0.808 per rupee invested, followed by IW/CPE = 0.8 with a net profit of Rs.8715.00 and a net return of Rs.0.726 per rupee invested. Among the fertility levels F_2 (FYM 18 t + 60 : 30 : 60 kg ha^{-1}) produced the maximum net profit of Rs.9285.00 with a net return of Rs.0.659 per rupee invested.

The present study indicated that scheduling irrigation (3 cm depth) to bittergourd grown in the summer rice fallows at the IW/CPE ratio 1.2 was the most economic water management practice under the prevailing conditions. This involved irrigation at an approximate interval of 4 - 5 days after the establishment of the crop. Irrigation at the IW/CPE ratio of 0.8 (approximate interval 6 - 8 days) was also found to be an economic one under limited availability of water. The crop responded well to fertilizers also and the highest level tried viz. Farmyard manure 18 t + NPK 60 : 30 : 60 kg ha^{-1} produced the maximum yield and net returns.

References

REFERENCES

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 Agropecuria Brasileira. 13(3): 35-45.

Agarwala, S.C., and C.P. Sharma (1976). Plant nutrients - Their functions and uptake. In 'Soil fertility - Theory and Practice' (Ed. J.S. Kanwar) I.C.A.R., New Delhi. pp. 7-64.

Alexandrova, M. (1971)*. The effect of nitrogen fertilization on the nitrogen content and certain physiological characteristics of cucumbers. Grandinarska Lozarska Nauka. 8(4): 63-73.

Anonymous (1978). Cultivation practices for vegetables. University of Agricultural Sciences, Bangalore. pp. 85.

Anonymous (1980). Annual Report 1979-80, Co-ordinated project for research on water management (ICAR), Chalakudy Centre.

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

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

Anonymous (1981 c). Annual report 1979-80. Kerala Agricultural University, Vellanikkara.

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

Anonymous (1982b). Annual report 1980-81. Kerala Agricultural University, Vellanikkara.

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 dry land crop production. In 'Physiological aspects of dry land farming' (Ed. U.S. Gupta). Oxford and IBH Publishing Co., New Delhi, Bombay, Calcutta. pp. 3-145.

Bains, K.S. (1967). Effect of applied nutrients on soil fertility, chemical composition and yield of field beans. Indian J. Agron. 12(2): 200-206.

Balakumaran, N. (1981). Response of cowpea (Vigna unguiculata (L.) Walp) to water management practices and phosphorus nutrition. M.Sc.(Ag) thesis, College of Agriculture, Vellayani, Trivandrum.

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

Belik, V.F., and M.Ya. Veselovskii (1975)*. The characteristics of growth and development of irrigated watermelons. Nauchnye Trudy NII Ovoshch Kh. Va. 5: 254-257.

Bhosale, R.J., S.A. Khanvilkar, and R.K. Andhale (1978). Yield performance of watermelon (Citrullus vulgaris schard) Var. Sugar baby under graded levels of N, P and K. J. Maharashtra Agrl. Univs. 3(2): 93-95.

Bishop, R.F., E.W. Chipman, and C.R. Mc Eachern (1969). Effect of nitrogen, phosphorus and potash on yields and nutrient levels in laminae and petioles of pickling cucumbers. Canadian J. Soil Sci. 49: 297-304.

Blatter, E., J.F. Caius, and K.S. Mhaskar (1935). Indian Medicinal Plants. Second edition. M/s. Bishen Singh, Mahendrapal Singh, New Connaughat Place, Dehra Dun, 1130-1132.

Bodman, G.B. (1942). Nomograms for rapid calculation of soil density, water content and total porosity relationships. Amer. Soc. Agron. J. 34: 883-893.

Borna, Z. (1969)*. The effect of fertilization and sprinkler irrigation on cucumber and celery yields. Roczniki Wyzszej Szkoly Rolniczej W Poznania. 44: 15-26.

Bray, R.H., and L.T. Kurtz (1945). Determining total organic and available forms of phosphate in soils. Soil Sci. 59: 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.

Cantliffe, D.J. (1977 a). Nitrogen fertilizer requirements of pickling cucumbers grown for once - over harvest I. Effect on yield and fresh quality. J. American Soc. Hort. Sci. 102(2): 112-114.

Cantliffe, D.J. (1977 b). Nitrogen fertilizer requirements of pickling cucumber grown for once over harvest II. Effect on plant tissue, mineral nutrient concentrations. J. American Soc. Hort. Sci. 102(2): 115-119.

