RESPONSE OF VEGETABLE COWPEA (*Vigna unguiculata* subsp.*sesquipedalis (L)* verdcourt) TO NITROGEN AND POTASSIUM UNDER VARYING LEVELS OF IRRIGATION.

By

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THESIS

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Dedicated to my
Dear parents

DECLARATION

I hereby declare that this thesis entitled ' **RESPONSE OF VEGETABLE COWPEA (*Vigna unguiculata* subsp. *sesquipedalis* (L.) verdcourt) TO NITROGEN AND POTASSIUM UNDER VARYING LEVELS OF IRRIGATION'** 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 'RESPONSE OF VEGETABLE COWPEA (*Vigna unguiculata* subsp. *sequipedalis* (L.)verdcourt) TO NITROGEN AND POTASSIUM UNDER VARYING LEVELS OF IRRIGATION'. is a record of research work done independently by Mrs. Geetha,V., Under my guidance and supervision and that has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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ABBREVIATION

@	- At the rate of
ASM	- Available soil moisture
ASMD	- Available soil moisture depletion
cm	- centimeter
CPE	- Cumulative pan evaporation
Cu	- Consumptive use
DAS	- Days after sowing
DMP	- Dry matter production
FYM	- Farm yard manure
g	- gram
ha^{-1}	- per hectare
I	- Irrigation
IW	- irrigation water
K	- potassium
kg	- kilogram
LAI	- Leaf area index
m	- meter
MEP	- Moisture extraction pattern
mm	- millimeter
N	- nitrogen
P	- phosphorus

Re^{-1}	- per rupee
Rs	- Rupees
S	- Sulphur
t	- tonnes
WUE	- water use efficiency
Zn	- Zinc

INTRODUCTION

1. INTRODUCTION

Vegetables play an important role in human nutrition, as a protective food. Due to the greater appreciation of its food value, the interest in vegetable production has increased rapidly during recent years. Vegetable production, processing and marketing are significant contributors of income particulary among members of weaker sections of society. So there is great scope for bringing the entire vegetable industry on more scientific and productive level in the country.

The world scenario indicated that India is the second largest producer of vegetables, next to China. The country produces 48 million tonnes of vegetables from an estimated area of 4.5 million ha. The percapita daily consumption of vegetables is only 135g which is low compared to the recommended requirement of 295g.

Kerala state is blessed with a favourable agroclimatic condition for the production of many of the tropical vegetables throughout the year . However, the production of vegetables in the state is only 6 lakh tonnes as per the reports of Kerala State Land Use Board (1997). The gap is mainly met from the vegetables imported from the neighbouring states. With all these sources a total quantity of 13 lakh tonnes is consumed in the state, which amount to 125g percapita. So it is evident that consumption of vegetables in Kerala is much less than the required rate and even below the national average.

The major limiting factor for vegetable production in Kerala is the availability of suitable land for cultivation. In order to increase the vegetable production, it is necessary to explore all the possible avenues. By the utilization of the interspaces of coconut gardens and the summer rice fallows with irrigation facilities, vegetable cultivation can be intensified in the state.

Cowpea is grown throughout the country for its long green pods as vegetables, seeds as pulses and foliages as vegetables and fodder. The cultivars grown for their immature pods are variously known as asparagus bean, snake bean or yard long bean. There are three subspecies of cowpea, which are *sinensis*, *cylindrica* and *sesquipedalis*. The plants of *sinensis* subspecies has short pendent pods with small seeds and is the common vegetable cowpea. The subspecies *cylindrica* produces smaller pods with small and thicker kidney shaped seeds. The *sesquipedalis* types, grown in south India have very long pods and are commonly called as the yard long bean . Several popular varieties of vegetable cowpea has been developed by different research institutes for local adaptation . The Kerala Agricultural University has developed varieties for both upland and lowland conditions of the state The test variety *Malika* was developed for the southern zone of the state.

Among the various vegetable crops grown in Kerala, vegetable cowpea or yard long bean occupies a prime position. This crop can be cultivated throughout the year in the state. During the rainy season it is mainly cultivated as an upland crop either in open as a pure crop or as an intercrop in coconut gardens. During the summer season it can be cultivated as an irrigated crop in the uplands or in rice fallows. At present in the command areas, educated unemployed youth and the farm labourers are leasing land for vegetable cultivation and vegetable cowpea is taken as the main crop.

Cowpea being a shallow rooted crop requires less moisture for its growth. Availability of irrigation water becomes a major problem for summer vegetable cultivation. As cowpea is a leguminous crop, it has the ability to fix atmospheric nitrogen. Then also a starter dose of nitrogen is found to enhance its early growth and establishment. Potassium is found to help in the effective use of irrigation water and to overcome the stress during summer season. At present, only a general recommendation of irrigation and nutrient requirements for grain cowpea is available with the Package of Practices recommedations' Crops', KAU (1996). In the case of vegetable cowpea as the harvesting period is prolonged, their response to irrigation and nutrients may vary.

Keeping these views under consideration, the present investigation entitled "Response of vegetable cowpea (*Vigna unguiculata* subsp. *sesquipedalis* [L.] Verdcourt) to nitrogen and potassium under varying levels of irrigation" was taken up with the objectives of studying the effect of nitrogen and potassium at different growth stages of the crop under varying levels of irrigation and to work out the economics of various treatment combinations.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Water is essential for crop production and the best use of available water must be done for better crop production. Due to uncertainty and insufficiency of rainfall, irrigation is essential to get good response from other inputs. In order to get full benefit from irrigation water there is an urgent need to increase the water use efficiency through suitable agronomic practices such as optimum and timely use of fertilizers, correct time of planting etc, which had proved to be efficient tools in increasing productivity, facilitating better use of resources like land, labour, water etc. The results of the experiments conducted in India and elsewhere on the growth , yield, yield attributing components, nutrient uptake and contents, soil moisture studies and economic analysis of vegetable cowpea and related crops as influenced by nitrogen and potassium under varying levels of irrigation and their interaction effects are reviewed here.

2.1. Effect of irrigation

The increase in growth and yield characters of crops irrigated at an optimum schedule could be ascribed to the optimum moisture condition in the root zone (Trivedi *et al.*, 1994). The plant nutrients remain in a more soluble and easily available form and their transport to the root surface under optimum moisture condition was found faster than that under unirrigated conditions besides a better root growth (Rajput *et al.*, 1991)

2.1.1 Effect of irrigation on growth characters

2.1.1.1 Length of vine

Singh and Lamba (1971) reported that higher regimes of available soil moisture (ASM) in the root zone resulted in an increase in the plant height of cowpea. Ahlawat *et al.* (1979) also noted a significant increase in plant height in cowpea by irrigating the crop at 75 per cent ASM compared to irrigating at 50 and 25 per cent ASM. Vegetable cowpea grown as summer crop gave an increase in plant height at 80 to 100 per cent ASM in 0-30cm soil depth as compared to 60 to 100, 40 to 100 and 20 to 100 per cent of ASM (Patel, 1979). Increasing the frequency of irrigation increased the plant height at all the growth stages and the optimum IW/CPE ratio appeared to be 0.50 in summer cowpea (Balakumaran,1981). Farghaly *et al.* (1990) observed that in cowpea, an increase in irrigation interval from one week to three weeks decreased the plant height. Similarly Kher *et al.* (1994) noticed a higher value for plant height when summer cowpea was irrigated according to a schedule based on the IW/CPE ratio of 0.8 as compared to 0.4 and 0.6 IW/CPE ratios. In a study conducted on vegetable cowpea grown as summer crop, Jyothi (1995) also observed a favourable influence of frequent irrigation on plant height. In another study conducted at Vellayani on vegetable cowpea, Mini (1997) revealed that plant height was significantly influenced by frequent light irrigation.

Increase in plant height with higher levels of irrigation has been reported in other pulse crops viz., green gram (Ali and Alam, 1973; Vasimalai and Subramanian, 1980; Prasad *et al.*, 1991; Trivedi *et al.*, 1994) black gram (Jayaraj, 1987; Rao *et al.*, 1991; Singh and Tripathi, 1992; Jeyaraman, 1994), red gram (Ramshe and surve, 1984; Singh *et al.*, 1992) pea (Yadhav *et al.*, 1990) and cluster bean (Meena *et al.*, 1991).

2.1.1.4 Dry matter production (DMP)

Singh and Lamba (1971) reported that higher ASM in the root zone enhanced the dry matter production in cowpea. Ramamurthy *et al.* (1990) noticed that in cowpea protective irrigations at 27^{th} and 55^{th} days after sowing recorded higher DMP compared to no irrigation. In an experiment on a vegetable cowpea cv.CO-2 at Bhavanisagar, Subramanian *et al.* (1993) noticed that irrigation at frequent intervals (0.8 IW/CPE) enhanced the DMP over wider intervals (0.6 IW/CPE). Jyothi (1995) noticed in summer vegetable cowpea that maximum DMP was obtained by irrigating the crop at 75 per cent of field capacity than by irrigating at 50 per cent of field capacity or its combinations during different growth stages. Mini (1997) noticed that in summer vegetable cowpea frequent light irrigations also produced maximum DMP at all growth stages.

Two irrigations each at flowering and pod development stages recorded the maximum DMP in black gram (Rao *et al.*, 1991). In another experiment conducted with summer black gram, Singh and Tripathi (1992) observed that maximum DMP was obtained by irrigating at an IW/CPE of 0.8 compared to 0.4 and 0.6 ratios. In comparison with irrigating at 0.5 IW/CPE ratio, irrigating at 0.7 IW/CPE ratio recorded significantly higher DMP in summer green gram (Trivedi *et al.*, 1994). Dabhi *et al.*(1998) concluded that frequent irrigation at 0.75 IW/CPE ratio appreciably enhanced the DMP per plant in summer green gram. Reddy and Ahlawat(1998) found that two irrigations at branching and pod development stages markedly contributed to higher DMP in chickpea.

2.1.2 Effect of irrigation on yield and yield attributing characters.

2.1.2.1 Flowering.

It was reported by Hiler *et al.* (1972) that the retardation of growth and yield was most drastic due to lack of soil moisture at the flowering stage, in grain cowpea. Ali and Alam (1973) opined that soil moisture stress reduced the initiation and retention of floral buds in green gram. In summer planted moong bean, irrigation at an IW/CPE ratio of 1.0 significantly influenced 50 per cent flowering by six days as compared to irrigations at IW/CPE ratio of 0.4 and 0.6 and by two days over 0.8 (Yadhav and Warsi, 1988). In summer vegetable cowpea early flowering was noticed when moisture availability was higher during the early growth stages (Jyothi, 1995). In another study on vegetable cowpea, Mini (1997) observed that the number of days taken for 50 per cent flowering was minimum when light irrigation of 10mm was given every day. Dabhi *et al.* (1998) noticed that frequent irrigation at 0.75 IW/CPE ratio recorded minimum days for 50 per cent flowering (39.7 and 37.7 days) for surface and mini sprinkler method of irrigation.

Contrary to these reports the influence of varying moisture regimes on days to attain 50 per cent flowering was documented as insignificant by Balakumaran (1981)in cowpea and Ramshe and Surve (1984) in pigeon pea.

2.1.2.2 Other yield attributing characters.

Ahlawat *et al.* (1979) observed in spring cowpea that a higher level of ASM in the root zone during the cropping season by irrigating at 75 per cent ASM resulted in a significant improvement in the number of pods per plant over 50 and 25 per cent ASM. In summer vegetable cowpea, soil moisture regimes of 50 -100 per cent ASM appreciably increased the number and weight of green pods per plant as compared to 60-100, 40-100 and 20-100 per cent ASM (Patel, 1979). Increased wetness significantly increased the number and weight of pods in summer cowpea (Balakumaran, 1981) and an IW/CPE ratio of 0.5 was the optimum. In an experiment conducted on vegetable cowpea, Subramanian *et al.* (1993) concluded that irrigation had no significant influence on pod length and number of seeds per pod. In a field trial with summer vegetable cowpea an increase in the number and length of pods and number of seeds per pod was noted with increase in soil wetness (Jyothi, 1995). In a recent study, Mini (1997) reported that maximum number of pods was produced when light irrigation of 10mm was given everyday.

Irrigation at an IW/CPE ratio of 0.8 favoured the formation of maximum number of pods and grains per pod as against wetter and drier regimes in summer mung (Yadhav and Warsi, 1988). Prasad and Yadhav(1990) refers to a decline in the pod number per plant and 1000 grain weight in black gram and green gram when irrigation was given at an IW/CPE ratio of 0.6 and 0.4 as compared to 0.8. An increase in the pods per plant and test weight in summer black gram irrigated at an IW/CPE ratio of 0.8 over the ratios 0.6 and 0.4 was reported by Singh and Tripathi (1992). In another study conducted in green gram Trivedi *et al.* (1994) reported a significantly more number of pods per plant, pod length, grains per pod and test weight when irrigated at an IW/CPE ratio of 0.7 as compared to a ratio of 0.5. In another experiment with black gram in rice fallows, Jeyaraman (1994) reported significantly higher values for number of pods per plant and pod length for plants irrigated at an IW/CPE ratio of 0.7 over plants irrigated at IW/CPE ratios of 0.5 and 0.3. Dabhi *et al.* (1998) observed that the maximum number of pods per plant, grains per pod and 1000 grain weight were obtained when irrigation was scheduled at an IW/CPE ratio of 0.75 in summer green gram. Nandan and Prasad (1998) noted that pods per plant, seeds per pod and 1000 seed weight responded favourably with an increase in irrigation regimes upto 3 irrigations applied either through IW/CPE ratio or at days interval in french bean. Two irrigations at branching and pod development stages markedly contributed to increase in pods per plant (Reddy and Ahlawat, 1998).

2.1.3 Effect of irrigation on yield

Ahlawat *et al.*(1979) noted that maximum grain yield was obtained by irrigating cowpea at 75 per cent ASM at 0-30cm depth over 50 and 25 per cent ASM. In summer vegetable cowpea, Patel (1979) noticed that a soil moisture regime of 80-100 per cent of ASM gave 12.87 per cent higher yield of green pods compared to a moisture regime of 60 to 100 per cent ASM. Grain yield was significantly higher with wetter soils in summer cowpea and an IW/CPE ratio of 0.5 was recorded as optimum (Balakumaran, 1981). Farghaly *et al.* (1990) reported from a study with 5 cowpea cultivars that wider irrigation intervals from one week to 3 weeks reduced the seed yield. In a study conducted with vegetable cowpea cv. CO-2 at Bhavanisagar, it was summerised that irrigation at an IW/CPE ratio of 1.00 gave maximum vegetable yield and was on per with 0.8 IW/CPE ratio and was significantly superior to 0.6 IW/CPE ratio (Subramanian *et al.*, 1993). Kher *et al.* (1994) reported in summer cowpea that maximum grain and fodder yield was recorded under IW/CPE ratio of 0.8 which was significantly superior over the ratio of 0.6 and 0.4. An increasing trend in pod and haulm yields towards wetter regimes was reported by Jyothi (1995) in summer vegetable cowpea. Mini (1997) noted a significant influence on green pod and haulm yields when light irrigation of 10 mm was given everyday in summer vegetable cowpea.

Significantly high grain yield was observed in summer moong by Yadhav and Warsi (1988) by irrigating the crop at an IW/CPE ratio of 0.8 as compared to wetter and drier regimes. Gupta and Rai (1989) recorded the favourable effect of 60 per cent ASM in the root zone on yield as compared to 20 and 40 per cent ASM. Irrigation given at an IW/CPE ratio of 0.8 produced highest biological and grain yield of green gram as compared to IW/CPE ratio of 0.6 and 0.4 (Prasad and Yadhav, 1990). Scheduling irrigation at 0.5 and 0.8 IW/CPE ratio were on par and gave significantly higher seed yield than irrigation at branching and pod formation stages in summer green gram (Dwangan *et al.*, 1992). In comparison with irrigation at 0.5 IW/CPE ratio, irrigation at 0.7 IW/CPE ratio recorded significantly more DMP, grain and stover yields in summer green gram (Trivedi *et al.*, 1994). From another experiment on green gram, Vijayalekshmi *et al.* (1994) opined that irrigation at 0.6 IW/CPE ratio gave higher yield compared to irrigation at 0.45 and 0.75 IW/CPE ratios. Application of irrigation at 0.75 IW/CPE ratio to green gram resulted in significantly higher grain yield and stover yield under mini sprinkler method of irrigation (Dabhi *et al.*, 1998).

Varughese *et al.* (1986) concluded that irrigating black gram in summer rice fallows at an IW/CPE ratio of 0.5 was adequate since higher ratios did not influence the yield. From an experiment with summer black gram, Singh and Tripathi (1992) noted that maximum DMP and grain yield were obtained by irrigating the crop at an IW/CPE ratio of 0.8 as over 0.4 and 0.6 ratios. In another experiment with rice fallow black gram, Jeyaraman (1994) found that irrigation at 0.7 IW/CPE was optimum. However, Vijayalekshmi and Aruna (1994) reported that irrigating black gram at an IW/CPE ratio of 0.6 resulted in higher grain yield over 0.75 and 0.9 ratios.

In french bean, Nandan and Prasad (1998) concluded that significant increase in seed yield was recorded with 3 irrigations. In another study with chickpea, Reddy and Ahlawat (1998) reported that grain and straw yield increased markedly when two irrigations were given at branching and pod development stages over single irrigation at any of the stages.

2.1.4 Effect of irrigation on moisture-extraction pattern (MEP), consumptive use (Cu) and water -use efficency (WUE)

Ahlawat *et al.* (1979) found that the Cu and WUE of cowpea increased with increasing levels of irrigation and the maximum value was recorded by irrigating at 75 per cent ASM as compared to 50 and 25 per cent ASM. Another trial conducted on a summer crop of vegetable cowpea revealed that the WUE increased with increasing levels of soil moisture regimes, ie, from 20 to 100 per cent ASM to 80 to 100 per cent ASM (Patel, 1979). Subramanian *et al.* (1993) observed that the vegetable cowpea crop irrigated at an IW/CPE ratio of 1.0 consumed more water than those irrigated at 0.6 and 0.8 ratios. In summer cowpea scheduling of irrigation based on an IW/CPE ratio of 0.8 gave significantly higher Cu of water over rest of the levels of IW/CPE ratios, ie, 0.4 and 0.6 while different ratios didnot exert any significant influence on WUE (Kher *et a*l., 1994). In a study conducted in summer vegetable cowpea, Jyothi (1995) reported that percentage depletion of moisture decreased with moisture stress from 0-15 cm soil depth. But from 15-30 and 30-45 cm depths, the percentage depletion increased with moisture stress. The highest WUE was recorded by irrigating the crop at 50 per cent field capacity during 0-33 days and at 75 per cent field capacity there after. In a recent study conducted in summer vegetable cowpea, Mini (1997) reported that the percentage extraction of moisture from the top layer (0-15 cm) was found to be higher with wetter regimes but from 15-30 and 30-45 cm depths, the percentage extraction increased with drier regimes. The highest WUE was recorded when irrigation was given at 15mm CPE value at a depth of 20mm.

Mohanty and Sharma (1985) observed that the Cu of water and WUE were higher under two irrigations at 30 and 45 DAS as compared to one irrigation at any one stage in green gram. Bachchhav *et al*.(1993) reported that in summer green gram, the lowest Cu of water was observed with irrigation at critical growth stages (Seedling, branching, flowering, post flowering and pod development stages) and the highest with scheduling of irrigation at 50 mm CPE. However, WUE was highest with irrigation at 100 mm CPE and least with 50 mm CPE. In another study on moong bean, soil moisture contents and moisture use from the top 45 cm increased with the frequency of irrigation. The maximum water use was recorded by irrigation at 20mm CPE and lowest by unirrigated treatment, whereas the maximum WUE was recorded by unirrigated plot and the lowest by irrigation at 20mm CPE (Pannu and Singh, 1993).

Singh and Tripathi (1992) opined that in summer black gram Cu of water was maximum when irrigated at an IW/CPE ratio of 0.8 compared to 0.4 and 0.6 IW/CPE. The crop receiving maximum number of irrigations utilized more moisture from the upper layers(0-30cm) than the lower ones (30 - 60 cm). But a reverse phenomenon was obtained when frequency of irrigation was low. For rice fallow black gram, irrigation at an IW/CPE ratio of 0.3 recorded maximum WUE compared to irrigation at 0.5 and 0.7 IW/CPE (Jeyaraman, 1994). Similarly Vijayalekshmi and Aruna (1994) reported that irrigating black gram at an IW/CPE ratio of 0.6 resulted in higher WUE over 0.75 and 0.9 ratios. Nandan and Prasad (1998) revealed that in french bean WUE decreased with an increase in irrigation frequency from 1 to 3 and maximum WUE was recorded with one irrigation scheduled at 25 days.

2.1.5 Effect of irrigation on nutrient composition and uptake

Subramanian *et al.* (1993) observed that in cowpea, differences in P content due to irrigation was not significant, but uptake of P was maximum by scheduling irrigation at an

IW/CPE ratio of 0.8 compared to both lower and higher ratios of 0.6 and 1.00. Jyothi (1995) observed that when the crop was irrigated at 75 per cent field capacity throughout the crop growth the uptake of nitrogen, phosphorus and potassium was maximum in summer vegetable cowpea. In another study, Mini (1997) observed in summer vegetable cowpea that irrigation levels profoundly influenced the nutrient uptake and was maximum when daily light irrigation was given at a depth of 10mm.

Bachchhav *et al.* (1993) found that the nitrogen uptake in the seed and straw of green gram was significantly more with irrigation scheduled at 10mm CPE critical growth stages than with 50 and 75mm CPE. Rao *et al.* (1991) observed in black gram that irrigation had a favourable influence on the P uptake. Two irrigations each at flowering and pod development stages recorded the maximum P uptake compared to no irrigation and one irrigation at flowering or pod development stages. Singh and Tripathi (1992) reported that the highest uptake of 121.7 kg N ha^{-1}, 11.2kg P ha^{-1} and 5.8 kg K ha^{-1} were recorded for irrigation given at an IW/CPE ratio of 0.8. Parihar and Tripathi (1989) observed that in chickpea effect of irrigation was not significant on the nitrogen content of the grain. However, phosphorus and potassium contents increased with an increase in moisture level.

