PRODUCTION POTENTIAL OF AMARANTHUS UNDER IRRIGATION AND NITROGEN LEVELS

BY

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THESIS

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Dedicated to my beloved parents and sisters

DECLARATION

I hereby declare that this thesis entitled "Production potential of amaranthus under irrigation and nitrogen 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 "Production potential of amaranthus under irrigation and nitrogen levels" is a record of research work done independently by Sri. Rajan, S. 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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LIST OF ABBREVIATIONS

mm	-	millimetre
cm	-	centimetre
g	-	gram
kg	-	kilogram
l	-	litres
ha	-	hectare
N	-	Nitrogen
IW	-	Irrigation water
CPE	-	Cumulative pan evaporation
Fig	-	Figure
DAP	-	Days after planting
BCR	-	Benefit cost ratio
LAI	-	Leaf area index
FYM	-	Farm yard manure

INTRODUCTION

INTRODUCTION

India is the second largest producer of vegetables in the world. At present, the vegetables occupy nearly 2 to 2.5 per cent of the total cropped area with an annual production of 45 million tonnes (Seshadri, 1990). Among the vegetable crops, leafy vegetables constitute a major item of human diet. The importance of leafy vegetables in supplying valuable nutrients, particularly vitamins and minerals in human diet has been well established. They promote the process of digestion and neutralise the acidic compounds produced in the course of digestion. Dieticians recommend a daily consumption of at least 280 g of vegetables in a balanced diet. However the present percapita consumption of vegetables in India is low to the tune of only 100 to 120 g a day. It is estimated that the anticipated production will be much lower than the requirement of vegetables in future. This necessitates concerted research efforts to increase the productivity and improve the quality of the vegetable products.

As far as Kerala is concerned, the extent of cultivable land is limited and hence the vegetable production can be enhanced only through intensive multiple cropping practices giving more emphasis to the efficient use and management of water resources and other productive inputs. Therefore growth and yield of amaranthus and optimum irrigation requirement of the crop are lacking. Similarly information on the influence of nitrogen on growth and yield of amaranthus under irrigated condition is also meagre.

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

1. The effect of irrigation on growth and yield of amaranthus varieties grown in summer rice fallows.
2. The effect of different levels of nitrogen on growth and yield of amaranthus.
3. Optimum irrigation requirement for amaranthus grown in summer rice fallows.
4. Optimum nitrogen dose for amaranthus grown in summer rice fallows and
5. Economics of cultivation.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Studies on the water and nutritional requirements of vegetables in Kerala is limited and as such literature on this aspect is relatively less. Available literature however emphasised the importance of moisture regimes, frequent irrigations in low water table conditions and judicious application of manures and fertilizers under standard field conditions. In the case of amaranthus, very little research has been reported on the irrigation and nitrogen requirements of the crop. Wherever sufficient information is lacking, relevant literature on other vegetables and related crops are also reviewed.

2.1. Effect of irrigation

Soil moisture is one of the most limiting factors in vegetable production. The growth and development of vegetables depend on the availability of soil moisture. Increased growth and higher yields can be expected when there is adequate soil moisture during cropping period.

2.1.1. Growth and yield

Dastane *et al*. (1963) in a field trial on tomato in a sandy loam soil of medium fertility observed best growth of the plants in the range of 50 to 100 per cent available soil moisture level. In another experiment, Dunkel (1966) grown tomatoes and cucumbers at different soil moisture conditions in the upper 10 cm soil and irrigated the crops using overhead sprinklers. He obtained the highest yield of both the crops when the soil moisture did not drop below 70 per cent of field capacity and a water requirement of 600 to 700 mm was reported for optimal yields. The necessity of daily irrigation to bitter gourd during summer season in Kerala was emphasised by Hali (1969). A parabolic relationship between yield and soil moisture content was observed in cucumber by Varga (1971). He also found that the optimum soil moisture content for the crop was 68 to 75 per cent of field capacity.

In a study with broad beans, Tamaki and Naka (1971) reported that high soil moisture content (85 per cent of field capacity) increased the number of branches, stem length, leaf number and dry weight of various aerial parts at later stages of growth. In an experiment with melon, Neil and Zunino (1972) reported that irrigation given upto 80 per cent of maximum evaporation which amounts to 60 per cent of the potential evapotranspiration was economically feasible. Average irrigation requirement worked out was 2000 m^3/ha. Raising the irrigation rate produced heavier melons with improved flavour and decreased firmness. Varga (1973) after 10 years of field trials in cucumber reported that the optimum number of irrigation was three to five. He indicated that 30 to 40 days between flowering and fruit ripening was a critical phase for the crop and recommended irrigation with 40 mm water. He also reported that excessive watering was deleterious. Dimitrov (1974) in a glasshouse trial recorded the highest yield of cucumber when the soil moisture was maintained at 70 per cent of field capacity before picking and 90 per cent during the picking period. The yield was 26 per cent higher than the control when 70 per cent of the field capacity was maintained during the entire growing season.

In trials with brinjal, Umrani and Khot (1974) obtained the highest yield with irrigation at 45 mm Cumulative Pan Evaporation (CPE) as compared to irrigation at every 15, 30, 60 or 75 mm CPE. Hafeez and Cornillon (1976) observed increased growth in brinjal with five irrigations per week and least with one per ten days. Motoki and Kurokowa (1977) applied irrigation to melons at different soil moisture regimes ranging from pF 2.7 to 2.0 and obtained optimum plant growth and yield with irrigation at pF 2.5. Katyal (1977) recommended frequent irrigations for bittergourd at an interval of three to four days during dry weather conditions. In field trials, tomato yields were higher with irrigation at an IW/CPE of 0.7 (Pugila *et al*., 1977). Rudich *et al*. (1978) reported that irrigation during the fruitset and fruit development stages of tomato increased yield by 53 t/ha as compared to unirrigated plants. Pai and Hukheri (1979) while noting the water requirement of vegetables suggested that for good growth of vegetables, the soil moisture should be maintained at or above 75 per cent of availability in the active root zone. They further explained that water requirement would depend upon the soil and the season in which the crops were grown and suggested three to four irrigations per month for summer and two irrigations per month for rabi at a place like New Delhi. In three year trials with head cabbage, Kolota (1979) reported that irrigation raised the total yield by 53.40 per cent and improved the head quality.

Imbamba *et al*. (1979) studied the effect of soil moisture stress on photosynthesis, transpiration and leaf enlargement of *Amaranthus lividus*. They observed that severe desiccation for three days or more greatly reduced the rates of leaf expansion, photosynthesis and transpiration. When desiccated plants were rewatered, recovery of leaf water potential to the original levels was incomplete even after 18 hours.

Preliminary studies on scheduling irrigation to bittergourd at the Agronomic Research Station, Chalakkudy, Kerala, indicated that three cm irrigation at IW/CPE ratio of 0.4 was optimum for the crop in summer rice fallows (Anon., 1980). Both the number of fruits per plant and 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). Another experiment conducted at Chalakkudy in summer rice fallows to evaluate drip irrigation in ashgourd recorded the highest yield at IW/CPE ratio of 1.0 followed by 0.7. However these two treatments were on a par and significantly superior over 0.4 IW/CPE ratio (Anon., 1982).

Smittle and Threadgill (1982) compared two irrigation levels in a field trial with cucumber. They observed that the highest marketable fruit yield resulted from irrigation at 0.3 bar soil water tension. George Thomas (1984) found that bittergourd responded well to irrigation. Biometric characters like length of vine, LAI and dry matter production were favourably influenced by frequent irrigation.

Jayakrishnakumar (1986) reported that bhindi responded well to frequent irrigation and application of nitrogen in lesser number of splits. Plant height, LAI, dry matter production and yield contributing characters like number of fruits and length and weight of fruits were favourably influenced by frequent irrigation and application of nitrogen in lesser number of splits. In an experiment with onion, Hegde (1986) found that irrigation when soil water potential reached 0.45 to 0.65 bar resulted in maximum dry matter production, nutrient uptake and yield. Results of the field trials on cabbage revealed that irrigation increased yields and reduced yield fluctuations (Redai and Islam, 1987). Hegde (1987) reported that irrigating watermelon when soil matric potential at 15 cm depth reached -25 kpa resulted in the highest dry matter production (193 g/plant) and fruit yield (35.58 t/ha).

In field trials with radish, highest seed yield was recorded with IW : CPE ratio 1.6 and by far the lowest with 0.4 ratio during the first year of study (Mehla et al., 1987). Such differences were however, non-significant during the second year. They also suggested optimum nitrogen rates for radish as 66.61, 66.60, 67.92 and 63.20 kg/ha with 0.4, 0.8, 1.2 and 1.6 IW : CPE ratios respectively. Alagia Pillai (1987) studied the water requirement of tomato and reported that there was increase in fruit yield by 67 per cent at 40 per cent available soil moisture (ASM), 116 per cent at 60 per cent ASM and 125 per cent at weekly irrigations.

Chukwuma (1988) conducted lysimetric studies on *Amaranthus hybridus*. Results of the experiment revealed that moisture stress had adverse effect on vegetable and seed production. He also found that irrigation frequency fell but amount of water applied increased with increasing moisture stress before irrigation. For optimum use of limited water supplies in the dry season, irrigation at 50 per cent field capacity was recommended. Field experiments indicated that on an average, irrigation based on 0.7 IW/CPE ratio with 60 mm depth recorded 8.0, 24.2 and 164.5 per cent increase in bulk yield of onion over 0.9, 0.5 IW/CPE ratio and unirrigated control respectively (Palled *et al*., 1988). Sammis and Wu (1989) studied the yield response of head cabbage to 10 different trickle irrigation rates (0.42 to 1.94 mm/day). They found that marketable yield increased linearly with increasing water application. Subba Rao (1989) reported that cucumber responded well to frequent irrigations and higher levels of nitrogen and potassium. Growth characters like length of vine, number of leaves, Leaf area index (LAI) and dry matter production (DMP) as well as yield components like mean length, girth, weight and number of fruits were favourably influenced by one or more of the above factors.

The above review clearly reveals the importance of irrigation in enhancing growth and yield of certain vegetable crops. It also indicates the efficient use of water and its efficient management under limited supply by following certain methods of irrigation. Moisture stress condition invariably reduces the yield components and yield of vegetables.

2.1.2. Plant nutrient content and uptake

Plant nutrient content and uptake are closely related to water use.

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

In another study, George Thomas (1984) observed that the levels of irrigation did not produce any significant influence on the content of nitrogen and phosphorus in plant parts of bittergourd. But the irrigation practices significantly influenced the potassium content of leaves and the daily irrigated plots showed maximum potassium content. He also reported that nitrogen, phosphorus and potassium uptake of the crop was significantly increased by higher levels of irrigation. Jayakrishnakumar (1986) reported that in bhindi uptake of nitrogen, phosphorus and potassium recorded at 40th and 55th days was significantly increased by frequent irrigation schedules.

Ferreyra et al. (1987) observed that excessive water application (1.3 times pan evaporation) significantly reduced N, P and K absorption by *Capsicum* plants. Yield was highest with 0.7 times pan evaporation which resulted in N, P and K absorption rates of 138 to 150, 14.0 to 15.42 and 122 to 142 kg/ha respectively.

Hegde (1988a) found that irrigation at high soil water potential either tended to decrease or failed to change the concentration of N, P, K, Ca and Mg in leaves and bulbs of onion plants, but the uptake of these nutrients generally increased due to higher drymatter production.

2.1.3. Consumptive use and moisture extraction pattern

In experiments with melon crop, Neil and Zunino (1972) found that total water uptake by the crop was 2730 m^3/ha. The water uptake in successive growth stages was 560 m^3/ha between germination and fruitset, 1008 m^3/ha upto fruit enlargement, 882 m^3/ha upto prematurity and 280 m^3/ha upto harvest. Experiments with cauliflower at IARI, New Delhi, in sandy loam soils indicated that major amount of soil moisture (90 per cent) was utilised by the crop from the zero to 45 cm soil layer. About 50 per cent of the total moisture extraction was from zero to 15 cm soil layer (Sharma and Parashar, 1979).

George Thomas (1984) observed that consumptive use increased with increase in the level of irrigation in the case of bittergourd. In another experiment with bhindi, Jayakrishnakumar (1986) observed that total consumptive use increased with increase in irrigation frequency. Field water use efficiency was high in less frequently irrigated treatments. He also reported that bhindi on an average extracted 68.53 per cent of the total water use from the top 30 cm layer.

Sharma and Kuma (1989) studied the effect of irrigation and nitrogen on growth, yield, consumptive use and water use efficiency of Indian mustard. Results of the study revealed that water use and water use efficiency increased with irrigation and with nitrogen application. Field experiments on cucumber (Subba Rao, 1989) also showed that field water use efficiency was high in the less frequently irrigated treatments and higher levels of nitrogen and potassium. He also reported that cucumber extracted as much as 60 per cent of the total water used from the top 30 cm layer of soil.

2.1.4. Quality of vegetable

Irrigation and moisture availability have got qualitative as well as quantitative effects on plant constituents. It affects the economic yield and quality of the product.

Dikil et al. (1980) observed that irrigation of brinjal reduced the contents of total sugars, protopectin, cellulose, acids and total fat but increased the contents of water soluble pectin. They also observed that irrigation had a variable effect on the mineral composition and vitamin content of fruits.

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

However the effect of irrigation was not significant in influencing the crude protein content of bhindi fruits (Jayakrishnakumar, 1986).

2.2. Effect of nitrogen

2.2.1. Growth and yield

Sharma and Shukla (1972) observed a significant increase in yield of pumpkin in both rainy and summer seasons by increasing nitrogen levels. Suggested rates for economic production were 103 kg N/ha for summer crop and 96 kg N/ha for the rainy season crop. In a study to find out the influence of different levels of nitrogen on the composition and yield of water melon, Locascio et al. (1972) noticed that mean length and fresh weight of vines were significantly improved under high doses of nitrogen application. Diaz et al. (1973) studied the effect of nitrogen, phosphorus and potassium fertilization on cucumber yield. The study revealed that additional nitrogen application increased the total yield in various cucurbits.

Chauhan and Gupta (1973) in their experiments found a linear increase in okra yield upto highest level of nitrogen fertilization under study (67.5 kg N/ha) in sandy loam soils. In another field experiment, Verma et al.

(1974) observed the highest fruit yield in bhindi with 150 kg N/ha, applied in the proportion of 3 foliar : 1 soil. Foliar sprays were applied at weekly intervals starting from 25 days after sowing. Antoniani (1974) in a fertilizer trial with cabbage obtained highest yields with nitrogen at 200 kg/ha in combination with 300 kg P_2O_5/ha and 200 kg K_2O/ha. In chemical fertilizer trials on amaranthus conducted in Dahomey, good results were obtained with 400 to 800 kg/ha NPK (10-10-20) plus 10 to 20 t/ha organic manure (Grubben, 1974).

Borna (1974) in two series of field experiments observed highest yields of cabbage and cauliflower with applications of 600 kg NPK (2-2-3)/ha without irrigation and 900 kg/ha with furrow irrigation. The highest yields of tomatoes were recorded with 200 kg NPK/ha without and 600 kg NPK/ha with furrow irrigation. Leek yield was the highest with 400 kg NPK/ha, without and 600 kg/ha with furrow irrigation. He also observed that cucumbers and celery performed best with 300 kg NPK/ha without and 500 kg/ha with sprinkler irrigation. Katyal (1977) reported that the application of 50 t/ha of farm yard manure (FYM) as basal dose and a top dressing of ammonium sulphate at the rate of 100 kg/ha soon after flowering was sufficient for a successful crop of bittergourd.

Vuurmans and Grubben (1977) studied the effect of nitrate application on yield and composition of tropical leaf vegetables. The study revealed that nitrate application increased the fresh and dry weight, leaf production of all vegetables (notably amaranthus) and their total nitrogen, nitrate, protein, oxalic acid and carotene contents. Voigtander (1978) reported that application of one to four side dressings of a liquid nitrogenous fertilizer by sprinkler irrigation gave higher yields of lettuce and cabbage. Dziezyc et al. (1978) observed that under irrigated conditions an increase of the nitrogen doses increased head cabbage and leek yields but had no effect on celery. In the crops, the nitrogen content rose with increasing nitrogen rates.

Gupta and Rao (1979) experimented with okra to study the different levels of nitrogen fertilization and soil moisture regimes on fruit size and yield. They concluded that nitrogen fertilization significantly increased the fruit size and yield of okra. Subbiah and Ramanathan (1980) reported that the optimum fertilizer dose for Co 1 and Co 2 amaranthus as 60 kg N and 20 kg K/ha along with a basal application of 50 kg/ha of P_2O_5 and 10 t/ha of FYM. The effect of fertilizer application on the grain yield of amaranthus was studied by Alejandre and Gomez (1981).

They found that highest grain yield of 2.28 t/ha was obtained with 90 kg N + 30 kg P_2O_5 at a population density of 30,000 plants/ha. Keskar *et al.* (1981) studied the comparative efficacy of soil and foliar application of nitrogen through urea on yield of leafy vegetable *chaulai* (*Amaranthus blitum*). The highest yield (200.8 q/ha) of *Amaranthus blitum* was obtained from plots sown at 100 kg seeds/ha receiving 50 kg N/ha.

In a field experiment, Batal and Smittle (1981) observed that the highest marketable yield of bell pepper (*Capsicum annuum* L.) resulted when sufficient N was added to maintain soil NO_3-N levels between 20 ppm (spring) and 30 ppm (fall). They also noticed that yields of bell pepper were improved by frequent irrigation and nitrogen top dressing. Frequent irrigation influenced the yield increase only when additional nitrogen was applied to maintain a high soil NO_3-N level. In field trials on the response of *Capsicum annuum* to nitrogen fertilization, Srinivas and Prabhakar (1982) found that application of 150 kg N/ha in three split doses namely at planting and 30 and 60 days after planting gave the highest yield of better quality fruits. Singh *et al.* (1983) reported that out of the four levels of nitrogen (0, 25, 50, 75 kg/ha) maximum number of fruits, maximum diameter of fruits, seed yield and thousand seed weight in round melon were observed with 75 kg N/ha. In two season trials (summer and autumn) Ramachandra and Thimmaraju (1983) observed highest yield (116 q/ha in summer and 106 q/ha in autumn) of amaranthus receiving 200 kg N/ha. Keskar et al. (1983) experimented on amaranthus with nitrogen at 20 to 50 kg/ha applied through foliage. The highest average yield (121 to 127 q/ha) was obtained from plants which received 45 kg N/ha through soil + five kg N/ha through the foliage.

In Kerala, an experiment to study the response of bittergourd to different water management practices and fertilizer levels in summer rice fallows revealed that higher levels of fertilizers (N, P and K) increased the leaf area index (LAI) and dry matter production (DMP) (George Thomas, 1984). In a pot culture study, Nawawi et al. (1985) raised amaranthus plants under 0, 25 and 50 per cent shade and at four levels of nitrogen 0, 34.5, 69 and 103 kg/ha. They obtained the highest number of leaves, largest leaf area and greatest leaf dry weight on the 49th day from plants which received 69 kg N/ha grown without shade. Singh et al. (1985) conducted field experiments to study the effect of split application of nitrogen on growth and yield of amaranthus. The nitrogen levels tried were 0, 20, 40 and 60 kg N/ha with three modes of application and ten stages of clipping. Results revealed that application of 60 kg N/ha in two equal splits, first half as basal and the rest as top dressing after the fifth clipping (eight weeks after sowing) was found to be the best for getting maximum plant height and optimum leaf/stem ratio resulting in high green leaf yield.

Veeraraghavaiah et al. (1985) studied the response of coriander varieties to nitrogen fertilization using five levels of nitrogen (0, 15, 30, 45 and 60 kg/ha) and three varieties. The results indicated that there was an increase in yield components and yield with increase in the dose of nitrogen. They reported that response of coriander to nitrogen application was quadratic and increase in plant height and number of seeds/plant was significant only upto 45 kg N/ha. The economic optimum dose of nitrogen worked out was 41 kg/ha. In field experiments with grain amaranthus, Bressani et al. (1987) applied NPK fertilizer (12-24-12) at four levels 0, 30, 60 and 90 kg/ha. They obtained maximum plant height of 180 cm with highest fertilizer dose. However the effect of fertilizer on crop yield was not significant. Results of the field experiments on cabbage revealed that head yield of cabbage increased with increasing dose of nitrogen upto 150 kg/ha (Prabhakar and Srinivas, 1987).