Chernovol, A.E. (1979)*. Cucumber yield in relation to the time of irrigation. Nauch-Tekhn. Byul. Ukr. NII Ovoschchevodi i Bakhchevod. No.10: 8-10.

Choudhary, B. (1979). Vegetables. 6th edition. National Book Trust, India, New Delhi. pp. 214.

Cocueci, S., M. Cocueci, and C.P. Treecani (1976)*. Effect of water defecit on the growth of squash fruit. Physiologiya Plantarum. 36(4): 379-382.

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

Cummins, T.L., and D.W. Kretchman (1974)*. Moisture stress relations to growth and development of the pickling cucumber. Out door vegetables crops research - 1974, Research summary. Ohio Agricultural Research and Development Centre, 1975 No.81: 23-24.

Dastane, N.G. (1972). A practical mannual for water use research in agriculture - 2nd edition. Navabharat Prakashan, 702, Budhawar Peth, Poona-2. pp. 120.

Dhesi, N.S., D.S. Padda, J.C. Kumar and B.S. Malik (1966). Response of bittergourd to N, P and K fertilization. Indian J. Hort. 23: 169-171.

Dimitrov, Z. (1973)*. Seasonal irrigation pattern of watermelons. Gradinarstvo. 15(11): 31-34.

Dimitrov, Z. (1974)*. Green house cucumber irrigation. B'lgarski Plodove Zelenchutsi i Konservi (1974). pp. 120-122.

Downes, J.D., and R.E. Lucas (1966)*. Pickling cucumbers yield in relation to NPK fertilization and P - K soil tests. Proc. 17th Int. Hort. Congr. Md, 1, Abstr. 456.

Duokel, K-H. (1966)*. The effect of varying water supply on yield of tomatoes and cucumbers under glass. Acta Hort. 4: 42-49.

Ermokhin, Yu.I., and I.V. Naumenko (1975)*. Regulation of cucumber nutrition by means of soil analysis. Nauchnya Trudy Omskogo S-kh Institute 140: 98-100.

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

Fiskell, J.G.A., and H.L. Breland (1967)*. Fertilizer requirements of watermelons. AR. Fla. Agric. Expt. Stats. pp. 97.

Fiskell, J.G.A., S.J. Locasio, and F.G. Martin (1970)*. Pattern of fertilization for watermelons II. Influence on nutrient distribution in soil and plant uptake. Proc. 83rd Ann. Meeting of the Florida State Hort. Soc. 83: 149-154.

Flocker, W.J., J.C. Lingle, R.M. Davis, and R.J. Miller (1965). Influence of irrigation and nitrogen fertilization on yield, quality, and size of cantaloupes. Proc. Amer. Soc. Hort. Sci. 86: 424-432.

Gardner, W.R. (1968). Availability and measurement of soil water. In 'Water Defecits and Plant growth' Vol.I (Ed. T.T. Kozlowski) Academic Press, New York. pp. 367-385.

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.

Ghildyal, B.P. (1971)*. Soil and water management for increased water and fertilizer use efficiency for rice production. Int. Symp. Soil Fert. Eval. Proc. Vol.I.

Grozdova, N. Ju. (1970)*. Uptake of N, P and K by cucumbers and tomato plants during different growth phases as a basis for a fertilizing system in pit houses. IZV. Akad. Nauko Azerb. SSR., Ser. biol., Nauka. No.I. pp. 100-104.

Hali, R. (1969). Bittergourd - a Kerala favourite. Indian Fmg. 19(5): 30-31.

Haynes, R., and S. Herring (1980)*. Effect of trickle irrigation on yield and quality of summer squash. Arkansas Farm Research. 29(5): 6.

Jackson, M.L. (1958). 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 Warzywnicky. 18: 47-61.

Jassal, N., K.S. Nandpuri and K.S. Randhawa (1972). Studies on the influence of irrigation and different doses of N, P and K on the flowering behavier and absorption of nutrient elements in muskmelon (Cucumis melo L.) J. Res. 9(2): 242-247.

Jassal, N.S., K.S. Randhawa, and K.S. Nandpuri (1970). A study on the effect of irrigation and certain doses of N, P and K on the weight of fruit and yield of muskmelon. (Cucumis melo L.). Punjab Hort. J. 10: 143-149.

Jose Mathew (1981). Response of groundnut (Arachis hypogaea L.) to phosphorus and potassium under different water management practices. M.Sc.(Ag.) thesis. College of Agriculture, Vellayani, Trivandrum.