2.1.6 Effect of irrigation on the economics of cultivation.

In a study conducted on summer vegetable cowpea, Patel (1979) learned that the highest net profit (4165 Rs ha^{-1}) was obtained by maintaining the crop at 80-100 per cent ASM, while the lowest net profit (Rs. 1426 ha^{-1}) was obtained by maintaining at 20-100 per cent ASM. The treatment combination of 20 per cent ASMD with 60 kg P_2O_5 ha^{-1} produced the maximum pod yield and net realization in cluster bean (Bhatt, 1983). The net profit (Rs. ha^{-1}) and benefit-cost relationship (Rs. Re^{-1}investment) increased due to different water regimes in groundnut on the order of 1.2 IW/CPE>0.9 IW/CPE>0.6IW/CPE (Katre *et al.*, 1988). Patel and Patel (1994a) noticed that in red gram the highest net realization of Rs. 5104 ha^{-1} was obtained for the treatment with an irrigation schedule of 0.25 IW/CPE ratio compared to 0.5 and 0.75 IW/CPE ratios. In a study conducted with summer vegetable cowpea, Jyothi (1995) reported that net returns and benefit-cost ratio (BCR) increased with an increase in the frequency of irrigation. Mini (1997) noted that irrigating the crop to a depth of 20mm at 10mm CPE value gave the maximum net returns and BCR and was significantly economic.

2.2 Effect of nitrogen

Nitrogen plays a key role for proper growth and development of all cultivated crops. In legumes, it is necessary to provide a starter dose of nitrogen for the crop establishment. Through rhizobial nitrogen fixation many legumes fix nitrogen to the tune of 25 to 35 kg ha^{-1}. Patel (1979) and Raj and Patel (1991) found that cowpea responds well to moderate application of nitrogen .

2.2.1 Effect of nitrogen on growth characters

2.2.1.1 Length of vine

George (1981) reported that in grain cowpea 20 kg N ha^{-1} was applied as basal dose followed by 10 kg N ha^{-1} in soil at vegetative phase gave maximum plant height at all stages of growth. Jyothi (1995) noticed that in summer vegetable cowpea the plant height was appreciably increased at 20 kg N ha^{-1} up to 75 DAS.

Experiment conducted on green gram revealed that increasing the level of nitrogen from 0 to 60 kg ha^{-1} significantly increased the plant height from 27.6cm to 30.4cm (Panda, 1972). According to Lenka and Satpathy (1976) application of 20 or 40 kg N ha^{-1} increased plant height in red gram. There was a significant improvement in plant height with increasing levels of N upto 50 kg N ha^{-1} at 60 DAS in pigeon pea (Chittapur *et al.*, 1994). Dwivedi *et al.* (1994) reported in french bean that with increase in nitrogen levels there is an increase in plant height. Baboo *et al.*(1998) noted a significant increase in plant height with increasing levels of nitrogen upto 120 kg N ha^{-1} in french bean.

2.2.1.2 Number of leaves

Savithri (1980) revealed that in cowpea high levels of nitrogen significantly influenced the number of leaves in the early stages of plant growth up to 15 DAS only. George (1981) reported that in cowpea at mid pod filling stage and at maturity maximum number of leaves per plant was produced when 20 kg N ha^{-1} was applied as basal dose followed by 10 kg N ha^{-1} in soil at vegetative phase. Jyothi (1995) reported that different nitrogen levels did not influence the production of leaves per plant in summer vegetable cowpea.

Nandan and Prasad (1998) noted that in french bean leaves per plant varies from 80 kg N ha^{-1} to 120 kg N ha^{-1}. Chittapur *et al.*(1994) reported in pigeon pea that at maturity higher number of leaves were noticed with the application of 50 kg N ha^{-1}.

2.2.1.3 Leaf area index (LAI)

According to George (1981),at mid pod filling stage the leaf area indices varied significantly when N was applied at the rate of 20 kg N ha^{-1} basal and 10 kg N ha^{-1} in soil at vegetative phase in vegetable cowpea. In another experiment on cowpea, Ramamurthy *et al.*(1990) found that application of 20 kg N ha^{-1} recorded the maximum leaf area index. Jyothi (1995) noted in summer vegetable cowpea that maximum LAI wasrecorded when 20 kg N ha^{-1} was applied.

In french bean an increase in N levels upto 80 kg ha^{-1} increased LAI (Hegde and Srinivas,1989). With an increase in nitrogen levels, leaf area index of groundnut increased significantly at different stages of growth upto 60 DAS (Barik *et al.*,1998).

2.2.1.4 Dry matter production (DMP)

Savithri (1980) noted in cowpea that an increase in the levels of nitrogen resulted in an increase in the dry matter yield. Minchin (1981) found that providing inorganic nitrogen during the vegetative and reproductive phase stimulated DMP in nodulated cowpea plants.Jyothi (1995) noted that the application of nitrogen appreciably influenced the DMP at all stages of growth and also found that nitrogen at the rate of 30 kg ha^{-1} registered the maximum DMP . Akter *et al.* (1998) reported that dry weight of plants increased significantly with increased levels of nitrogen upto 40 kg ha^{-1} in cowpea.

Application of 20 kg N ha^{-1} increased DMP per plant in bengal gram (Prasad and Singh, 1987). Singh and Khangarot (1987) reported that application of nitrogen profoundly enhanced the total dry matter production in Chickpea .Reddy *et al.*(1992) reported that in green gram the dry matter production was higher at all the stages of crop growth.

2.2.2 Effect of nitrogen on yield and yield attributing characters

2.2.2.1 Flowering

Jyothi (1995) noticed that in vegetable cowpea nitrogen levels did not influence the time taken for 50 per cent flowering. However, a trend of earliness in flowering was observed at 30 kg N ha^{-1}.

2.2.2.2 Other yield attributing characters

In cowpea, Malik *et al.* (1972) noted that application of 20 to 40 kg N ha^{-1} had not influenced the seed weight. Kumar and Pillai (1979) reported the maximum number of pods per plant, number of seeds per pod, pod length, 100 seed weight, grain- haulm ratio by the application of 20 kg N ha^{-1} in a cowpea var. P 118. According to Patel (1979) the application of 20 kg

N ha^{-1} to cowpea remarkably influenced the yield attributes like number and weight of green pods per plant. Ramamurthy *et al.* (1990) found that application of 25 kg N ha^{-1} to cowpea produced maximum number of pods and pod weight per plant. In a study on summer cowpea Raj and patel (1991) reported that application of 20 kg N ha^{-1} significantly improved the pod length and number of grains per pod. Jyothi (1995) reported that in summer vegetable cowpea application of 30 kg N ha^{-1} resulted in a significant increase in the number of pods per plant, length of pods and number of seeds per pod. Akter *et al.*(1998) found that number of pods per plant was increased by nitrogen application and a profound increase was obtained with 20 kg N ha^{-1} over lower levels in grain cowpea.

In french bean number of pods and grain yield per plant increased significantly with N fertilization over control as reported by Dahatonde *et al.*(1992). When 80 kg N ha^{-1} was applied, there was an improvement in yield contributing characters viz., grains per pod and test weight in french bean (Dwivedi *et al*; 1994). Singh *et al.*(1996) observed that yield contributing characters *viz.,* plant height, number of branches per plant, pod length, number of grains per pod and test weight increased with increasing levels of N upto 120 kg N ha^{-1} in french bean. Nandan and Prasad (1998) found a significant improvement in pods per plant upto 120 kg N ha^{-1} where as seeds per pod and test weight responded only up to 80 kg N ha^{-1} in french bean. Baboo *et al.*(1998) reported that there was significant increase in number of pods per plant, number of seeds per pod and 100 seed weight on french bean with increasing N levels upto 120 kg N ha^{-1}. Singh *et al.*(1992) reported that when garden pea was fertilized with 18 kg N ha^{-1} it recorded maximum filled pods per plant, grains per pod and test weight. Chittapur *et al.*(1994) noted that an improvement in grain weight per plant and also number of pods per plant with the application of 50 kg N ha^{-1} in pigeon pea. Application of recommended dose of fertilizer ie; 20 kg N + 40 kg P_2O_5 ha^{-1} resulted in the maximum number of pods per plant, seeds per pod and length of pod and was found significantly superior to the control in summer green gram (Patel and Patel, 1994). Khade *et al.* (1986) observed that application of 25 kg N ha^{-1} resulted in the maximum number of pods per plant, grain weight per plant, number of grains per plant, weight of dry pods per plant and number of grains per pod in black gram compared to 12.5 and 37.5kg N ha^{-1}.

2.2.2.3 Effect of nitrogen on yield

In an experiment, Malik *et al.*(1972) found that application of 20 to 40 kg N ha^{-1} to cowpea had not influenced the grain yield. Nangju (1976) reported maximum yield in cowpea by the application of 30 kg N ha^{-1}. According to Sharma (1977) in cowpea, application of 20 kg N ha^{-1} recorded significantly higher yield over no nitrogen. In a study conducted at Pattambi, Viswanathan *et al.*(1978) observed that in cowpea, an increase in N levels from 0 to 40 kg N ha^{-1} progressively increased the yield. Kumar and Pillai (1979) and Kumar *et al.*(1979) observed that application of 20 kg N ha^{-1} significantly influenced the grain yield in cowpea. Patel (1979) from an experiment on summer vegetable cowpea also observed that application of 20 kg N ha^{-1} significantly influenced the pod yield. Savithri (1980) noted that there was no difference in grain yield due to levels of nitrogen. Still an increasing trend in grain yield was noted upto 30 kg N ha^{-1} after which the yield considerably reduced in cowpea. Application of 25 kg N ha^{-1} produced significantly higher yield in cowpea (Ramamurthy *et al.*, 1990; Gandhi *et al.*,1991). In summer cowpea, Raj and Patel (1991) concluded that application of 20 kg N ha^{-1} recorded significantly higher grain yield over no nitrogen. Jyothi (1995) reported that in summer vegetable cowpea the application of 30 kg N ha^{-1} resulted in maximum grain and haulm yield. Akter *et al.*(1998) reported that in cowpea, grain yield increased with increasing levels of nitrogen but the most threshold effect was found with 20 kg N ha^{-1} .

Khade *et al.* (1986) reported that the highest grain yield was obtained by the application of 25 kg N ha^{-1} compared to both higher and lower levels in black gram. Singh and Khangarot(1987) reported that in chickpea the mean grain and straw yield increased by 9.2 and 7.3 per cent due to 20 kg N ha^{-1} over no nitrogen. Dahatonde *et al.* (1992) and Nandan and Prasad (1998) revealed that in french bean nitrogen application upto 120 kg ha^{-1} increased the grain yield. Similar yield increase upto 100 kg ha^{-1} was noticed by Dwivedi *et al.*(1994) and upto 160 kg ha^{-1} by Singh *et al.* (1996). Patel *et al.* (1992) reported that application of 30 kg N ha^{-1} produced more grain and straw yields than the other levels in green gram.Tank *et al.*(1992) noticed that the crop fertilized with 20 kg N ha^{-1} out yielded the rest of the higher and lower levels of N by recording significantly highest grain yield in summer green gram. The yield increased with an increase in nitrogen level upto 20 kg ha^{-1} and further increase declined the yield. However, Bachchhav *et al.*(1993) noticed that application of 30 kg N ha^{-1} recorded significantly more seed and haulm yield in green gram. Negi(1992) in vegetable pea reported that application of N at the rate of 20 kg ha^{-1}significantly increased the green pea yield over no nitrogen. Chittapur *et al.*(1994) reported that higher level of N increased the yield significantly over the lower levels of nitrogen in pigeon pea.

2.2.2.4 Effect of nitrogen on moisture- extraction pattern (MEP), consumptive use(Cu) and water-use efficiency(WUE).

In an experiment with lentil, Varma and Kalra (1985) noticed that the moisture depletion from the top layer (0-23cm) was more and from the deeper layers was less without nitrogen application compared to 20 and 40 kg ha^{-1}. Appliation of 25 kg N ha^{-1} recorded the maximum consumptive use efficency in green gram compared to 12.5 kg and 37.5 kg N ha^{-1}(Khade *et al.,* 1986)

The maximum value of Cu and WUE were noticed in groundnut with a fertilizer dose of 25 kg N +50 kg P_2O_5 ha^{-1} and at this level, moisture extraction from the surface layer increased as compared to control (Kadam and Patil, 1992). The maximum WUE was obtained with 30 kg N ha^{-1} in green gram compared to control, 15 and 45 kg ha^{-1} (Bachchhav *et al.,* 1993)

Tank *et al.*(1992) observed that when 20 kg N ha^{-1} was applied to green gram the WUE was high. Jyothi (1995) noticed in summer vegetable cowpea that the percentage depletion of moisture decreased from 0-15 cm soil depth with an increase in nitrogen levels from 30 to 40 kg ha^{-1} and increased from 15-45 cm soil depth with higher nitrogen levels. The maximum WUE was noticed with 30 kg N ha^{-1}. Nandan and Prasad (1998) reported in french bean that higher nitrogen levels up to 120 kg ha^{-1} resulted in significantly higher water use efficiency.

2.2.2.5 Effect of nitrogen on nutrient composition and uptake.

Kumar *et al.* (1979) observed that application of 20 kg N ha^{-1} in combination with 40 kg P_2O_5 ha^{-1} recorded the maximum uptake of nitrogen in cowpea. Savithri (1980) reported in cowpea that application of nitrogen upto 30 kg N ha^{-1} resulted in maximum uptake of nitrogen. Jyothi (1995), reported that maximum uptake was noticed when 30 kg N+ 45 kg P_2O_5 ha^{-1} was applied in summer vegetable cowpea.

In an experiment with green gram, Reddy (1986) observed that N uptake by the crop was significantly increased by the application of 15 kg N ha^{-1} +50 kg P_2O_5 ha^{-1}.Patel *et al.* (1992) observed in green gram that when a combination of 30 kg N+ 60 kg P_2O_5 ha^{-1} was applied the uptake was maximum (71.30). Reddy *et al.* (1992) reported in green gram that application of manures or fertilizers increased the N and K content in plant tissues. Bachchhav *et al.*(1993) noticed in green gram that application of 30 and 45 kg N ha^{-1} significantly increased the N uptake by the seed compared with the control and 15 kg ha^{-1}.

In a pot culture study, Kadwe and Badhe (1973) observed that in black gram, application of 50 kg P_2O_5 ha^{-1} with 1-12 kg Mo ha^{-1} appreciably increased the plant uptake of nitrogen. George (1981) reported in cowpea that plants supplied with higher amounts of nitrogen resulted in higher uptake of nitrogen. In general 30 kg N ha^{-1} either as soil or soil plus foliar application have resulted in higher uptake. Singh and Tripathi (1992) noticed that P application accelerated the uptake of N significantly upto 40 kg P_2O_5 ha^{-1} in black gram. The N uptake increased significantly with increasing levels of N upto 30 kg ha^{-1}. Similarly enhancing N levels significantly increased P content of grain and straw in pigeon pea (Rana *et al.*, 1998).

2.2.2.6 Effect of nitrogen on the economics of cultivation

Maximum net profit of Rs 1432 ha^{-1} was obtained by applying N at the rate of 20 kg ha^{-1} as basal or half as basal and remaining as foliar at mid pod filling stage in grain cowpea (George , 1981). Azad *et al.* (1992) observed a net profit of Rs 134 per kg N ha^{-1} in field pea. Singh *et al.* (1992) reported that highest returns were obtained in field pea when N, P, K and Zn were applied at the rate of 18, 46, 40 and 25 kg ha^{-1}. Patel *et al.* (1992) noticed that in green gram application of N, P, S at the rate of 30, 40 and 30 kg ha^{-1} resulted in maximum net profit(Rs 5186ha^{-1}) and benefit : cost ratio(1.19:1). Patel and Patel (1994 a) reported in pigeon pea that the net realization increased with successive increase in N level and the highest net realization of Rs 5,680 ha^{-1} was recorded with 20 kg N ha^{-1}. Singh *et al.* (1994) reported in soybean that net profit increased with increasing level of N and P. The highest net profit was obtained with a combination of 40 kg N and 80 kg P_2O_5 ha^{-1}. But the benefit cost ratio was maximum at lower fertilizer rate (10 kg N+ 20 kg P_2O_5 ha^{-1}) and it decreased at higher fertilizer rates.

In vegetable cowpea maximum net returns (Rs 2,538.22 ha^{-1}) and BCR (1.17:1) were recorded when a combination of 30kgN + 45kg P_2O_5 ha^{-1} was applied to summer vegetable cowpea (Jyothi, 1995).

2.3 Effect of potassium

Plant requirements for available K are quite high. It plays an important role in enzyme activation, water relations, energy relation ,translocation of assimulates and N uptake and protein synthesis. Grain legumes in general require high quantity of potassium for normal growth and development (Yahiya *et al.*, 1996). In the case of legumes potassium enhances carbohydrate transport to nodules and utilization for synthesis of amino acids (Tisdale *et al.*, 1993).

2.3.1 Effect of potassium on growth characters.

2.3.1.1. Length of vine

Savithri (1980) observed in green gram that higher levels of potash (30 and 20 kg K_2O ha^{-1}) influenced the plant height significantly over the lowest level of 10kg. Shah *et al.* (1994) reported that in black gram the application of 40 kg K_2O ha^{-1} significantly influenced the plant height at 45 and 55 DAS. Yahiya *et al.* (1996) noted that application of potassium influenced favourably all the growth parameters in pigeon pea. In an experiment conducted with pea, Kanaujia *et al.* (1997) observed that potassium showed pronounced effect on plant height at 90 kg K_2O ha^{-1}.

Nair (1978) reported a significant increase in the height of plants due to application of 50 kg K_2O ha^{-1} in groundnut. Mathew (1981) observed that application of incremental doses of potash had significantly increased plant height at 60th day after sowing and at harvest in groundnut. Patra *et al.* (1996) reported that application of 50 kg K_20 ha^{-1} significantly increased plant height in groundnut.

2.3.1.2 Number of leaves

Savithri (1980) noted that application of potash influenced the number of leaves only during the early stages of plant growth. Higher doses of potash (20 and 30 kg K_2O ha^{-1}) increased the number of leaves significantly over the lowest level of 10 kg K_2O in green gram.

In groundnut, Nair (1978) noted that number of leaves were not significantly influenced by potassium application. Mathew (1981) found that levels of potash significantly influenced leaf production at harvest only, in groundnut.

2.3.1.3 Leaf area index

Khanna *et al.* (1980) reported that addition of K enhanced the rate of leaf expansion in both irrigated and unirrigated maize seedlings. Mathew (1981) found that higher potash levels tended to increase leaf area index at all stages, but it reached the level of significance only at 60th day and at 60th day 75 kg K_2O ha^{-1} had significantly increased leaf area index over the lower doses in groundnut. Yahiya *et al.* (1996) reported that the leaf area index significantly increased upto 75 kg K_2O ha^{-1} in pigeon pea.

2.3.1.4 Dry matter production

Blanchet (1962) reported in lucern that dry matter accumulation increased with increase in potassium application. Sekhon *et al.* (1977) reported that biomass production of cowpea significantly improved with 60 kg K_2O ha^{-1}. Savithri (1980) noted that higher level of 30 kg K_2O ha^{-1} significantly increased the dry matter yield over the lowest level of 10 kg which was on par with 20 kg K_2O ha^{-1} in green gram. Shah *et al.* (1994) reported in black gram that application of 40 kg K_2O ha^{-1} significantly influenced the dry matter production per plant at 45 and 55 DAS. Yahiya *etal.* (1996) reported that shoot dry weight significantly increased due to potassium application, 50 kg ha^{-1} proving best at most stages in pigeon pea. Kanaujia *et al.*, (1997) found that drymatter was significantly influenced by the potassium level upto 60 kg K_2O ha^{-1} in pea.

Rao (1979) observed that the dry matter production was increased with increase in levels of potassium in groundnut. Mathew (1981) noted that potassium, when applied @ 75 kg K_2O ha^{-1} had increased dry matter accumulation significantly except during 30th day in groundnut.

2.3.2. Effect of potassium on yield and yield attributing characters.

2.3.2.1 Yield attributing characters

Kanaujia *et al.*(1997) observed in pea that there was no significant response in the case of days taken for first flowering. Singh *et al.* (1992) observed that when 40 kg K_2O ha^{-1} was applied maximum filled pods per plant, grains per plant and 1000-seed weight (g) was produced in pea. Yahiya *et al.* (1996) noted that application of 50 kg K_2O ha^{-1} significantly increased pods per plant, 1000-seed weight, harvest index and seed yield over control.

Shekawat *et al.* (1969) observed an increase in green pod yield with 33.6 kg K_2O ha^{-1} and further increase in level upto 67.1 kg K_2O ha^{-1} did not correspondingly affect the green pod yield. Nair (1978) reported a significant increase in the number of pegs per plant, number of mature pods per plant, weight of mature pods per plant, 100 pod weight and 100 kernal weight due to potassium application in groundnut. Rao (1979) observed that number of filled pods and shelling per cent were also increased with higher levels of potassium in ground nut. Mathew (1981) noted that increasing potash application in groundnut increased the number of pods per plant, weight of 100 pods and weight of 100 kernals upto 75 kg K_2O ha^{-1}. Potash levels did not significantly increase the shelling percentage. Devarajan and Kothandaraman (1982) reported an increase in pod weight in groundnut. Gnanamurthy and Balasubramanian (1992) observed in groundnut that plants receiving 150 per cent of the recommended dose of K produced more number of pods, 100- kernal weight was also higher but shelling per cent did not vary. Yakadri *et al.*(1992) observed that yield component like filled pods per plant and 100 - kernal weight were significantly influenced by the increasing levels of potassium at 60 kg ha^{-1}. Singh *et al.* (1994) reported that potassium application increased all the yield contributing characters and observed significant effect on number of pods per plant only. Patra *et al.* (1996) noted that application of potassium had no significant effect on yield attributes in kharif groundnut.

2.3.2.2 Effect of potassium on yield.

Manjhi and Chowdhary (1971) reported that the response of potash to various agricultural crops was not significant as majority of Indian soils are not so deficient in potash. Savithri (1980) noted that higher level of 30 kg K_2O ha^{-1} increased the grain yield significantly over 10 kg K_2O ha^{-1} in green gram. Singh *et al.* (1992) observed in pea that application of 40 kg K_2O ha^{-1} significantly increased grain yields compared with the control. Singh *et al.* (1992) reported that grain and straw yield was found to improve with increase in levels of potassium in pigeon pea. In a pot culture experiment Singh *et al.* (1992) reported that there was a significant increase in grain and straw yield with increase in levels of potassium in pea. Shah *et al.* (1994) revealed that straw and biological yields were significantly influenced by the application 40 kg K_2O ha^{-1} . Yahiya *et al.* (1996) reported in pigeon pea that application of 50 kg K_2O ha^{-1} significantly increased pod yield. Kanaujia *et al.* (1997) reported that green pod yield was increased by potassium application and highest values were recorded with 60 kg K_2O ha^{-1} in pea.

Mathew(1981) observed that higher levels of potash significantly influenced pod yield and haulm yield and was highest with 75 kg K_2O ha^{-1} in groundnut.Yakadri *et al.* (1992) reported in groundnut that pod yield were significantly influenced by the increasing levels of potassium upto 60 kg ha^{-1}. Deshmukh *et al.* (1993) noted that the pod and haulm yields of groundnut increased significantly with application of 40 kg K_2O ha^{-1} over lower doses. Singh *et al.* (1994) noted in groundnut that potassium application increased pod yield with an increase in K level. Patra *et al.* (1996) observed that application of potassium at the rate of 50 kg ha^{-1} significantly increased pod yield in groundnut.