Pal (1987) in field trials to study the effect of four levels of nitrogen (0, 46, 230 and 460 kg/ha/year) and phosphorus (0, 16, 32 and 64 kg/ha/year) on betelvine observed that the application of higher dose of nitrogen appreciably increased the leaf size and total number of marketable leaves. Mangal et al. (1987) reported that the effect of nitrogen on length of muskmelon vines was on a par for 60 kg and 120 kg N/ha. Growth of vine was significantly poor where nitrogen application was not made. Mean length of vine and fresh weight of plant were significantly improved under higher doses of nitrogen application. In a study with water melon, Hegde (1987) reported that increasing levels of nitrogen fertilization upto 180 kg/ha increased the fruit yield. In field trials over three seasons, Vadivel et al. (1988) reported that among the five levels of nitrogen tried, viz., 0, 100, 200, 300 and 400 kg/ha, 300 kg N/ha produced maximum yield of brinjal cultivar Annamalai. 400 kg N/ha did not produce the expected increase in the yield obviously due to the diminishing utility of nitrogen beyond 300 kg/ha. The response of vegetable french bean to different levels of nitrogen from zero to 160 kg/ha was studied by Srinivas and Naik (1988). They observed that pod yield increased with increasing rate of nitrogen and maximum yield was obtained at 160 kg/ha. Leskovar et al. (1989) raised capsicum plants in sand culture at three nitrogen levels (56, 84 and 112 mg/litre). They reported that nitrogen stimulated root and shoot growth of capsicum and this effect was significantly different for the root components. In an experiment to study the influence of NPK fertilization on growth and yield of bittergourd variety VK-1 (Priya) under partially shaded conditions of coconut gardens, it was found that higher levels of nitrogen (upto 90 kg/ha) had profound influence on growth characters of bittergourd and the response to nitrogen levels was linear (Ravikrishnan, 1989).

The above review brings about the fact that most of the growth characteristics are favourably affected by nitrogen application. It was evident in most experiments that irrespective of the crop, as the nitrogen levels were increased, proportionate increase was also observed in growth and yield.

2.2.2. Plant nutrient contents and uptake

As a consequence of nitrogen application, Tayel et al. (1965) observed that both nitrogen percentage and the total nitrogen content were increased in different plant parts of cucumber. It was also observed that the total nitrogen absorbed by the plants per unit area increased with nitrogen fertilization. Alexandrova (1971) found that in cucumber, increasing nitrogen rates increased the leaf nitrogen content significantly. Top dressing with nitrogen fertilizers increased productivity only in a soil with low nitrate availability (less than 12 mg/100 g). Jassal et al. (1972) reported that the nitrogen contents in plant tissues of muskmelons were the highest after maximum application of nitrogen irrespective of irrigation frequency.

Leela et al. (1975) observed that application of fertilizers (a quarter as foliar spray and the rest applied to the soil) at the rate of 125 kg N/ha produced the highest content of nitrogen in bhindi leaf. In a fertilizer cum irrigation trial on snap beans, Smittle (1976) observed the highest yield with nitrogen application to maintain the petiole NO_3-N level above 1500 ppm (pre-blossom) and 1000 ppm during fruit development. Results of glasshouse experiments revealed that nitrate application increased the iron, calcium and magnesium contents of tropical leafy vegetables including amaranthus (Vuurmans and Grubben, 1977). Batal and Smittle (1981) reported that sufficient nitrogen must be added to maintain soil NO_3-N level between 20 and 30 ppm for capsicum so as to get optimal concentration of nitrogen in plant tissues (2.5 per cent). George Thomas (1984) found that the nitrogen and potassium contents of bittergourd were enhanced by higher levels of fertilization. However effect of higher levels of fertilizers on phosphorus content was not significant. He also noted increased uptake of NPK at higher levels of fertilization.

2.2.3. Quality characteristics of vegetables

Schuphan (1971) observed that increasing N-fertilization in spinach was accompanied by a greater water content and a decrease in sugars and to a lesser extent ascorbic acid. Mani and Ramanathan (1981) reported that crude fibre content of bhindi fruits was significantly decreased by nitrogen fertilization. Singh (1984) reported that application of nitrogen at the rate of 60 kg/ha for maximum yield, quality characteristics such as crude protein, amino acids, carotene and chlorophyll contents of amaranthus. Application of 20 kg N/ha as basal was found to be beneficial not only to increase the contents of ascorbic acid and minerals like Mg and Fe, but also to minimise the contents of HCN and oxalic acid.

The experiments reviewed here lucidly depicted the effects of irrigation and nitrogen fertilization on certain vegetable crops. When the vegetable crop is a leafy vegetable, where the economic yield is almost equal to the total biomass production, these two aspects assume paramount importance.

Hence in this experiment an attempt is made to study the effects of irrigation and nitrogen fertilization on amaranthus, one of the prominent leafy vegetables grown in our country.

MATERIALS AND METHODS

MATERIALS AND METHODS

The present investigation was undertaken to study the response of water management practices in relation to application of nitrogen in amaranthus. Two field experiments were conducted during the summer seasons of 1989 and 1990. The materials used and methods adopted for the study are briefly described below:

3.1 MATERIALS

3.1.1 Experimental site

The field experiments were conducted in the summer rice fallows of the Instructional Farm attached to the College of Agriculture, Vellayani. This location is situated at 8.5° N latitude and 76.9° E longitude at an altitude of 29 m above mean sea level.

3.1.2 Soil

The soil of the experimental site is sandy clay loam in texture with the bulk density 1.4 g/cm^3 and acidic in reaction. The important physical and chemical properties of the soil are given overleaf.

A. Mechanical composition

Constituent	Content in soil (%)	Method used
Coarse sand	13.80	Bouyoucos Hydrometer method (Bouyoucos, 1962)
Fine sand	33.50	
Silt	28.00	
Clay	24.70	
Textural class	Sandy clay loam	

B. Important physical constants of the soil

Particulars	Depth of soil layer Zero to 30 cm	Method used
Field capacity (%)	19.9	Pressure membrane apparatus method (Richards, 1947)
Permanent wilting point (%)	8.9	
Bulk density (g/cm^3)	1.4	Using core sampler (Bodman, 1942)

C. Chemical composition

(i) Before experiment 1

Constituent	Content in soil	Rating	Method used
Available nitrogen	185 kg/ha	Low	Alkaline potassium permanganate method (Subbaiah and Asija, 1956)
Available P_2O_5	37 kg/ha	Medium	Bray Colorimetric method (Jackson, 1973)
Available K_2O	134 kg/ha	Medium	Ammonium acetate method (Jackson, 1973)
Organic carbon	0.79%	High	Walkely and Black rapid titration method (Jackson, 1973)
pH	5.2	Acidic	1:2 soil solution ratio using pH meter

(ii) Before experiment 2

Constituent	Content in soil	Rating	Method used
Available nitrogen	170 kg/ha	Low	Alkaline potassium permanganate method (Subbiah and Asija, 1956)
Available P_2O_5	55 kg/ha	High	Bray colorimetric method (Jackson, 1973)
Available K_2O	140 kg/ha	Medium	Ammonium acetate method (Jackson, 1973)
Organic carbon	0.83%	High	Walkely and Black rapid titration method (Jackson, 1973)
pH	5.2	Acidic	1:2 soil solution ratio using pH meter

3.1.3 Cropping history of the field

The location for experiment 1 conducted during the summer season of 1989 was under a bulk crop of rice before the commencement of the experiment. After experiment 1, and prior to experiment 2 conducted during summer 1990, the field was under two bulk crops of rice.

3.1.4 Season

The crops were raised during the summer months of the years 1989 (April and May) and 1990 (January and February) which corresponded to the regular growing season of amaranthus in rice fallows all over Kerala.

3.1.5 Weather conditions

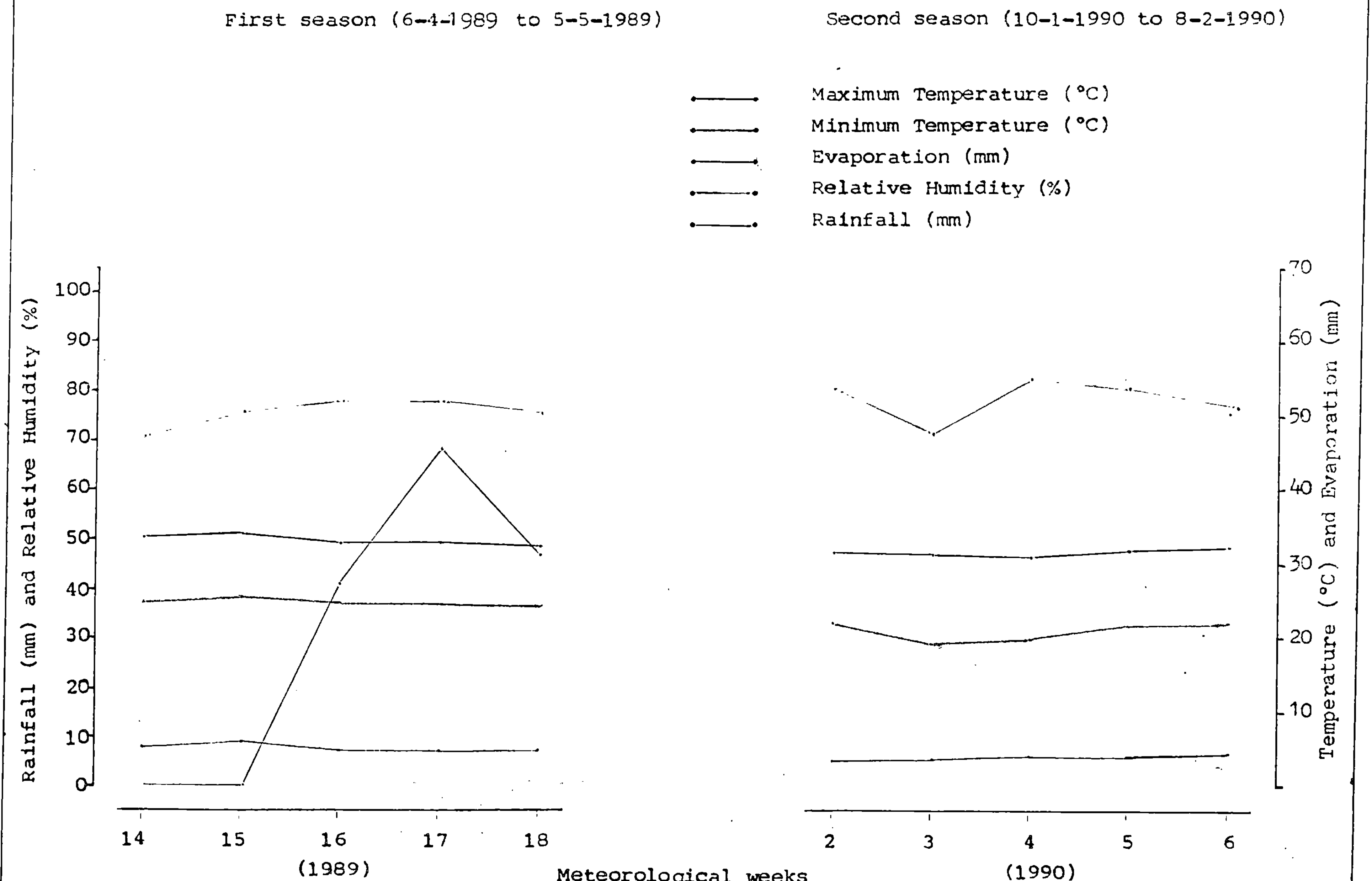
The weekly averages of temperatures, evaporation, relative humidity and the weekly totals of rainfall during the cropping periods collected from the meteorological observatory at the College of Agriculture, Vellayani are presented in Fig. 1 and Table 1.

Table 1. Meteorological data during the cropping periods
1st crop - 6-4-1989 to 5-5-1989
2nd crop - 10-1-1990 to 8-2-1990

Period	Meteorological week	Maximum temp. °C	Minimum temp. °C	Rainfall (mm)	Evaporation (mm)	R.H. (%)
1989 I	14	33.50	25.01	-	5.30	71
	15	33.74	25.39	-	5.95	76
	16	32.84	24.57	41.6	4.73	78
	17	32.81	24.46	68.2	4.73	78
	18	32.33	24.25	47.0	4.96	76
1990 II	2	31.52	22.10	-	3.36	81
	3	31.16	19.37	-	3.94	72
	4	30.86	20.00	-	4.51	83
	5	31.64	21.77	-	4.30	81
	6	32.34	21.94	-	4.60	76

The weekly averages of maximum temperature ranged between 32.33°C and 33.74°C and minimum temperature 24.25°C

Fig. 1. Weather data during cropping periods



and 25.39°C during the first experiment. The weekly averages of maximum temperature ranged between 30.86°C and 32.34°C and minimum temperature 19.37°C to 22.1°C during the second experiment.

The crop received 126.5 mm of rainfall during the first experiment and no rain during the second experiment periods.

The relative humidity during the first and second experiment periods ranged from 71 to 78 per cent and 72 to 83 per cent respectively.

The mean weekly pan evaporation values varied from 4.73 mm to 5.95 mm per day during the first experiment and from 3.36 mm to 4.60 mm per day during the second experiment.

3.1.6 Cultivar

Two promising local varieties of amaranthus (red and green types) were selected and used for the study.

3.1.7 Source of seed material

The seeds for the experiments were obtained from Instructional Farm, Vellayani and Mitraniketan, Vellanad.

3.1.8 Manures and fertilizers

Farm yard manure (0.4:0.3:0.2 % N:P_2O_5:K_2O) obtained from the Department of Animal Husbandry, College of Agriculture, Vellayani was used in the study. Urea (46% N), Superphosphate (16% P_2O_5) and Muriate of potash (60% K_2O) were used as the sources of nitrogen, phosphorus and potassium respectively.

3.1.9 Source of irrigation water

Pond water from the experimental area having pH 6.8 and EC 0.20 d.S/m was used for irrigation.

3.2 METHODS

3.2.1 Details of the experiments

3.2.1.1 Design and Layout

The field experiments were laid out in split plot design with a combination of two varieties and four irrigation levels as main plot treatments and four nitrogen levels as sub plot treatments with three replications. The layout of the experiments are given in Fig. 2.

3.2.1.2 Treatment details

Main plot treatments

Varieties - 2. V_1 - red type

V_2 - green type

Fig. 2. LAYOUT PLAN

Design - Split-plot

Replication - 3

Plot size - 2.4 m x 2 m

Main plot treatments - Varieties - 2 V_1 and V_2

Irrigation levels - 4 I_1, I_2, I_3 and I_4

Sub plot treatments - Nitrogen levels - 4 N_1, N_2, N_3 and N_4

N ↑

$V_1I_1N_1$	$V_1I_1N_4$	$V_2I_1N_2$	$V_2I_1N_1$
$V_1I_1N_3$	$V_1I_1N_2$	$V_2I_1N_4$	$V_2I_1N_3$
$V_1I_3N_2$	$V_1I_3N_3$	$V_2I_3N_4$	$V_2I_3N_2$
$V_1I_3N_4$	$V_1I_3N_1$	$V_2I_3N_3$	$V_2I_3N_1$
$V_1I_4N_3$	$V_1I_4N_2$	$V_2I_4N_1$	$V_2I_4N_4$
$V_1I_4N_1$	$V_1I_4N_4$	$V_2I_4N_3$	$V_2I_4N_2$
$V_2I_2N_1$	$V_2I_2N_4$	$V_1I_2N_3$	$V_1I_2N_4$
$V_2I_2N_3$	$V_2I_2N_2$	$V_1I_2N_2$	$V_1I_2N_1$

REPLICATION-1

$V_2I_3N_3$	$V_2I_3N_4$	$V_1I_3N_1$	$V_1I_3N_4$
$V_2I_3N_1$	$V_2I_3N_2$	$V_1I_3N_3$	$V_1I_3N_2$
$V_2I_4N_3$	$V_2I_4N_4$	$V_1I_4N_1$	$V_1I_4N_4$
$V_2I_4N_1$	$V_2I_4N_2$	$V_1I_4N_3$	$V_1I_4N_2$
$V_2I_1N_4$	$V_2I_1N_1$	$V_1I_1N_2$	$V_1I_1N_4$
$V_2I_1N_3$	$V_2I_1N_2$	$V_1I_1N_1$	$V_1I_1N_3$
$V_2I_2N_4$	$V_2I_2N_1$	$V_1I_2N_1$	$V_1I_2N_4$
$V_2I_2N_2$	$V_2I_2N_3$	$V_1I_2N_2$	$V_1I_2N_3$

REPLICATION-2

$V_1I_2N_4$	$V_1I_2N_3$	$V_2I_2N_1$	$V_2I_2N_4$
$V_1I_2N_2$	$V_1I_2N_1$	$V_2I_2N_3$	$V_2I_2N_2$
$V_2I_1N_2$	$V_2I_1N_4$	$V_1I_1N_2$	$V_1I_1N_3$
$V_2I_1N_3$	$V_2I_1N_1$	$V_1I_1N_4$	$V_1I_1N_1$
$V_2I_3N_1$	$V_2I_3N_3$	$V_1I_3N_2$	$V_1I_3N_4$
$V_2I_3N_4$	$V_2I_3N_2$	$V_1I_3N_3$	$V_1I_3N_1$
$V_1I_4N_3$	$V_1I_4N_1$	$V_2I_4N_3$	$V_2I_4N_4$
$V_1I_4N_2$	$V_1I_4N_4$	$V_2I_4N_1$	$V_2I_4N_2$

REPLICATION-3

Levels of irrigation - 4. $I_1 - \frac{IW}{CPE} = 0.75$

$I_2 - \frac{IW}{CPE} = 1.00$

$I_3 - \frac{IW}{CPE} = 1.25$

I_4 - Cultivators' practice (8 lit/m^2/day in two splits in morning and evening)

IW - 23 mm of water

Sub plot treatments

Levels of Nitrogen - 4. N_1 - 50 kg/ha (Package of practices recommendations, KAU)

N_2 - 75 kg/ha

N_3 - 100 kg/ha

N_4 - 125 kg/ha (cultivator's practice)

The treatments I_4 and N_4 were standardised after surveying local farmer's practices.

Number of treatment combinations		-	32
Number of replications		-	3
Total number of plots		-	96
Plot size	Gross	2.4 m x 2 m =	4.8 sq.m
	Net	1.8 m x 1.2 m =	2.16 sq.m
Spacing	30 cm x 20 cm		

Number of plants per plot	Gross	-	80
	Net	-	36

One row was left as border row all round the plot. Two additional rows were left along the length of the plot, one as sampling row and the adjacent row as border row.

3.3 Field culture

3.3.1 Land preparation

The experimental plots were ploughed, stubbles removed, clods broken and the fields were laid out into blocks and plots. Buffer area of 50 cm width was left all around each plot.

3.3.2 Manures and fertilizers

Farm yard manure at the rate of 50 tons/ha was applied uniformly to all the plots and mixed well with the top soil. Nitrogen, phosphorus and potash were applied to the plots in the form of urea, superphosphate and muriate of potash respectively. Uniform dose of phosphorus at the rate of 50 kg/ha and potash at the rate of 50 kg/ha were supplied to all the plots. The entire quantity of phosphorus and potash and 50 per cent nitrogen were applied as basal dose one day prior to transplanting. The remaining quantity of nitrogen was applied as top dressing 15 DAP.

3.3.3 Seedlings and planting

Separate nurseries were raised and healthy seedlings of 15 to 20 days old with uniform growth were selected, carefully pulled out and transplanted in the main field at a spacing of 30 cm x 20 cm. Immediately after planting shade was provided using plant twigs.

3.3.4 After cultivation

Gap filling with healthy seedlings was done on subsequent days after planting. Regular weeding operations were carried out to keep the plots weed free for the entire cropping period.

3.3.5 Irrigation requirement

The quantity of water required for each irrigation per plot was calculated using the formula

$$d = \frac{FC - PWP}{100} \times AS \times D$$

where d = Depth of irrigation water (cm)

FC - Field capacity of the soil layer (zero to 30 cm)

PWP - Permanent wilting point of the soil layer (zero to 30 cm)

AS - Apparent specific gravity of the soil

D - Root zone depth (zero to 30 cm)

Soil samples from zero to 30 cm depth were collected from the field before the experiment. The field capacity and permanent wilting point of the soil were found out by using pressure membrane apparatus. From this the depth of water for irrigation was computed and 50 per cent moisture was fixed for irrigation, assuming the irrigation is given at 50 per cent depletion of available soil moisture.