Kagohashi, S., H. Kano, and M. Kagayama (1978)*. Studies on the nutrition of muskmelon (Cucumis melo L.) I. Characteristics of nutrient uptake by muskmelon. J. Japaneese Soc. Hort. Sci. 47(2): 203-208.

Kano, H., S. Kagohashi, and M. Kagayama (1978)*. Studies on the nutrition of muskmelon (Cucumis melo L.) II. Effects of restricted nutrient supply after pollination on the growth and fruit quality of muskmelon. J. Japaneese Soc. Hort. Sci. 47(3): 357-364.

Katyal, S.L. (1977). Vegetable growing in India. Oxford and IBH Publishing Co., New Delhi, Bombay, Calcutta pp. 153.

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

Konishi, K. (1974)*. The amount and nature of water consumption in muskmelon plants. Scientific reports of the Faculty of Agriculture, Okayama University. No.43: 27-37.

Kramer, P.J. (1969). Plant and soil water relations: Modern synthesis McGraw - Hill Inc., New York, London.

Largskii, Yu.N. (1971)*. The effect of fertilizers on changes in mobile forms of soil nutrients and on cucumber quality. Agrokhimiya (1971). No.2: 138-141.

Laske, P. (1979)*. Test to establish the nutrient uptake of a domestic cucumber crop. Bodenkultur 30(1): 7-20.

Locascio, S.T. (1967)*. Fertilizer requirements of water melons. AR. Fla. Agric. Exp. Stats. pp.105.

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.

Mahakal, K.G., A.T. Joshi, P.P. Deshmukh, and P.R. Pawar (1977). Effect of N, P and K on tinda (Citrullus vulgaris var. fistulosus) Orissa J. Hort. 5(1/2): 62-63.

Mani, S., and K.M. Ramanathan (1980). Studies on the available potassium status of soil as influenced by the application of nitrogen and potassium. Madras Agric. J. 67(12): 777-779.

Mc Collum, R.E., and C.H. Miller (1971). Yield, nutrient uptake and nutrient removal by pickling cucumbers. J. Amer. Soc. Hort. Sci. 96: 42-45.

Mengal, K., and L.C. Von Braunschweig (1972). The effect of soil moisture upon the availability of potassium and its influence on the growth of young maize plants (Zea mays L.) Soil Sci. 114: 142-147.

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

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

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

Mukhtar Singh, S.B. Mukheri, and N.B. Singh (1968). Response of potato to varying moisture regimes, nitrogen, phosphorus and potassium. Indian J. Agri. Sci. 38(1): 76-89.

Muminov, T.G. (1973)*. Forecasting the times of melon irrigation by means of leaf water content. Nauchnye Trudy N11 Ovoschche - Balchchevykh Ku'tar i Karo Felya No.10: 62-74.

Muthuvel, P., and K.K. Krishnamoorthy (1980). Influence of soil moisture and added N on P availability. Madras Agric. J. 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.

Nadkarni, K.M. (1954). Indian Materia Medica. Revised and enlarged by A.K. Nadkarni. Popular Book Depot, Bombay.

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

Novotorova, D.A. (1976)*. The effect of P fertilization on leaf P content and yield of green house cucumbers. Trudy Gor'kov. S-Kh Instituta (1976). 94: 13-15.

Ogunremi, E.A. (1978). Effect of nitrogen on melon (Citrullus lanatus) at Ibandan, Nigeria. Exptl. Agrl. 14(4): 357-365.

Olitta, A.F.L., T.A. DE, Abreu, and D.A.B. Marchetti (1978)*. Comparative study of irrigation by furrow and drip methods in melons. Solo. 70(2): 7-14.

Ortega, D.G., and D.W. Kretchman (1982). Water stress effects on pickling cucumbers. J. Amer. Hort. Sci. 107(3): 409-412.

Padda, D.S., B.S. Malik, and J.C. Kumar (1969). Response of muskmelon to nitrogen, phosphorus and potash fertilization. Indian J. Hort. 26: 172-175.

Pai, A.A., 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.

Pandey, R.P. and K. Singh (1973). Note on the effect of nitrogen and maleic hydrazide on sex expression, sex ratio and yield of bottlegourd (Lagenaria siceraria (Mol) Slandle) Indian J. Agri. Sci. 43(9): 882-883.

Pandey, U.C., Kirti Singh, M.S. Saimbhi (1974). Response of muskmelon (Cucumis melo L.) to foliar and soil application of nitrogen. Pl. Sci. 6: 74-79.