2.3.2.3 Effect of potassium on moisture extraction pattern (MEP), consumptive use (Cu) and water use efficiency (WUE)

Blanchet *et al.* (1962) reported that K nutrition influences the uptake and translocation of water and better extraction of moisture from soil. It was also reported that the

WUE was high when tissue K content was 1.3 per cent and drastrically decreased at tissue K concentration of 0.8 per cent and below.

Thomas (1998) reported in soybean that K improves the WUE and helps to maintain crop yield under moisture stress and the uptake of water by roots and ability of roots to exploit soil water depends on potassium nutritional status of plants.

2.3.2.4. Effect of potassium on nutrient composition and uptake.

Deshpande (1974) reported that in groundnut the percentage of N, P and K in various plant parts at harvest were not influenced by potassium application. Nair (1978) reported in groundnut that a significant difference in nitrogen content of haulm, shell and kernal due to difference in levels of potash application. N content of shell and kernal was significantly decreased by higher levels of potassium. He also observed a significant increase in phosphorus and potassium content of shell and kernal due to the increasing levels of potassium. Mathew (1981) reported that in groundnut different levels of potassium did not excert significant influence on nitrogen content in dry matter, shell and kernal. He also found that potash level of 75 kg K_2O ha^{-1} significantly influenced the P content in drymatter and kernal and also K content in drymatter, shell and kernal. Uptake of N,P and K was enhanced with higher levels of potassium and it was highest with 75 kg K_2O ha^{-1}.

2.3.2.5 Effect of potassium on economics of cultivation.

In an experiment with field pea singh *et al.* (1992) observed a net profit of Rs 13,281 ha^{-1} when N, P,K,Zn were applied at the rate of 18, 46,40 and 25 kg ha^{-1}. Singh *et al.* (1994) noted in soybean that the mean net return increased by Rs 111 ha^{-1} only at 20 kg K_2O ha^{-1}, however, some reduction was observed when 30 or 40 kg K_2O ha^{-1} was applied. Patra *et al.* (1996) reported that the application of K had no significant effect on net return in groundnut.

2.4. Proline content

Free proline accumulation in the leaf is used as one of the parameters for screening the crop varieties for relative drought tolerance. In soybean, Waldren and Teare (1974) reported that accumulation of proline under water stress could be an indicator of drought resistance or susceptibility. Udayakumar *et al.* (1976) reported that increasing levels of K had a marked effect on proline accumulation both under normal and stress condition in cowpea. Parameshwara and Krishnasastry (1980) observed that in sorghum, the magnitude of proline accumulation was high when stress was induced at initial vegetative phase and decreased at other stages. Sinha and Nicholas (1981) reported that potassium application was found to increase the proline at all the levels of water stress. Balasubramanian (1982) reported that in cowpea K induced proline accumulation in both stressed and unstressed plants. Krishnasasthry (1982) noted that when K-deficient leaves of finger millet and groundnut were enriched with KCl prior to moisture stress, proline accumulated considerably. Mukherjee *et al.* (1982) studied the degree of drought resistance in cowpea in relation to proline accumulation and concluded that plants having an inherant capacity to accumulate proline during moisture stress can also acquire the property of drought resistance under such conditions. Krishnasastry (1985) reported that K increased proline in finger millet and groundnut under water stress condition as a result of promotion of proline biosynthesis via potassium mediated arginase activity . Anitha (1989) observed in green gram that accumulation of proline during stress is considered to be an adaptive mechanism for drought tolerance. Thus the varieties showing accumulation of proline during stress will be drought tolerent and high yielding. Mareena (1989) found that high yielding varieties had relatively low content of proline in cowpeas. Sharma and Kumar (1991) reported that mean free proline content was higher in stress than in no stress conditions by 10.4 times at 60 days and 12.0 times at 80 days. Mukane *et al.* (1996) reported that accumulation of free proline and carbohydrates in the leaves of pigeon pea can be used as biochemical markers of drought tolerance. Somal and Paj (1998) reported from an experiment on cowpea that drought enhanced the proline levels. In soybean, Thomas(1998) found that K is involved in the biosynthesis of proline and crop variety with high proline content are reported to have high yield stability and high productivity under moisture stress.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The objective of this investigation was to assess the effect of nitrogen and potassium on vegetable cowpea var. *Malika* under varying moisture regimes and to work out the economics of different treatment combinations. The field experiment was conducted during the summer season of 1999. The materials used and the methods adopted for the study are briefly described below.

3.1. Materials.

3.1.1. Experimental site:

The experiment was conducted at the Instructional Farm (IF), attached to the College of Agriculture (COA), Vellayani located at 8.5^{o} N latitude and 76.9^{o} E longitude at an altitude of 29m above the mean sea level.

3.1.2. Soil.

The soil of the experimental area was sandy clay loam in texture and of the order oxisol. The data on the physico-chemical properties of the soil of the experimental site are furnished in Table 3.1.

Table 3.1 Physico-chemical properties of soil

A. Mechanical composition

Slno	Constituents	content in soil(percentage)	Method used
1.	Coarse sand	14.20	Bouyoucos (1962)
2.	Fine sand	33.30	Hydrometer method
3.	Silt	27.50	(Bouyoucos, 1962)
4.	Clay	25.60	

Textural class - Sandy clay loam.

B. Important soil physical constants.

Particulars	Depth of soil layer(0-45cm)			Method used
	0-15	15-30	30-45	
Field capacity (per cent)	24.6	21.5	26.0	Core sampler method (Dasthane, 1967)
Bulk density (Mg/m^3)	1.32	1.34	1.37	(Dakshinamurthy and Gupta,1968)

C. Chemical composition

Slno	Parameters	Contents	Rating	Method used
1.	Available N (Kg/ha)	232.45	Low	Alkaline potassium permanganate method (Subbiah and Asija, 1956)
2.	Available P_2O_5 (Kg/ha)	32.8	Medium	Bray Colorimetric method (Jackson, 1973)
3.	Available K_2O (Kg/ha)	52.39	Low	Ammonium acetate method(Jackson, 1973)
4.	pH	5.1	Acidic	pH meter with glass electrode(Jackson, 1973)

3.1.3. Cropping history of the field.

During the previous two seasons, bulk crops of bhindi and amaranthus were taken under uniform package of practices in the experimental area.

3.1.4. Season

The study was conducted during the summer season (Period extending from the second fortnight of January to the first week of May 1999)

3.1.5. Weather data

The meteorological data including weekly averages of temperature, relative humidity and weekly totals of rainfall during the cropping period was collected from the Agrometeorological observatory attached to the Department of Agronomy, COA, Vellayani and are presented in Table 3.2 and Fig.1. The daily evaporation reading was also taken for computing the scheduling of irrigation and printed in Appendix I.

3.1.6. Crop and Variety.

Vegetable cowpea cv. *Malika* was selected for the study. This variety was released from COA, Vellayani and found suitable for cultivation in the uplands of southern Kerala and also suitable for the summer rice fallows. The morphological characters of the variety are given in Table 3.3.

3.1.7. Source of seed material.

The seed for the experiment was collected from the Instructional Farm, COA, Vellayani.

Table 3.2 Weather data during cropping period

Period	Standard week	Maximum temperature(^{0}c)	Minimum temperature(^{0}c)	Rainfall (mm) (weekly total)	Evaporation (weekly total)	Relative humidity (percentage)
1999	3	31.34	22.53	0	25.13	92.50
	4	31.36	21.27	0	15.89	77.43
	5	30.63	21.37	2.03	24.71	76.29
	6	30.94	22.27	78.61	27.79	83.0
	7	31.4	23.06	0	26.39	81.64
	8	31.8	23.14	0	26.39	84.39
	9	31.93	23.11	0	27.72	80.00
	10	32.20	23.09	0	30.17	78.79
	11	32.7	24.31	1.82	30.38	80.71
	12	32.53	25.23	54.18	31.57	81.21
	13	32.73	25.34	2.17	28.21	82.00
	14	32.44	24.9	0	29.61	80.71
	15	32.3	25.06	29.05	31.08	81.14
	16	32.04	25.41	0.98	28.42	82.57
	17	29.1	24.00	110.81	19.11	87.64

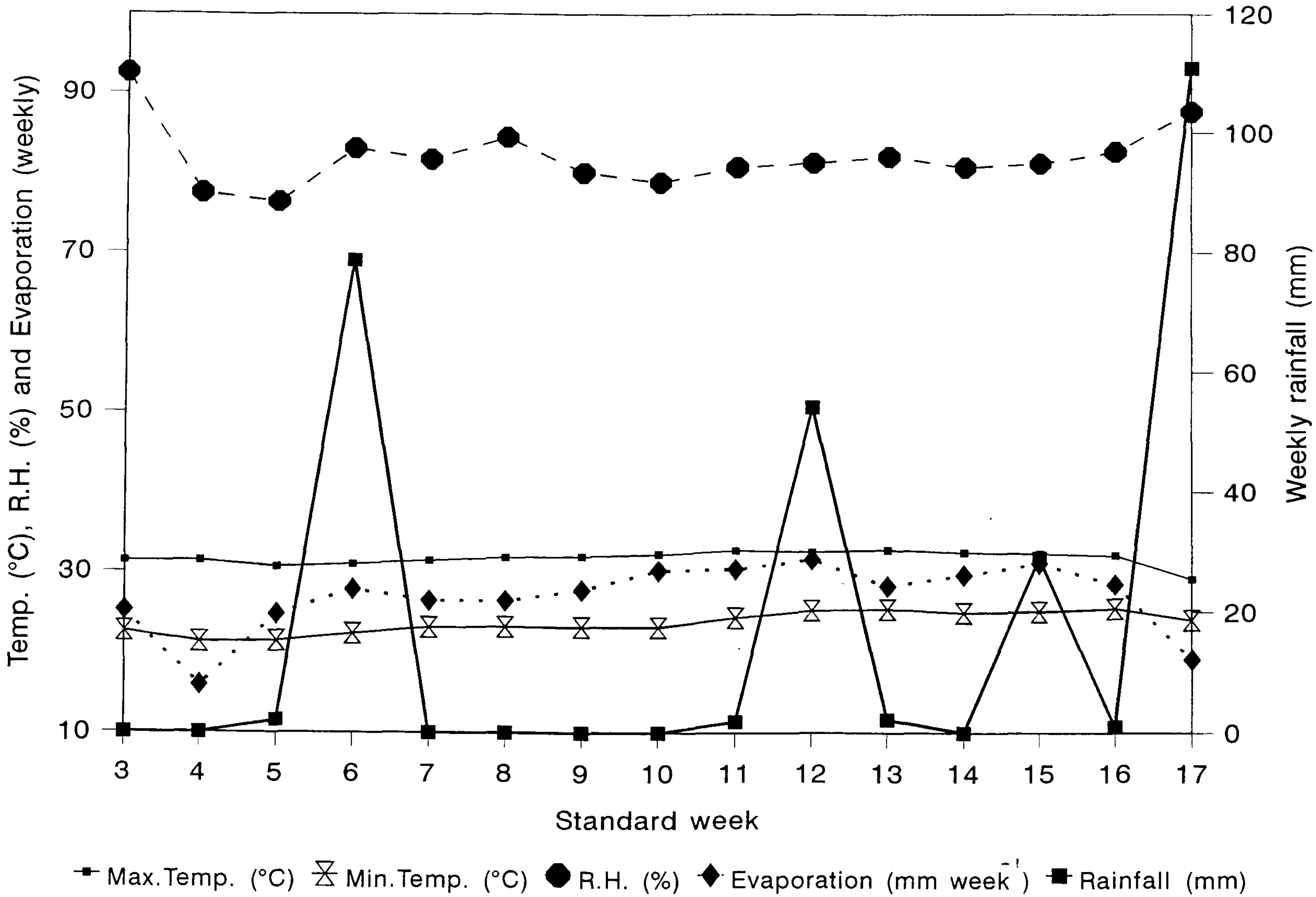

Fig. 1. Weather parameters during the crop period

Table 3.3 Morphological characters of vegetable cowpea cv. *Malika*

Parentage	: Single plant selection from 'Trivandrum local'
Growth habit	: Twining and climbing
Petiole colour	: Light green
Stem colour	: Light green
Peduncle colour	: Light green
Pod attachment to peduncle	: Pendent
Immature pod colour	: Light green
Dry pod colour	: Straw
Seed shape	: Kidney-shaped
Seed colour	: Brown colour with a white speck of irregular shape at one end.
Days to 50 per cent flowering	: 45 to 50 days after sowing (DAS)
Length of pod	: 43.5 cm
Number of seed per pod	: 17.1
Weight of 100 seeds	: 16.1g
Productivity	: 9.8 t ha^{-1}
Duration	: 100 days.

3.1.8. Manures and fertilizers.

Well decomposed and dried farm yard manure (FYM) was used in the study. Along with that, fertilizers of the following analysis was also used as sources of nitrogen, phosphorus and potassium respectively.

Urea	-	46 per cent N
Mussoriephos	-	22 per cent P_2O_5
Muriate of Potash	-	60 per cent K_2O

3.2. Methods

3.2.1. Design and layout

The field experiment was laid out in a 3^3 Confounded Factorial Experiment, confounding INK in Replication I and INK^2 in Replication II. The layout is presented in Fig.2.

3.2.2. Treatment details

Treatment combinations - 27

(Combination of three levels of irrigation, nitrogen and potassium.)

Irrigation Levels

I_1- Irrigating the crop at 20mm CPE value with a depth of 40mm water through surface method.

I_2- Irrigating the crop at 10mm CPE value with a depth of 20mm water through micro sprinkler.

I_3- Farmer's practice (light irrigation with 10mm water everyday by pot watering).

Fig.2 Layout plan of the experimental plot

I- Irrigation levels (3)

I_1- Irrigating at 20 mm CPE with a depth of 40mm water through surface method

I_2- Irrigating at 10mm CPE with a depth of 20mm water through micro sprinkler.

I_3- Farmer's practice (light irrigation with 10mm water everyday by pot watering)

N- Nitrogen levels (3)

N_1- 0 kg N ha^{-1}

N_2- 20 kg N ha^{-1}

N_3- 40 Kg N ha^{-1}

K- Potassium levels (3)

K_1- 0 kg K_2O ha^{-1}

K_2- 20 kg K_2O ha^{-1}

K_3- 40 kg K_2O ha^{-1}

3^3 Confounded factorial experiment confounding INK- Rep I

INK^2- RepII

Gross plot size- 4.0 x 3.6 m

Net plot size - 3.0 x 2.4 m

$I_1N_1K_1$	$I_2N_2K_3$	$I_1N_3K_1$
$I_2N_3K_1$	$I_3N_2K_2$	$I_2N_2K_1$
$I_1N_2K_3$	$I_2N_3K_2$	$I_3N_1K_1$
$I_3N_1K_2$	$I_1N_2K_1$	$I_2N_3K_3$
$I_1N_3K_2$	$I_3N_1K_3$	$I_1N_1K_3$
$I_2N_1K_3$	$I_1N_3K_3$	$I_3N_3K_2$
$I_3N_3K_3$	$I_2N_1K_1$	$I_1N_2K_2$
$I_2N_2K_2$	$I_3N_3K_1$	$I_2N_1K_2$
$I_3N_2K_1$	$I_1N_1K_2$	$I_3N_2K_3$
$I_2N_2K_3$	$I_3N_1K_1$	$I_1N_1K_3$
$I_3N_3K_2$	$I_1N_2K_3$	$I_3N_3K_1$
$I_1N_3K_3$	$I_2N_2K_1$	$I_1N_3K_3$
$I_3N_2K_1$	$I_1N_2K_1$	$I_2N_3K_1$
$I_2N_1K_2$	$I_3N_2K_2$	$I_1N_2K_1$
$I_1N_1K_1$	$I_2N_3K_2$	$I_3N_2K_3$
$I_2N_3K_1$	$I_3N_3K_3$	$I_2N_2K_2$
$I_1N_2K_2$	$I_2N_1K_3$	$I_3N_1K_2$
$I_3N_1K_3$	$I_1N_1K_2$	$I_2N_1K_1$

Nitrogen levels

N_1	-	O Kg ha^{-1}N
N_2	-	20 Kg ha^{-1} N
N_3	-	40 Kg ha^{-1} N

Potassuim levels

K_1	-	O Kg ha^{-1} K_2O
K_2	-	20 Kg ha^{-1} K_2O
K_3	-	40 Kg ha $^{-1}$ K_2O

3.2.3 Size of the plot

Gross plot size	-	4.0 x 3.6m
Net plot size	-	3.0 x 2.4m

3.3 Field culture

3.3.1 Land preparation

The experimental field was ploughed with a power tiller, stubbles were removed and levelled properly. The field was then laid out into blocks and plots.

3.3.2 Manures and fertilizers.

FYM @ 20t ha^{-1} was applied uniformly to all the plots and mixed well with top soil. A common dose of phosphorus @ 45 kg ha^{-1}(results from the previous experiements) was given to all treatments. Full dose of phosphorus and potash and half dose of nitrogen was applied as basal and the remaining half dose of nitrogen was applied in three equal split doses 20, 30 and 40 DAS as soil application.

3.3.3 Sowing

Furrows of width 30cm were taken along the length of the plot at one meter distance and seeds were dibbled at the rate of three per hole at a depth of 5cm in the furrows and at a spacing of 60cm between plants.

3.3.4 After cultivation

Uniform germination was obtained in the field. Five DAS gap filling was done in a few plots. The crop was thinned one week after emergence and a single plant was maintained and trailed on standards. The crop was given regular hand weedings throughout the cropping period. Earthing up was also done after top dressing of N 30 DAS, five plants were selected randomly from the net plot area and tagged as observational plants.

3.3.5 Irrigation

The irrigation was scheduled to the crop one week after sowing as per the treatments. Soil samples were taken periodically from each plot and moisture content was calculated by gravimetric method. Measured quantities of water was given to the plots according to the treatments at CPE values of 20 and 10mm to a depth of 40 and 20mm respectively in treatments I_1 and I_2 and daily irrigation treatment given to I_3 at a depth of 10mm.

3.3.6 Plant protection

BHC 10 per cent dust was applied along the furrows and also around each individual plot after sowing to prevent the attack of ants feeding on seeds and also

Table 3.4

Rainfall and evaporation during the period of irrigation study. (February 1999-April 1999)

Date	Rainfall(mm)	Evaporation (mm)	Treatment irrigated
February			
05-02-99	3.6	3.4	I_1, I_2, I_3
06-02-99	62.4	6.2	-
07-02-99	0	3.7	-
08-02-99	11.8	3.3	-
09-02-99	0.8	3.9	-
10-02-99	0	3.6	I3
11-02-99	0	3.3	I_3
12-02-99	0	3.7	I_3
13-02-99	0	3.9	I_3
14-02-99	0	4.0	I_3
15-02-99	0	4.0	I_3
16-02-99	0	3.9	I_3
17-02-99	0	3.7	I_3
18-02-99	0	3.8	I_3
19-02-99	0	3.6	I_3
20-02-99	0	3.6	I_3
21-02-99	0	2.6	I_3
22-02-99	0	3.9	I_3
23-02-99	0	5.2	I_3
24-02-99	0	4.0	I_3
25-02-99	0	3.6	I_3
26-02-99	0	4.0	I_3
27-02-99	0	4.0	I_2, I_3
28-02-99	0	3.5	I_3

Contd. **Table 3.4**

March

01-03-99	0	4.3	I_3
02-03-99	0	4.3	I_1,I_2, I_3
03-03-99	0	4.2	I_3
04-03-99	0	5.2	I_3
05-03-99	0	4.0	I_2, I_3
06-03-99	0	4.3	I_3
07-03-99	0	4.0	I_1,I_2, I_3
08-03-99	0	4.5	I_3
09-03-99	0	4.0	I_3
10-03-99	0	4.0	I2, I_3
11-03-99	0	3.9	I_3
12-03-99	0	4.0	I_1,I_2, I_3
13-03-99	1.0	4.4	I_3
14-03-99	0	4.0	I_3
15-03-99	0	5.7	I2, I_3
16-03-99	0.8	4.4	I_3
17-03-99	0	4.8	I_1,I_2, I_3
18-03-99	54.2	5.5	-
19-03-99	0	4.7	-
20-03-99	0	4.0	I_3
21-03-99	0	4.0	I_3
22-03-99	0	4.0	I_3
23-03-99	0	4.6	I_3
24-03-99	0	4.0	I_3
25-03-99	0	4.0	I_3
26-03-99	0	3.9	I_3
27-03-99	0	4.0	I_3
28-03-99	0	4.9	I_3
29-03-99	0	3.9	I_3
30-03-99	2.2	3.5	I_3
31-03-99	0	4.0	I_3

Contd. **Table 3.4**

April			
01-04-99	0	5.0	I_2
02-04-99	0	4.6	I_3
03-04-99	0	3.2	I_3
04-04-99	0	4.7	I_1,I_2, I_3
05-04-99	0	3.7	I_3
06-04-99	0	4.4	I_3
07-04-99	10.2	2.2	-
08-04-99	5.0	4.9	-
09-04-99	0	6.0	I_3
10-04-99	0	3.5	I2, I_3
11-04-99	0	4.9	I_3
12-04-99	0	4.3	I_1,I_2, I_3
13-04-99	14.0	5.3	-
14-04-99	0	3.9	I_3
15-04-99	0	4.5	I_3
16-04-99	0	4.0	I_3
17-04-99	0	4.8	I_2
18-04-99	0.4	4.0	I_3
19-04-99	0.6	4.1	I_3
20-04-99	0	3.1	I_1,I_2, I_3
21-04-99	0	4.0	I_3
22-04-99	1.4	3.2	I_3
23-04-99	1.0	2.0	I_3
24-04-99	78.0	1.5	-
25-04-99	29.2	2.4	-
26-04-99	1.2	2.0	-
27-04-99	0	4.0	I_3
28-04-99	0	4.1	I_3
29-04-99	5.6	3.4	I_3
30-04-99	0.6	4.4	I_3

Note:-

I_1 - Irrigating the crop at 20mm CPE value with a depth of 40mm water through surface method

I_2 - Irrigating the crop at 10mm CPE value with a depth of 20mm water through microsprinkler

I_3 - Farmer's practice (light irrigation with 10mm water every day by pot watering)

Quantity of water received by each irrigation treatment during the crop period

Treatment	Irrigation (mm)	Effective Rainfall(mm)	Total amount of water requirement (mm)
I_1	320	80	400
I_2	300	60	360
I_3	700	60	760

grasshoppers cutting the young seedlings at the collar region. Dusting was repeated every week till one month. Spraying of dicofol at 0.30 per cent was given once at 15 DAS against mite attack. Quinalphos at 0.3 per cent and phosphamidon at 0.1 per cent were sprayed at 20 and 30 DAS as a prophylactic measure against aphids and shoot borer.