The quantity of water in litres required for irrigation for each plot was calculated from the depth and applied uniformly to the entire plot by pot watering.

3.3.6 Irrigation

The differential irrigations according to treatments were started only from sixth day after planting. A pre-planting pot irrigation (20 litres) was given uniformly to all the plots. Thereafter, daily pot watering at the rate of 20 litre per day per plot was given uniformly to all the plots in two equal splits, in mornings and in evenings upto the 5th day. On the sixth day, 23 mm irrigation was uniformly given to all the plots receiving irrigation on the basis of IW/CPE ratios. The evaporation readings from a USWB class A open pan evaporimeter were recorded daily and whenever the cumulative pan evaporation values attained the treatment values, irrigation was given to the concerned plots with 23 mm depth of water.

In the I_4 treatment (farmer's practice) from 6th day onwards, pot watering was given daily except on rainy

Table 2. Details of irrigation given (6th day onwards)

First experiment

Sl. No. of irrigation	I_1 IW/CPE = 0.75	I_2 IW/CPE = 1.0	I_3 IW/CPE = 1.25	I_4 Daily (@ 8 mm)
1.	*11th April	*11th April	*11th April	Daily (12 irrigations)
2.	15th April	14th April	13th April	
3.			17th April	
Total No. of irrigations	2	2	3	
Quantity of water applied(mm)	46	46	69	**96
Pre-treatment irrigation (mm)	**20	**20	**20	**20
Rainfall (mm)	126.5	126.5	126.5	126.5
Total quantity of water applied (mm)	192.5	192.5	215.5	242.5

* Common irrigation

** Equivalent water delta

Table 3. Details of irrigation given (6th day onwards)

Second experiment

Sl. No. of irrigation	I_1 IW/CPE = 0.75	I_2 IW/CPE = 1.0	I_3 IW/CPE = 1.25	I_4 Daily (@ 8 mm)
1.	*15th January	*15th January	*15th January	Daily (24 irrigations)
2.	22nd January	20th January	19th January	
3.	30th January	26th January	24th January	
4.	6th February	31st January	28th January	
5.		6th February	1st February	
6.			6th February	
Total No. of irrigations	4	5	6	
Quantity of water applied (mm)	92	115	138	**192
Pretreatment irrigation (mm)	**20	**20	**20	**20
Total quantity of water applied (mm)	112	135	158	212

* Common irrigation

** Equivalent water delta

days at the rate of 8 l/m^2 area in two equal splits in morning and in evening. The details of irrigation provided are presented in Tables 2 and 3.

3.3.6 Plant protection

Malathion at 0.01 per cent concentration was sprayed on the foliage when leaf webber attack was noticed. Leaf eating hairy caterpillars and egg masses occurring on plants were removed and destroyed as and when occurred.

3.3.7 Harvesting

The crops were harvested 30 DAP. The plants were pulled out on 5-5-1989 in the case of first experiment and on 8-2-1990 in second experiment.

3.4 Biometric observations

3.4.1 Height of the plant

The height of the plant was recorded from five randomly selected observational plants at three stages of growth viz., 10th and 20th DAP and at harvest. The height was measured from the ground level to the topmost leaf-bud of all observational plants, mean values were computed and expressed in cm.

3.4.2 Girth of main stem

The girth of main stem was measured using a non-elastic twine at the collar region of each observational plant, means worked out and expressed in cm.

3.4.3 Number of branches

Total number of branches of each observational plant was counted, and the mean worked out for each plant at three stages of growth viz., 10th and 20th DAP and at harvest.

3.4.4 Number of leaves

Total number of leaves in each observational plant was counted and the average recorded for each plant at three stages of growth viz., 10th and 20th DAP and at harvest.

3.4.5 Spread of plants

Spread of plants was worked out by taking the product of the distance between the terminal parts of the largest branches on two perpendicular planes, mean worked out and expressed in square cm at three stages viz., 10th and 20th DAP and at harvest stage.

3.4.6 Leaf area index (LAI)

Leaf area of plants from each plot was measured at the stage of harvest using LI-3100 leaf area meter and expressed in square centimetre. Leaf area index was then worked out using the equation

$$LAI = \frac{\text{Total leaf area}}{\text{spacing}}$$

3.4.7 Yield per plant

Yield per plant was recorded by dividing the total yield of all observational plants of a plot by the number of plants and expressed as g/plant.

3.4.8 Yield

The border plants were harvested first. Then the plants in the net area were harvested and yield/ha was worked out.

3.4.9 Leaf : stem ratio

Leaf : stem ratio was recorded at the stage of harvest as the ratio of dry weight of leaves to the dry weight of stem.

3.4.10 Dry weight of leaves and stem

After recording the fresh weight of leaves and stem from each plot, they were first sun dried separately and then in a hot air oven at 65°C for 10 hours till two consecutive weights coincided. The final weight was averaged and expressed as g/plant.

3.4.11 Root dry weight at harvest

Root masses of observational plants were carefully separated from the soil at harvest stage. They were washed with clean water and dried to a constant weight at 65°C for 10 hours in a hot air oven. From the data obtained, mean value was worked out and expressed as g/plant.

3.5 Water use efficiency

Field water use efficiency was calculated by dividing the economic crop yield (Y) by the total amount of water used in the field (WR) and is expressed in kg/ha mm.

$$\text{Field water use efficiency, Eu} = \frac{Y}{WR}$$

3.6 Analytical procedures

3.6.1 Soil analysis

3.6.1.1 a) Physical properties

Mechanical analysis of the soil was carried out by Bouyoucos hydrometer method (Bouyoucos, 1962). Soil was classified into textural group using ISSS system.

b) Bulk density

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

c) Field capacity

Field capacity of the soil was determined using pressure-membrane apparatus (Richards, 1947).

C. Permanent wilting percentage

Permanent wilting percentage of the soil was determined using pressure membrane apparatus (Richards, 1947).

3.6.1.2 Chemical properties

Soil samples were taken from the experimental area before and after the experiment. The air dried soil samples were analysed for available nitrogen, available phosphorus and available potash contents. Available nitrogen content was estimated by alkaline potassium permanganate method (Subbiah and Asija, 1956). Available phosphorus content was estimated by Bray colorimetric method (Jackson, 1973) and available potash by ammonium acetate method (Jackson, 1973).

3.6.2 Water analysis

pH of irrigation water was analysed using a pH meter. The Electrical conductivity (EC) of water was measured using a solubridge (Dastane, 1972).

3.6.3 Plant analysis

The plant samples were analysed for nitrogen, phosphorus and potassium at the final harvest. The plants were chopped and dried in an air oven at 80 ± 5°C separately till constant weights were achieved. Samples were then ground to pass through a 0.5 mm mesh in a Wiley mill. The required quantity of samples were then weighed out accurately in a physical balance and analysed.

3.6.3.1 Uptake of nitrogen

The nitrogen content in plant was estimated by modified microkjeldahl method (Jackson, 1973) and the uptake of nitrogen was calculated based on the content of this nutrient in plants and the drymatter produced.

3.6.3.2 Uptake of phosphorus

The phosphorus content in plant was estimated colorimetrically (Jackson, 1973) after wet digestion of the sample using 2:1 mixture of nitric acid and perchloric acid and developing colour by Vanadomolybdo phosphoric yellow colour method and read in a Bausch and Lomb Spectronic 2000 Spectrophotometer. Based on the phosphorus content in plants and the drymatter produced at harvest, the uptake was worked out.

3.6.3.3 Uptake of potassium

The potassium content in plants was estimated by the flame photometric method in a Perkin-Elmer 3030 Atomic Absorption Spectrophotometer after wet digestion of the sample using diacid mixture. The uptake of potassium was calculated based on the potassium content in plants and dry matter produced.

3.6.3.4 Moisture content of plants

Plant samples of known fresh weights were first sun dried and then to a constant weight in an air oven at 80°C and from the data moisture content was worked out and expressed as percentage.

3.6.3.5 Protein content of plants

The plant nitrogen values were multiplied by the factor 6.25 to obtain the protein content of plants and the values were expressed as percentages (Simpson et al., 1965).

3.6.3.6 Fibre content of plants

The fibre content of plants was determined by the A.O.A.C. method (A.O.A.C., 1975).

3.7 Economics of cultivation

The economics of cultivation of amaranthus was worked out and the net income and benefit-cost ratio were calculated as follows:

Net income (Rs./ha) = Gross income - cost of cultivation

$$\text{Benefit cost ratio} = \frac{\text{Gross income}}{\text{Cost of cultivation}}$$

3.8 Statistical analysis

Data relating to each character were analysed by applying the analysis of variance technique and significance was tested by 'F'-test (Snedecor and Cochran, 1967). In cases where the effects were found to be significant, CD was calculated by using standard techniques.

The data were analysed using a Keltron Versa IWS computer system.

RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

The experimental data collected were statistically analysed and the results of the experiments are presented and discussed in this chapter under the following sections.

4.1 Growth and yield attributing characters

4.2 Quality aspects

4.3 Uptake of nutrients

4.4 Soil analysis

4.5 Moisture studies

4.6 Economics of cultivation

4.1 Growth and yield attributing characters

4.1.1 Height of plant

Data on height of plant recorded at different growth stages of the crop viz., 10th and 20th DAP and at the stage of harvest of the crop are presented in Table 4 and Fig. 3

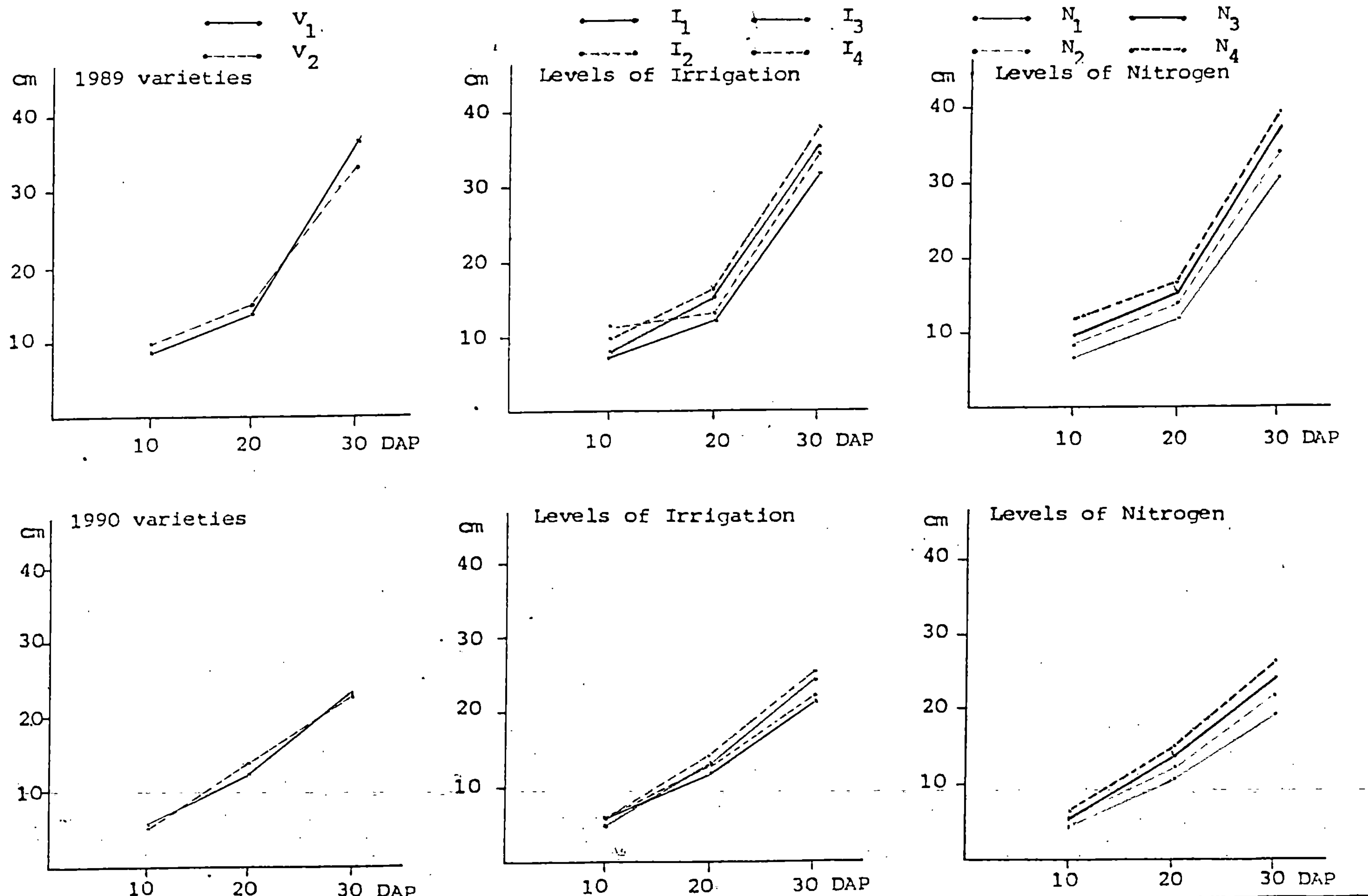
There was significant difference in height of plant between varieties at different growth stages during the first season and only at 20 DAP during the second season. During first season at 10 and 20 DAP the variety V_2 recorded the maximum height of 9.58 cm and 14.79 cm while the variety V_1 recorded 8.58 cm and 13.65 cm. But at the time of harvest variety V_1 recorded the maximum height of

Table 4. Effect of varieties, irrigation and nitrogen on the plant height (cm) at different growth stages

	10 DAP		20 DAP		30 DAP	
	1989	1990	1989	1990	1989	1990
V_1	8.58	5.42	13.65	12.35	36.74	23.04
V_2	9.58	5.34	14.79	13.48	33.22	22.83
CD	0.158	NS	0.208	0.172	0.223	NS
I_1	7.03	5.51	12.21	11.63	31.36	21.56
I_2	11.40	5.56	13.28	12.97	34.95	21.92
I_3	8.15	4.81	14.96	13.17	35.50	24.03
I_4	9.74	5.61	16.45	13.88	38.09	24.23
CD	0.224	0.187	0.294	0.243	0.316	1.673
N_1	6.29	4.21	11.66	10.28	30.15	19.04
N_2	8.11	5.05	13.82	12.18	33.57	22.43
N_3	9.76	5.75	15.16	13.91	37.07	24.16
N_4	12.15	6.47	16.25	15.29	39.11	26.09
CD	0.295	0.190	0.294	0.287	0.372	1.631
SE/plot±	0.47	0.31	0.49	0.47	0.61	2.69

NS - Not Significant

Fig. 3. Effect of varieties, irrigation and nitrogen on plant height at various growth stages



36.74 cm and variety V_2 recorded a height of 33.22 cm. In the second season, the varieties did not show any significant difference in plant height at 10 DAP and at the time of harvest. At 20 DAP, the variety V_2 showed a significant increase in height over variety V_1. At the time of harvest, the variety V_1 recorded a maximum height of 23.04 cm which was not significant over the other treatments.

From the data presented, it can be seen that the variety V_1 recorded the maximum height. This variation may be due to the fact that plant height is genetically controlled and varietal variation is commonly noted in different species. Similar results were reported by Prasad *et al*. (1980) and Mathai *et al*. (1981) in amaranthus.

It can be observed from the Table that during first season plants recorded a maximum height of 36.74 cm while in the second season, the maximum height recorded was only 23.04 cm. This may be due to a dry spell prevailed during the second season compared to the rainy days in the later stages of growth during the first season. This is also evident from the weather data presented in Table 1.

Irrigation treatments significantly influenced the height of plant at all stages of crop growth. At 10 DAP, I_2 recorded the maximum height of 11.4 cm followed by I_4, I_3 and I_1 in the first season while I_4 recorded the maximum height of 5.61 cm in the second season. But the treatments I_4, I_2 and I_1 were found to be on par and were significantly higher than I_3. At 20 DAP, maximum height was recorded by I_4 followed by I_3, I_2 and I_1 in both seasons. However in the second season, I_3 was found to be on par with I_2. At the stage of harvest of the crops, I_4 recorded the maximum height followed by I_3, I_2 and I_1 in both seasons. However in the second season, I_4 was on par with I_3 and I_2 was on a par with I_1.

An increasing trend in plant height was noted with increasing ratios of irrigation ranging from 0.75 to 1.2 and to cultivator's practice at 20 DAP and at the stage of harvest of the crops. During both seasons, farmers' practice of irrigating the crop twice a day recorded the maximum height. No such trend was noted at 10 DAP during both seasons which could be due to the uniform irrigations received by the crop in the initial stages of growth. Water is one of the important factors contributing to plant growth. It is not only a solvent and medium of biochemical reactions but forms part of the structural and working machinery of life. The increased growth of plants is due to increased soil moisture availability which in turn increased the turgidity of cells favouring cell enlargement and cell division. Water deficit is likely to affect the two vital processes of growth viz., cell division and cell enlargement. According to Begg and Turner (1976) cell enlargement is more affected resulting in poor growth. General consideration is that growth is suspended during water stress and resumed upon its elimination (Arnon, 1975). Significant increase in plant height noted at the later stages of growth of the crop with increasing levels of irrigations could thus be attributed to increased metabolic activities. Similar increase in plant height due to irrigation have been reported by George Thomas (1984) in bittergourd, Jayakrishnakumar (1986) in bhindi, Tamaki and Naka (1971) in broadbeans.

Nitrogen had a significant influence on height of plant at various growth stages. Nitrogen at 125 kg/ha recorded the maximum height at all the stages of growth during both seasons followed by N at 100, 75 and 50 kg/ha.

It is seen from the data that the effect of nitrogen on height of plant was significant at various growth stages of the crop during both seasons and an increasing trend was observed in this character with increasing levels of nitrogen. The main function of nitrogen is to promote vegetative growth (Tisdale *et al*., 1985). As the nitrogen levels were increased, the vegetative growth was promoted which naturally enhanced the height of plants. Similar increase in plant height due to nitrogen fertilization have been reported by Singh et al. (1985) and Bressani et al. (1987) in amaranthus, Mohamed Kunju (1968) in chilli and Ramachandra and Thimmaraju (1983) in amaranthus.

4.1.2 Girth of stem

Data on girth of stem recorded at various growth stages of the crop are presented in Table 5.

Effect of varieties on this parameter was not significant at 10 DAP during both seasons. However it was significant at 20 DAP. Variety V_2 recorded the maximum girth of 2.62 cm while variety V_1 recorded 2.57 cm during the first season and in the second season, variety V_1 recorded the maximum girth of 3.66 cm while variety V_2 recorded only 3.58 cm. At the stage of harvest of the crop, the effect of varieties on girth of stem was significant only during the first season and variety V_1 recorded the maximum girth of stem.

It can be seen from the data that the varietal effect on girth of stem was inconsistent during the early stages of growth of the crop while in the later stages, variety V_1 showed an increasing trend which may be due to the branching character exhibited by the variety V_1.

Table 5. Effect of varieties, irrigation and nitrogen on the stem girth (cm) at different growth stages

	10 DAP		20 DAP		30 DAP	
	1989	1990	1989	1990	1989	1990
V_1	1.21	1.39	2.57	3.66	5.00	5.22
V_2	1.23	1.42	2.62	3.58	4.92	5.16
CD	NS	NS	0.022	0.068	0.058	NS
I_1	0.96	1.39	2.44	3.68	4.68	5.04
I_2	1.45	1.36	2.78	3.60	5.15	4.92
I_3	1.13	1.45	2.51	3.25	4.89	5.56
I_4	1.34	1.41	2.64	3.95	5.11	5.24
CD	0.023	NS	0.032	0.097	0.082	0.463
N_1	1.03	1.35	2.34	3.46	4.43	4.75
N_2	1.17	1.39	2.51	3.55	4.81	5.14
N_3	1.30	1.39	2.75	3.65	5.13	5.43
N_4	1.38	1.48	2.77	3.82	5.47	5.44
CD	0.024	0.091	0.036	0.108	0.069	0.290
SE/plot±	0.04	0.15	0.06	0.18	0.11	0.48

NS – Not Significant

Different levels of irrigation significantly influenced the girth of stem at all stages of growth except at 10 DAP during second season. During first season, $\frac{IW}{CPE}$ ratio of 1.00 recorded maximum stem girth in all stages of growth followed by farmers' practice of irrigation and the ratios of 1.25 and 0.75. But during the second season, the results were found inconsistent. The difference in branching character combined with the influence of different levels of nitrogen might have influenced the effect of irrigation on girth of stem. Increase in stem diameter due to irrigation was earlier reported by Bhella (1985) in muskmelon.