Parikh, H.S. and A. Chandra (1969). Effect of nitrogen on the number of male and female flowers in cucumber (Cucumis sativus L.). Allahabad Fmr. 43: 337-338.

Penny, M.G., K.G. Moore, and P.H. Lovell (1976 a). Some effects of K defeciancy on seedling development. Annls. Bot. 40(168): 801-813.

Penny, M.G., K.G. Moore. and P.H. Lovell (1976 b). Effects of K defeciancy on cotyledon photosynthesis and seedling development in Cucumis sativus L. Annls. Bot. 40(169): 981-991.

Pestova, S.T., and V.I. Pestova (1973)*. Changes in some physiological studies of melons in relation to the nutrient and water regimes. Nauchnya Trudy Nii Ovoschche Bakhchevykh Kul'tar Kartofelya No.10: 75-83.

Pettiet, J.V. (1971)*. Fertility requirements for mechanically harvested cucumbers. Misc. Fm. Res. 34(3): 7-8.

Pew, W.D., and B.R. Gardner (1983). Effect of irrigation practices on vine growth, yield and quality of muskmelon. J. Amer. Soc. Hort. Sci. 108(1): 134-137.

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

Prasad, S.R., and V. Singh (1979). Nitrogen and water requirements of cheena when grown after different crops. II. Consumptive use, pattern of soil moisture extraction and water use efficiency. Indian J. Agron. 24(4): 399-404.

Rajendran, P.C. (1981). Studies on the effects of graded doses of N, P and K on growth, yield and quality of pumpkin var. CM-14. M.Sc.(Hort.) thesis. College of Horticulture, Vellanikkara, Trichur.

Randawa, K.S., D.S. Cheema, and K.S. Sandhu (1981). The effects of nitrogen, phosphorus and potassium on growth, yield and quality of new muskmelon varieties. Haryana J. Hort. Sci. 10(1/2): 88-94.

Rankov, V., and M. Aleksandrova (1982)*. The uptake of nutrients by gherkins. Fiziologiya na Resteniyata 8(3): 59-65.

Rekhi, S.S., K.S. Nandpuri, and H. Singh (1968). Influence of fertilizer application on sex expression of muskmelon. J. Res., Ludhiana. 5: 199-202.

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

Rhodes, P.R., and K. Matsuda (1976). Water stress. rapid polyribosome reductions and growth. Plant Physiol. 58(5): 631-635.

Sahu, S.K., and B. Behera (1972). Note on the effect of rhizobium inoculation on cowpea, groundnut and green gram. Indian J. Agron. 17(4): 359-360.

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

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, C.B., and V. Shukla (1972). Response of pumpkin to nitrogen and phosphate applications and their optimum levels. Indian J. Hort. 29(2): 179-183.

Sharma, R.P., and K.P. Parashar (1979). Effect of different water supplies, levels of N and P on consumptive use of water, water use efficiency and moisture extraction pattern by cauliflower (var. Snowball-16). Indian J. Agron. 24(3): 315-321.

Silk, W.K. (1980)*. Plastochron indices in cantaloupe grown on an irrigation line source. Bot. Gazette 141(1): 73-78.

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 ina hot arid climate. Agron. J. 70(6): 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. 24(3): 267-275.

Singh, N.P., and S.K. Sinha (1977). Water use efficiency in crop production. In 'Water requirement and Irrigation Management of crops in India'. Water Technology Centre, IARI, New Delhi. pp. 286-335.

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-16. pp. 593.

Stanberry, C.D., and M. Lorey (1965). Barley production under various nitrogen and moisture levels. Agron. J. 57: 31-34.

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

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. Teck. Bull. 3: 1-80.

Tayel, M.A., M.A. Moursi, and K. Habbasha (1965)*. Effect of some cultural treatments on the nitrogen metabolism of cucumber plants. Ann. Agri. Sci. Cairo. 10(2): 261-278.

Tesi, R., L. Giustiniani and A. Graifenbery (1981)*. Nutritional requirements of courgetts grown under glass (Cucurbita pepo). Rivisita della Ortafloroftutticoltura Italiana. 65(4): 265-277.

Tisdale, S.L., and W.L. Nelson (1975). Soil Fertility and Fertilizers. 3rd edition. Mac Millan Publishing Co., Inc. New York. pp.694.

Tomitaka, Y. (1974)*. Studies on the amount of evapotranspiration from crop plants. III. The effect of moisture regimes on evaporation from cucumber plants. J. Agrl. Sci. (Japan) 19(1): 19-24.