3.3.7 Harvesting.

Vegetable picking commenced from 52 DAS. Subsequent harvests of immature pods from the net plot area was done in alternate days uniformly from all the treatments upto 100 DAS and fresh weight was recorded seperately.

3.4 Biometric observations.

3.4.1 Height of the plant.

The mean value of the height of five randomly selected observational plants from the net plot area were computed at 30,45,60, 75 and 90 DAS and recorded. The height was measured from the base of the plant to the terminal leaf bud and expressed in centimeters.

3.4.2. Number of leaves.

The mean values of number of leaves per plant from 5 observatonal plants at 30, 45,60,75 and 90 DAS were computed and recorded.

3.4.3. Leaf area index (LAI)

The leaf area of a plant from each plot was measured at 30,45,60,75 and 90 DAS using LI-3100 leaf area meter and expressed in square centimeter. Leaf area index was then computed using the equation

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

3.4.4. Dry matter production(DMP)

DMP was recorded during five growth stages viz; 30,45,60,75 and 90 DAS. One plant was uprooted from the destructive row at each stage carefully without damaging the roots and seperated into leaves, stem and roots. These were dried under shade seperately and then oven dried at 80$\pm$ 5°c for about 10 hours till two consecutive weights coincided. The final weight were totalled and expressed in grams per plant.

3.4.5. Days for 50 per cent flowering

The date of flowering of 50 per cent of the net population was recorded for each treatment, and the period taken was recorded as number of days.

3.4.6. Number of pods per plant.

The pods collected from the five observational plants per net plot were counted and average worked out.

3.4.7. Pod yield per plant.

The pods obtained from the five observational plants per net plot were weighed seperately and averages were recorded.

3.4.8. Pod yield in kg ha^{-1}.

Yield of immature pods obtained from each harvest was recorded seperately according to treatment and totalled up at the end of the cropping period and expressed in kg ha^{-1}.

3.4.9. Haulm yield in kg ha^{-1}

After the pods were picked from each net plot the plants were uprooted, sundried uniformly and weighed. The weight was expressed in kg ha^{-1}.

3.4.10. Number of picking.

Number of pickings of immature pods from each plot during the total crop period was recorded.

3.4.11. Crop duration.

The duration of the crop from sowing up to the end of the cropping period ie, till the vegetable yield came below the economic level, was recorded as number of days.

3.5 Moisture studies

3.5.1 Moisture depletion pattern

The average relative soil moisture depletion from each soil layer in the root zone at 0-15cm, 15-30cm, 30-45cm was worked out for an interval of 15 days for each treatment. The total loss from each layer was determined on percentage basis at the end of the cropping period.

3.5.2 Water use efficency(WUE)

Field water use efficency was calculated by dividing the economic crop yield by the total quantity of water applied in the field (WR) and expressed in kg ha^{-1} mm^{-1}.

3.6 Analytical procedures

3.6.1 Soil analysis

Soil samples were taken from the experimental area before and after the experiment. The air dried soil samples were analysed for available N, P_2O_5 and K_2O content. Available N content was determined by Alkaline potassium permanganate method (Subbiah and Asija, 1956), available P_2O_5 content by Bray colorimetric method (Jackson, 1973) and available K_2O by Ammonium acetate method (Jackson, 1973).

3.6.2. Plant analysis.

Plant samples were analysed for N,P and K content at 3 stages of crop growth viz., 30,60 and 90 DAS. Samples were chopped and dried in an oven at 80 ± 5°c till constant weights were obtained. Samples were ground and sieved through 60 mesh sieve. The required quantity of samples were then weighed out accurately in an electronic balance and used for chemical analysis.

3.6.3. Uptake studies.

Total uptake of N,P and K at 30,60 and 90 DAS was computed based on the content of these nutrients in plants and the dry matter produced (Jackson, 1973).

3.6.4. Biochemical studies.

3.6.4.1. Proline content of leaves.

The free proline was estimated by the method of Bates *et al.* (1973). A fresh sample of 0.5g was homogenized in 3 per cent aqueous sulphosalicylic acid, filtered and the extraction was repeated till 10ml extract was obtained. Two ml of the aliquot was mixed with

2 ml of acid ninhydrin (0.625 g of ninhydrin in a warm mixture of 15ml glacial acetic acid and 10ml of 6 molar phosphoric acid) followed by 2ml of glacial acetic acid. The mixture was incubated at 100°c in a hot water bath for one hour. This was immediately transferred to ice water bath to stop the reaction. Later 4 ml of toluene was added and the contents were shaken thoroughly. The toluene colour complex was aspirated and read at 520 nm. Proline content was estimated at 30,60 and 90 DAS and expressed in m moles g^{-1} fresh weight.

3.7 Economic analysis

The economics of cultivation of the crop was worked out and the net income and benefit cost ratio (BCR) were calculated as follows.

$$BCR = \frac{\text{Gross income}}{\text{Total cost of cultivation}}$$

3.8 Statistical analysis

Data relating to each character was analysed by applying the Analysis of Variance Technique (ANOVA)as suggested by Panse and Sukhatme (1954).

RESULT

4. RESULTS

A field experiment was conducted at the Instructional farm attached to the College of Agriculture, Vellayani during the summer season of 1999 to study the response of vegetable cowpea cv. *Malika* to nitrogen and potassium under varying levels of irrigation. The experimental data collected were statistically analysed to find out the effect of graded levels of irrigation, nitrogen and potassium as well as their interaction effects. The results obtained are presented below.

4.1 Growth characters

Growth characters as influenced by irrigation, nitrogen and potassium was measured in terms of plant height,number of leaves, leaf area index and dry matter production at fortnighty intervals from 30DAS to 90DAS

4.1.1 Plant height

Plant height as influenced by irrigation, nitrogen and potassium are presented in table 4.1, 4.1.1 and 4.1.4. During all the different stages of crop growth, plant height increased progressively upto 90 DAS by the effect of main effects and their interactions.

Table 4.1

Effect of irrigation, nitrogen and potassium on plant height (cm)

Treatments	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
Irrigation					
I_1	70.27	225.67	321.67	423.5	430.78
I_2	75.67	223.33	311.39	410.5	427.39
I_3	73.17	224.72	331.89	426.45	433.72
$F_{2, 22}$	0.38^{ns}	0.055^{ns}	1.714^{ns}	1.134^{ns}	0.159^{ns}
SE_D	6.19	7.02	11.07	11.18	11.23
CD(0.05)					
Nitrogen					
N_1	69.89	222.28	314.67	414.83	432.06
N_2	81.28	229.06	323.28	424.33	431.45
N_3	67.95	222.39	327	421.23	428.39
$F_{2, 22}$	2.70^{ns}	0.612^{ns}	0.653^{ns}	0.371^{ns}	0.061^{ns}
SE_D	6.19	7.02	11.07	11.18	11.23
CD(0.05)					
Potassium					
K_1	74.33	230.33	327.89	423.5	440.72
K_2	79.56	227.06	328	427.28	434.88
K_3	65.22	216.33	309.06	409.67	416.28
$F_{2,22}$	2.74^{ns}	2.18^{ns}	1.94^{ns}	1.354^{ns}	2.585^{ns}
SE_D	6.19	7.02	11.07	11.18	11.23
CD(0.05)					

Irrigation Levels

I_1- Irrigating the crop at 20mm CPE value with a depth of 40mm water through surface method.

I_2- Irrigating the crop at 10mm CPE value with a depth of 20mm water through micro sprinkler

I_3- Farmer's practice (light irri gating with 10mm water everyday by pot watering)

Nitrogen Levels

N_1- 0 kg N ha^{-1}

N_2- 20 kg N ha^{-1}

N_3- 40 kg N ha^{-1}

Potassium Levels

K_1-0 kg K_2O ha^{-1}

K_2-20 kg K_2O ha^{-1}

K_3-40 kg K_2O ha^{-1}

Table 4.1.1.

Interaction effect of irrigation and nitrogen on plant height (cm)

Treatments	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
I_1N_1	64.33	222.83	318.33	421.33	428.67
I_1N_2	94.17	242	338.17	440.17	447.17
I_1N_3	52.33	212.17	308.5	409	416.5
I_2N_1	67.67	219.33	300.33	398.17	436
I_2N_2	63.5	214.33	291.33	391.5	396.83
I_2N_3	95.83	236.33	342.5	441.83	449.33
I_3N_1	77.67	224.67	325.33	425	431.5
I_3N_2	86.17	230.83	340.33	441.33	450.33
I_3N_3	55.67	218.67	330	413	419.33
$F_{4, 22}$	7.519^{**}	2.39^{ns}	2.48^{ns}	2.96^{*}	3.21^{*}
SE_D	6.19	7.02	11.07	11.18	11.23
CD(0.05)	22.25			40.47	40.34

* Significant at 5 per cent level

** Significant at 1 per cent level

Table 4.1.4

Interaction effect of irrigation, nitrogen and potassium on plant height (cm)

Treatments	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
$I_1N_1K_1$	53.5	222.00	309.00	411.00	419.00
$I_1N_1K_2$	89.5	232.00	340.5	442.5	449.5
$I_1N_1K_3$	50.00	214..5	305.0	410.5	417.5
$I_1N_2K_1$	102.5	259.5	353.00	454.5	460.00
$I_1N_2K_2$	92.5	236.00	348.00	450.5	459.00
$I_1N_2K_3$	87.5	230.5	313.5	415.5	422.5
$I_1N_3K_1$	58.5	228.00	313.5	413.5	420.5
$I_1N_3K_2$	57.5	225.5	310.00	411.5	419.5
$I_1N_3K_3$	41.0	18.3	302.00	402.00	409.5
$I_2N_1K_1$	56.0	213.5	275.5	370.00	471.5
$I_2N_1K_2$	94.00	242.00	360.00	459.5	466.5
$I_2N_1K_3$	53.0	202.5	265.5	365.00	370.00
$I_2N_2K_1$	57.5	219.00	298.00	402.00	480.00
$I_2N_2K_2$	55.5	203.5	269.00	367.5	374.00
$I_2N_2K_3$	77.5	220.5	307.00	405.00	408.5
$I_2N_3K_1$	115.5	251.5	364.5	463.5	471.5
$I_2N_3K_2$	84.0	223.5	324.5	422.5	429.5
$I_2N_3K_3$	88.00	234.00	338.5	439.5	447.00
$I_3N_1K_1$	97.00	235.00	347.00	450.5	456.5
$I_3N_1K_2$	70.00	221.00	317.00	413.5	419.00
$I_3N_1K_3$	66.00	218.00	312.00	411.00	419.00
$I_3N_2K_1$	83.00	230.5	335.5	436.5	443.5
$I_3N_2K_2$	97.00	235.00	359.5	426.00	474.00
$I_3N_2K_3$	78.5	227.00	326.00	425.5	433.5
$I_3N_3K_1$	45.5	214.00	355.00	410.00	416.00
$I_3N_3K_2$	76.00	225.00	323.5	416.00	423.00
$I_3N_3K_3$	45.5	217.00	311.5	413.00	419.00
$F_{2,22}$	4.174*	2.93	2.32	3.23	2.58
SE_D					
CD(0.05)	27.25				

* Significant at 5 per cent level

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Eventhough, an increasing trend was noticed in plant height, the differences were not significant due to the levels of I, N and K. The interactions between IxN excerted a remarkable influence in plant height at 30, 75and 90 DAS and the treatment I_2N_3 (95.83) recorded the maximum plant height at 30 DAS and I_3N_2 recorded the maximum plant height at 75 and 90 DAS. The interactions IxK and NxK did not have any effect on plant height.

The three factor interaction between irrigation, nitrogen and potassium produced a significantly higher plant height only at 30 DAS. I_2N_3K, recorded the maximum height (115.5cm) which was on par with $I_1N_2K_1$ (102.5), $I_3N_1K_1$ (97), $I_3N_2K_2$ (97), $I_2N_1K_2$ (94), $I_1N_2K_2$ (92.5) and $I_1N_1K_2$ (89.5)

4.1.2. Number of leaves

Data showing the influence of I,N and K treatment on the number of leaves are given in table 4.2. and 4.2.1.

Throghout the plant growth, the production of leaves was not influenced by the effect of I, N and K. However, the interaction of I and N significantly influenced the number of leaves at 30 DAS and the treatment I_3N_2 registered the highest number and was on par with I_2N_3, I_1N_2 and I_3N_1. The interactions of IxK and NxK also did not varied the production of leaves..

The combined interactions of the three factors viz., I,N and K also failed to exert any applicable influence on leaf number at any stages of the crop growth.

4.1.3. Leaf area index (LAI)

The main values of LAI as influenced by I,N and K are furnished in table 4.3, 4.3.1, and 4.3.4. The main effects of the treatments failed to influence the LAI during the entire period of crop growth.

Table 4.2.

Effect of irrigation, nitrogen and potassium on number of leaves.

Treatments	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
Irrigation					
I_1	10.28	35.39	55.89	76.45	69.56
I_2	10.39	34.06	53.78	74.95	68.89
I_3	11.11	34.72	54.72	75.45	69.06
$F_{2,22}$	0.436^{ns}	0.240^{ns}	0.643^{ns}	0.405^{ns}	0.095^{ns}
SE_D	0.97	1.92	1.87	1.70	1.59
CD(0.05)					
Nitrogen					
N_1	10.00	34.39	54.06	75.11	68.39
N_2	11.72	35.67	55.95	76.39	70.11
N_3	10.06	34.11	54.39	75.33	69.00
$F_{2,22}$	2.042^{ns}	0.372^{ns}	0.584^{ns}	0.324^{ns}	0.603^{ns}
SE_D	0.97	1.92	1.87	1.70	1.59
CD(0.05)					
Potassium					
K_1	11.06	34.89	55.06	76.06	69.83
K_2	11.39	35.67	55.67	76.39	69.83
K_3	9.33	33.61	53.67	74.39	67.83
$F_{2,22}$	2.60^{ns}	0.582^{ns}	0.604^{ns}	0.797^{ns}	1.055^{ns}
SE_D	0.97	1.92	1.87	1.70	1.59
CD(0.05)					

Irrigation Levels

I_1- Irrigating the crop at 20mm CPE value with a depth of 40mm water through surface method.

I_2- Irrigating the crop at 10mm CPE value with a depth of 20mm water through micro sprinkler

I_3- Farmer's practice (light irri gating with 10mm water everyday by pot watering)

Nitrogen Levels

N_1- 0 kg N ha^{-1}
N_2- 20 kg N ha^{-1}
N_3- 40 kg N ha^{-1}

Potassium Levels

K_1-0 kg K_2O ha^{-1}
K_2-20 kg K_2O ha^{-1}
K_3-40 kg K_2O ha^{-1}

Table 4.2.1.

Interaction effect irrigation and nitrogen on number of leaves.

Treatments	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
I_1N_1	9.50	34.83	55.17	75.83	68.50
I_1N_2	12.50	37.33	58.00	78.33	71.83
I_1N_3	8.83	34.00	54.50	75.15	68.33
I_2N_1	9.50	32.67	52.33	73.67	67.33
I_2N_2	9.00	32.83	53.17	73.50	67.83
I_2N_3	12.67	36.67	55.83	77.67	71.50
I_3N_1	11.00	35.67	54.67	75.83	69.33
I_3N_2	13.67	36.83	56.67	77.33	70.67
I_3N_3	8.67	31.67	52.83	73.17	67.17
$F_{4, 22}$	3.96^{*}	1.21^{ns}	0.711^{ns}	1.320^{ns}	1.31^{ns}
SE_D	1.68	3.33	3.23	2.94	2.75
CD(0.05)	3.48				

* Significant at 5 per cent level

** Significant at 1 per cent level

Table 4.3

Effect of irigation, nitrogen and potassium on leaf area index.

Treatments	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
Irrigation					
I_1	0.15	0.75	1.24	2.25	2.58
I_2	0.15	0.84	1.22	2.32	2.66
I_3	0.16	0.80	1.39	2.39	2.70
$F_{2, 22}$	0.029^{ns}	1.322^{ns}	2.14^{ns}	0.567^{ns}	0.325^{ns}
SE_D	0.02	0.06	0.09	0.13	0.16
CD(0.05)					
Nitrogen					
N_1	0.14	0.80	1.24	2.22	2.56
N_2	0.18	0.81	1.38	2.45	2.75
N_3	0.15	0.78	1.23	2.30	2.62
$F_{2, 22}$	1.395^{ns}	0.152^{ns}	1.74^{ns}	1.556^{ns}	0.789^{ns}
SE_D	0.02	0.06	0.09	0.13	0.16
CD(0.05)					
Potassium					
K_1	0.16	0.80	1.33	2.40	2.73
K_2	0.17	0.86	1.35	2.41	2.73
K_3	0.13	0.73	1.17	2.16	2.46
$F_{2, 22}$	2.314^{ns}	2.61^{ns}	2.47^{ns}	2.346^{ns}	2.052^{ns}
SE_D	0.02	0.06	0.09	0.13	0.16
CD(0.05)					

Irrigation Levels

I_1- Irrigating the crop at 20mm CPE value with a depth of 40mm water through surface method.

I_2- Irrigating the crop at 10mm CPE value with a depth of 20mm water through micro sprinkler

I_3- Farmer's practice (light irri gating with 10mm water everyday by pot watering)

Nitrogen Levels

N_1- 0 kg N ha^{-1}

N_2- 20 kg N ha^{-1}

N_3- 40 kg N ha^{-1}

Potassium Levels

K_1-0 kg K_2O ha^{-1}

K_2-20 kg K_2O ha^{-1}

K_3-40 kg K_2O ha^{-1}

Table 4.3.1

Interaction effect of irrigation and nitrogen on LAI

Treatments	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
I_1N_1	0.13	0.73	1.21	2.13	2.46
I_1N_2	0.19	0.84	1.37	2.51	2.87
I_1N_3	0.13	0.67	1.13	2.11	2.41
I_2N_1	0.13	0.85	1.18	2.18	2.52
I_2N_2	0.13	0.71	1.14	2.09	2.43
I_2N_3	0.20	0.96	1.34	2.68	3.01
I_3N_1	0.15	0.82	1.34	2.34	2.70
I_3N_2	0.21	0.88	1.62	2.74	2.96
I_3N_3	0.11	0.71	1.20	2.10	2.45
$F_{4, 22}$	2.83^{ns}	3.32^{*}	2.186^{ns}	4.033^{*}	2.65^{ns}
SE_D	0.04	0.09	0.15	0.23	0.27
CD(0.05)		0.199		0.476	

* Significant at 5 per cent level

** Significant at 1 per cent level

Table 4.3.4

Interaction effect of irrigation, nitrogen and potassium on LAI

Treatments	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
$I_1N_1K_1$	0.13	0.70	1.18	2.04	2.46
$I_1N_1K_2$	0.19	0.83	1.3	2.37	2.64
$I_1N_1K_3$	0.09	0.67	1.15	1.99	2.29
$I_1N_2K_1$	0.21	0.86	1.50	2.72	3.08
$I_1N_2K_2$	0.2	0.85	1.38	2.50	2.93
$I_1N_2K_3$	0.17	0.82	1.25	2.32	2.6
$I_1N_3K_1$	0.16	0.73	1.23	2.30	2.55
$I_1N_3K_2$	0.15	0.70	1.19	2.13	2.46
$I_1N_3K_3$	0.075	0.59	0.98	1.92	2.22
$I_2N_1K_1$	0.1	0.68	1.12	2.08	2.43
$I_2N_1K_2$	0.23	1.27	1.45	2.58	2.99
$I_2N_1K_3$	0.07	0.59	0.97	1.89	2.16
$I_2N_2K_1$	0.15	0.71	1.13	2.09	2.51
$I_2N_2K_2$	0.08	0.67	1.07	1.99	2.26
$I_2N_2K_3$	0.15	0.74	1.22	2.2	2.54
$I_2N_3K_1$	0.24	1.13	1.49	3.07	3.42
$I_2N_3K_2$	0.17	0.81	1.26	2.48	2.75
$I_2N_3K_3$	0.21	0.95	1.28	2.50	2.85
$I_3N_1K_1$	0.23	0.91	1.61	2.80	3.1
$I_3N_1K_2$	0.13	0.81	1.26	2.15	2.61
$I_3N_1K_3$	0.11	0.74	1.16	2.06	2.39
$I_3N_2K_1$	0.17	0.84	1.57	2.59	2.86
$I_3N_2K_2$	0.30	0.99	1.94	3.07	3.19
$I_3N_2K_3$	0.16	0.82	1.36	2.56	2.83
$I_3N_3K_1$	0.10	0.63	1.15	1.94	2.25
$I_3N_3K_2$	0.13	0.81	1.31	2.4	2.80
$I_3N_3K_3$	0.11	0.69	1.15	1.97	2.32
$F_{2,22}$	3.48^*	4.28^*	3.36^{ns}	3.18^{ns}	1.97^{ns}
SE_D					
CD(0.05)	0.102	0.244			

* Significant at 5 per cent level

The interactions of IxN induced a significant differnce in LAI during 45 DAS and 75 DAS. The treatment I_2N_3 registered the highest LAI and was on par with I_3N_2, I_2N_1, I_1N_2 and I_3N_1 at 45 DAS. I_3N_2 recorded the maximum LAI at 75 DAS and I_2N_3, I_1N_2 and I_3N_1 were on par with the superior treatment.

The interactions of all the three factors viz., I, N and K significantly influenced the LAI at 30 and 45 DAS. The treatment $I_3N_2K_2$ and $I_2N_1K_2$ showed the highest LAI at 30 and 45 DAS respectively.

4.1.4 Dry Matter production (DMP)

The data on total DMP at different growth stages as influenced by the different treatments and their interactions are summarised in table 4.4, 4.4.1 and 4.4.2. The data revealed that DMP increased with the increase in plant growth. The irrigation treatments influenced the DMP at 45 DAS. The highest dry matter production of 1552 kg ha^{-1} was recorded in I_1 and was on par with I_3 (1518.66). Nitrogen had a significant influence on DMP at 75 DAS and N_1 recorded the maximum DMP which was on par with N_3. The influence of K on DMP was not observed at any stage of the crop growth.

Interaction effect of IxN significantly influenced the DMP only at 30DAS . I_2N_3 (310.58) registered the maximum DMP and was on par with I_1N_2, I_3N_2 and I_1N_1. Interaction effect of IxK produced a significant influence on DMP at 75 DAS and the treatment I_1K_2 recorded the maximum DMP of 3848.70 kg ha^{-1}. The higher order interactions of IxNxK was not observed during the entire crop growth period.