Effect of nitrogen on this parameter was significant at all the stages of growth during both seasons. Nitrogen at 125 kg/ha recorded the maximum girth of stem on all stages of growth. At 10 DAP, different levels of nitrogen significantly influenced the girth of stem during first season while during second season, nitrogen at 125 kg/ha was found to be on par with nitrogen at 100 and 75 kg/ha and nitrogen at 100 kg/ha was on par with other two lower levels of nitrogen. At 20 DAP, the higher two levels of nitrogen were found to be on par during the first season while during second season, the highest level of 125 kg N/ha was found to produce the maximum girth of stem and among the lower three levels of nitrogen, consecutive levels were found to be on par. At 30 DAP, there was significant difference in girth of stem due to the influence of different levels of nitrogen during first season while during second season, 125 kg N/ha was on par with 100 kg N/ha, the latter on par with 75 kg N/ha.

It is seen from the data that effect of nitrogen was significant on girth of stem at various growth stages of the crop. There was increase in the girth with the increase in the levels of nitrogen. The effect of nitrogen in increasing the growth of plant is well known. The increased availability of nitrogen might have resulted in rapid cell division and enlargement.

4.1.3 Number of branches per plant

The data on number of branches per plant recorded at 10th and 20th DAP and at the stage of harvest of the crop are presented in Table 6, and fig. 4.

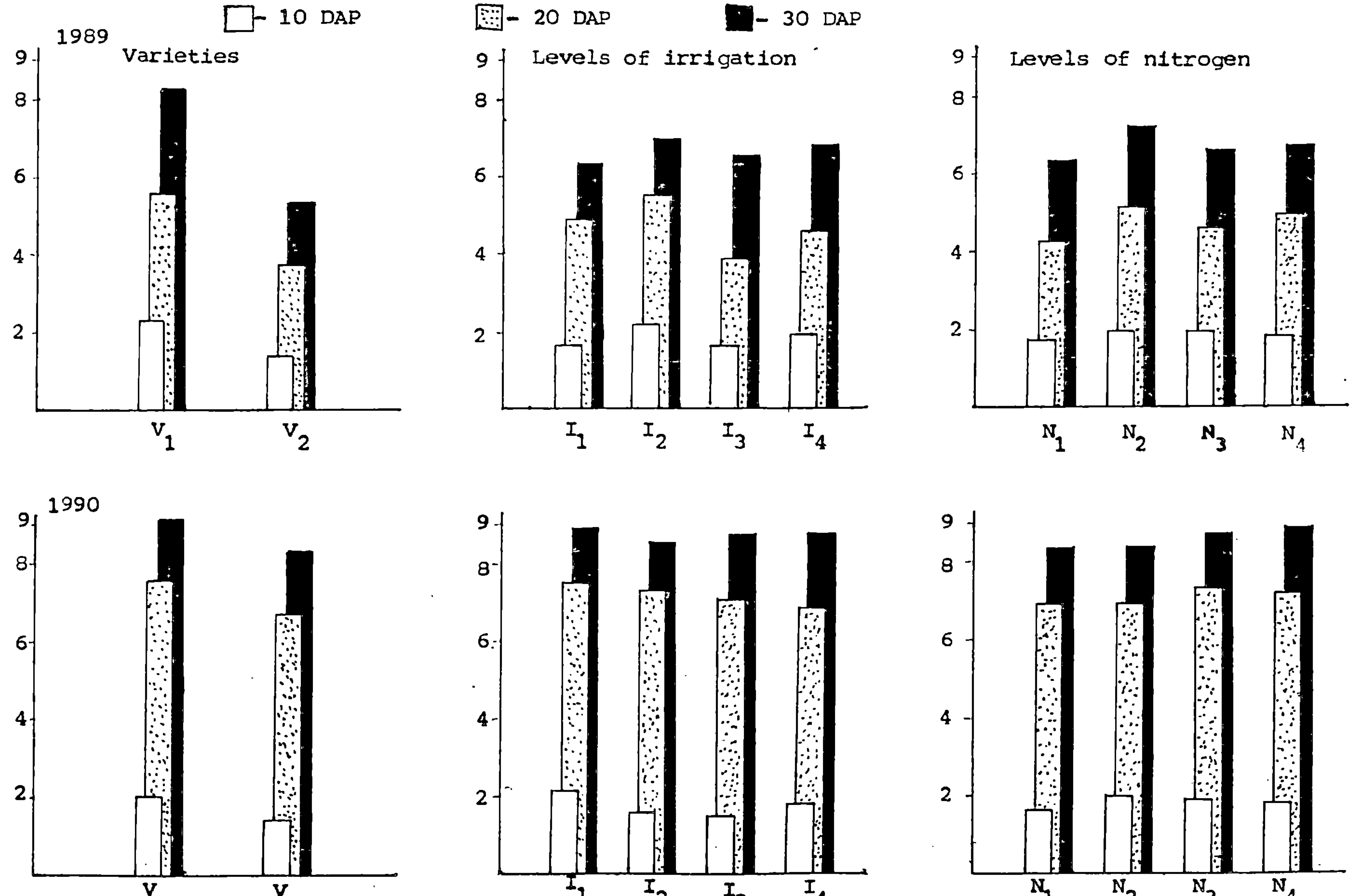
Significant difference in the number of branches was observed between the varieties at all stages of growth. Maximum number of branches was recorded by variety V_1 at various growth stages. This difference in number of branches may be due to the genetic differences between the cultivars. Significant varietal differences on the number

Table 6. Effect of varieties, irrigation and nitrogen on the number of branches at different growth stages

	10 DAP		20 DAP		30 DAP	
	1989	1990	1989	1990	1989	1990
V_1	2.3	2.0	5.7	7.7	8.2	9.2
V_2	1.5	1.6	3.8	6.7	5.3	8.4
CD	0.14	0.18	0.23	0.11	0.21	0.55
I_1	1.8	2.2	4.9	7.6	6.4	8.9
I_2	2.2	1.7	5.6	7.2	7.1	8.6
I_3	1.6	1.5	3.9	7.1	6.6	8.7
I_4	2.0	1.8	4.7	6.9	6.8	8.9
CD	0.19	0.25	0.32	0.15	0.30	NS
N_1	1.7	1.7	4.2	6.9	6.3	8.4
N_2	2.0	1.8	5.2	7.1	7.3	9.1
N_3	2.0	1.9	4.7	7.4	6.5	8.8
N_4	1.9	1.8	4.9	7.3	6.8	8.8
CD	0.22	NS	0.43	0.29	0.44	NS
SE/plot$\pm$	0.36	0.44	0.70	0.48	0.72	1.02

NS - Not Significant

Fig.4. Effect of varieties, irrigation and nitrogen on number of branches per plant at various growth stages



of branches were earlier reported by Prasad et al. (1980).

The irrigation treatments had significantly influenced the number of branches per plant at all the stages of growth of the crop. However it was not significant at the stage of harvest of the crop during second season. In the first season, irrigation at $\frac{IW}{CPE}$ ratio of 1.00 recorded maximum number of branches while in the second season, irrigation at the ratio of 0.75 recorded maximum number of branches. The effects of other irrigation treatments were found inconsistent. This may be due to the fact that number of branches is a varietal character and the different irrigation treatments may have added to that effect. Significant effect of irrigation on number of branches was earlier reported by Tamaki and Naka (1971) in broad beans, Samui et al. (1986) in mustard.

The levels of nitrogen significantly influenced the number of branches at all stages of growth during first season while during second season, significant difference was noted only at 20 DAP. During the first season, nitrogen at 75 kg/ha produced the maximum number of branches at all stages of growth. The rainfall occurred in the later stages of crop growth during the first season and a comparatively dry condition prevailed during the second season might have caused significant difference in soil moisture regimes during the two seasons which might have caused the variations in the effect of nitrogen.

Nitrogen being the most potential nutrient element for the vegetative growth and development of plants, its supply and availability would have helped the plant to produce more branches. Significant influence of nitrogen on branching character was earlier reported by Mohamed Kunju (1968), Subramoniam et al. (1979) and Ghosh and Maj (1985).

4.1.4 Number of leaves

The data on number of leaves recorded at 10, 20 and 30 DAP are presented in Table 7 and fig. 5

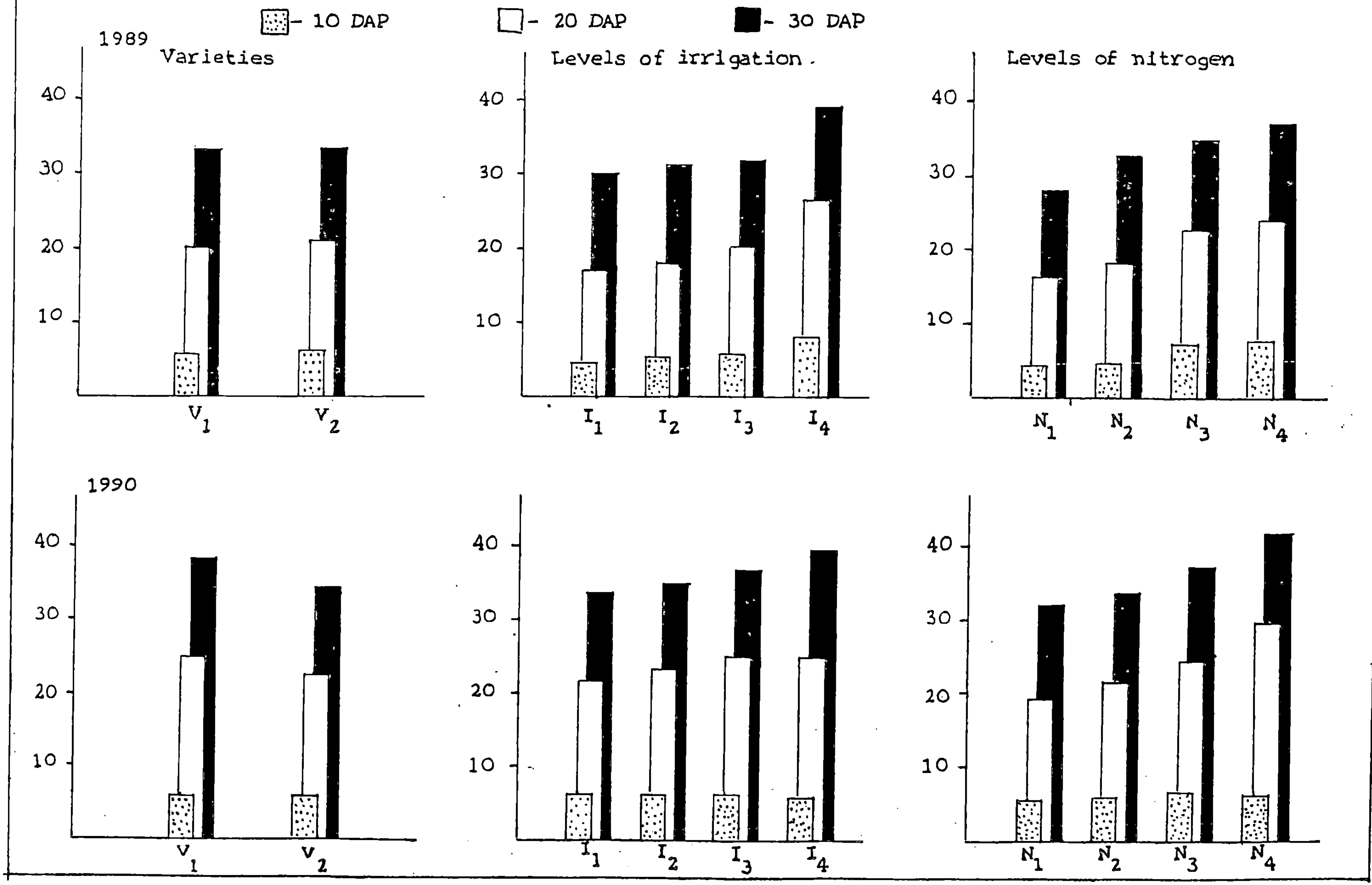
Varieties differed significantly in the number of leaves per plant at 10th and 20th DAP during both seasons, and at harvest stage of the second crop. It is seen from the data that varietal differences in the number of leaves per plant were not stable during the two seasons. In the first season variety V_2 recorded maximum number of leaves at 10 and 20 DAP. At the stage of harvest of the crop during the first season, the number of leaves of the varieties were on par. This may be due to the fact that significantly higher number of branches produced by variety V_1 at 30 DAP during the first season (Table 6) might have equalled the number of leaves produced by variety V_2 and

Table 7. Effect of varieties, irrigation and nitrogen on the number of leaves per plant at different growth stages

	10 DAP		20 DAP		30 DAP	
	1989	1990	1989	1990	1989	1990
V_1	5.8	6.3	20.2	24.6	33.0	38.0
V_2	6.2	6.0	20.7	22.4	33.1	33.8
CD	0.11	0.23	0.36	0.48	NS	1.61
I_1	4.7	6.3	17.1	21.5	29.9	33.6
I_2	5.3	6.1	18.0	23.0	31.5	34.7
I_3	5.9	6.2	20.1	24.6	31.8	36.3
I_4	8.1	6.0	26.6	24.8	39.2	39.0
CD	0.15	NS	0.51	0.68	0.36	2.27
N_1	4.3	5.9	16.5	19.5	28.2	32.9
N_2	4.9	6.1	18.4	21.4	32.4	33.6
N_3	6.7	6.4	23.0	23.9	34.7	36.8
N_4	7.9	6.3	24.0	29.1	37.1	41.3
CD	0.17	NS	0.38	0.88	0.42	2.10
SE/plot±	0.28	0.74	0.64	1.46	0.69	3.46

NS - Not Significant

Fig.5. Effect of varieties, irrigation and nitrogen on number of leaves per plant at various growth stages



hence the effect of varieties was found not significant in the production of leaves per plant in the final stage. In the second season, variety V_1 recorded maximum number of leaves than variety V_2 at all stages of growth. This may be because V_1 had higher number of branches than V_2 (Table 6). It may be noted that in the first season, when there was sufficient moisture in the soil due to rainfall received during the later part of the season, variety V_2 recorded maximum number of leaves. In the second season, when there was a dry condition due to lack of rainfall, variety V_1 recorded maximum number of leaves. This indicates that variety V_1 is more adapted to stress conditions.

It is seen that irrigation had a significant influence on number of leaves per plant at various growth stages viz., 10, 20 and 30 DAP during the first season and except at 10th DAP in the second season. An increasing trend in number of leaves per plant was noted with increasing ratios of irrigation. The farmers' practice of irrigating the field with 8 l/m^2/day in two splits recorded maximum number of leaves during both seasons. No significant difference was noted between the ratios 1.25 and 1.00 at harvest stage. The leaf number depends on the number of growing points, the number of branches, the length of time during which leaves are produced, the rate of leaf production during the period and the length of life of leaves. Irrigation hastens the process of leaf formation in plants. Similar reports were made by Geissler and Schwierz (1974) in amaranthus and Asoegwu (1988) in fluted pumpkin. From the data it is seen that effect of irrigation was not significant on this parameter at 10 DAP in the second season which could be due to the uniform irrigations received by the crop in the initial growth stages.

Effect of nitrogen was found to be significant on this parameter at all the growth stages during the first season. During second season except at 10th DAP, effect of nitrogen was significant at remaining stages of growth. An increasing trend was noted in this character with increasing levels of nitrogen from 50 to 125 kg N/ha. Nitrogen being the most potential nutrient element for the vegetative growth and development of plants, its supply and availability would have helped the plant to produce more number of leaves. Similar findings were reported by Vuurmans and Grubben (1977) in leafy vegetables, Nawawi et al. (1985) in amaranthus.

4.1.5 Spread of plant

The data on this parameter recorded at various growth stages of the crop are presented in Table 8.

Table 8. Effect of varieties, irrigation and nitrogen on the spread of plants (cm^2) at different growth stages

	10 DAP		20 DAP		30 DAP	
	1989	1990	1989	1990	1989	1990
V_1	222	135	622	828	1280	1326
V_2	286	158	675	879	1507	1435
CD	10.8	9.2	18.2	43.1	51.5	NS
I_1	225	139	589	817	1292	1308
I_2	287	154	646	841	1340	1324
I_3	233	146	712	937	1417	1514
I_4	270	146	647	819	1526	1377
CD	15.2	NS	25.8	60.9	72.8	NS
N_1	209	152	619	786	1250	1202
N_2	232	153	640	872	1410	1393
N_3	298	141	717	897	1493	1414
N_4	277	140	618	859	1421	1515
CD	16.7	NS	39.6	51.4	93.5	102.0
SE/plot±	27.5	23.9	65.4	84.8	154.2	168.3

NS - Not Significant

The data showed significant difference between the varieties at different growth stages during the first and second seasons. Variety V_2 recorded maximum spread than variety V_1. But in the second season, varietal difference was significant only at 10th and 20th DAP.

Spread of plant mainly depends on the growth habit of a plant and is highly influenced by population per unit area. It is seen from the data that variety V_2 recorded maximum spread than variety V_1. It was also noted that variety V_2 produced lesser number of branches than variety V_1 (Table 6). Lesser number of branches might have promoted more extensive lateral growth of branches and hence better spread of plants. More number of branches with resultant high level of competition for growth resources might have restricted the spread of plants. Similar reports were made earlier by Dutt (1981) and Kovithayakoran (1982).

Effect of irrigation was found to be significant on this parameter at all stages of crop growth during the first season. However the main effect of irrigation was significant at 20th DAP only in the second season.

The analysis did not reveal any consistent results. It suggests that spread of plant is mainly influenced by the population per unit area, nature of growth and branching habit of a crop. So irrigation might have played little influence on the spread of the plant.

Effect of nitrogen on this parameter was significant at all stages of crop growth during both seasons except at 10 DAP in the second season. In general it was observed that treatments 100 kg N/ha and 125 kg N/ha gave better spread and N at 50 kg/ha recorded least spread.

Eventhough the data revealed a significant effect of nitrogen on the spread of plants, the results obtained were found to be inconsistent. This may be due to the multiple influence of various factors like growth habit of plant, nature of branching and levels of irrigation on the levels of nitrogen.

4.1.6 Leaf area index (LAI)

The data on this parameter recorded at the stage of harvest of the crop are presented in Table 9 and Fig. 6

During both seasons, variety V_2 recorded the maximum LAI followed by variety V_1. However, the variation was significant only during the first season.