Varga, D. (1973)*. The problem of cucumber irrigation in Hungary. Zanradnictvi (1973). 199-211.

Varga, G. (1971)*. The combined effect of temperature and water supply on yield. Agrarta Domanyi Egyetem Kozlemenyei No.2: 345-347.

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 green gram. Indian J. Agric. Sci. 45(1): 11-16.

Vittum, M.T., and W.J. Flocker (1967). Vegetable crops. In 'Irrigation of Agricultural Lands' (Ed. R.M. Hagan, H.R. Haise, and T.W. Edminister) American Society of Agronomy, Wisconsin, USA: 674-685.

Wilcox, G.E. (1973). Muskmelon response to rates and sources of nitrogen. Agron. J. 65(5): 694-697.

Zabara, Yu.M. (1977)*. The effect of irrigation on root distribution in cucumbers grown on derno-podzolic soils. Nauch. Trudy Belorus Nll Kartofelvedi i Plodoovoschchevod No.2. 147-150.

* Original not seen

Appendices

Appendix I. Abstract of analysis of variance
Biometric observations

Source	Df	Mean squares				
		Length of vine		Number of leaves		LAI
		20th day	35th day	20th day	35th day	55th day
Blocks	2	37.3441*	136.1128	1.1791	121.5916	0.2221
Irrigation (W)	3	11.2298	356.2935	0.2230	150.3404	0.3106*
Fertility levels (F)	2	4.5251	374.8770	2.4987	300.7832**	0.3664*
Interaction (W x F)	6	2.1906	13.7789	0.1801	23.8947	0.0533
Error	22	8.6660	154.7769	0.8505	50.1655	0.0671

* Significant at 5 per cent level.
** Significant at 1 per cent level.

Appendix I contd...

Source	Df	Dry matter production		Number of days taken for 50 per cent flowering	
		55th day	Final harvest	Male flowers	Female flowers
Blocks	2	320.9427	234.8193	3.5850	5.7800
Irrigation (W)	3	956.5226**	38399.7903**	5.5567	6.1133
Fertility levels (F)	2	4289.8826**	17703.8731**	2.0850	11.4450
Interaction (W x F)	6	562.0587	3313.0555*	7.9717	5.2217
Error	22	401.0600	1289.3517	8.0073	8.7473

* Significant at 5 per cent level.

** Significant at 1 per cent level.

Appendix II. Abstract of analysis of variance
Yield components, yield and water use efficiency

Source	Df	Mean squares						
		Number of fruits per plant	Length of fruit	Girth of fruit	Mean weight per fruit	Yield per plant	Yield per hectare	Field water use efficiency
Block	2	1.260	0.061	0.293	71.483	0.014	307018	1.359
Irrigation (W)	3	32.530**	10.339**	0.570	318.586**	0.478**	40971644**	65.639**
Fertility levels (F)	2	25.100**	5.307*	0.085	135.050*	0.271**	23217295**	177.623**
Interaction (W x F)	6	1.160	0.189	0.247	16.730	0.013	1105694	6.530
Error	22	3.060	1.406	0.231	36.115	0.015	1294618	10.376

*Significant at 5 per cent level

** Significant at 1 per cent level

Appendix III. Abstract of analysis of variance
Content of nitrogen in leaves, vines and fruits

Source	Df	Mean squares				
		Leaves		Vines		Fruits
		55th day	Final harvest	55th day	Final harvest	
Blocks	2	3.3060*	1.4761	0.1251	0.0640	0.0868
Irrigation (W)	3	0.3100	0.3171	0.1040	0.0306	0.1122
Fertility levels (F)	2	1.4450*	1.1358	0.4715**	0.3405	0.6999**
Interaction (W x F)	6	0.5700	0.3678	0.0510	0.2108	0.0958
Error	22	0.3720	0.3137	0.0730	0.2457	0.0610

* Significant at 5 per cent level

** Significant at 1 per cent level

Appendix IV. Abstract of analysis of variance
Content of phosphorus in leaves, vines and fruits

Source	Df	Mean squares				
		Leaves		Vines		Fruits
		55th day	Final harvest	55th day	Final harvest	
Blocks	2	0.00721	0.00450	0.00890	0.00139	0.00940
Irrigation (W)	3	0.00126	0.00990	0.00573	0.01908	0.00447
Fertility levels (F)	2	0.00151	0.00180	0.00735	0.00273	0.00010
Interaction (W x F)	6	0.00169	0.00140	0.00723	0.00267	0.00368
Error	22	0.00291	0.00500	0.00942	0.00705	0.00551