Table 4.4

Effect of Irrigation , nitrogen and potassium on DMP

Treatments	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
Irrigation					
I_1	292.05	1552.00	2716.55	3481.39	4392.03
I_2	290.97	1442.99	2649.78	3670.81	4541.72
I_3	284.74	1518.66	2700.89	3555.06	4476.29
$F_{2,22}$	0.792^{ns}	3.62^{*}	1.011^{ns}	1.678^{ns}	0.639^{ns}
SE_D	6.27	41.51	49.11	104.23	132.75
CD(0.05)		86.09			
Nitrogen					
N_1	285.71	1492.22	2680.78	3691.02	4614.54
N_2	291.25	1532.68	2728.32	3376.94	4377.25
N_3	290.80	1488.76	2658.12	3639.32	4418.25
$F_{2,22}$	0.481^{ns}	0.691^{ns}	1.065^{ns}	5.221^{*}	1.825^{ns}
SE_D	6.27	41.51	49.11	104.23	132.75
CD(0.05)				216.17	
Potassium					
K_1	292.22	1519.37	2700.14	3561.78	4481.92
K_2	292.43	1524.10	2716.74	3534.19	4407.58
K_3	283.11	1470.19	2650.33	3611.31	4520.54
$F_{2,22}$	1.441^{ns}	1.034^{ns}	0.990^{ns}	0.281^{ns}	0.374^{ns}
SE_D	6.27	41.51	49.11	104.23	132.75
CD(0.05)					

Irrigation Levels

I_1- Irrigating the crop at 20mm CPE value with a depth of 40mm water through surface method.

I_2- Irrigating the crop at 10mm CPE value with a depth of 20mm water through micro sprinkler

I_3- Farmer's practice (light irri gating with 10mm water everyday by pot watering)

Nitrogen Levels

N_1- 0 kg N ha^{-1}

N_2- 20 kg N ha^{-1}

N_3- 40 kg N ha^{-1}

Potassium Levels

K_1-0 kg K_2O ha^{-1}

K_2-20 kg K_2O ha^{-1}

K_3-40 kg K_2O ha^{-1}

Table 4.4.1.

Interaction effect of irrigation and nitrogen on DMP

Treatments	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
I_1N_1	288.72	1539.25	2702.22	3539.06	4580.39
I_1N_2	302.42	1623.528	2781.305	3197.81	4242.86
I_1N_3	285.00	1493.22	2666.11	3707.33	4352.83
I_2N_1	283.17	1413.30	2643.67	3811.06	4667.33
I_2N_2	279.17	1410.39	2623.50	3650.92	4527.45
I_2N_3	310.58	1505.30	2682.17	3550.47	4430.39
I_3N_1	285.25	1524.11	2696.45	3722.94	4595.89
I_3N_2	292.17	1564.11	2780.14	3282.08	4361.44
I_3N_3	276.805	1467.75	2626.08	3660.14	4471.53
$F_{4, 22}$	3.456^{*}	1.517^{ns}	1.011^{ns}	1.733^{ns}	0.177^{ns}
SE_D	10.86	71.90	85.06	180.53	229.93
CD(0.05)	22.52				

* Significant at 5 per cent level

** Significant at 1 per cent level

Table 4.4.2

Interaction effect of irrigation and potassium on DMP

Treatments	30DAS	45DAS	60DAS	75DAS	90DAS
I_1K_1	295.53	1572.53	2734.75	3289.34	4306.50
I_1K_2	295.59	1585.61	2754.42	3488.61	4345.70
I_1K_3	285.03	1497.86	2660.47	3666.25	4523.89
I_2K_1	295.14	1462.25	2658.94	3686.11	4556.19
I_2K_2	292.75	1446.75	2655.28	3848.70	4400.61
I_2K_3	285.03	1419.99	2635.11	3477.64	4668.36
I_3K_1	286.00	1523.33	2706.72	3709.89	4583.06
I_3K_2	288.95	1539.95	2740.53	3265.25	4476.44
I_3K_3	279.28	1492.70	2655.42	3690.03	4369.36
$F_{4,22}$	0.038^{ns}	0.116^{ns}	0.121^{ns}	3.95^{*}	0.625^{ns}
SE_D	10.86	71.90	85.06	180.53	229.93
CD(0.05)				374.42	

* Significant at 5 per cent level

4.2 Yield and yield attributing characters

4.2.1 Days for 50 per cent flowering

The mean number of days taken for 50 per cent flowering is given in table 4.5. It was found that differential irrigation significantly influenced the days for 50 per cent flowering. The number of days taken for 50 per cent flowering was minimum for I_2 (39.17) which was significantly superior to the other two irrigation levels. However, N and K did not have any significant influence on the days for 50 per cent flowering. The interaction effects of different treatment combination were not observed at any stage of crop growth.

4.2.2 Number of pods per plant

The data pertaining to the mean number of pods per plant are furnished in table 4.6, 4.6.1, and 4.6.4.

Irrigation levels had a profound influence on number of pods per plant. I_2 (60.42) gave the maximum number of pods per plant which was significantly superior to I_1 and I_3. Eventhough N and K did not exert a significant influence on pod number per plant, the treatments N_2 and K_2 showed a trend of increase in this vital yield attributing character.

The interaction of IxN appreciably influenced the number of pods per plant and I_2N_3 (70.99) recorded a higher number of pods per plant compared to other combinations. However, the interaction between IxK and NxK was absent in the case of the number of pods per plant. The three factor interaction of I, N and K was significant. The treatment combination I_2N_3K1 (79.09) recorded the maximum number of pods per plant and was on par with $I_2N_1K_2$ (72.60), $I_2N_3K_3$ (70.82) and $I_1N_2K_1$ (67.85).

Table 4.5.

Effect of irrigation, nitrogen and potassium on days for 50 per cent flowering

Treatments	days for 50 per cent flowering
Irrigation	
I_1	45.22
I_2	39.17
I_3	42.28
$F_{2, 22}$	58.706**
SE_D	
CD(0.05)	1.16
Nitrogen	
N_1	42
N_2	42.61
N_3	42.06
$F_{2,22}$	0.732 ns
SE_D	
CD(0.05)	
Potassium	
K_1	41.5
K_2	42.72
K_3	42.45
$F_{2,22}$	2.629ns
SE_D	
CD(0.05)	

Irrigation Levels

I_1- Irrigating the crop at 20mm CPE value with a depth of 40mm water through surface method.

I_2- Irrigating the crop at 10mm CPE value with a depth of 20mm water through micro sprinkler

I_3- Farmer's practice (light irri gating with 10mm water everyday by pot watering)

Nitrogen Levels

N_1- 0 kg N ha^{-1}
N_2- 20 kg N ha^{-1}
N_3- 40 kg N ha^{-1}

Potassium Levels

K_1-0 kg K_2O ha^{-1}
K_2-20 kg K_2O ha^{-1}
K_3-40 kg K_2O ha^{-1}

Table 4.6

Effect of irrigation, nitrogen and potassium on number of pods per plant

Treatments	Number of pods
Irrigation	
I_1	52.06
I_2	60.42
I_3	51.74
$F_{2,22}$	6.557**
SE_D	2.72
CD(0.05)	5.64
Nitrogen	
N_1	51.53
N_2	57.01
N_3	55.68
$F_{2, 22}$	2.206 ^{ns}
SE_D	2.72
CD(0.05)	
Potassium	
K_1	56.40
K_2	57.15
K_3	50.67
$F_{2, 22}$	3.412 ^{ns}
SE_D	2.72
CD(0.05)	

Irrigation Levels

I_1- Irrigating the crop at 20mm CPE value with a depth of 40mm water through surface method.
I_2- Irrigating the crop at 10mm CPE value with a depth of 20mm water through micro sprinkler
I_3- Farmer's practice (light irri gating with 10mm water everyday by pot watering)

Nitrogen Levels

N_1- 0 kg N ha^{-1}
N_2- 20 kg N ha^{-1}
N_3- 40 kg N ha^{-1}

Potassium Levels

K_1-0 kg K_2O ha^{-1}
K_2-20 kg K_2O ha^{-1}
K_3-40 kg K_2O ha^{-1}

Table 4.6.1.

Interaction effect of irrigation and nitrogen on number of pods per plant

Treatments	Number of pods
I_1N_1	47.27
I_1N_2	60.33
I_1N_3	48.59
I_2N_1	56.07
I_2N_2	54.20
I_2N_3	70.99
I_3N_1	51.27
I_3N_2	56.49
I_3N_3	47.46
$F_{4, 22}$	5.986**
SE_D	4.71
CD(0.05)	9.76

** Significant at 1 per cent level

Table 4.6.4

Interaction effect of irrigaion , nitrogen and potassium on number of pods per plant

Treatments	No of Pods per plant
$I_1N_1K_1$	45.75
$I_1N_1K_2$	56.88
$I_1N_1K_3$	39.17
$I_1N_2K_1$	67.85
$I_1N_2K_2$	61.62
$I_1N_2K_3$	51.53
$I_1N_3K_1$	49.37
$I_1N_3K_2$	51.45
$I_1N_3K_3$	44.97
$I_2N_1K_1$	51.15
$I_2N_1K_2$	72.60
$I_2N_1K_3$	44.45
$I_2N_2K_1$	52.25
$I_2N_2K_2$	50.09
$I_2N_2K_3$	60.25
$I_2N_3K_1$	79.09
$I_2N_3K_2$	63.09
$I_2N_3K_3$	70.82
$I_3N_1K_1$	61.02
$I_3N_1K_2$	45.80
$I_3N_1K_3$	47.00
$I_3N_2K_1$	51.69
$I_3N_2K_2$	66.42
$I_3N_2K_3$	51.37
$I_3N_3K_1$	49.42
$I_3N_3K_2$	46.5
$I_3N_3K_3$	46.45
$F_{2,22}$	6.91**
SE_D	
CD(0.05)	11.96

4.2.3 Pod yield per plant

The mean values on pod yield per plant as influenced by I, N and K and their interaction are summarised in table 4.7, 4.7.1 and 4.7.4.

The differential levels of irrigation excerted a significant influence in the pod yield per plant. Where as the effect of N and K were not significant. The irrigation treatment I_2 recorded a significantly higher yield than I_1 and I_3

The interaction effect IxN was significant. The combination I_2N_3 gave an appreciable increase in pod yield per plant, while the interaction effects IxK and NxK were not significant.

The higher order interaction between the main factors of I,N and K significantly influenced the pod yield per plant. I_2N_3K1 recorded the highest pod yield per plant which was on par with $I_2N_1K_2$, $I_2N_3K_3$ and $I_1N_2K_1$.

4.2.4 Pod and haulm yield

The data pertaining to the mean values of pod and haulm yield are presented in table 4.8., 4.8.1 and 4.8.4.

Differntial levels of irrigation excerted a significant influence on green pod yield. The irrigation level at I_2 registered significantly superior pod yield over the other two levels. Nitrogen and potassium also induced a profound influence on green pod yield. Higher pod yield was noticed at N_2 and K_2 levels and was on par with N_3 and K_1. However, the I, N and K main effect was not noticed in case of haulm yield .

Table 4.7

Effect of irrigation, nitrogen and potassium on pod yield per plant(g)

Treatments	Pod yield per plant(g)
Irrigation	
I_1	520.46
I_2	604.19
I_3	517.39
$F_{2, 22}$	6.57**
SE_D	27.18
CD(0.05)	56.37
Nitrogen	
N_1	515.35
N_2	569.87
N_3	556.82
$F_{2,22}$	2.194^{ns}
SE_D	27.18
CD(0.05)	
Potassium	
K_1	564.11
K_2	571.26
K_3	506.67
$F_{2, 22}$	3.395^{ns}
SE_D	27.18
CD(0.05)	

Irrigation Levels

I_1- Irrigating the crop at 20mm CPE value with a depth of 40mm water through surface method.

I_2- Irrigating the crop at 10mm CPE value with a depth of 20mm water through micro sprinkler

I_3- Farmer's practice (light irri gating with 10mm water everyday by pot watering)

Nitrogen Levels

N_1- 0 kg N ha^{-1}

N_2- 20 kg N ha^{-1}

N_3- 40 kg N ha^{-1}

Potassium Levels

K_1-0 kg K_2O ha^{-1}

K_2-20 kg K_2O ha^{-1}

K_3-40 kg K_2O ha^{-1}

Table 4.7.1.

Interaction effect of irrigation and nitrogen on pod yield per plant(g)

Treatments	Pod yield per plant(g)
I_1N_1	472.67
I_1N_2	602.77
I_1N_3	485.94
I_2N_1	560.67
I_2N_2	541.95
I_2N_3	709.95
I_3N_1	512.72
I_3N_2	564.89
I_3N_3	474.56
$F_{4,22}$	5.968**
SE_D	47.08
CD(0.05)	97.64

** Significant at 1 per cent level

Table 4.7.4.

Interaction effect of irrigation, nitrogen and potassium on pod yield per plant(g) and number of pickings.

Treatments	Pod yield per plant (g)	Number of pickings
$I_1N_1K_1$	457.5	9.00
$I_1N_1K_2$	568.83	10.5
$I_1N_1K_3$	391.67	9.00
$I_1N_2K_1$	679.83	10.00
$I_1N_2K_2$	613.17	10.5
$I_1N_2K_3$	515.33	10.5
$I_1N_3K_1$	493.67	10.5
$I_1N_3K_2$	514.5	9.5
$I_1N_3K_3$	449.67	9.5
$I_2N_1K_1$	511.5	10.5
$I_2N_1K_2$	726.00	10.5
$I_2N_1K_3$	444.5	9.5
$I_2N_2K_1$	522.5	10.5
$I_2N_2K_2$	500.84	9.00
$I_2N_2K_3$	602.5	9.00
$I_2N_3K_1$	790.84	10.00
$I_2N_3K_2$	630.84	11.00
$I_2N_3K_3$	708.17	10.5
$I_3N_1K_1$	610.17	10.5
$I_3N_1K_2$	458.00	10.5
$I_3N_1K_3$	470.00	9.5
$I_3N_2K_1$	516.84	11.00
$I_3N_2K_2$	664.17	10.5
$I_3N_2K_3$	513.67	10.5
$I_3N_3K_1$	494.17	10.00
$I_3N_3K_2$	465.00	9.5
$I_3N_3K_3$	464.5	10.00
$F_{2,22}$	6.96**	0.74^{ns}
SE_D		
CD(0.05)	119.58	

Table 4.8

Effect of irrigation, nitrogen and potassium on pod yield and haulm yield (kg ha^{-1})

Treatments	Pod yield kg ha^{-1}	Haulm yield kg ha^{-1}
Irrigation		
I_1	8674.37	16637.82
I_2	10059.27	16214.12
I_3	8623.15	16829.12
$F_{2,22}$	10.891**	1.197^{ns}
SE_D	349.15	406.98
CD(0.05)	724.13	
Nitrogen		
N_1	8589.19	16929.63
N_2	9487.35	16294.60
N_3	9280.24	16456.83
$F_{2, 22}$	3.629*	1.315 ^{ns}
SE_D	349.15	406.98
CD(0.05)	724.13	
Potassium		
K_1	9391.36	16596.81
K_2	9520.99	16516.42
K_3	8444.43	16567.83
$F_{2, 22}$	5.668**	0.021^{ns}
SE_D	349.15	406.98
CD(0.05)	724.13	

Irrigation Levels

I_1- Irrigating the crop at 20mm CPE value with a depth of 40mm water through surface method.

I_2- Irrigating the crop at 10mm CPE value with a depth of 20mm water through micro sprinkler

I_3- Farmer's practice (light irri gating with 10mm water everyday by pot watering)

Nitrogen Levels

N_1- 0 kg N ha^{-1}

N_2- 20 kg N ha^{-1}

N_3- 40 kg N ha^{-1}

Potassium Levels

K_1-0 kg K_2O ha^{-1}

K_2-20 kg K_2O ha^{-1}

K_3-40 kg K_2O ha^{-1}

Table 4.8.1.

Interaction effect of irrigation and nitrogen on pod and haulm yield (kg ha^{-1})

Treatments	Pod yield kg ha^{-1}	Haulm yield kg ha^{-1}
I_1N_1	7877.77	17160.85
I_1N_2	10046.28	16374.21
I_1N_3	8099.05	16378.39
I_2N_1	9344.44	16245.34
I_2N_2	9000.94	5981.43
I_2N_3	11832.42	16415.58
I_3N_1	8545.36	17382.69
I_3N_2	9414.83	16528.15
I_3N_3	7909.25	16576.52
$F_{4, 22}$	10.169**	0.315^{ns}
SE_D	604.78	704.91
CD(0.05)	1254.24	

** Significant at 1 per cent level

Table 4.8.4.

Interaction effect of irrigation, nitrogen and potassium on pod yield and Haulm yield (kg ha^{-1})

Treatments	Pod yield (kg ha^{-1})	Haulm yield (kg ha^{-1})
$I_1N_1K_1$	7625.00	16962.81
$I_1N_1K_2$	9480.5	17247.19
$I_1N_1K_3$	6527.81	17272.55
$I_1N_2K_1$	11330.58	16255.82
$I_1N_2K_2$	10219.42	16457.06
$I_1N_2K_3$	8588.83	16409.75
$I_1N_3K_1$	8227.75	16852.35
$I_1N_3K_2$	8575.00	15427.45
$I_1N_3K_3$	7494.42	16855.39
$I_2N_1K_1$	8525.00	16290.83
$I_2N_1K_2$	12100.00	16695.53
$I_2N_1K_3$	7408.33	15749.67
$I_2N_2K_1$	8613.92	16147.21
$I_2N_2K_2$	8347.25	15864.7
$I_2N_2K_3$	10041.67	15932.4
$I_2N_3K_1$	13180.59	15779.54
$I_2N_3K_2$	10513.92	16033.78
$I_2N_3K_3$	11802.75	17433.42
$I_3N_1K_1$	10169.42	17222.69
$I_3N_1K_2$	7633.33	17289.72
$I_3N_1K_3$	7833.34	17635.65
$I_3N_2K_1$	8613.92	17265.82
$I_3N_2K_2$	11069.5	16357.04
$I_3N_2K_3$	8561.09	15961.6
$I_3N_3K_1$	8236.09	16594.2
$I_3N_3K_2$	7750.00	17275.32
$I_3N_3K_3$	7741.67	15860.03
$F_{2,22}$	11.82^{**}	1.23^{ns}
SE_D		
CD(0.05)	1536.12	

Interacion effect of IxN had a profound influence on pod yield and I_2N_3 recorded a significantly superior yield compared to other combinations. Interaction between IxK and NxK did not influence the pod yield. Similar to the main effects the interaction effect of treatments were also not seen in case of haulm yield.

The combination of the three factors, *viz.*, irrigation, nitrogen and potassium influenced the pod yield while such an effect was not noticed in case of haulm yield. $I_2N_3K_1$ (13180.59) recorded the maximum green pod yield which was on par with $I_2N_1K_2$ (12100) and $I_2N_3K_3$(11802.75)

4.2.5 Number of pickings

The influence of the different irrigation, nitrogen and potassium treatment and their interactions on the number of picking are summarised in table 4.9 and 4.9.1.

The main effects of I,N and K was not found to have any effect on the number of pickings. Interactions between IxN profoundly influenced the number of pickings and the treatment I_3N_2 recorded the maximum number of pickings. Interaction between IxK and NxK did not inflence the number of pickings.

4.3. Soil moisture studies

4.3.1 Moisture depletion patterns

The moisture depletion pattern from different soil layers is presented in table 4.10, 4.10.1, 4.10.2, 4.10.3, and 4.10.4. The data clearly reveals the effect of I, N and K and their interactions on moisture depletion.

Table 4.9.

Effect of irrigation, nitrogen and potassium on number of pickings

Treatments	No: of pickings
Irrigation	
I_1	9.88
I_2	10.06
I_3	10.22
$F_{2,22}$	0.95ns
SE_D	0.24
CD(0.05)	
Nitrogen	
N_1	9.94
N_2	10.17
N_3	10.06
$F_{2,22}$	0.423 ns
SE_D	0.24
CD(0.05)	
Potassium	
K_1	10.222
K_2	10.17
K_3	9.78
$F_{2,22}$	2.01ns
SE_D	0.24
CD(0.05)	

Irrigation Levels

I_1- Irrigating the crop at 20mm CPE value with a depth of 40mm water through surface method.

I_2- Irrigating the crop at 10mm CPE value with a depth of 20mm water through micro sprinkler

I_3- Farmer's practice (light irri gating with 10mm water everyday by pot watering)

Nitrogen Levels

N_1- 0 kg N ha^{-1}

N_2- 20 kg N ha^{-1}

N_3- 40 kg N ha^{-1}

Potassium Levels

K_1-0 kg K_2O ha^{-1}

K_2-20 kg K_2O ha^{-1}

K_3-40 kg K_2O ha^{-1}

Table 4.9.1.

Interaction effect of irrigation and nitrogen on number of pickings

Treatments	No. of pickings
I_1N_1	9.5
I_1N_2	10.33
I_1N_3	9.83
I_2N_1	10.17
I_2N_2	9.5
I_2N_3	10.5
I_3N_1	10.17
I_3N_2	10.67
I_3N_3	9.83
$F_{4, 22}$	3.279*
SE_D	0.42
CD(0.05)	0.868

* Significant at 5 per cent level

Table 4.10

Effect of irrigation, nitrogen and potassium on moisture depletion pattern (Percentage)

Treatments	0-15cm	15-30cm	30-45cm
Irrigation			
I_1	62.43	27.11	10.44
I_2	65.27	24.96	9.70
I_3	64.08	26.40	9.54
$F_{2,22}$	30.56^{**}	15.46^{**}	15.53^{ns}
SE_D	0.37	0.39	0.71
CD(0.05)	0.76	0.82	
Nitrogen			
N_1	64.04	25.96	10.01
N_2	63.61	26.51	9.82
N_3	64.11	26.01	9.86
$F_{2,22}$	1.09^{ns}	1.185^{ns}	0.701^{ns}
SE_D	0.37	0.39	0.71
CD(0.05)			
Potassium			
K_1	64.86	24.92	10.20
K_2	61.90	28.21	9.90
K_3	65.01	25.33	9.59
$F_{2,22}$	46.39^{**}	41.32^{**}	6.43^{**}
SE_D	0.37	0.39	0.71
CD(0.05)	0.76	0.82	0.36

Irrigation Levels

I_1- Irrigating the crop at 20mm CPE value with a depth of 40mm water through surface method.

I_2- Irrigating the crop at 10mm CPE value with a depth of 20mm water through micro sprinkler

I_3- Farmer's practice (light irri gating with 10mm water everyday by pot watering)

Nitrogen Levels

N_1- 0 kg N ha^{-1}

N_2- 20 kg N ha^{-1}

N_3- 40 kg N ha^{-1}

Potassium Levels

K_1-0 kg K_2O ha^{-1}

K_2-20 kg K_2O ha^{-1}

K_3-40 kg K_2O ha^{-1}

Table 4.10.1.