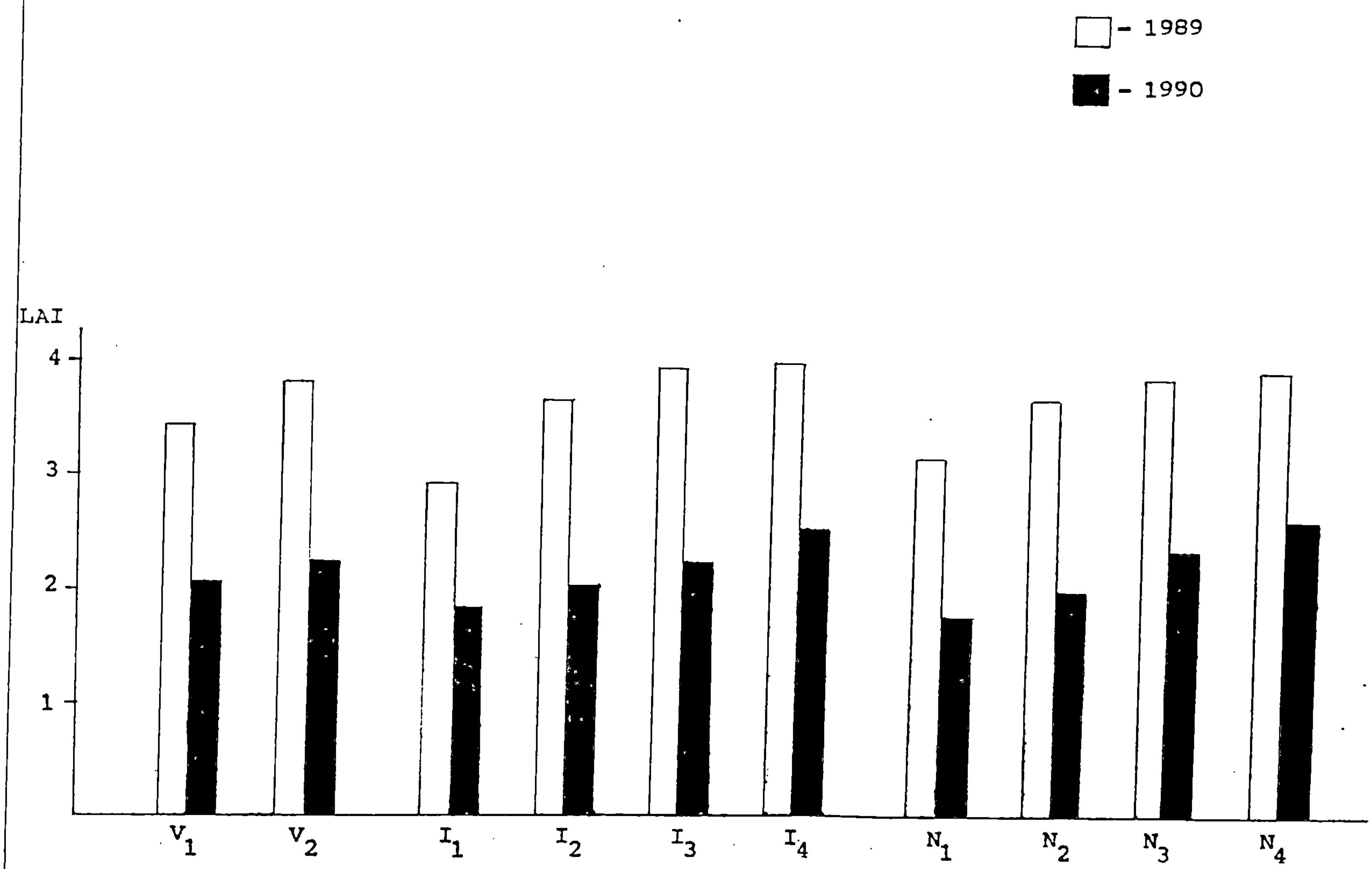
An appraisal of the data revealed the significant effect of varieties on LAI. This variation may be due to the inherent capacity of the variety V_2 to produce comparatively larger leaves. During second season, the increased

Table 9. Effect of varieties, irrigation and nitrogen on the LAI and Leaf : Stem ratio at harvest stage of the crop

	LAI		Leaf : Stem ratio	
	1989	1990	1989	1990
V_1	3.43	2.08	0.96	2.19
V_2	3.80	2.24	1.21	2.52
CD	0.169	NS	0.146	NS
I_1	2.94	1.84	1.16	2.25
I_2	3.63	2.09	1.07	2.44
I_3	3.93	2.20	1.03	2.28
I_4	3.96	2.51	1.08	2.45
CD	0.239	0.278	NS	NS
N_1	3.12	1.75	1.16	2.53
N_2	3.65	1.98	1.09	2.26
N_3	3.82	2.32	1.06	2.30
N_4	3.87	2.59	1.05	2.34
CD	0.309	0.206	NS	NS
SE/plot±	0.51	0.34	0.35	0.85

NS - Not Significant

Fig. 6 Effect of varieties, irrigation and nitrogen on LAI at harvest stage



number of leaves produced by the variety V_1 might have reduced the difference in LAI and hence the difference in LAI was not significant.

Effect of irrigation on LAI was significant in both seasons. Treatment I_4 recorded the maximum LAI of 3.96 during first season and 2.51 in the second season, followed by I_3, I_2 and I_1. I_4 and I_3 were found on par during the first season, but during the second season, I_3 and I_2 and I_2 and I_1 were on par.

It is seen from the data that LAI showed an increasing trend with increasing ratios of irrigation. During both seasons, farmers' practice of applying 8 l of water/m^2/day in two splits recorded maximum LAI closely followed by $\frac{IW}{CPE}$ ratio of 1.25. Leaf size is primarily 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. The reduction in LAI observed under lower irrigation treatments may be due to the sensitivity of cell enlargement to moisture stress conditions leading to smaller leaf area (Begg and Turner, 1976). Thomas Mathew (1985) also observed the production of smaller leaves under moisture stress conditions. George Thomas (1984) also reported reduction in leaf area of bittergourd due to moisture stress.

Effect of nitrogen on LAI was also significant during both seasons. Nitrogen at 125 kg/ha recorded the maximum LAI followed by N at 100, 75 and 50 kg/ha during first and second seasons. During first season the effects of N at 125 kg/ha, 100 kg/ha and 75 kg/ha were statistically on par and were superior to 50 kg N/ha. During second season, the effect of nitrogen levels were found to be significantly different. Sufficient rainfall received during the later stages of first season might have significantly reduced the variations in the effects of higher levels of nitrogen while in the second season, when there was a rainless period, the effects of nitrogen levels were found to be significantly different.

It is seen that nitrogen enhanced the number of leaves produced and the expansion of leaves which in turn increased the LAI. Russel (1973) reported that extra protein produced as a result of increase in nitrogen supply to plant allows the plant leaves to grow larger and to have more surface area available for photosynthesis causing an increase in the LAI. Similar results have been reported by George Thomas (1984) in bittergourd and Jayakrishnakumar (1986) in bhindi.

4.1.7 Leaf:stem ratio

The data on leaf:stem ratio recorded at the stage of harvest of the crop are presented in Table 9 .

Significant difference in leaf:stem ratio of the two varieties was observed during the first season only. In the first season, variety V_2 recorded a maximum leaf:stem ratio of 1.21 over a leaf:stem ratio of 0.97 of variety V_1.

A perusal of the data revealed that variety V_2 produced higher leaf:stem ratio in both seasons. It was also noted that stem dry weight of variety V_2 was significantly lower than that of variety V_1 (Table 11). This might have attributed to the higher leaf:stem ratio in variety V_2. Moreover the number of leaves and leaf area give a clue to the leaf:stem ratio in plants. The higher leaf area of variety V_2 (Table 9) also might have contributed to the higher leaf:stem ratio of variety V_2. Lack of significant variation in the second season may be due to a relatively dry climate prevailed during the season.

Effects of irrigation and nitrogen treatments were found to be not significant on this parameter during both seasons.

4.1.8 Yield per plant

The data on yield per plant are presented in Table 10 and Fig.7

The data revealed that there was significant difference between varieties during first season and the variety V_1 recorded the maximum yield of 238.4 g per plant followed by variety V_2 which recorded an yield of 197.0 g per plant. During second season, the varieties did not show any significant difference in yield per plant.

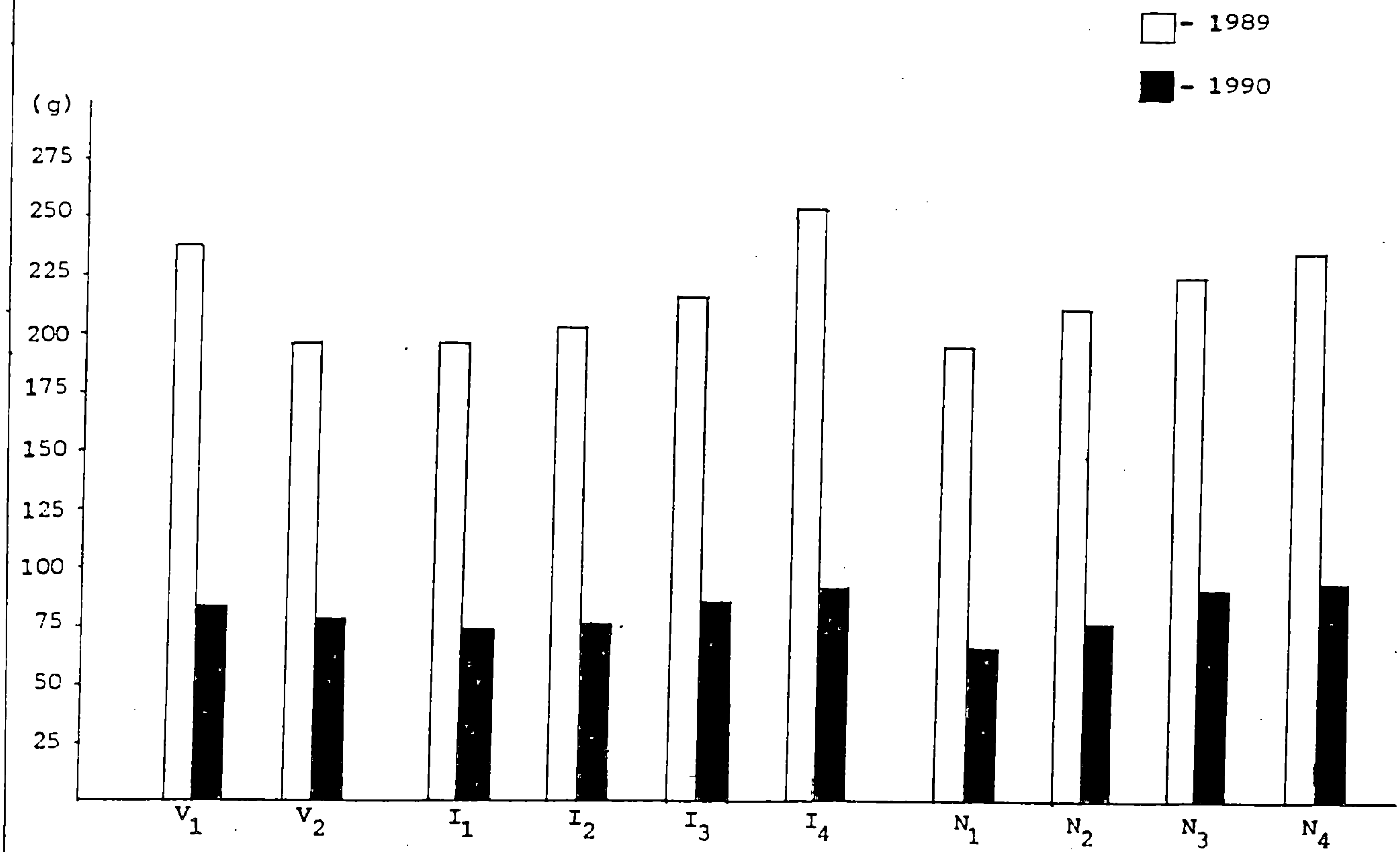
The yield of any crop is a very complex competitive character resulting from different factors, the more important being the yield per plant and number of plants per unit area (Tanaka et al., 1964). Yield per plant is controlled by many factors such as the nutrients taken up by the plants, the genetic potential and the environmental conditions to which it is subjected during its life cycle. As far as leafy vegetables are concerned, yield is the fixed expression of all the yield attributing characters like plant height, girth of stem, number of branches, number of leaves etc. and variations are commonly noted between varieties. Mathai et al. (1981) also reported wide variability for total green yield of stem and leaf per plant of different varieties of Amaranthus caudatus and A. tricolor, variability being higher in the case of

Table 10. Effect of varieties, irrigation and nitrogen on the yield/plant (g) and yield/unit area (tonnes/ha)

	Yield/plant		Yield/unit area	
	1989	1990	1989	1990
V_1	238.4	85.4	30.77	13.04
V_2	197.0	78.5	27.22	12.05
CD	15.07	NS	NS	NS
I_1	196.1	74.5	24.92	11.10
I_2	203.6	76.3	27.28	12.06
I_3	216.3	85.2	29.44	13.05
I_4	254.8	91.9	34.34	13.98
CD	21.31	11.90	5.37	1.62
N_1	195.6	66.5	25.59	9.79
N_2	212.5	76.3	27.67	11.56
N_3	226.0	91.8	30.25	13.99
N_4	236.7	93.3	32.46	14.85
CD	15.31	7.41	2.55	1.12
SE/plot±	25.25	12.23	4.20	1.80

NS - Not Significant

Fig. 7. Effect of varieties, irrigation and nitrogen on yield/plant



A. tricolor. The data show that yield per plant during the second season is only 1/3rd of yield obtained in the first season. This may be due to a rainless climate prevailed during the second season.

Effect of irrigation on yield per plant was significant in both seasons. The treatment I_4 recorded maximum yield per plant followed by I_3, I_2 and I_1. In the first season, I_3, I_2 and I_1 were statistically on par but during the second season, I_4 was on par with I_3 and the latter was on par with I_2 and I_1.

A perusal of the data revealed the significant effect of irrigation on yield per plant and farmers' practice of irrigating the crop daily in two splits recorded the highest yield per plant followed by higher ratios of irrigation. The role of water in plant growth and development has been discussed earlier. High water availability might have increased the availability and uptake of nutrients required for growth and development of plants with resultant increase in yield per plant. Many workers reported increase in yield per plant due to irrigation. Borna (1974) and Dziezyc (1978) in cabbage, Henricksen (1980) in ridge cucumbers, Smittle and Threadgill (1982) in squash, Redai and Islam (1987) in cabbage also reported increased yields with irrigation.

Effect of nitrogen on yield per plant was significant in both seasons. Yield per plant was progressively increased as the levels of nitrogen were increased from 50 kg to 125 kg/ha. However during the first season, 125 kg N/ha was on par with 100 kg N/ha, the latter being on par with 75 kg N/ha. During second season, 125 kg N/ha was on par with 100 kg N/ha while 75 kg N/ha and 50 kg N/ha differed significantly.

The results of the present study confirms the well accepted influence of nitrogen on the vegetative growth of plants. The treatments receiving the highest dose of nitrogen could promote greater vegetative growth resulting in higher yield. The favourable influence of nitrogen on yield attributing characters can also be ascribed to the increased availability and uptake of nutrients required for the growth and development of plants. The importance of nitrogen on the synthesis of amino acids, proteins and other metabolic products needs little explanation (Tisdale et al., 1985). Significant increase in the yield of vegetative parts as a result of application of higher levels of nitrogen fertilizers was observed by several workers, Peck (1981) in cabbage, Veeraraghavaiah et al. (1985) in coriander, Singh (1984) in amaranthus.

4.1.9 Yield

The data on yield recorded as tonnes/ha are presented in Table 10.

The data showed that variety V_1 recorded maximum yield. But the varietal difference was found to be not significant during both seasons.

The data revealed significant effect of irrigation on yield during both seasons. This parameter showed an increasing trend with the increase in the ratios of irrigation. During both seasons, the farmers' practice of irrigating the crop daily in two splits was found to give the maximum yield. This was on par with $\frac{IW}{CPE}$ ratio of 1.25. The lowest yield was recorded by the lowest ratio of 0.75.

It is seen from the data that yield showed an increasing trend with the increase in the quantity of water applied. The yield increased from 24.92 to 34.34 t/ha during the first season and from 11.10 to 13.98 t/ha during the second season when the irrigation ratio increased from 0.75 to 1.25 and to farmers' practice of daily irrigation. The increment in yield was 2.36, 2.16 and 4.90 t/ha during the first season and 0.96, 0.99 and 0.93 t/ha during the second season when the irrigation ratios increased from 0.75 to 1.00, 1.00 to 1.25 and 1.25 to daily irrigation.

The favourable effects of irrigation in increasing the yield/plant have been discussed earlier. This increased yield/plant might have resulted in higher yield per hectare noted with higher irrigation treatments. Similar reports were made earlier by Umrani and Khot (1974) in brinjal, Jayakrishnakumar (1986) in bhindi, Sammis and Wu (1989) in cabbage. A comparatively higher yield obtained during the first season may probably be due to the favourable effect of the rainfall received during the later part of the crop growth.

The effect of nitrogen levels was significant on influencing the yield. The yield increased with increasing levels of nitrogen tried in the experiment. In the first season, nitrogen at 125 kg/ha was on par with 100 kg N/ha and 75 kg N/ha was on par with 50 kg N/ha. In the second season, 125 kg N/ha was on par with 100 kg N/ha and the effects of 75 kg and 50 kg N/ha differed significantly.

When the nitrogen levels increased from 50 to 125 kg/ha, yield increased from 25.59 to 32.46 t/ha during the first season and from 9.79 to 14.85 t/ha during the second season. The increment in yield during first and second season were 83.2 and 70.8 kg per kg of N respectively when the nitrogen dose increased from 50 to 75 kg N/ha. The yield increase was 103.2 kg during first season and

97.2 kg per kg N during second season when the nitrogen dose increased from 75 to 100 kg/ha. As the nitrogen dose increased from 100 to 125 kg/ha, the increment in yield was 88.4 kg and 34.4 kg per kg N during the first and second season respectively. An appraisal of the data revealed the significant effect of nitrogen in increasing the yield of plants. These results confirm the influence of nitrogen on vegetative growth and yield of plants. The results obtained are in agreement with those of Keskar *et al.* (1983) in amaranthus, Voigtander (1978) in lettuce and cabbage, Prabhakar and Srinivas (1987) in cabbage.

4.1.10 Dry weight of leaves per plant

The data on dry weight of leaves per plant recorded at the stage of harvest of the crops are presented in Table 11.

There was no significant difference between the varieties in the dry weight of leaves during both seasons.

The dry weights of leaves showed proportionate increase with the irrigation levels; however the differences were not statistically significant in both seasons.

Effect of nitrogen was significant during both seasons. The treatment N_4 recorded a maximum dry weight of 7.56 g during first season and 4.95 g during the second

Table 11. Effect of varieties, irrigation and nitrogen on the dry weight of leaves, stem and roots (g/plant)

	Leaf dry weight		Stem dry weight		Root dry weight	
	1989	1990	1989	1990	1989	1990
V_1	6.63	4.33	7.42	2.03	1.38	1.94
V_2	6.41	4.21	5.47	1.78	3.28	2.07
CD	NS	NS	0.824	0.172	NS	NS
I_1	6.13	3.99	5.60	1.79	2.92	1.42
I_2	6.44	4.09	6.45	1.85	3.04	1.69
I_3	6.55	4.17	6.75	1.96	3.23	2.20
I_4	6.96	4.84	6.98	2.02	3.74	2.69
CD	NS	NS	NS	NS	0.481	0.901
N_1	5.53	3.50	5.18	1.56	2.68	1.67
N_2	6.22	4.15	5.97	1.86	2.92	1.85
N_3	6.77	4.50	6.79	1.99	3.46	2.09
N_4	7.56	4.95	7.83	2.21	3.87	2.40
CD	0.833	0.428	1.017	0.258	0.414	0.384
SE/plot±	1.37	0.71	1.68	0.43	0.68	0.63

NS - Not Significant

season. In the first season, consecutive levels of nitrogen were on par. But in the second season, only the effects of N_3 and N_2 were on par.

An increase in the dry weight of leaves was noted with increasing doses of nitrogen from 50 to 125 kg N/ha. The role of nitrogen in the vegetative growth of plant has been discussed earlier. 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 other organic components of the plant. The amount of drymatter 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 organs of photosynthesis and an increase in the number of leaves and leaf area due to nitrogen fertilization might have increased the leaf dry weight also. Similar increase in dry weight due to nitrogen fertilization has been reported by Samui et al. (1986), Upasani and Sharma (1986), Nawawi et al. (1985).

4.1.11 Dry weight of stem per plant

The data on dry weight of stem per plant recorded at the stage of harvest of the crop are presented in Table 11.

Effect of varieties was significant on this parameter during both seasons. Variety V_1 recorded the maximum dry weight of stem during both seasons which were statistically significant over that of variety V_2.

It can be observed from the Tables 4, 5 and 6 that growth characters like height of the plant, girth of stem and number of branches are significantly higher in variety V_1. These parameters together may have contributed towards a significant increase in the dry weight of stem of that variety.

Main effect of irrigation was not significant during both seasons. However an increasing trend in dry weight of stem per plant was noted with frequent irrigation treatments. This may be due to better accumulation of drymatter under moist conditions. Similar increase in dry weight of stem due to irrigation was earlier reported by Tamaki and Naka (1971).

Main effect of nitrogen was significant during both seasons. The treatment 125 kg N/ha recorded maximum dry weight of stem per plant in both seasons followed by N at 100, 75 and 50 kg/ha. But in the first season, 100 kg N/ha was on par with 75 kg N/ha and the latter was on par with 50 kg N/ha. In the second season, 125 kg N/ha was on par with 100 kg N/ha, the latter being on par with 75 kg N/ha.

The data revealed significant effect of nitrogen on dry weight of stem. The influence of nitrogen in increasing the growth characters like height, girth of stem and number of branches might have contributed to an increase in the dry weight of stem. Similar increase in dry weight due to nitrogen application has been reported by Vuurmans and Grubben (1977).

4.1.12 Dry weight of root

The data on dry weight of roots per plant recorded at the stage of harvest of the crop are presented in Table 11.

There was no significant difference between the varieties during both seasons.