Appendix V. Abstract of analysis of variance

Content of Potassium in leaves, vines and fruits

Source	Df	Mean squares				
		Leaves		Vines		Fruits
		55th day	Final harvest	55th day	Final harvest	
Blocks	2	0.0178	0.7322	0.2986	0.2713	0.1263
Irrigation (W)	3	0.4505*	0.0730	0.1706	0.3997	0.4335
Fertility levels (F)	2	0.7192**	1.1541**	0.5864	1.4288**	0.1654
Interaction (W x F)	6	0.1806	0.1112	0.3468	0.3211	0.0867
Error	22	0.0961	0.1328	0.2806	0.1898	0.1528

* Significant at 5 per cent level

** Significant at 1 per cent level

Appendix VI. Abstract of analysis of variance
Uptake of major nutrients

Source	Df	Mean squares					
		Nitrogen uptake		Phosphorus uptake		Potassium uptake	
		55th day	Final harvest	55th day	Final harvest	55th day	Final harvest
Blocks	2	123.442*	152.396	1.107	0.150	15.685	117.604
Irrigation (W)	3	150.010**	1362.267**	3.383**	50.916**	201.433**	2719.003**
Fertility levels(F)	2	505.539**	1686.241**	5.101**	18.836**	549.596**	2856.473**
Interaction (W x F)	6	55.785	203.605*	0.392	6.115*	33.380	117.216
Error	22	26.648	58.855	0.531	1.756	30.687	112.613

* Significant at 5 per cent level

** Significant at 1 per cent level

Appendix VII. Abstract of analysis of variance
Soil chemical properties

Source	Df	Mean squares			
		Organic carbon (%)	Available N (kg ha^{-1})	Available P_2O_5 (Kg ha^{-1})	Available K_2O (Kg ha^{-1})
Blocks		0.00024	126.004	12.176	4929.303**
Irrigation (W)		0.00096	114.576	71.518	12801.279**
Fertility levels (F)		0.00079	1988.191**	7.268	9481.503**
Interaction (W x F)		0.00347	268.658	37.474	829.635
Error		0.00257	202.841	49.656	609.974

** Significant at 1 per cent level

WATER MANAGEMENT PRACTICES FOR BITTER GOURD (*Momordica charantia* L) UNDER DIFFERENT FERTILITY LEVELS

By

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ABSTRACT OF A THESIS

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ABSTRACT

An experiment was conducted at the Agronomic Research Station, Chalakudy during 1982-83 summer season to study the response of bittergourd (Momordica charantia L.) to different water management practices and fertility levels. The treatments consisted of four levels of irrigation (irrigation at IW/CPE ratios of 0.4, 0.8 and 1.2 and the farmers' practice) and three fertility levels (Farmyard manure (FYM) 18 t ha^{-1}, FYM 18 t + NPK 30 : 15 : 30 kg ha^{-1} and FYM 18 t + NPK 60 : 30 : 60 kg ha^{-1}). The experiment was laid out as a factorial experiment in randomised block design with three replications.

The study revealed that bittergourd responded well to frequent irrigations and higher levels of fertilizers. Biometric characters like leaf area index and dry matter production and yield contributing characters like mean number of fruits per plant, mean length of fruit and mean weight of fruit were favourably influenced by frequent irrigations and higher levels of fertilizers. Total fruit yields were also higher in frequently irrigated and well fertilized plots.

Field water use efficiency was higher in the less frequently irrigated treatments (IW/CPE = 0.4 and 0.8).

Soil moisture extraction pattern showed that bittergourd extracted 66 - 71 per cent of the total water use from the top 30 cm soil layer. Total consumptive use was maximum in IW/CPE = 1.2.

Nitrogen content in plant parts at all the stages of analysis except in vines at final harvest, was enhanced by fertilizer application. Potassium content of leaves (all the stages) and vines (at final harvest) was increased by fertilizer application. In general major nutrient composition of plant parts was less affected by irrigation. Nitrogen, phosphorus and potassium uptake of the crop followed the trend more or less similar to that of dry matter production at all the stages.

Available potassium status of the soil after the experiment was considerably reduced by frequent irrigations. Fertilizer application markedly increased the available nitrogen and available potassium status of the soil.

Among the irrigation schedules IW/CPE = 1.2 recorded the maximum net profit and net return per rupee invested followed by IW/CPE = 0.8. Among the fertilizer levels, Farmyard manure 18 t + NPK 60 : 30 : 60 kg ha^{-1} produced the maximum net profit and net return per rupee invested.