Interaction effect of irrigation and nitrogen on moisture depletion pattern (Percentage)

Treatments	0-15cm	15-30cm	30-45cm
I_1N_1	60.39	29.35	10.23
I_1N_2	63.47	25.33	11.21
I_1N_3	63.41	26.65	9.88
I_2N_1	66.28	23.23	10.46
I_2N_2	64.92	26.24	8.66
I_2N_3	64.59	25.41	9.99
I_3N_1	65.45	25.3	9.34
I_3N_2	62.44	27.95	9.59
I_3N_3	64.34	25.96	9.69
$F_{4,22}$	15.01**	17.67**	15.21**
SE_D	0.63	0.68	0.30
CD(0.05)	1.31	1.42	0.62

** Significant at 1 per cent level

Table 4.10.2

Interaction effect of Irrigation and potassium on moisture depletion pattern (Percentage)

Treatments	0-15cm	15-30cm	30-45cm
I_1K_1	64.71	24.83	10.43
I_1K_2	59.10	29.90	10.95
I_1K_3	63.47	26.60	9.45
I_2K_1	68.50	21.89	9.60
I_2K_2	65.10	25.34	9.56
I_2K_3	62.20	27.65	9.96
I_3K_1	61.37	28.05	10.58
I_3K_2	61.50	29.40	9.20
I_3K_3	69.37	21.76	8.86
$F_{4,22}$	76.11**	47.16**	9.54**
SE_D	0.63	0.68	0.30
CD(0.05)	1.31	1.42	0.62

** Significant at 1 per cent level

Table 4.10.3

Interaction effect of nitrogen and potassium on moisture depletion pattern (Percentage)

Treatments	0-15cm	15-30cm	30-45cm
N_1K_1	64.38	25.70	9.90
N_1K_2	60.83	28.84	10.42
N_1K_3	66.92	23.34	9.71
N_2K_1	65.59	24.18	10.21
N_2K_2	63.18	27.11	9.71
N_2K_3	62.07	28.23	9.54
N_3K_1	64.62	24.89	10.49
N_3K_2	61.68	28.70	9.57
N_3K_3	66.04	24.44	9.51
$F_{4, 22}$	20.77**	16.74**	3.16*
SE_D	0.63	0.68	0.30
CD(0.05)	1.31	1.42	0.62

** Significant at 1 per cent level

Table 4.10.4

Interaction effect of irrigation, nitrogen and potassium on moisture depletion pattern. (Percentage)

Treatments	0-15cm	15-30cm	30-45cm
$I_1N_1K_1$	63.08	27.67	9.25
$I_1N_1K_2$	52.24	35.93	11.80
$I_1N_1K_3$	65.88	24.45	9.66
$I_1N_2K_1$	67.04	21.08	11.86
$I_1N_2K_2$	65.03	23.77	11.22
$I_1N_2K_3$	58.36	31.14	10.55
$I_1N_3K_1$	64.03	25.76	10.20
$I_1N_3K_2$	60.03	30.00	9.84
$I_1N_3K_3$	66.17	24.2	9.62
$I_2N_1K_1$	66.65	22.36	10.94
$I_2N_1K_2$	67.32	22.73	9.94
$I_2N_1K_3$	64.88	24.59	10.5
$I_2N_2K_1$	70.01	21.57	8.42
$I_2N_2K_2$	67.84	23.81	8.35
$I_2N_2K_3$	56.93	33.35	9.21
$I_2N_3K_1$	68.84	21.75	9.43
$I_2N_3K_2$	60.13	29.48	10.39
$I_2N_3K_3$	64.81	25.00	10.17
$I_3N_1K_1$	63.4	27.08	9.51
$I_3N_1K_2$	62.94	27.86	9.54
$I_3N_1K_3$	70.02	20.97	8.99
$I_3N_2K_1$	59.72	29.91	10.37
$I_3N_2K_2$	56.68	33.75	9.56
$I_3N_2K_3$	70.94	20.20	8.86
$I_3N_3K_1$	60.99	27.16	11.85
$I_3N_3K_2$	64.88	26.61	8.50
$I_3N_3K_3$	67.15	24.11	8.74
$F_{2,22}$	28.68**	20.45**	4.99*
SE_D			
CD(0.05)	1.60	1.74	0.756

* Significant at 5 per cent level

** Significant at 1 per cent level

The percentage depletion of moisture from the top layer (0-15 cm) was higher with a maximum at I_2 followed by I_3 and I_1. At 15-30cm and 30-45cm depth I_1 registered the highest percentage depletion of moisture. Nitrogen did not have any influence on moisture depletion pattern. Potassium on the other hand influenced the moisture depletion pattern significantly. At 0-15cm depth K_3 recorded the highest per cent depletion of moisture followed by K_1 and K_2.

Interaction between IxN, IxK and NxK excerted a profound influence on moisture depletion. At 0-15cm depth the highest moisture depletion was noticed for the treatment I_2N_1 which was on par with I_3N_1. The combination I_3K_3 and I_2K_1 recorded the highest depletion of moisture at 0 - 15 cm depth. Similarly N_1K_3 recorded a remarkable depletion of moisture from the top layer of the soil.

The combined effect of the three factors, *viz.*, I,N and K showed a significant influence on the moisture depletion pattern. At 0-15cm depth I_3N_2K3 recorded the highest moisture depletion and was on par with $I_3N_1K_3$ and $I_2N_2K_1$ while at 15-30cm depth $I_1N_1K_2$ recorded the maximum per cent moisture depletion.

4.3.2. Water use efficency (WUE)

The data on WUE as affected by I, N and K are presented in table 4.11, 4.11.1 and 4.11.2 Significant effect of treatment and their interactions is evident from the data.

The treatment I_2,N_2 and K_2 recorded the maximum WUE, which was significantly superior to other levels of the main effects.

Interactions between IxN and NxK significantly influenced the WUE and the combination I_1N_2 recorded the highest WUE in both the cases. Interaction effect of IxK did not influence the WUE.

Table 4.11

Effect of irrigation, nitrogen and potassium on WUE (Kg ha^{-1} mm^{-1})

Treatments	WUE
**********************************	
Irrigation	
I_1	11.69
I_2	14.13
I_3	9.02
$F_{2,22}$	113.28**
SE_D	0.34
CD(0.05)	0.71
Nitrogen	
N_1	10.95
N_2	12.16
N_3	11.73
$F_{2,22}$	6.511**
SE_D	0.34
CD(0.05)	0.71
Potassium	
K_1	11.97
K_2	12.27
K_3	10.60
$F_{2,22}$	13.65**
SE_D	0.34
CD(0.05)	0.71

Irrigation Levels

I_1- Irrigating the crop at 20mm CPE value with a depth of 40mm water through surface method.
I_2- Irrigating the crop at 10mm CPE value with a depth of 20mm water through micro sprinkler
I_3- Farmer's practice (light irri gating with 10mm water everyday by pot watering)

Nitrogen Levels

N_1- 0 kg N ha^{-1}
N_2- 20 kg N ha^{-1}
N_3- 40 kg N ha^{-1}

Potassium Levels

K_1-0 kg K_2O ha^{-1}
K_2-20 kg K_2O ha^{-1}
K_3-40 kg K_2O ha^{-1}

Table 4.11.1

Interaction effect of irrigation and nitrogen, irrigation and potassium and nitrogen and potassium on WUE

Treatment	WUE	Treatments	WUE	Treatments	WUE
I_1N_1	10.75	I_1K_1	12.37	N_1K_1	11.09
I_1N_2	13.72	I_1K_2	12.87	N_1K_2	12.70
I_1N_3	10.60	I_1K_3	9.83	N_1K_3	9.06
I_2N_1	13.11	I_2K_1	14.23	N_2K_1	12.31
I_2N_2	12.68	I_2K_2	14.49	N_2K_2	12.51
I_2N_3	16.61	I_2K_3	13.68	N_2K_3	11.67
I_3N_1	8.99	I_3K_1	9.30	N_3K_1	12.50
I_3N_2	10.10	I_3K_2	9.46	N_3K_2	11.59
I_3N_3	7.96	I_3K_3	8.29	N_3K_3	11.08
$F_{4,22}$	22.29**	$F_{4,22}$	2.45^{ns}	$F_{4,22}$	4.84**
SE_D	0.59	SE_D	0.59	SE_D	0.59
CD(0.05)	1.22	CD(0.05)		CD(0.05)	1.22

ns non significant

** Significant at 1 per cent level

Table 4.11.2

Interaction effect of irrigation, nitrogen and potassium on WUE ($kg\ ha^{-1}\ mm^{-1}$)

Treatments	WUE
$I_1N_1K_1$	10.41
$I_1N_1K_2$	12.94
$I_1N_1K_3$	8.91
$I_1N_2K_1$	15.47
$I_1N_2K_2$	13.95
$I_1N_2K_3$	11.73
$I_1N_3K_1$	11.24
$I_1N_3K_2$	11.71
$I_1N_3K_3$	8.87
$I_2N_1K_1$	11.97
$I_2N_1K_2$	16.98
$I_2N_1K_3$	10.40
$I_2N_2K_1$	12.22
$I_2N_2K_2$	11.72
$I_2N_2K_3$	14.09
$I_2N_3K_1$	18.5
$I_2N_3K_2$	14.76
$I_2N_3K_3$	16.57
$I_3N_1K_1$	10.91
$I_3N_1K_2$	8.19
$I_3N_1K_3$	7.87
$I_3N_2K_1$	9.24
$I_3N_2K_2$	11.87
$I_3N_2K_3$	9.18
$I_3N_3K_1$	7.76
$I_3N_3K_2$	8.31
$I_3N_3K_3$	7.82
$F_{2,22}$	23.89**
SE_D	
CD(0.05)	1.50

The higher order interaction of the three factors viz., I,N and K did not influence the WUE. The treatment $I_2N_3K_1$ recorded the maximum values.

4.4 Nutrient studies

4.4.1 Soil nutrient status after the experiment

The influence of main effects and their interactions on the soil nutrient status after the experiment is as depicted in table 4.12.

The data reveals that N alone influenced the nutrient status of the soil after the experiment. Nutrient status at N_3 recorded the highest available soil N content after the experiment. While the N levels did not influence the available soil P_2O_5 and K_2O content.

The two factor and higher order interactions of the main effects were not significant in the case of nutrient status of the soil after the experiment. Similarly the combined effect of the three main effects also did not have any influence on the available soil nutrient status after the experiment.

4.4.2 Uptake of nitrogen

The data showing the mean values of N uptake during 30, 60 and 90 DAS as influenced by differential levels of I,N and K are furnished in tables 4.13 and 4.13.1.

Among the main effects, levels of N at 60 DAS alone influenced the uptake of N. The treatment N_2 excerted a remarkable influence on the uptake of nitrogen and was an par with N_3. The data also reveals that I, N and K increased the uptake of nitrogen till 60 DAS and thereafter a decreasing trend was seen.

Table 4.12

Effect of irrigation, nitrogen and potassium on the soil nutrient status after the experiment.

Treatments	Available N Content (kg/ha)	Available P_2O_5 Content (kg/ha)	Available K_20 Content (kg/ha)
Irrigation			
I_1	286.79	42.22	62.10
I_2	289.14	45.24	64.45
I_3	283.93	41.85	61.62
$F_{2,22}$	3.16 ns	0.862 ns	1.64 ns
SE_D	2.07	2.83	1.67
CD(0.05)			
Nitrogen			
N_1	236.07	45.41	62.48
N_2	293.39	41.78	61.85
N_3	330.41	42.11	63.84
$F_{2,22}$	1052.48 **	1.008 ns	0.74 ns
SE_D	2.07	2.83	1.67
CD(0.05)	4.30		
Potassium			
K_1	285.11	44.38	61.11
K_2	286.06	42.57	62.89
K_3	288.70	42.36	64.17
$F_{2,22}$	1.61 ns	0.31 ns	1.689 ns
SE_D	2.07	2.83	1.67
CD(0.05)			

Irrigation Levels

I_1- Irrigating the crop at 20mm CPE value with a depth of 40mm water through surface method.

I_2- Irrigating the crop at 10mm CPE value with a depth of 20mm water through micro sprinkler

I_3- Farmer's practice (light irri gating with 10mm water everyday by pot watering)

Nitrogen Levels

N_1- 0 kg N ha^{-1}

N_2- 20 kg N ha^{-1}

N_3- 40 kg N ha^{-1}

Potassium Levels

K_1-0 kg K_2O ha^{-1}

K_2-20 kg K_2O ha^{-1}

K_3-40 kg K_2O ha^{-1}

Table 4.13

Effect of irrigation, nitrogen and potassium on uptake of nitrogen (kg ha^{-1})

Treatments	30 DAS	60DAS	90DAS
Irrigation			
I_1	13.07	47.14	40.95
I_2	12.38	47.07	40.39
I_3	12.14	48.11	41.44
$F_{2,22}$	2.64^{ns}	0.171^{ns}	0.589^{ns}
SE_D	0.73	1.99	0.97
CD(0.05)			
Nitrogen			
N_1	12.21	44.79	41.86
N_2	12.70	50.46	40.08
N_3	12.67	47.08	40.84
$F_{2,22}$	0.843^{ns}	4.11*	1.704^{ns}
SE_D	0.73	1.99	0.97
CD(0.05)		4.13	
Potassium			
K_1	12.85	48.73	40.79
K_2	12.47	47.76	40.51
K_3	12.27	45.84	41.47
$F_{2,22}$	1.01^{ns}	1.092^{ns}	0.525^{ns}
SE_D	0.73	1.99	0.97
CD(0.05)			

Irrigation Levels

I_1- Irrigating the crop at 20mm CPE value with a depth of 40mm water through surface method.

I_2- Irrigating the crop at 10mm CPE value with a depth of 20mm water through micro sprinkler

I_3- Farmer's practice (light irri gating with 10mm water everyday by pot watering)

Nitrogen Levels

N_1- 0 kg N ha^{-1}

N_2- 20 kg N ha^{-1}

N_3- 40 kg N ha^{-1}

Potassium Levels

K_1-0 kg K_2O ha^{-1}

K_2-20 kg K_2O ha^{-1}

K_3-40 kg K_2O ha^{-1}

Table 4.13.1

Interaction effect of irrigation and nitrogen on the uptake of nitrogen (kg ha^{-1})

Treatments	30.DAS	60DAS	90DAS
I_1N_1	12.69	48.63	42.65
I_1N_2	14.05	46.45	39.55
I_1N_3	12.46	46.35	40.63
I_2N_1	11.65	41.84	40.98
I_2N_2	11.39	52.67	40.01
I_2N_3	14.10	46.70	40.18
I_3N_1	12.30	43.89	41.93
I_3N_2	12.66	52.27	40.67
I_3N_3	11.45	48.18	41.72
$F_{4,22}$	5.957**	2.033 ns	0.291 ns
SE_D	0.73	3.45	1.68
CD(0.05)	1.51		

ns non significant

** Significant at 1 per cent level

At 30DAS alone the interaction between IxN profoundly influenced the uptake of N and the treatment combination of I_2N_3 recorded the maximum uptake and was on par with I_1N_2, I_1N_1 and I_3N_2. The other second and third order interactions of the main effects did not influence the uptake of N.

4.4.3 Uptake of phosphorus

The effect of varying levels of I, N and K and their interactions on the uptake of phosphorus at 30,60 and 90 DAS are summarised in table 4.14.

The irrigation treatments significantly influenced the uptake of phosphorus only at 90 DAS. I_3 registered the maximum uptake of phosphorus and was on par with I_1. The effect of N and K levels and the interaction of the main effects on the uptake of P was not noticed at any stages of the crop growth.

4.4.4 Uptake of potassium.

The data pertaining to the uptake of potassium as influenced by I, N and K during 30, 60 and 90 DAS are given in table 4.15 and 4.15.4.

The data showed that both N and K levels excerted a significant influence in the uptake of K. While the irrigation treatments failed in influencing the uptake of K. It was noticed that at 30 DAS the nitrogen level N_2 recorded the maximum uptake of potassium and was on par with N_3. At 90 DAS N_1 and K_2 registered the highest values for the uptake of potassium.

Table 4.14

Effect of irrigation, nitrogen and potassium on uptake of phosphorus (kg ha^{-1})

Treatments	30 DAS	60DAS	90DAS
Irrigation			
I_1	3.67	49.16	42.05
I_2	3.53	47.66	39.68
I_3	3.71	49.71	42.84
$F_{2,22}$	0.542 ^{ns}	2.056 ^{ns}	5.00*
SE_D	0.18	1.05	1.04
CD(0.05)			2.16
Nitrogen			
N_1	3.63	48.49	42.53
N_2	3.69	49.69	41.39
N_3	3.59	48.36	40.65
$F_{2,22}$	0.123 ^{ns}	0.987^{ns}	1.66 ^{ns}
SE_D	0.18	1.05	1.04
CD(0.05)			
Potassium			
K_1	3.74	48.27	41.09
K_2	3.58	48.83	41.69
K_3	3.59	49.44	41.79
$F_{2,22}$	0.461 ^{ns}	0.626 ^{ns}	0.267 ^{ns}
SE_D	0.18	1.05	1.04
CD(0.05)			

Irrigation Levels

I_1- Irrigating the crop at 20mm CPE value with a depth of 40mm water through surface method.

I_2- Irrigating the crop at 10mm CPE value with a depth of 20mm water through micro sprinkler

I_3- Farmer's practice (light irri gating with 10mm water everyday by pot watering)

Nitrogen Levels

N_1- 0 kg N ha^{-1}

N_2- 20 kg N ha^{-1}

N_3- 40 kg N ha^{-1}

Potassium Levels

K_1-0 kg K_2O ha^{-1}

K_2-20 kg K_2O ha^{-1}

K_3-40 kg K_2O ha^{-1}

Table 4.15

Effect of irrigation, nitrogen and potassium on uptake of potassium (kg ha^{-1})

Treatments	30 DAS	60DAS	90DAS
Irrigation			
I_1	13.20	205.27	190.98
I_2	12.98	204.99	190.07
I_3	13.57	208.42	193.46
$F_{2,22}$	1.973 ^{ns}	0.315 ^{ns}	0.437 ^{ns}
SE_D	0.29	4.80	3.75
CD(0.05)			
Nitrogen			
N_1	12.82	209.16	198.80
N_2	13.62	206.86	189.28
N_3	13.31	202.66	186.42
$F_{2,22}$	3.67 *	0.942 ^{ns}	5.963 **
SE_D	0.29	4.80	3.75
CD(0.05)	0.622		7.78
Potassium			
K_1	13.32	201.74	185.45
K_2	13.31	211.18	194.89
K_3	13.11	205.76	194.16
$F_{2,22}$	0.314 ^{ns}	1.948 ^{ns}	3.919 *
SE_D	0.29	4.80	3.75
CD(0.05)			7.78

Irrigation Levels

I_1- Irrigating the crop at 20mm CPE value with a depth of 40mm water through surface method.

I_2- Irrigating the crop at 10mm CPE value with a depth of 20mm water through micro sprinkler

I_3- Farmer's practice (light irri gating with 10mm water everyday by pot watering)

Nitrogen Levels

N_1- 0 kg N ha^{-1}

N_2- 20 kg N ha^{-1}

N_3- 40 kg N ha^{-1}

Potassium Levels

K_1-0 kg K_2O ha^{-1}

K_2-20 kg K_2O ha^{-1}

K_3-40 kg K_2O ha^{-1}

Table 4.15.4

Interaction effect of irrigation, nitrogen and potassium on uptake of potassium (kg ha^{-1})

Treatments	30 DAS	60 DAS	90 DAS
$I_1N_1K_1$	12.45	197.73	194.14
$I_1N_1K_2$	12.93	208.58	203.15
$I_1N_1K_3$	12.28	202.59	201.28
$I_1N_2K_1$	14.98	201.21	191.91
$I_1N_2K_2$	13.74	205.48	191.24
$I_1N_2K_3$	14.21	203.79	191.07
$I_1N_3K_1$	13.09	204.32	175.94
$I_1N_3K_2$	12.81	212.86	185.64
$I_1N_3K_3$	12.34	210.85	184.44
$I_2N_1K_1$	12.4	205.27	185.77
$I_2N_1K_2$	14.19	220.32	214.72
$I_2N_1K_3$	11.76	213.21	195.76
$I_2N_2K_1$	12.10	200.31	173.45
$I_2N_2K_2$	12.28	214.78	184.14
$I_2N_2K_3$	13.77	210.58	198.10
$I_2N_3K_1$	14.59	190.49	174.21
$I_2N_3K_2$	13.25	197.75	192.16
$I_2N_3K_3$	12.46	192.17	192.32
$I_3N_1K_1$	13.51	213.56	189.52
$I_3N_1K_2$	12.49	216.83	204.81
$I_3N_1K_3$	13.35	204.35	200.05
$I_3N_2K_1$	12.98	202.53	188.09
$I_3N_2K_2$	14.36	215.25	194.52
$I_3N_2K_3$	14.20	207.79	190.99
$I_3N_3K_1$	13.79	200.21	196.04
$I_3N_3K_2$	13.78	208.79	183.63
$I_3N_3K_3$	13.65	206.51	193.45
$F_{2,22}$	5.07*	0.821^{ns}	0.674^{ns}
SE_D			
CD(0.05)	1.32		

The interaction effect of IxN, IxK and NxK did not influence the uptake of potassium. But the combined effect of I, N and K influenced the uptake of potassium only at 30DAS. The treatment combination $I_1N_2K_1$ recorded the maximum uptake of K.

4.5. Economics of cultivation

The mean values of net returns and benefit-cost ratio as influenced by irrigation, nitrogen and potassium and their interactions are given in table 4.16, 4.16.1 and 4.16.4.

The main effects showed no significant influence on the returns and BCR. While interaction between IxN significantly influenced the economics of cultivation. In the case of net returns the combinations I_2N_3 (63529.07) recorded a highest value. The treatment combination I_1N_2 (1.50) gave the highest BCR. Interaction between IxK and NxK did not have any influence on the economics of cultivation.

The combined effect of the three main effects excerted a significant influence on the economics of cultivation. The treatment combination $I_2N_3K_1$ (75742.58) recorded the maximum net returns and was on par with $I_2N_1K_2$ (66067.31), $I_3N_2K_2$ (65604.61), $I_2N_3K_3$(63182.07) and $I_1N_2K_1$ (61856.92). The combination $I_3N_2K_2$ (1.93) recorded the maximum benefit cost ratio and was on par with $I_1N_2K_1$ (1.89), $I_2N_3K_1$(1.77), $I_3N_1K_1$(1.71), $I_1N_1K_2$ (1.6) and $I_2N_1K_2$(1.55).

4.6 Proline content

The main values of the proline content in the leaves at 30,45, 60, 75 and 90 DAS as influenced by I,N and K is presented in table 4.17, 4.17.1 and 4.17.2 .