Effect of irrigation was significant during both seasons. The treatment I_4 recorded the maximum root dry weight per plant in the two seasons. The effects of I_3, I_2 and I_1 were on par during both seasons. However the effects of I_3 and I_4 were found to be on par during the second season only.

The data showed an increasing trend in dry weight of roots per plant with increasing ratios of irrigation from 0.75 to 1.25 and to farmers' practice. Root growth primarily depends upon the rooting pattern of the crop and moisture and nutrient availability. Adequate supply of water during the growth phase of the crop might have favoured the lateral spread of roots rather than going downward. The weight of root is determined by the spread of primary roots rather than the depth of tap root. The increase in available soil moisture with higher irrigation treatments might have favoured higher lateral spread of roots which might have resulted in higher root weight. This is again in agreement with the findings of Kramer (1978) and Thomas Mathew (1985).

Effect of nitrogen was significant on this parameter during both seasons. The treatment N_4 recorded maximum dry weight of roots followed by the treatments N_3, N_2 and N_1 in both seasons. In the first season, N_3 and N_4 were on par and N_2 and N_1 were on par. But in the second season, successive levels of nitrogen were found to be on par.

It is seen from the data that dry weight of roots per plant increased as the levels of nitrogen were increased from 50 kg to 125 kg/ha. Increased growth of top portion due to nitrogen application might have influenced the extensive root development and spread which might have resulted in higher root dry weight per plant. Similar increase in root dry weight due to nitrogen fertilization has been reported by Leskovar et al. (1989).

4.2 Quality aspects

4.2.1 Moisture content of leaves

The data on moisture content of leaves as percentage are presented in Table 12.

All the main effects of varieties, irrigation and nitrogen levels were found not significant in influencing the moisture content of leaves during both the seasons.

4.2.2 Moisture content of stem

The data on moisture content of stem as percentage are presented in Table 12.

Data showed that moisture content of stems of varieties V_1 and V_2 were statistically on par during both seasons.

Effect of irrigation was significant only during the first season. Treatment I_4 recorded the maximum moisture content of 90.34 per cent followed by I_3, I_2 and I_1 which registered the moisture content of 88.62, 88.29 and 87.79 per cent respectively. However I_3, I_2 and I_1

Table 12. Effect of varieties, irrigation and nitrogen on the moisture content of leaves and stem

	Leaves (%)		Stem (%)	
	1989	1990	1989	1990
V_1	88.84	87.17	88.62	90.78
V_2	88.84	87.61	88.89	91.39
CD	NS	NS	NS	NS
I_1	88.22	87.45	87.79	90.62
I_2	88.81	87.33	88.29	90.83
I_3	88.97	87.22	88.62	91.23
I_4	89.35	87.55	90.34	91.65
CD	NS	NS	1.335	NS
N_1	88.35	87.46	86.93	90.16
N_2	88.47	87.56	88.92	91.14
N_3	89.19	87.18	89.49	91.32
N_4	89.34	87.37	89.69	91.71
CD	NS	NS	1.484	0.916
SE/plot±	2.53	2.07	2.45	1.51

NS - Not Significant

were on par. In general, it is seen that moisture content of stem was not influenced by the different irrigation treatments.

Effect of nitrogen on moisture content of stem was significant during both seasons. Moisture content of stem was maximum at 125 kg N/ha followed by N at 100, 75 and 50 kg/ha. However the higher three levels of nitrogen were found to be on par and significantly superior over 50 kg N/ha during both seasons.

Role of nitrogen in vegetative growth of plant is well established. Increase in the production of new tissues as a result of increased levels of nitrogen might have increased the total water content of stem. Similar increase in moisture content due to nitrogen fertilization has been reported by Schuphan (1971) in spinach.

4.2.3 Protein content

The data on protein content of plant are presented in Table 13 and Fig.8

Varieties differed significantly in their protein content. Variety V_1 recorded maximum protein content during both the seasons followed by variety V_2.

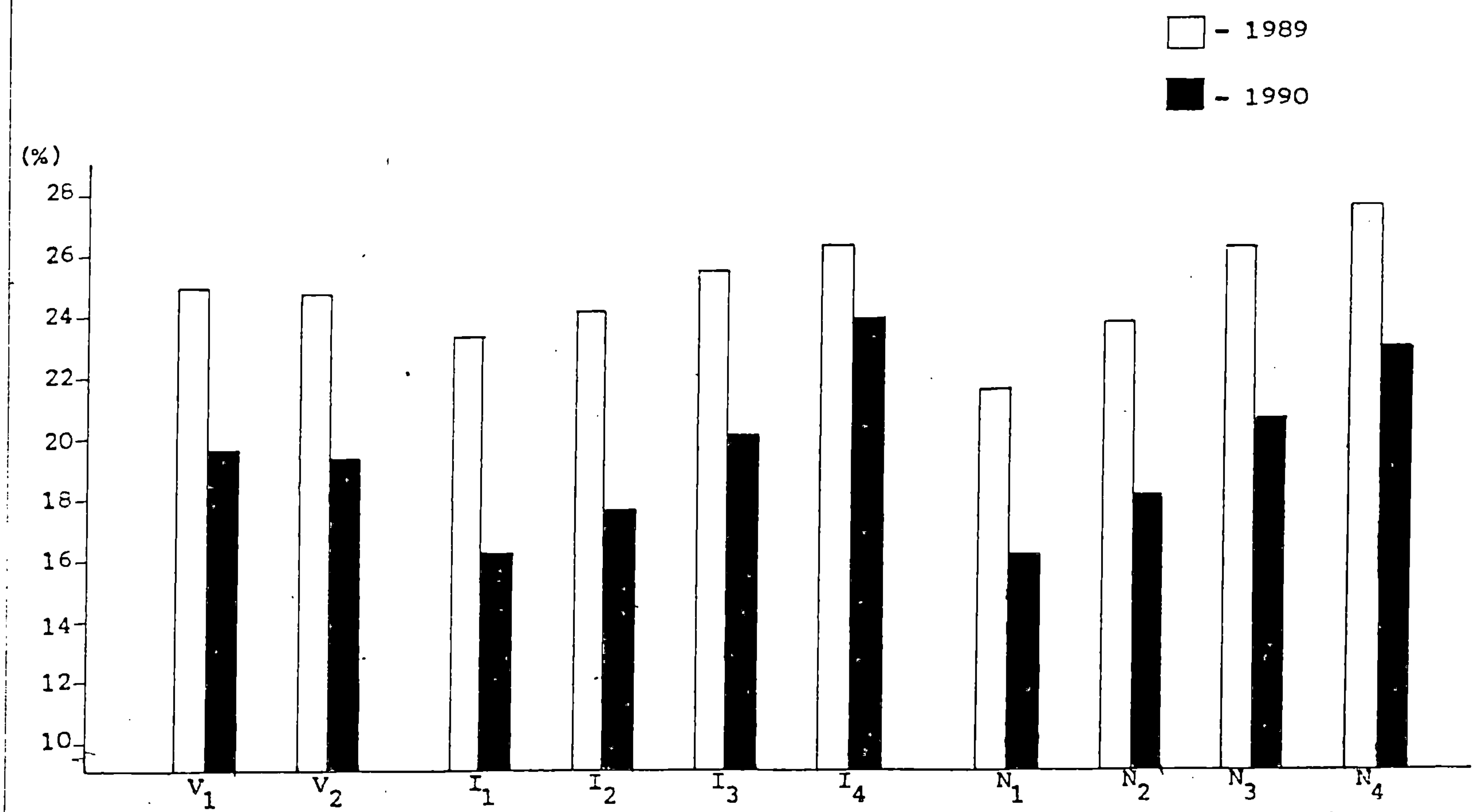
The analysis revealed significant variations in protein content of the varieties tried. The better response

Table 13. Effect of varieties, irrigation and nitrogen on the protein and fibre content of plant

	Protein (%)		Fibre (%)	
	1989	1990	1989	1990
V_1	24.89	19.59	10.69	10.53
V_2	24.59	19.23	10.21	10.21
CD	0.257	0.209	0.195	0.107
I_1	23.23	16.09	10.84	10.44
I_2	24.14	17.57	10.60	10.17
I_3	25.39	20.05	9.96	10.55
I_4	26.22	23.93	10.40	10.32
CD	0.364	0.297	0.276	0.151
N_1	21.56	16.16	11.87	11.68
N_2	23.76	18.06	10.67	10.79
N_3	26.15	20.52	10.14	9.86
N_4	27.51	22.89	9.18	9.15
CD	0.371	0.232	0.181	0.152
SE/plot±	0.61	0.38	0.31	0.26

NS - Not Significant

Fig.8. Effect of varieties, irrigation and nitrogen on protein content of plants



of variety V_1 for the utilization of nitrogen might have increased the nitrogen content in the plant and the protein content. Similar variation in the protein content of varieties was earlier reported by Mathai et al. (1981).

Effect of irrigation was found to be significant on this parameter during both seasons. Among the irrigation treatments farmers' practice of daily irrigation recorded the maximum of 26.22 per cent during the first season and 23.93 per cent in the second season followed by irrigation at $\frac{IW}{CPE}$ ratios of 1.25, 1.00 and 0.75.

The analysis showed a significant effect of irrigation on protein content of plant. This increase in protein content may be due to the increase in plant nitrogen content with resultant increase in protein synthesis favoured by higher irrigation treatments. Similar increase in protein content due to higher water availability has been reported by Cocueci et al. (1976) and Henricksen (1980).

Protein content of plant increased with increased doses of nitrogen. Nitrogen at 125 kg/ha recorded the maximum protein content of 27.51 per cent and 22.89 per cent in the first and second season respectively followed by nitrogen at 100, 75 and 50 kg/ha.

Results revealed that although trend of protein content is largely controlled by genetic factors, the amount of protein is governed by environmental factors especially nitrogen supply (Tisdale et al., 1985). The increase in protein content is only an expression of the part played by nitrogen in protein synthesis. The higher protein content of plants recorded during the first season may be due to the favourable source-sink relationship prevailed during the season due to frequent rainfall. Similar increase in protein content under nitrogen fertilization has been reported by Vuurmans and Grubben (1977) in leafy vegetables and Singh (1984) in amaranthus.

4.2.4 Fibre content

The data on fibre content of plants recorded at the stage of harvest of the crop are presented in Table 13.

Varietal difference was significant on this parameter during both seasons. Variety V_1 recorded a maximum fibre content of 10.69 per cent and 10.53 per cent in the first and second season respectively followed by variety V_2.

The data showed significant difference in the fibre content of the two varieties. This difference in fibre content may be due to the genetic differences between the cultivars.

Effect of irrigation was significant on this parameter during both seasons. In the first season, maximum fibre content of 10.84 per cent was recorded by the treatment I_1 followed by the treatments I_2, I_4 and I_3. I_1 was on par with I_2 which was on par with I_4. In the second season, maximum fibre content of 10.55 per cent was recorded by I_3 followed by the treatments I_1, I_4 and I_2. I_3 was on par with I_1, I_1 on par with I_4 and I_4 on a par with I_2.

Eventhough different irrigation treatments significantly influenced the fibre content of plant, the results are found inconsistent. Hence it is difficult to draw any conclusion about the superiority of any treatment in this regard.

Nitrogen levels markedly influenced this character. A decreasing trend in fibre content was noted with increasing levels of nitrogen from 50 kg to 125 kg N/ha during both seasons. Maximum fibre content of 11.87 per cent was recorded against nitrogen at 50 kg/ha during the first season and 11.68 per cent during the second season. The treatment 50 kg N/ha was followed by the treatments 75, 100 and 125 kg N/ha during both seasons.

Results showed that the fibre content of amaranthus was significantly decreased by nitrogen fertilization.

Increasing levels of nitrogen application causing an increase in the succulence could have decreased the fibre content. Mani and Ramanathan (1981) also reported a reduction in the fibre content of bhindi fruits due to higher nitrogen fertilization.

4.3 Uptake of nutrients

4.3.1 Nitrogen uptake by plants

The mean data on nitrogen uptake by plants in kg/ha recorded at the stage of harvest of the crop are presented in Table 14 and Fig.9.

There was significant difference between the varieties in the nitrogen uptake during the first season. Variety V_1 recorded the maximum nitrogen uptake in both seasons.

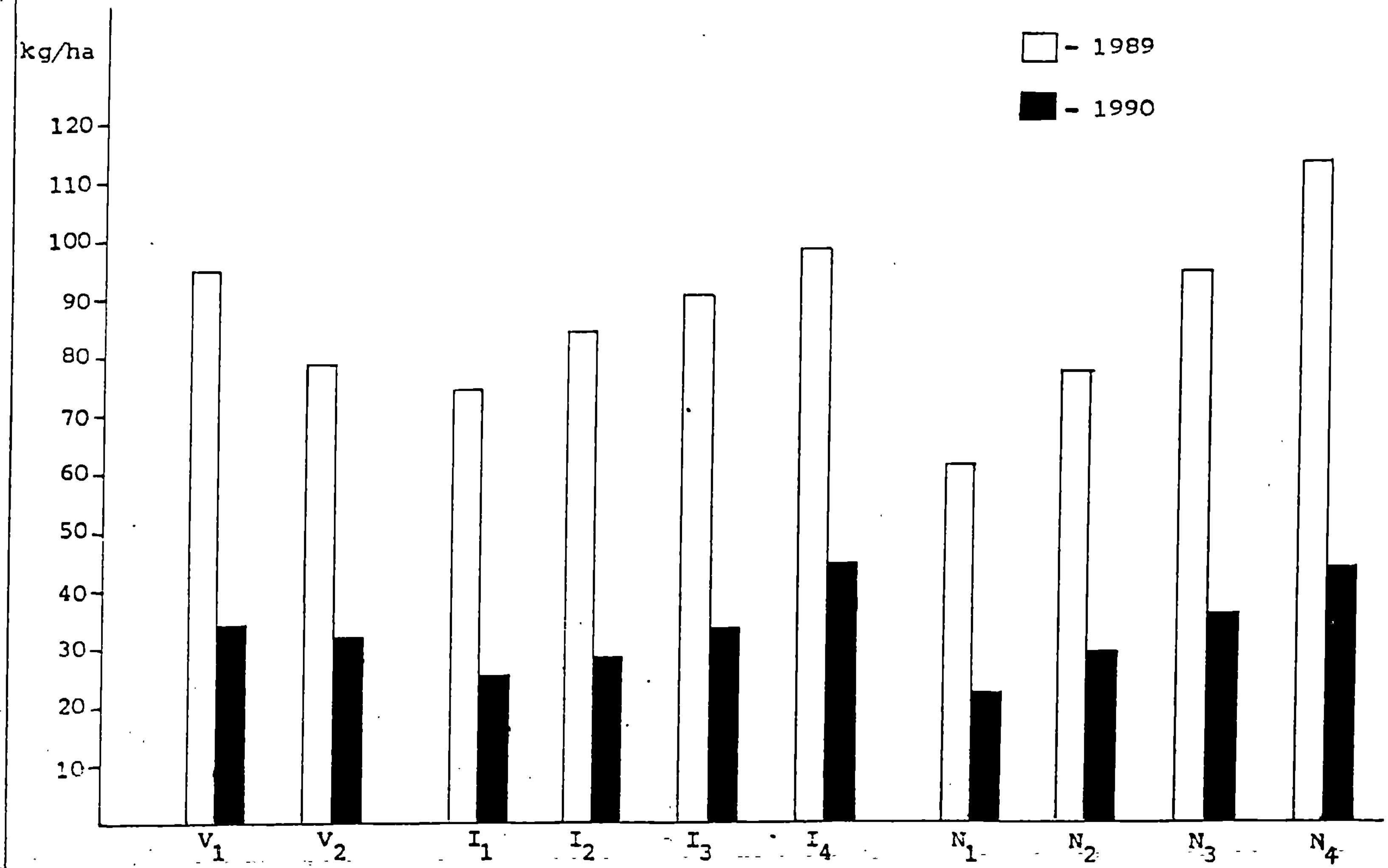
From the data it is seen that the nitrogen uptake recorded by variety V_1 in the first and second season were 94.70 and 33.76 kg/ha respectively. The analysis showed that the nitrogen uptake of variety V_1 was greater than variety V_2. This is evident from the fact that all the growth characters and yield are higher in variety V_1. The higher values of uptake of nitrogen recorded during the first season may probably be due to the better minerali-sation of nitrogen and favourable soil-water relationship caused by congenial climatic conditions.

Table 14. Effect of varieties, irrigation and nitrogen on the uptake of nitrogen, phosphorus and potassium by plants (kg/ha)

	Nitrogen		Phosphorus		Potassium	
	1989	1990	1989	1990	1989	1990
V_1	94.70	33.76	20.40	5.25	109.30	52.86
V_2	78.97	31.89	17.42	4.97	102.34	54.11
CD	7.376	NS	1.703	NS	NS	NS
I_1	74.14	25.10	15.95	4.41	101.97	48.02
I_2	84.06	28.53	19.27	5.01	99.23	49.90
I_3	90.81	33.27	19.39	4.59	107.91	49.18
I_4	98.34	44.41	21.02	6.44	114.18	66.83
CD	10.431	5.479	2.408	0.899	NS	8.178
N_1	61.86	22.01	16.64	4.11	92.68	50.64
N_2	77.55	29.33	17.88	5.06	100.40	49.98
N_3	94.88	35.97	19.09	5.49	109.39	56.15
N_4	113.05	43.99	22.03	5.78	120.82	57.16
CD	9.842	2.883	2.026	0.552	11.141	6.233
SE/plot±	16.23	4.75	3.49	0.95	19.20	10.74

NS - Not Significant

Fig. 9. Effect of varieties, irrigation and nitrogen on uptake of nitrogen by plants



Effect of irrigation on this parameter was significant during both seasons. The daily irrigation treatment recorded the maximum N-uptake value followed by irrigation ratios of 1.25, 1.00 and 0.75 during the two seasons. However the daily irrigation treatment was on a par with irrigation at $\frac{IW}{CPE}$ ratio of 1.25 and the consecutive irrigation ratios were found to be on a par during the first season. In the second season, the ratio 1.25 was on a par with the ratio 1.00 and the latter was on a par with the ratio 0.75.

The data showed that the plant uptake of nitrogen increased when the frequency of irrigation was increased and a maximum was observed at farmers' practice of daily irrigation. Mineralisation of nitrogen increases as the water content of soil increases from permanent wilting percentage to field capacity and saturation. The data on yield and dry matter production were the highest in the daily irrigation treatment during both seasons showing the efficiency of utilisation of the nutrient nitrogen at this moisture regime for higher production. This result is in agreement with that of Balakumaran (1981), George Thomas (1984) and Hegde (1986).