Table 4.16

Effect of irrigation, nitrogen and potassium on net returns and BCR

Treatments	Net returns	Benefit cost ratio(BCR)
Irrigation		
I_1	43868.41	1.33
I_2	47633.23	1.11
I_3	43082.45	1.27
$F_{2,22}$	1.022^{ns}	3.157^{ns}
SE_D		0.09
CD(0.05)		
Nitrogen		
N_1	42259.66	1.18
N_2	45977.80	1.29
N_3	46346.62	1.24
$F_{2,22}$	0.882^{ns}	0.785^{ns}
SE_D		0.09
CD(0.05)		
Potassium		
K_1	46678.06	1.29
K_2	47452.77	1.31
K_3	40453.26	1.11
$F_{2,22}$	2.542^{ns}	2.96^{ns}
SE_D		0.09
CD(0.05)		

Irrigation Levels

I_1- Irrigating the crop at 20mm CPE value with a depth of 40mm water through surface method.

I_2- Irrigating the crop at 10mm CPE value with a depth of 20mm water through micro sprinkler

I_3- Farmer's practice (light irri gating with 10mm water everyday by pot watering)

Nitrogen Levels

N_1- 0 kg N ha^{-1}

N_2- 20 kg N ha^{-1}

N_3- 40 kg N ha^{-1}

Potassium Levels

K_1-0 kg K_2O ha^{-1}

K_2-20 kg K_2O ha^{-1}

K_3-40 kg K_2O ha^{-1}

Table 4.16.1

Interaction effect of irrigation and nitrogen on net returns and BCR

Treatments	Net returns	Benefit- cost ratio(BCR)
I_1N_1	42566.84	1.30
I_1N_2	49109.99	1.50
I_1N_3	39928.41	1.20
I_2N_1	41259.80	0.97
I_2N_2	38110.80	0.89
I_2N_3	63529.07	1.48
I_3N_1	42952.35	1.27
I_3N_2	50712.61	1.49
I_3N_3	35582.38	1.04
$F_{4,22}$	7.374**	6.738 **
SE_D		0.16
CD(0.05)	12225.96	0.325

** Significant at 1 per cent level

Table 4.16.4

Interaction effect of irrigation,nitrogen and potassium on net returns and BCR

Treatments	Net returns	BCR
$I_1N_1K_1$	35871.91	1.1
$I_1N_1K_2$	52491.41	1.6
$I_1N_1K_3$	39337.20	1.2
$I_1N_2K_1$	61856.92	1.89
$I_1N_2K_2$	44401.39	1.35
$I_1N_2K_3$	41071.66	1.25
$I_1N_3K_1$	41166.66	1.21
$I_1N_3K_2$	44211.91	1.35
$I_1N_3K_3$	34406.65	1.04
$I_2N_1K_1$	33949.81	0.79
$I_2N_1K_2$	66067.31	1.55
$I_2N_1K_3$	23762.28	0.56
$I_2N_2K_1$	34707.55	0.81
$I_2N_2K_2$	32227.56	0.75
$I_2N_2K_3$	47397.30	1.1
$I_2N_3K_1$	75742.58	1.77
$I_2N_3K_2$	51662.55	1.2
$I_2N_3K_3$	63182.07	1.47
$I_3N_1K_1$	57648.85	1.71
$I_3N_1K_2$	34744.08	1.03
$I_3N_1K_3$	36464.13	1.07
$I_3N_2K_1$	43584.35	1.29
$I_3N_2K_2$	65604.61	1.93
$I_3N_2K_3$	42948.88	1.26
$I_3N_3K_1$	35573.88	1.05
$I_3N_3K_2$	35664.11	1.05
$I_3N_3K_3$	35509.14	1.04
$F_{2,22}$	13.77^{**}	13.77^{**}
SE_D		
CD(0.05)	14973.68	0.399

Table 4.17

Effect of irrigation, nitrogen and potassium on proline content of the leaves (m moles g^{-1} fresh weight)

Treatments	30DAS	45DAS	60DAS	75DAS	90DAS
Irrigation					
I_1	94.11	215.79	322.64	433.24	535.14
I_2	103.57	239.05	337.37	474.76	551.48
I_3	76.30	197.18	305.65	416.01	516.62
$F_{2,22}$	233.45**	351.92**	201.87**	803.50**	250.84**
SE_D	1.28	1.58	1.57	1.50	1.56
CD(0.05)	2.66	3.28	3.28	3.13	3.23
Nitrogen					
N_1	92.46	214.91	323.63	404.40	534.71
N_2	91.45	217.58	321.08	441.34	534.23
N_3	90.08	219.52	320.95	442.28	534.31
$F_{2,22}$	1.75ns	4.29 *	1.86 ns	0.76 ns	0.14 ns
SE_D	1.28	1.58	1.57	1.50	1.56
CD(0.05)		3.28			
Potassium					
K_1	82.41	205.30	307.81	428.27	522.67
K_2	91.25	216.36	322.72	442.10	533.62
K_3	100.32	230.35	335.13	453.65	546.95
$F_{2,22}$	97.55**	125.97**	149.92**	142.21**	121.90**
SE_D	1.28	1.58	1.57	1.50	1.56
CD(0.05)	2.66	3.28	3.28	3.13	3.23

Irrigation Levels

I_1- Irrigating the crop at 20mm CPE value with a depth of 40mm water through surface method.

I_2- Irrigating the crop at 10mm CPE value with a depth of 20mm water through micro sprinkler

I_3- Farmer's practice (light irri gating with 10mm water everyday by pot watering)

Nitrogen Levels

N_1- 0 kg N ha^{-1}
N_2- 20 kg N ha^{-1}
N_3- 40 kg N ha^{-1}

Potassium Levels

K_1-0 kg K_2O ha^{-1}
K_2-20 kg K_2O ha^{-1}
K_3-40 kg K_2O ha^{-1}

Table 4.17.1

Interaction effect of irrigation and nitrogen on proline content of the leaves (m moles g^{-1} fresh weight)

Treatments	30DAS	45DAS	60DAS	75DAS	90DAS
I_1N_1	96.43	213.50	322.72	433.77	535.45
I_1N_2	96.21	215.63	321.75	432.52	535.35
I_1N_3	89.68	218.23	323.33	433.45	534.64
I_2N_1	104.39	232.96	341.29	471.74	551.79
I_2N_2	101.10	240.42	337.00	475.88	549.20
I_2N_3	105.23	242.77	333.82	476.67	553.46
I_3N_1	76.56	197.28	306.77	415.70	516.89
I_3N_2	77.04	196.69	304.50	415.62	518.14
I_3N_3	75.31	197.57	305.69	416.71	514.82
$F_{4,22}$	3.241*	1.41 ns	1.20 ns	0.759 ns	0.984 ns
SE_D	2.22	2.74	2.74	2.61	2.70
CD(0.05)	4.60				

* Significant at 5 per cent level

ns non significant

Table 4.17.2

Interaction effect of irrigation and potassium on proline content of the leaves (m moles g^{-1} fresh weight)

Treatments	30DAS	45DAS	60DAS	75DAS	90DAS
I_1K_1	85.90	200.01	303.72	414.98	524.34
I_1K_2	93.97	216.20	325.48	435.85	535.29
I_1K_3	102.45	231.15	338.72	448.90	545.81
I_2K_1	94.38	226.40	323.87	463.77	537.96
I_2K_2	103.37	237.18	337.24	474.33	548.940
I_2K_3	112.97	253.56	351.00	486.18	567.55
I_3K_1	66.96	189.50	295.86	406.06	505.71
I_3K_2	76.42	195.70	305.44	416.11	516.63
I_3K_3	85.52	206.33	315.67	425.86	527.50
$F_{4,22}$	0.148 ns	3.93 *	4.45**	4.74**	1.912 ns
SE_D	2.22	2.74	2.74	2.61	2.70
CD(0.05)		5.68	5.68	5.41	

* Significant at 5 per cent level

** Significant at 1 per cent level

ns non significant

The differential levels of I and K significantly influenced the proline content of the leaves at all the stages of crop growth. The data showed that I_2 recorded significantly superior proline content at all the stages and K_3 resulted in the highest proline content followed by K_2 and K_1. Nitrogen influenced the proline content of the leaves only at 45 DAS and N_2 gave the maximum proline content.

The interaction between IxN significantly influenced the proline content only at 30 DAS and I_2N_3 resulted in highest proline content which was on par with I_2N_1 and I_2N_2. The treatment I_3N_3 recorded the lowest proline content in the leaves. The combinations of IxK recorded a remarkable influence on the proline content I_2K_3 recorded significantly higher proline content at 45DAS, 60DAS and 75DAS. The interaction of NxK did not influence the proline content of leaves.

DISCUSSION

5. DISCUSSION

The results of the experiment conducted to study the response of vegetable cowpea to nitrogen and potassium under varying levels of irrigation are presented in chapter 4 and are discussed below

5.1 Growth characters

In general, plant height, LAI and DMP increased progressively upto 90 DAS. In the case of number of leaves an increasing trend was observed only upto 75DAS. The main effects of irrigation, nitrogen and potassium did not excert any influence on plant height, LAI and number of leaves. But DMP was significantly influenced by irrigation at 45 DAS and by nitrogen at 75DAS.

The highest value for plant height was recorded in frequently irrigated treatments. This might be due to a continuous and uniform availability of soil moisture which in turn increased the turgidity of cells favouring cell enlargement and cell division. The low available soil moisture might have adversely affected the above processes and retarded growth (Begg and Turner, 1976). The increse in plant height and number of leaves due to irrigation at higher ASM in the root zone was reported by Singh and Lamba(1971) in cowpea. Similar increase in plant height due to frequent irrigation was noticed in other pulse crops viz., red gram, green gram and peas by Ishii(1969), Ali and Alam (1973), Ramshe and Surve(1984), Yadhav *et al.*,(1990) and Singh and Tripathi (1992). Eventhough nitrogen didnot excert any significant influence on plant height an increasing trend was observed with increase in N levels. Plant height increased upto 20 kg N ha^{-1} in all growth stages except at 90 DAS. The reason for this enhanced growth might be due to the growth promoting action of N as seen in many crops (Tisdale *et al.*, 1993). Similar increase in plant height was reported in green gram by Savithri (1980). Potassium also showed the same trend as that of nitrogen.

The number of leaves and LAI also showed an increasing trend with increasing levels of irrigation. The maximum number of leaves were recorded by I_1 from 45 DAS to 90 DAS where as at 30 DAS I_3 recorded the maximum number of leaves. The reduction in the rate of leaf initiation and cell division might have reduced the number of leaves when the total quantity of irrigation water was also reduced. Similar findings were reported by Ali and Alam(1973) in green gram, Manning *et al.*, (1977) in peas and Henrique *et al.*,(1978) in soybean. Highest LAI was reported by I_3 at all stages of growth except at 45 DAS. The increase in LAI due to frequent irrigation could be ascribed to the marked increase in leaf area through its favourable influence on leaf size as well as leaf number. Enhanced LAI was also noticed in green gram by Pannu and Singh (1993) by irrigating the crop at 300 mm CPE over 400 mm CPE. According to Golakiya and Patel (1992), LAI was severely affected when stress was imposed during the flowering stage. In the case of nitrogen and potassium N_2 and K_2 levels recorded the highest number of leaves per plant and LAI. Moderate rates of N application helped the plant for quick establishment till the formation of Rhizobium and helped in faster growth. Allows and Bartholomen(1959) pointed out that symbiotic system along cannot supply all the nitrogen for maximum growth and development of leguminous plants. Russel (1973) noticed that extra protein produced as a result of increased N supply hastened the plant to produce more number of larger leaves and to have more surface area available for photosynthesis causing an increase in LAI. Similar trend was noticed in bitter gourd by Thomas (1984) and in amaranthus by Rajan (1991). Potassium is an essential element for the promotion of growth of meristematic tissue (Tisdale *et al.*, 1993) which might have helped in increasing the leaf number in the present experiment . Potassium promotes cell expansion by regulating solute potential which may probably increase the rate of leaf expansion and LAI (Rao and Rao, 1983).

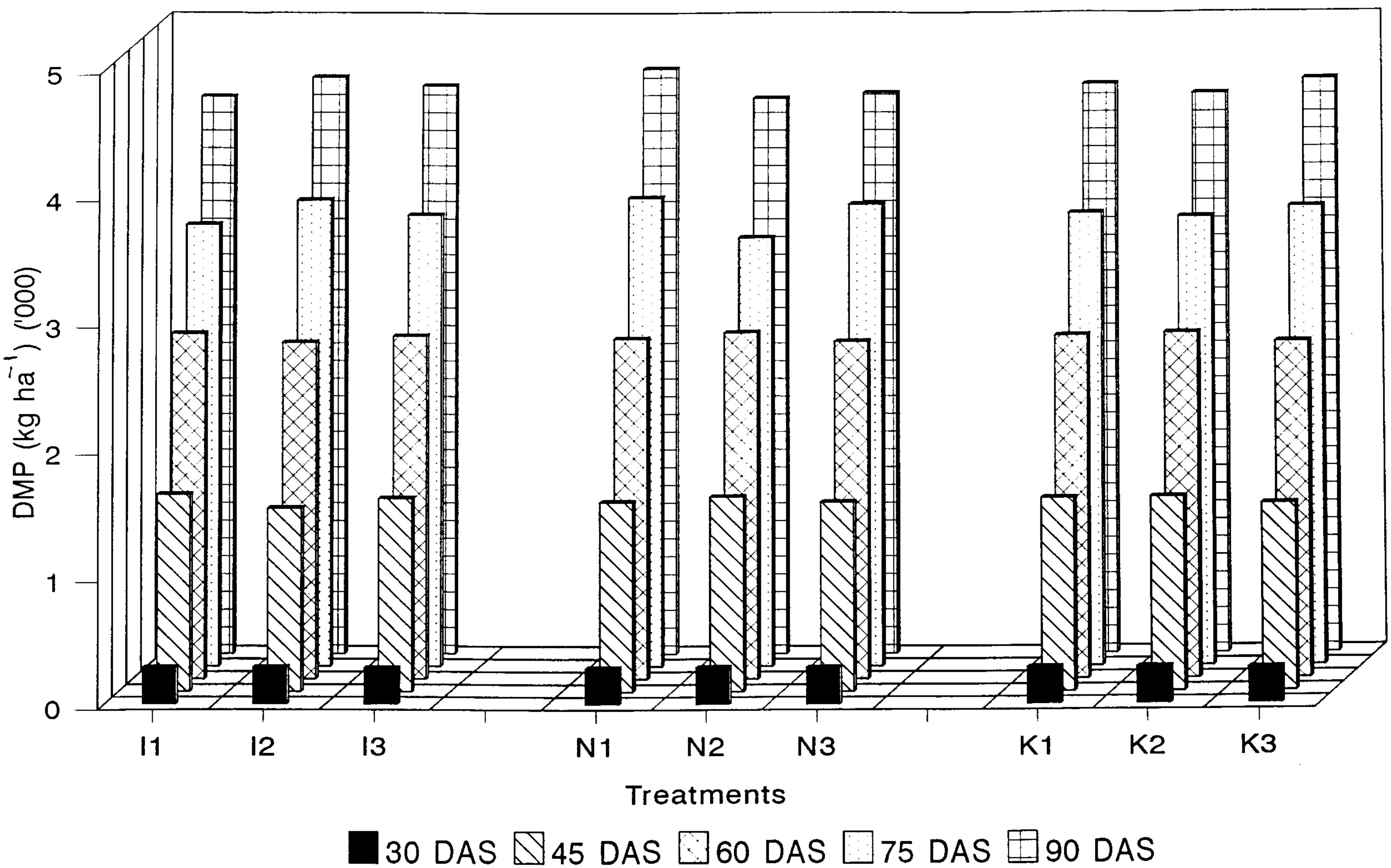

Fig. 3. Effect of irrigation, nitrogen and potassium on DMP (kg ha^{-1})

DMP showed a progressive increase through out the crop growth period and reached a significant level only at 45 DAS due to irrigation (Fig.3). During the early stages of crop growth I_1 recorded the maximum DMP while at 75 and 90 DAS I_2 showed the maximum DMP. At I_2 level of irrigation a greater partitioning of DMP to economic produce might have occured. Jyothi (1995) reported that vegetable cowpea subspecies *sesquipedalis* was more sensitive to moisture stress during flowering period. The greater DMP at I_1 during the early stages of crop growth might be due to the enhanced cell elongation, turgidity which promoted various physiological processes leading to improved plant growth. The different nitrogen levels did not influence the DMP at early stages eventhough a variation was noticed at 75DAS. Cowpea being a leguminous crop has the capacity to fix atmospheric nitrogen and at 75 DAS the nodules might have well developed and sizeable quantity of N might be fixed by the plants. There fore even at lower levels of nitrogen the DMP was significant.

Interaction effects of I x N showed a significant influence on plant height at 30 DAS, 75 DAS and 90DAS, LAI at 45 DAS and 75DAS. The number of leaves and DMP was influenced by the combined action of I and N only at 30 DAS. This might be due to the fact that with uniform uptake of nitrogen at higher levels was more and it resulted in the better expression of growth characters.

5.2 Days for 50 per cent flowering.

The differential irrigation showed significant influence on earliness for attaining 50 per cent flowering where as nitrogen and potassium did not influence the time taken for 50 per cent flowering. The number of days taken for flowering was minimum for I_2 level of irrigation given through micro sprinkler. Reason for early flowering under this treatment might be due to the fact that uniform availability of moisture in the top layers of the soil and better micro climatic conditions in the field which helped in better nutrient absorbtion and early flowering.

5.3 Yield and yield attributes.

5.3.1 Number of pods per plant.

Number of pods per plant was influenced significantly by the irrigation treatments. The irrigation treatment at I_2 recorded the maximum number of pods per plant. Water deficits generally induced changes like retardation of floral primordia development, reduction in the number of flowers produced, fruits set and early fruit abscission as noticed by Kaufmann (1972). The increase in the number of pods per plant when irrigation was given through micro sprinkler might be due to favourable moisture condition maintained in the effective root zone, which ultimately resulted in higher grain yield compared to surface methods of irrigation. A higher level of available moisture in the soil might have maintained better soil - plant water balance and the scorching effect of advection and summer heat could have interfered with the normal plant metabolism (Singh and Singh ., 1974)

An increasing trend in the number of pods per plant was noticed with the applicaition of nitrogen at N_2 level and potassium at K_2 level. The increase in yield attributes with N fertilization was due to the increased supply of photosynthates and also better uptake of nutrients. An adverse effect on yield attributes by the application of N beyond 30 kg N ha^{-1} was reported by Sarnaik *et al*,(1984). The increase in number of pods per plant due to the application of potassium might be due to enhanced photosynthetic activity followed by an efficient transfer of metabolites and its subsequent accumulation and partition as pods.

5.3.2 Pod and haulm yield

From the data presented in Table 4.8 it is clear that green pod yield was significantly influenced by irrigation treatments. Irrigation at I_2 level recorded the maximum green pod yield as compared to I_1 and I_3 (Fig.4). However, the impact of irrigation was not pronounced in the production of haulm yield. Better performance by micro sprinkler method of irrigation was probably due to the favourable micro climatic conditions, availability of uniform and

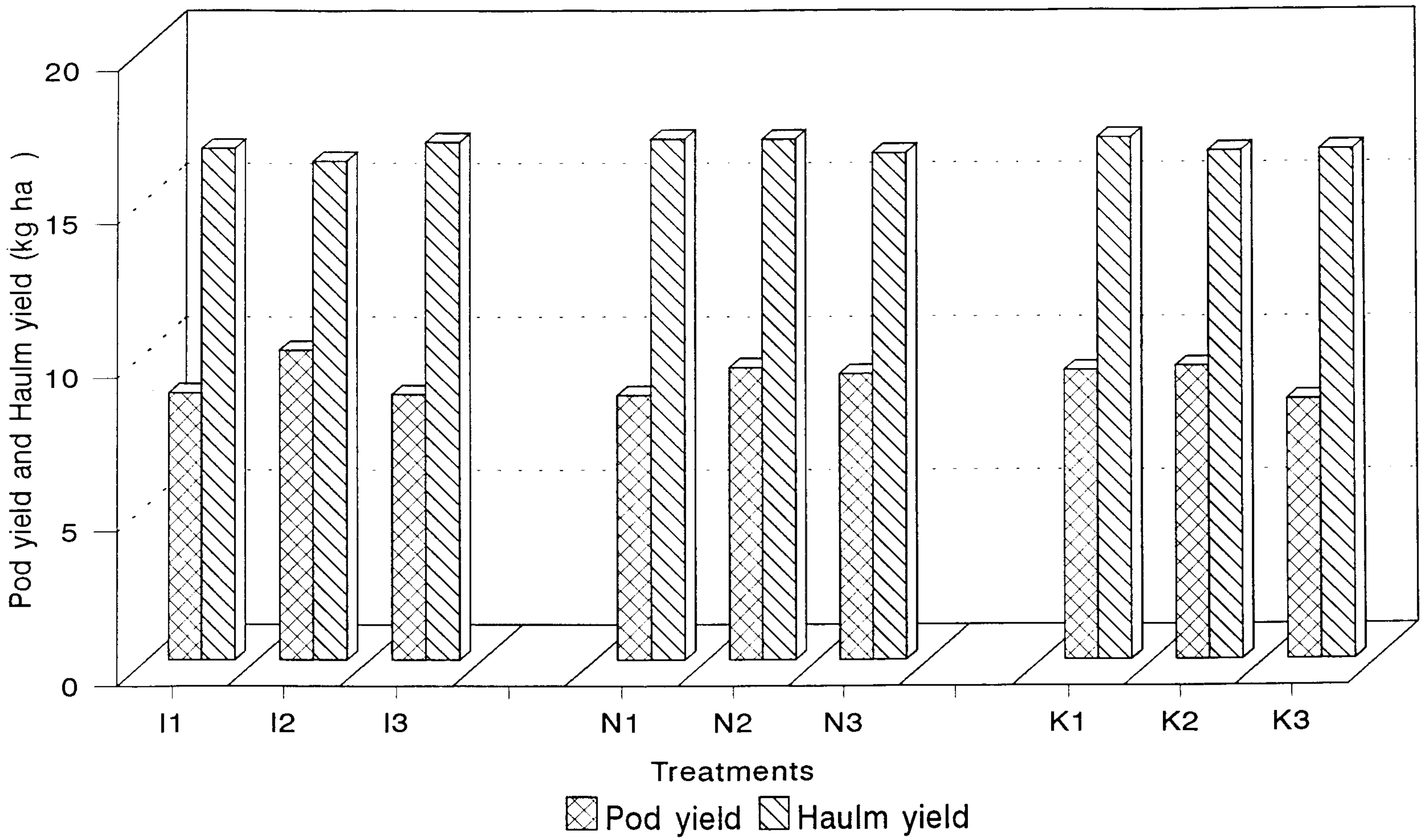

Fig. 4. Effect of irrigation, nitrogen and potassium on pod yield and haulm yield (kg ha^{-1})

adequate moisture for plant growth and keeping the soil structure loose and friable which was conducive to good aeration resulting for the better growth and partitioning of DMP. (Dabhi *et al.*, 1998) . These findings are in agreement with the report of Annon(1988) in groundnut. Generally a reduction in yield in lesser irrigated treatments might be due to the mild stress experienced by the crop. Under unsaturated moisture environment a vapour gap would be formed around the roots by their turgour pressure. Such a gap if ever present would have reduced the availability of nutrients to roots probably due to lesser contact between roots and water particles causing drastic reduction in DMP and uptake of nutrients(Philips, 1966). In the present experiment, though the total quantity of irrigtion water was less, due to better application efficiency the micro sprinkler irrigated plots gave higher yield. The increase in number of pods per plant, the major yield attributing character as seen in the experiment is reflected in the pod yield also. The haulm yield though not siginificant, was greater in daily light irrigation treatment than the other two treatments. This indicate the marked vegetative growth of the crop without any concomitant increase in pod yield.