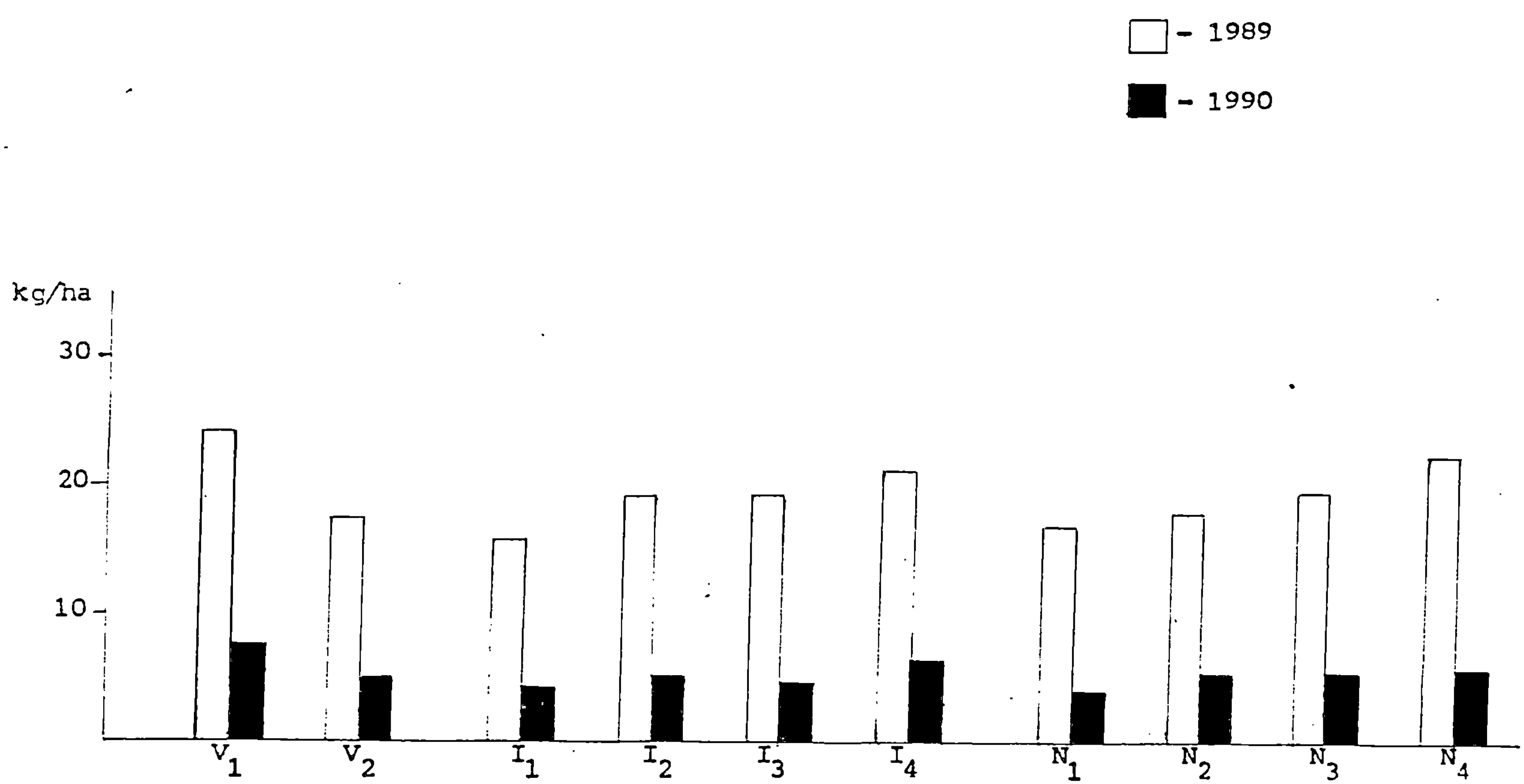
Effect of nitrogen was also significant in influencing the uptake by plants. Nitrogen at 125 kg/ha recorded the maximum uptake followed by nitrogen at 100, 75 and 50 kg/ha during both seasons.

The data showed that plant uptake of nitrogen increased with higher levels of application of this nutrient and maximum was obtained at the highest level of 125 kg N/ha in both the seasons. The nitrogen uptake by plants increased from 61.86 kg/ha to 113.05 kg/ha during the first season and from 22.01 kg/ha to 43.99 kg/ha during the second season as the levels of nitrogen increased from 50 kg/ha to 125 kg/ha. The data on number of branches, leaf number and yield were the highest at 125 kg/ha of nitrogen level thereby showing the efficient utilisation of absorbed nitrogen for growth and yield at this level. At higher levels of nitrogen, much of the photosynthates was allocated for the development of aerial part and the marked increase in yield is due to this fact. Increase in the uptake of nitrogen at higher rates of application of the nutrient is an already established fact. Tayel et al. (1965) and Ravikrishnan (1989) also reported increased plant uptake of nitrogen with higher doses of application.

4.3.2 Phosphorus uptake by plants

The data on phosphorus uptake by plants in kg/ha recorded at the stage of harvest of the crop are presented in Table 14 and Fig.10

Fig.10. Effect of varieties, irrigation and nitrogen on uptake of phosphorus by plants



The data revealed that variety V_1 recorded the highest phosphorus uptake of 20.40 and 5.25 kg/ha during the first and second season respectively. But the difference was significant only during the first season. The variation in growth habit with resultant increased dry matter production might have increased the phosphorus uptake by the variety V_1.

The effect of irrigation on the uptake of phosphorus was found to be significant in the first and second seasons. During both seasons, the daily irrigation treatment recorded the maximum phosphorus uptake. In the first season, the daily irrigation treatment and ratios of 1.25 and 1.00 were on a par while in the second season, the irrigation ratios of 0.75, 1.00 and 1.25 were on a par.

The results revealed the significant influence of irrigation on phosphorus uptake by plants. The uptake of nutrients is generally decided by the nutrient content and total dry matter production. According to Tanaka et al. (1964) the nutrient uptake is controlled by factors like nutrient availability in the soil, nutrient absorption power of roots and the rate of increase in dry matter. Higher irrigation treatments might have increased the dissolution of nutrients, promoted root growth and rendered nutrients more available. These results are in agreement with that of Balakumaran (1981) and George Thomas (1984).

Nitrogen significantly influenced the phosphorus uptake by plants. An increasing trend in phosphorus uptake was noted with increasing levels of nitrogen from 50 kg/ha to 125 kg/ha. In the first season, 100 kg N/ha was found to be on a par with 75 kg N/ha which in turn was on a par with 50 kg N/ha. But in the second season, 125 kg N/ha was on a par with 100 kg N/ha and the latter on a par with 75 kg N/ha.

The data showed that nitrogen levels significantly increased the phosphorus uptake by plants. The uptake of phosphorus by plants increased from 16.64 kg/ha to 22.03 kg/ha during the first season and from 4.11 kg/ha to 5.78 kg/ha during the second season as the levels of nitrogen were increased from 50 kg/ha to 125 kg/ha. Role of nitrogen in increasing the dry matter production is well known. A stimulated growth under higher nitrogen levels might have resulted in better proliferation of root system and increased intake efficiency of plants. Significant influence of nitrogen on phosphorus uptake by plants have been reported earlier by Ravikrishnan (1989), and George Thomas (1984).

4.3.3 Potassium uptake by plants

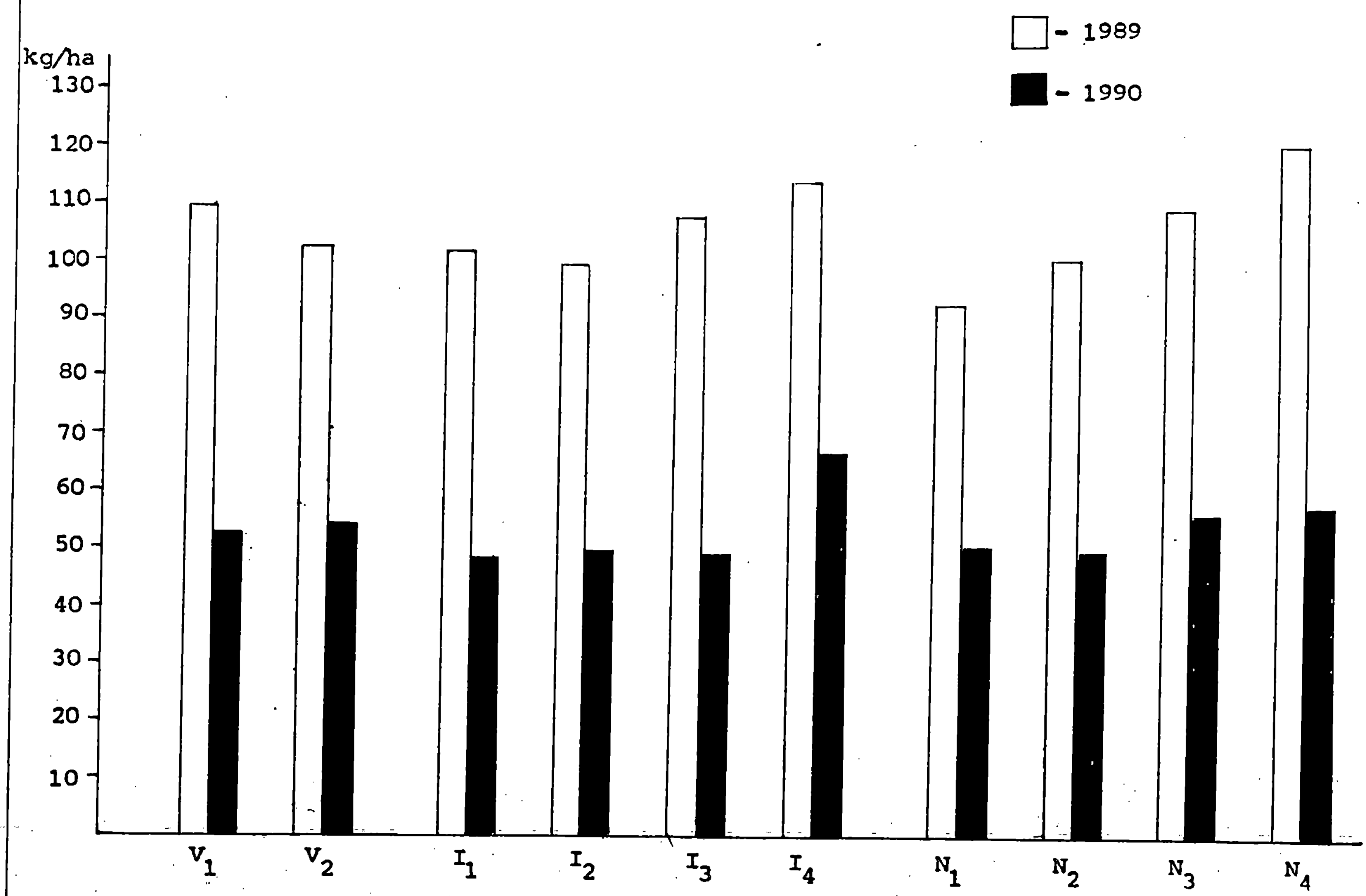
The data on potassium uptake in kg/ha recorded at the stage of harvest of the crop are presented in Table 14 and Fig.11.

Effect of varieties on potassium uptake by plants was found to be not significant during both the seasons.

Effect of irrigation on potassium uptake by plant was found to be significant only during the second season and the daily irrigation treatment recorded maximum potassium uptake of 66.83 kg/ha. However the effects of irrigation at $\frac{IW}{CPE}$ ratios of 0.75, 1.00 and 1.25 were found to be on par.

The data revealed that potassium uptake by plants increased from 48.02 kg/ha to 66.83 kg/ha as the frequency of irrigation was increased. The reason may be attributed to the increased yield and drymatter production at higher irrigation treatments. The availability of potassium decreases when the soil moisture stress increases (Michael, 1978). Similar increase in potassium uptake under higher levels of irrigation has been reported by George Thomas (1984), Hegde (1986) and Jayakrishnakumar (1986). The lack of significant difference in potassium uptake by plants during the first season may be due to the unprecedented rainfall received during the cropping period. This might have increased the availability of potassium in soil irrespective of the effect of irrigation treatments.

Fig.11. Effect of varieties, irrigation and nitrogen on uptake of potassium by plants



Effect of nitrogen was found to be significant on potassium uptake during both seasons. An increasing trend in potassium uptake was noted with increasing levels of nitrogen during the first season where 125 kg N/ha recorded the maximum. The treatment 100 kg N/ha was on par with 75 kg N/ha and 75 kg N/ha on par with 50 kg N/ha. In the second season also 125 kg N/ha recorded the maximum potassium uptake followed by 100, 50 and 75 kg N/ha. However 125 kg N/ha was on par with 100 kg N/ha and 100 kg N/ha was on par with 50 and 75 kg N/ha.

The data showed that nitrogen levels had a significant influence on the uptake of potassium by plants. Higher levels of nitrogen increased the LAI and stem and leaf dry weights. This might have increased the photosynthetic efficiency. It is considered that increased photosynthetic activity increases the uptake of potassium. Significant influence of nitrogen on potassium uptake by plant has been reported earlier by Hegde (1988b).

4.4 Soil analysis

4.4.1 Available nitrogen content of the soil after the experiment

The data on available nitrogen content of the soil after the experiment expressed as kg/ha are given in Table 15.

Table 15. Effect of varieties, irrigation and nitrogen on the available nitrogen, phosphorus and potassium in the soil after the experiment

	Available N (kg/ha)		Available P_2O_5 (kg/ha)		Available K_2O (kg/ha)	
	1989	1990	1989	1990	1989	1990
V_1	407.42	347.31	49.97	64.01	86.19	127.78
V_2	425.90	383.58	55.52	79.52	99.97	127.47
CD	6.554	3.306	0.584	0.415	0.788	NS
I_1	413.44	382.09	60.09	73.97	108.43	137.86
I_2	499.68	376.57	61.17	76.48	92.31	127.88
I_3	392.16	356.24	46.70	73.76	88.17	125.39
I_4	361.36	346.88	43.03	62.86	83.41	119.36
CD	9.268	4.675	0.827	0.587	1.114	2.721
N_1	374.52	336.16	73.20	68.73	96.09	137.73
N_2	400.00	350.36	44.95	78.16	95.24	125.32
N_3	401.68	369.09	44.98	73.97	94.16	124.89
N_4	490.44	406.16	47.86	66.21	86.83	122.57
CD	11.042	7.057	0.786	0.738	1.102	2.834
SE/plot±	18.21	11.64	1.29	1.22	1.82	4.67

NS - Not Significant

Available nitrogen status of the soil was maximum in plots where variety V_2 was raised during both the seasons. It can be seen from the data that available nitrogen status ranged from 407.42 to 425.90 kg/ha in the first season and from 347.31 to 383.58 kg/ha in the second season. Better utilisation of nitrogen by the variety V_1 as evident from the data on uptake of the nutrient (Table 14) might have resulted in the reduced available nitrogen status of the soil in those plots.

Irrigation had profound influence on the available nitrogen status of the soil during both seasons. Maximum available nitrogen content was recorded against the ratio 1.00 followed by the ratios 0.75 and 1.25 and cultivators' practice of daily irrigation in the first season, while in the second season maximum available nitrogen content was recorded against the ratio 0.75 followed by the ratios 1.00 and 1.25 and cultivators' practice of daily irrigation.

From the data it can be seen that available nitrogen content of soil decreased as the ratios of irrigation were increased from 0.75 to 1.25 and daily irrigation treatment recorded the lowest value. The higher water availability might have enhanced better mineralisation of nitrogen and consequently greater uptake by plant which might have reduced the available nitrogen content of soil in more frequent irrigation treatments. Similar results were advanced earlier by George Thomas (1984).

Effect of nitrogen fertilization was significant on this aspect. Maximum available nitrogen content was recorded against 125 kg N/ha followed by 100, 75 and 50 kg N/ha during both seasons. However 100 kg N/ha and 75 kg N/ha were on par during the first season.

It is evident from the data that available nitrogen content of the soil increased with increased levels of nitrogen addition. A high status of a particular nutrient in the soil consequent to its addition to the soil has been well established in many crop plants. This finding is in agreement with that of Ravikrishnan (1989) in bittergourd and Subba Rao (1989) in cucumber.

4.4.2 Available phosphorus content of the soil after the experiment

The data on available phosphorus content of the soil after completion of the experiment are given in Table 15.

The main effects of varieties, irrigation and nitrogen levels significantly influenced the available phosphorus content of the soil.

Maximum phosphorus content was recorded against variety V_2 in both seasons followed by variety V_1. The available phosphorus content of the soil ranged from 49.97 kg P_2O_5/ha to 55.52 kg P_2O_5/ha during the first season and from 64.01 to 79.52 kg P_2O_5/ha during the second season. This variation may be due to the difference in plant utilisation of phosphorus by the crop. The plant uptake of phosphorus was significantly influenced by the varieties and by irrigation and nitrogen. The increased uptake of this element by the influence of irrigation and nitrogen might have resulted in the significant difference in the available phosphorus content in the soil after the experiment.

Among the irrigation treatments, maximum available phosphorus content was noted against the ratio 1.00 and the minimum against daily irrigation treatment in both seasons. The ratios 0.75 and 1.25 were on par and were higher than daily irrigation treatment during the second season.

The analysis of the data revealed that available phosphorus content showed a decreasing trend with increasing levels of irrigation. This may be due to a greater uptake of this nutrient as a consequence of better dilution of phosphorus caused by increased water availability in soil. Such a decreasing trend in available phosphorus content of soil at higher irrigation treatments was earlier reported by George Thomas (1984).

Effect of nitrogen on available phosphorus content was marked and maximum value was recorded against nitrogen at 50 kg/ha followed by nitrogen at 125, 100 and 75 kg/ha during the first season. 100 kg N/ha and 75 kg N/ha were found to be on par. In the second season, maximum available phosphorus content was recorded against 75 kg N/ha followed by nitrogen at 100, 50 and 125 kg/ha, the difference being significant in all cases.

The data did not reveal any specific relationship between phosphorus content of soil and applied nitrogen levels. This variation in the available phosphorus content of the soil may be due to the direct effect of applied fertilizer nutrient over a uniform dose of FYM. FYM has considerable influence on the release of available nitrogen, phosphorus and potassium to plants (Venketasa Rao, 1985), Thangavel (1985) and Lavanya (1986).

4.4.3 Available potassium content of the soil after the experiment

The data on available potassium content of the soil in kg/ha after the experiments are presented in Table 15.

The data showed that varietal influence was significant only during the first season. Available potassium content of the plots in which variety V_1 was raised recorded

86.19 kg K_2O/ha while those in which variety V_2 was raised recorded 99.97 kg K_2O/ha.

The data revealed that available potassium content of the soil was significantly lowered by variety V_1. The uptake of this nutrient, the total drymatter production and water use efficiency were higher in variety V_1 proving that the total utilisation of all available resources for productivity was higher in variety V_1. This again clearly shows that the variety V_1 might have utilised the available potassium in the soil more efficiently.

Irrigation treatments significantly influenced the available potassium content of the soil after the experiment. In both seasons, the ratio 0.75 recorded the maximum available potassium content. There was a gradual reduction in available potassium content of soil as the ratios of irrigation increased from 0.75 to 1.25 and to daily irrigation. However in the second season, the effects of the ratios 1.00 and 1.25 were found to be on par.

It is seen that the available potassium content in the soil decreased with increase in the irrigation ratios from 0.75 to 1.25 and daily irrigation treatment. As the IW/CPE ratio increased from 0.75 to 1.25, the available potassium content decreased significantly and the lowest value was recorded against daily irrigation treatment.

The amount of water soluble potassium in soil depends mainly on the amount of exchangeable potassium and moisture regime of the soil. Soluble potassium is very easily available to plant. The increased uptake of this element at higher IW/CPE ratios shows the higher plant utilisation of the element at higher soil moisture content in the soil.

The data showed that different nitrogen levels significantly influenced the available potassium content of the soil after completing the experiments. In both seasons, maximum potassium content was recorded against 50 kg N/ha. There was a gradual reduction in the potassium content of soil when the nitrogen levels increased from 50 kg to 125 kg/ha. In the first season, 50 kg N/ha was on par with 75 kg N/ha, the latter on par with 100 kg N/ha. In the second season 75, 100 and 125 kg N/ha were found to be on par.

An appraisal of the data revealed the significant effect of nitrogen levels on the available potassium content of the soil. The higher levels of nitrogen might have increased the better utilisation of potassium. This is evident from the data on growth characters and yield. This might have reduced the available potassium content in the soil.

4.5 Moisture studies

4.5.1 Field water use efficiency

The data on field water use efficiency expressed as kg/ha mm on dry weight basis are presented in Table 16 and Fig. 12.

Water use efficiency of the varieties differed significantly during the first season only. During the first season, variety V_1 recorded the maximum water use efficiency of 11.14 while the variety V_2 recorded the minimum of 9.45. In the second season also variety V_1 recorded the maximum of 7.14 which was on par with that of variety V_2 which recorded the minimum of 6.77.

An appraisal of the data revealed that variety V_1 recorded the maximum water use efficiency than variety V_2. This may be due to increased yield of variety V_1 with the same quantity of water applied.

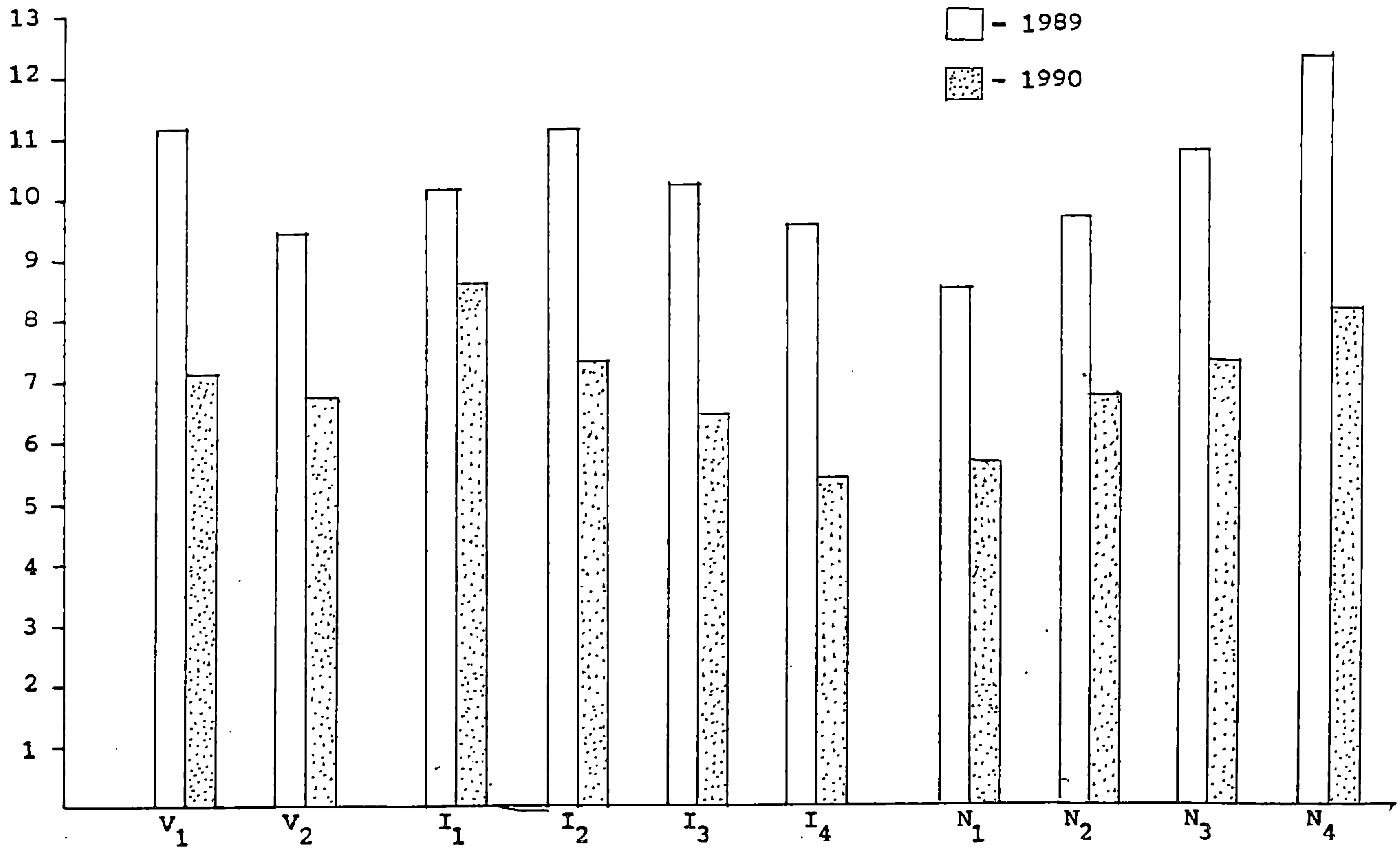
Effect of irrigation levels on field water use efficiency was significant only during the second season. In the second season, the maximum water use efficiency of 8.62 was recorded by irrigation at $\frac{IW}{CPE}$ ratio of 0.75. This was followed by the ratios 1.00 and 1.25 and farmers' practice of daily irrigation.

Table 16. Effect of varieties, irrigation and nitrogen on the Field Water Use Efficiency (kg/ha mm)

	Field WUE	
	1989	1990
V_1	11.14	7.14
V_2	9.45	6.77
CD	0.873	NS
I_1	10.15	8.62
I_2	11.16	7.32
I_3	10.28	6.47
I_4	9.59	5.40
CD	NS	0.811
N_1	8.52	5.68
N_2	9.66	6.72
N_3	10.74	7.31
N_4	12.26	8.11
CD	1.051	0.597
SE/plot±	1.81	1.03

NS - Not Significant

Fig.12 Effect of varieties, irrigation and nitrogen on field water use efficiency (kg/ha mm)



The results indicated that field water use efficiency was higher with less frequent irrigation schedules. Water use efficiency is likely to increase with decrease in soil moisture supply until it reaches the minimum critical level because the plants may try to economise water loss in the range from minimum critical to optimum soil moisture level. Water above the optimum level may be lost in the form of excessive evaporation, excessive transpiration or even as deep percolation. These findings are in agreement with that of Sharma and Parashar (1979) and Subba Rao (1989). Lack of any significant response in the water use efficiency of different irrigation treatments during the first season may be due to the occurrence of rainfall during the cropping period.

Main effect of nitrogen was found to be significant during both seasons. Field water use efficiency tended to increase with increasing levels of nitrogen. Nitrogen at 125 kg/ha recorded the maximum water use efficiency of 12.26 in the first season and 8.11 in the second season. This was followed by 100, 75 and 50 kg N/ha during both seasons. However in the second season, the effects of 100 and 75 kg N/ha were found to be on par.

From the data, it can be observed that application of nitrogen increased the water use efficiency due to increased yield with the same quantity of water applied. This result is in agreement with the findings of Sharma and Parashar (1979), Upasani and Sharma (1986).

4.6 Economics of cultivation

The data on economics of cultivation are presented in Table 17.

Among the two varieties, variety V_1 (red) recorded the maximum net income of Rs.8069.00 per hectare with a benefit : cost ratio (BCR) of 1.43. However in the case of variety V_2 (green), the net income was Rs.4041.00 only with a BCR of 1.21.

The analysis revealed that net income and BCR increased as the irrigation ratios were increased from 0.75 to 1.25 and cultivators' practice of daily irrigation recorded the maximum net income and BCR. Irrigation ratio of 0.75 registered a net income of Rs.2599.00 and BCR of 1.13. When the irrigation ratio increased to 1.00, the additional net income obtained was Rs.299.00 and BCR increased to 1.14. When the irrigation ratio increased to 1.25, the net income per hectare and BCR were Rs.3730.00 and 1.17 respectively. The daily irrigation treatment recorded the maximum net income of Rs.5849.00 and a BCR of 1.25. The economic analysis thus revealed that irrigating

Table 17. Economics of cultivation

Treatment	Cost of cultivation excluding the treatments Rs.	Additional cost Rs.	Total cost of production Y Rs.	Returns X Rs.	Net income X-Y Rs.	Benefit:Cost Ratio (BCR) $\frac{X}{Y}$
V_1	18917.00	-	18917.00	26986.00	8069.00	1.43
V_2	18917.00	-	18917.00	22958.00	4041.00	1.21
I_1	16631.00	3322.00	19953.00	22552.00	2599.00	1.13
I_2	16631.00	3800.00	20431.00	23329.00	2898.00	1.14
I_3	16631.00	4757.00	21388.00	25118.00	3730.00	1.17
I_4	16631.00	6407.00	23038.00	28887.00	5849.00	1.25
N_1	16631.00	4372.00	21003.00	21834.00	831.00	1.04
N_2	16631.00	4505.00	21136.00	24063.00	2927.00	1.14
N_3	16631.00	4638.00	21269.00	26488.00	5219.00	1.25
N_4	16631.00	4771.00	21402.00	27500.00	6098.00	1.29

Cost of cultivation excluding the treatments - Rs.16631.00

Cost of irrigation. I_1 - 2855.00; I_2 - 3333.00; I_3 - 4290.00; I_4 - 5940.00

Cost of nitrogen. N_1 - 267.00; N_2 - 400.00; N_3 - 533.00; N_4 - 666.00

1 kg N = Rs.5.33; 1 kg P_2O_5 = Rs.6.25; 1 kg K_2O = Rs.2.91; 1 ton FYM = Rs.250.00

the crop daily in two splits in mornings and evenings is the best practice for obtaining maximum net income as well as the highest BCR.

Nitrogen application markedly influenced the economics of production. The net income and BCR increased with increase in nitrogen dose from 50 to 125 kg/ha. The treatments 50, 75, 100 and 125 kg N/ha resulted in net income of Rs.831.00, Rs.2927.00, Rs.5219.00 and Rs.6098 and BCR of 1.04, 1.14, 1.25 and 1.29 respectively. The analysis thus revealed that nitrogen application substantially increased the net income and BCR upto the highest dose of 125 kg N/ha tried in the experiment. Such a trend could be expected when the vegetable yield increased markedly due to higher nitrogen fertilization.

SUMMARY

SUMMARY

An investigation was undertaken at the Instructional Farm of the College of Agriculture, Vellayani, during the summer seasons of 1989 and 1990 to find out the effect of irrigation and nitrogen on growth, yield, quality and uptake of major nutrients by red and green amaranthus varieties. The trial was conducted as a split-plot experiment with a combination of two varieties and four irrigation treatments as main plot treatments and four levels of nitrogen as sub plot treatments. Observations were made on growth, yield and quality characters and the results of the study are summarised below.

1. Significant difference in height of plant was noted between the varieties at various growth stages during the first season and only at 20 DAP during the second season. Irrigation significantly influenced the height of plant at all stages of growth of the crop and maximum height was recorded against daily irrigation treatment. The effect of nitrogen on the height of plant was significant at various growth stages of the crop. An increasing trend was observed in this character with increasing levels of nitrogen and the maximum height was recorded against 125 kg N/ha.

2. The varietal effect on girth of stem was inconsistent during the early stages of growth of the crop while in the later stages, red variety showed an increasing trend in this character. Different irrigation treatments significantly influenced the girth of stem at all stages of growth except at 10 DAP during second season. However the results were found to be inconsistent during both seasons. The effect of nitrogen was significant on girth of stem at various growth stages of the crop. There was increase in the girth of stem with the increase in the levels of nitrogen from 50 to 125 kg/ha and the maximum was recorded against 125 kg N/ha.

3. Significant difference in the number of branches was observed between the varieties at all stages of growth and the red variety recorded maximum number of branches. The irrigation treatments had significantly influenced the number of branches per plant at all the stages of growth of the crop during first season and at 10 and 20 DAP during the second season. During the first season, irrigation at $\frac{IW}{CPE}$ of 1.00 recorded maximum number of branches at various growth stages while during the second season, maximum number of branches was recorded against the ratio 0.75 at 10 and 20 DAP. The levels of nitrogen significantly influenced this character

at all stages of growth during the first season where 75 kg N/ha recorded the maximum number of branches. But in the second season, the effect of nitrogen was significant on this character only at 20 DAP and 100 kg N/ha recorded the maximum number of branches.

4. Varieties differed significantly in the number of leaves per plant at 10 and 20 DAP during both seasons and at the stage of harvest during the second season only. In the first season, green variety recorded maximum number of leaves while in the second season, red variety recorded maximum number of leaves. Irrigation had significant influence on number of leaves per plant at various growth stages during the first season and except at 10 DAP in the second season. During both seasons, farmer's practice of daily irrigation recorded the maximum number of leaves. Effect of nitrogen was found to be significant on this parameter at various growth stages during the first season and except at 10 DAP during the second season. An increasing trend was noted in this character with increasing levels of nitrogen from 50 to 125 kg/ha.

5. Significant difference in spread of plant was noted between the varieties at different growth stages during the first season and except at the stage of harvest of

the crop during the second season. The green variety recorded maximum spread. Eventhough the effects of irrigation and nitrogen were found to be significant on this parameter, the results were not consistent.

6. LAI of the two varieties differed significantly only during the first season where the green variety recorded the maximum LAI. Effect of irrigation on LAI was significant during both seasons. LAI increased as the irrigation ratios increased from 0.75 to 1.25 and the daily irrigation treatment recorded the maximum LAI. Effect of nitrogen on LAI was also significant and higher values of LAI were noted against higher levels of nitrogen tried in the experiment.

7. Varieties differed significantly in their leaf : stem ratio only during the first season, where the green variety recorded the maximum leaf : stem ratio of 1.21. However the effects of irrigation and nitrogen were found to be not significant in influencing the leaf : stem ratio during both the seasons.

8. The varietal difference in yield per plant was significant only during the first season and the red variety recorded the maximum yield per plant. Irrigation treatments significantly influenced this parameter and the yield per plant was maximum at daily irrigation treatment.

Effect of nitrogen was significant on this character and yield per plant was progressively increased when the levels of nitrogen were increased from 50 to 125 kg/ha.

9. Varieties did not differ in the yield during both seasons. Irrigation significantly influenced this character. The yield was progressively increased when the irrigation ratio increased from 0.75 to 1.25 and the cultivator's practice of daily irrigation recorded the maximum yield of 34.34 and 13.98 t/ha during the first and second season respectively. Yield was significantly influenced by nitrogen and maximum yield of 32.46 and 14.85 t/ha were recorded against 125 kg N/ha during the first and second season respectively.

10. There was no significant difference between the varieties in the dry weight of leaves. Effect of different irrigation treatments were also not significant on this character. The effect of nitrogen was significant and an increase in the dry weight of leaves was noted with increasing doses of nitrogen from 50 to 125 kg/ha tried in the experiment.

11. Effect of varieties was significant on dry weight of stem and red variety recorded maximum stem dry weight over green variety. Effect of irrigation was not

significant on this parameter during both seasons. Effect of nitrogen was significant and the dry weights of stem increased with increasing doses of nitrogen and the maximum was recorded at 125 kg N/ha.

12. Varietal difference was not significant on the root dry weight. The effect of irrigation was significant and increased dry weight of roots was noted with higher irrigation treatments. Nitrogen significantly influenced the dry weight of roots and highest values were noted against the highest level of 125 kg N/ha.

13. All the main effects of varieties, irrigation and nitrogen levels were not significant in influencing the moisture content of leaves.

14. The varietal variation was not significant on the moisture content of stem. The effect of irrigation was significant in influencing the moisture content of stem only during the first season where daily irrigation treatment recorded the maximum value. The effect of nitrogen was significant during both seasons and the moisture content of stem increased as the levels of nitrogen were increased from 50 to 125 kg/ha.

15. Varieties differed significantly in their protein content and red variety recorded the maximum. Effect of irrigation was also significant and protein content rose with

higher irrigation treatments. Nitrogen treatments also exerted significant influence and the protein content of plant increased with increased doses of nitrogen and the maximum was recorded at 125 kg N/ha.

16. Varietal difference was significant on the fibre content of plants and red variety recorded the maximum fibre content. Eventhough the different irrigation treatments significantly influenced the fibre content of plant, the results were inconsistent. Effect of nitrogen on this character was significant and fibre content of plant was decreased by nitrogen fertilization.

17. Varietal difference was significant in the total nitrogen uptake by plants during the first season only where the red variety recorded the maximum uptake of nitrogen. Effect of irrigation was also significant and the uptake of nitrogen was enhanced by more frequent irrigation treatments. The effect of nitrogen levels was significant on this aspect. The plant uptake of nitrogen increased with higher levels of nitrogen and maximum was recorded at the highest level of 125 kg N/ha during both seasons.

18. The results revealed that the red variety recorded higher phosphorus uptake during both seasons and the difference was significant only during the first season. The uptake

of phosphorus by plants was significantly influenced by irrigation treatments and the maximum phosphorus uptake was noted against the daily irrigation treatment. Nitrogen significantly influenced the phosphorus uptake by plants and an increasing trend in phosphorus uptake was noted with increasing levels of nitrogen from 50 to 125 kg/ha.

19. Effect of varieties on potassium uptake by plants was not significant during both seasons. Effect of irrigation on potassium uptake was found to be significant only during the second season and the daily irrigation treatment recorded the maximum potassium uptake. Nitrogen significantly influenced the potassium uptake during both seasons and the uptake of this nutrient increased as the nitrogen fertilization increased from 50 to 125 kg/ha.

20. Varietal effect was significant in influencing the available nitrogen status of the soil after the experiments. Available nitrogen content was high in plots where the green variety was raised during both the seasons. Irrigation and nitrogen treatments had significant influence on the available nitrogen status of the soil. The nitrogen content was low in more frequently irrigated treatments. However nitrogen

fertilization from 50 to 125 kg/ha significantly increased the available nitrogen content of the soil after the experiments.

21. All the main effects of varieties, irrigation and nitrogen levels had significantly influenced the available phosphorus content of the soil after the experiment. Available phosphorus content was maximum in plots where green variety was grown. Among the irrigation treatments, maximum available phosphorus content was recorded against the ratio 1.00 and as the frequency of irrigation increased, available phosphorus content of the soil showed a decreasing trend. Even-though the effect of nitrogen levels was found to be significant, the results did not reveal any specific relationship between phosphorus content of soil and applied nitrogen levels.

22. Available potassium content of the soil was significantly influenced by the varieties only during the first season. Maximum potassium content was recorded against the green variety and minimum against the red variety. Irrigation treatments significantly influenced the potassium content of the soil after the experiment and as the ratios of irrigation increased from 0.75 to 1.25 and to daily

irrigation, the available potassium content of the soil decreased. The effect of nitrogen levels was significant and as the levels of nitrogen increased from 50 to 125 kg/ha, the available potassium content of the soil was reduced.

23. The red variety showed maximum water use efficiency followed by green variety, the variation being significant only during the first season. Effect of irrigation treatments on field water use efficiency was significant only during the second season and the lower irrigation ratios showed higher water use efficiency. Effect of nitrogen was found to be significant and field water use efficiency tended to increase with increasing levels of nitrogen from 50 to 125 kg/ha.

24. Economic analysis revealed that net income and Benefit-Cost Ratio (BCR) were maximum for the red variety of amaranthus. The net income and BCR were increased when the irrigation ratios increased from 0.75 to 1.25 and the cultivator's practice of daily irrigation recorded the maximum net income and BCR. Such a trend was also noted when the nitrogen levels increased from 50 to 125 kg/ha and the maximum net income and BCR were obtained at 125 kg N/ha.

Future line of work

Since amaranthus is grown as a leafy vegetable and the crop is of short duration nature, ratooning is possible in amaranthus. The effect of water and fertilizer management under such a condition need be studied. Since the response to nitrogen in the present study was linear, more detailed investigations may be conducted after including different levels of phosphorus and potassium in combination with nitrogen to work out a precise fertilizer recommendation for the crop. The effect of nitrogen fertilization on quality aspects of the crop such as iron content, vitamins A and C contents, and concentration of NO_3-N in the leaves etc. are to be further investigated.

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PRODUCTION POTENTIAL OF AMARANTHUS UNDER IRRIGATION AND NITROGEN LEVELS

BY

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ABSTRACT

An experiment was conducted at the Instructional Farm, College of Agriculture, Vellayani, during the summer seasons of 1989 and 1990 to study the response of amaranthus to different water management practices and nitrogen doses. The trial was laid out in split-plot design with three replications. The main plot treatments consisted of a combination of two varieties (red and green) and four irrigation treatments. (Irrigation at $\frac{IW}{CPE}$ ratio of 0.75, 1.00 and 1.25 and the farmers' practice of daily irrigation). Sub plot treatments consisted of four levels of nitrogen (50, 75, 100 and 125 kg N/ha).

The study revealed that amaranthus responded well to frequent irrigations and higher levels of nitrogen. Red variety of amaranthus was superior to green variety in most of the growth and yield attributing characters studied. Biometric characters like height, girth of stem, number of branches, number of leaves, LAI, and dry weights of leaves, stem and roots were favourably influenced by frequent irrigations and higher nitrogen levels. Total yields were also higher in more frequently irrigated treatments and at higher nitrogen levels.

The moisture content of leaves was not influenced by irrigation and nitrogen treatments. However nitrogen

exerted, significant influence on the moisture content of stem. Protein content of red variety was maximum and as the frequency of irrigation and levels of nitrogen were increased, protein content of plant increased and the maximum was recorded at daily irrigation treatment and at 125 kg N/ha. A relatively higher fibre content was noted in red variety. The effect of irrigation treatments on the fibre content of plants were not conclusive but the nitrogen fertilization tended to decrease the fibre content of plants.

The red variety recorded a comparatively higher uptake of nutrients. The uptake of N, P and K were enhanced by frequent irrigations and nitrogen application upto 125 kg/ha.

Available N, P, K status of the soil after the experiment was reduced by red variety. Higher irrigation treatments reduced the N and K content of soil after the experiment. But the nitrogen fertilization increased the nitrogen content and reduced the potassium content of the soil after completing the experiment. However the effects of different irrigation and nitrogen treatments on available phosphorus content of the soil after the experiments were found to be inconsistent during the two seasons.

The red variety showed maximum water use efficiency than the green variety. Field water use efficiency was higher in the less frequently irrigated treatments (IW/CPE of 0.75 and 1.00) and at higher nitrogen fertilization (125 and 100 kg N/ha).

The results of economic analysis revealed that net income and benefit cost ratio were maximum for red variety and these were increased by more frequent irrigations and nitrogen fertilization upto 125 kg N/ha.