Application of nitrogen profoundly influenced the pod yield and the maximum yield was recorded at N_2 level (Fig.4). Higher level of nitrogen above N_2 caused reduction in pod yield. Misra and Ram (1971) reported that application of small amount of starter nitrogen significantly increased the yield and quality of produce in leguminous crop. Though they are able to fix the atmospheric nitrogen and normally do not depend on nitrogen from extraneous source, basal application of fertilizer nitrogen gives a vigorous start to crop growth. The increased DMP due to greater synthesis of photosynthates might have contributed in an enhanced pod yield per plant. The better plant growth and more number of pods per plant finaly resulted in higher pod yield. Kumar *et al.* (1976) reported that pod yield in cowpea was ultimately associated with the number of pods per plant, length of pods, number of seeds per pod and test weight. Similar results were reported in french bean by Dwivedi *et al.* (1994), Ali and Tripathi (1988) , Ali and Lal (1992), Singh *et al.* (1996) and Reddy and Ahlawat (1998). The reduction in yield at higher doses of N might be due to the excessive vegetative growth at the expense of pod production. In the case of haulm yield the effect of nitrogen was not visible .

The influence of potassium on pod yield was significant and the treatments at K_2 and K_1 levels gave more yield than K_3 Fig(4) . Potassium plays an active role in a number of physiological functions including translocation of photosynthates and symbiotic fixation of nitrogen. The package of practices recommendation for potassium is only 10 kg ha $^{-1}$ for grain cowpea(KAU, 1996). In the present study the treatment at 20 kg K_2O ha^{-1} gave the maximum yield indicating the possibility of higher requirement of potassium for vegetable cowpea. This might be due to staggered pattern of harvesting for a period of one and a half month. This is in confirmity with Patra *et al.* (1996). Higher yield in groundnut owing to application of K was also observed by Dubey (1993) and in pea by Kanaujia *et al.* (1997).

Interaction between I x N recorded a significant influence on pod yield and at I_2N_3 recorded the maximum pod yield. This can be attributed to the increase in growth characters like height, number of leaves, LAI and DMP and also the yield attributing characters,viz., number of pods per plant. Rao *et al.* (1991) reported that under moisture stress or lower moisture regime, the nitrogen response was observed at 120 kg ha^{-1}. This indicated that under moisture stress condition, higher levels of nitrogen application increased the N uptake by the crop. The moisture regimes did not influence the uptake of N by the crop in the absence of N application . However, the effect of moisture was marked in increasing the N uptake at higher levels of N.

5.3.3 Number of pickings

From the data it is evident that main effect of irrigation nitrogen and potassium didnot excert much variation in the number of pickings. The interaction between I xN showed a significant influence on number of pickings and the treatment I_3N_2 recorded the maximum number of pickings. The higher available soil moisture content and higher nitrogen levels might have resulted in a longer reproductive phase.

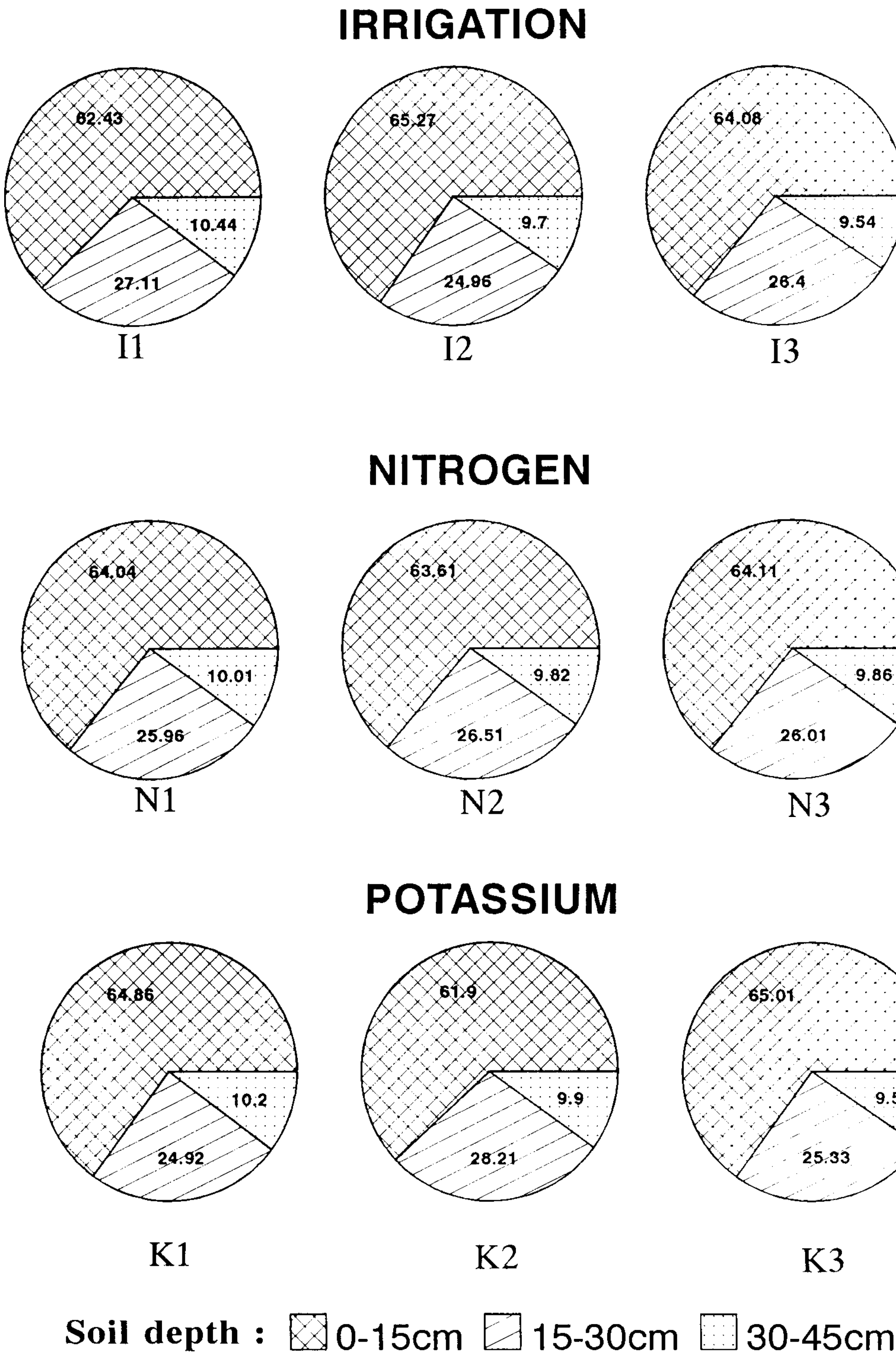

Fig. 5. Effect of irrigation, nitrogen and potassium on moisture depletion pattern (per cent)

5.4 Moisture studies.

5.4.1 Moisture depletion pattern.

A persual of data in table 4.10 indicated that the percentage depletion of moisture from the top layer (0-15 cm) was higher with micro sprinkler method of irrigaition and minimum with surface method of irrigation.

Frequent wetting of upper surface layer exposed to the hot atmospheric conditions prevailed in the summer season, caused a higher vapour pressure gradient, between the crop canopy and the atmosphere which might have resulted in a relatively larger loss of water from the surface soil at I_2 level than at I_1 level Fig(5). A substantial shift in the rooting pattern of the crop to the deeper layer in surface method of irrigation compared to micro sprinkler might have resulted in higher extraction of moisture from deeper layers under less frequently irrigated condition (Pannu and Singh, 1993). Black (1973) has observed that root grows deeper into the soil in search of water when the moisture supply is not adequate in the surface layer of soil. These results are in corroboration with the findings of Arya and Sharma (1990) and Bachchhav *et al.* (1993) in green gram and Singh and Tripathi (1992) in black gram. Dabhi *et al.* (1998) reported that sprinkler irrigated crop used more soil moisture from the upper soil profile. The findings are in confirmity with the report of Sivanappan(1987) in groundnut.

The influence of nitrogen on moisture depletion pattern was not significant while potassium showed a remarkable influence on it (Fig 5). At the top most layer ie 0-15 cm the maximum moisture depletion was noticed at K_3 level and was on par with K_1 Fig (5). Potassium nutrition in general influences the uptake and translocation of water. It also helps in root spread in many crops (Tisdale *et. al*.,1993). Blanchet *et al.* (1962) reported that higher K levels enhanced the moisture extraction from the surface layers of soil. Higher dose of NPK was found to enhance moisture depletion from top layers of soil in Congosignal (Jacob 1999).

The interaction between I xN, I x K and N x K also had a significant influence on moisture depletion pattern. This might be due to the cumulative effect of all the treatment combinations.

5.4.2 Water use efficiency.

The WUE of the crop was appreciably influenced by irrigation treatments. Maximum WUE was noticed at I_2 level of irrigation, while it was least with the daily irrigation treatment (I_3 -farmer's practice) (Fig 6). This clearly indicates that WUE was influenced by the frequency and method of irrigation. Usually there is an increase in WUE with a decrease in soil moisture supply. At a minimum critical level plants may try to economise water loss in the range from minimum critical to the optimum soil moisture level (Raghu and Choubey, 1983). Considering the availability of soil moisture it was found that in the sprinkler method of irrigation (I_2) the major portion of the available water was concentrated on the upper soil profile, and was able to meet the evaporative demand. Sivanappan (1987) reported that sprinkler irrigaition at frequent intervals improves the microclimate of plants by reducing soil, leaf and air temperature as compared to surface method in which plants were undergoing mild stress at the end of irrigation cycle, eventhough soil moisture was above 50 per cent of the available water range. Increased WUE due to less frequent irrigation was also reported by Kumar *et al.* (1992), Bachchhav *et al.* (1993); Dubey (1993), Vijayalekshmi and Aruna, (1994) and Yadhav *et al.* (1994). The lower WUE associated with higher soil moisture status can also be attributed to proportionately higher consumptive use of water without much increase in pod yield. These results are in agreement with findings of Grewal *et al.* (1984) . Slatyer(1967) reported that evapotranspiration is always at near potential rate when water is adequate, where as yield which is a complex phenomenon depending on several other factors may not be optimal. The present findings clearly indicated the wastage of irrigation water and labour in the treatment *viz.*, farmer's practice as compared to micro sprinkler method.

The nitrogen treatment also remarkably influenced the WUE of the crop The maximum WUE was registered at N_2 level and was on par with N_3 level. In the case of sprinkler method

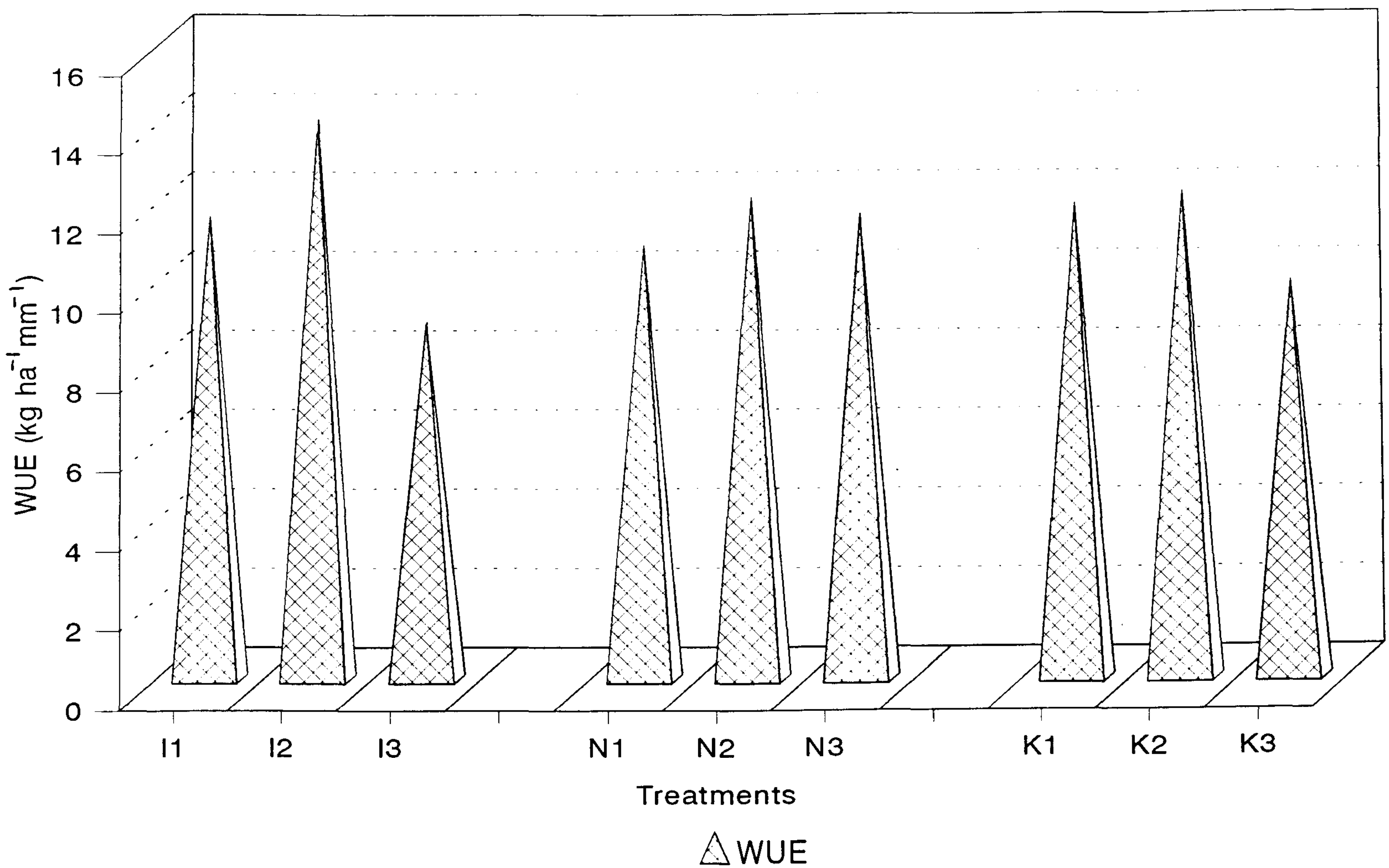

Fig. 6. Effect of irrigation, nitrogen and potassium on WUE (kg ha^{-1} mm^{-1})

much of the available soil moisture is present at the upper soil profile which leads to higher concentration of roots at this layer. This might have led to higher uptake of nutrients required for carrying out different physiological activities, there by improving the efficient use of water. Kher *et al.* (1994) reported that fertilizing cowpea with 20 kg N ha^{-1} recorded significantly higher Cu of water over rest of the higher and lower levels of N, while this level was found equally effective with 40 kg N ha^{-1} and recorded significantly higher WUE over the control . The present findings are in confirmity with the above results. This result also confirms the findings of Thomas (1984), Subharao(1989), Thampatti *et al.* (1993) and Lakshmi (1997) in cucurbits and Hegde(1988). Palled *et al.* (1988) and Sherly (1996) in chillies.

Application of potassium was also significant in its effect on WUE. Potassium level at K_2 recorded the highest WUE. Potassium content in the gaurd cells in regulating the stomatal opening and in stress situation partial closure of stomata was noticed in many cultivated crops. In the present experiment in all the three irrigation treatments a comparatively high quantity of irrigation water was applied. Even then the potassium level at K_2 showed a marked influence in WUE. The reason for this can be attributed to the role of potassium in economising the water. This is in agreement with the results obtained by Prasad and Singh (1979), Sharma and Parashar (1979), Pai and Hukeri (1979), Thomas (1984), Subbarao (1989) and Menon (1990) in different crops.

The interaction effect of I x N and Nx K showed significant influence on the WUE. Increased levels of nitrogen showed better WUE. Similarly potassium at 20 kg ha^{-1} also increased the WUE.

5.5 Soil nutrient status after the experiment.

The data revealed that the impact of irrigation treatments was not significant on soil nutrient status after the experiment. However, the levels of nitrogen showed a remarkable influence on the available nitrogen content after the experiment . The treatment N_3 recorded the maximum N content in the soil. Application of higher dose of N might have helped the crop to tap more nutrient from the applied fertilizer with little depletion from the soil pool. Due to the protracted flowering and prolonged harvesting of the crop, more nitrogen might have been absorbed from the soil at lower levels of N. Similar increase in N content with the increased application of fertilizer was reported by Gill *et al.* (1972) and Faroda and Tomer (1975). Potassium levels were not found to have any significant influence on nutrient status after the experiment.

5.6 Nutrient uptake

Among the major nutrients, only phosphorus uptake was influenced by irrigation at 90 DAS alone at I_3 level of irrigation (Fig 8). The quick growth and higher production of pods in vegetable cowpea removed a large quantity of nutrient indicating the comparitive level of absorbtion at all the stages of study. At 90 DAS probably due to crop scenesense higher accumulation of P was noticed in daily irrigation treatment.

Application of nitrogen at N_2 level significantly influenced the uptake of nitrogen and potassium and was on par with N_3 (Fig 7). The higher availability of nitrogen in the two treatments helped in greater uptake. According to Tanaka *et al.* (1964) the nutrient uptake is controlled by the factors like nutrient availability in the soil, nutrient absorption power of roots and the rate of increase in dry matter. Increased uptake of nutrients due to fertilizer application can thus be ascribed to direct manurial effects and increased tapping of nutrients from the soil, on accout of increased vigour and growth of roots in the fertilized zone. The findings of Thomas (1984), Subbarao (1989), Lakshmi (1997), Syriac(1998) also confirmed the results. Increased K uptake up to the application at the rate of 30 kg N ha^{-1} was reported by Savithri (1980) in green gram. Higher levels of N increased the LAI and DMP which might have increased the photosynthetic activity and hence a higher uptake. This is in confirmity with the results obtained by Jyothi (1995)

Potassuim application significantly influenced the uptake of potassium at later stages of crop growth ie, at 90 DAS Fig(9). Potassium at the levels of 20 and 40 kg ha^{-1} recorded the

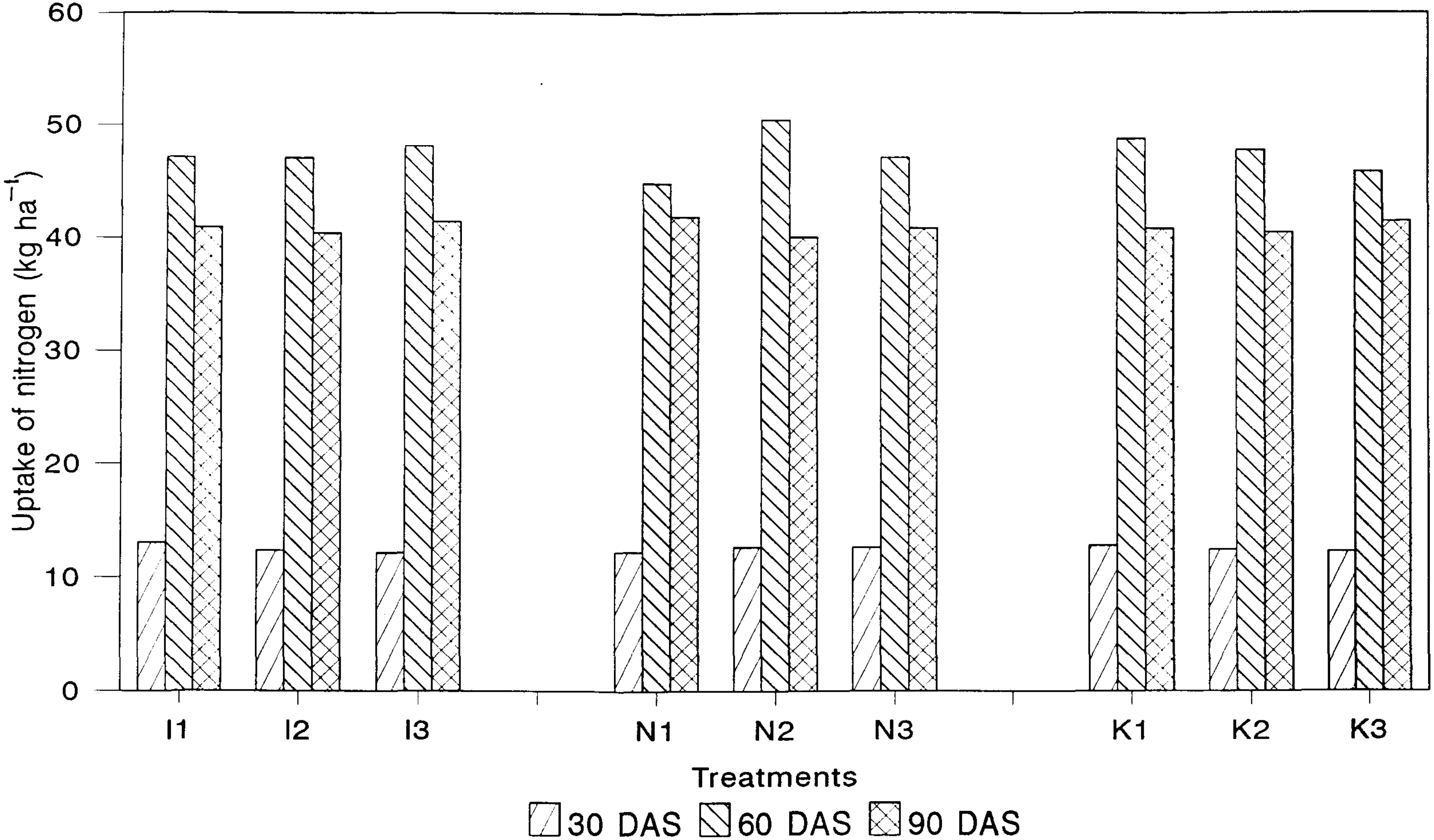

Fig. 7. Effect of irrigation, nitrogen and potassium on uptake of nitrogen (kg ha^{-1})

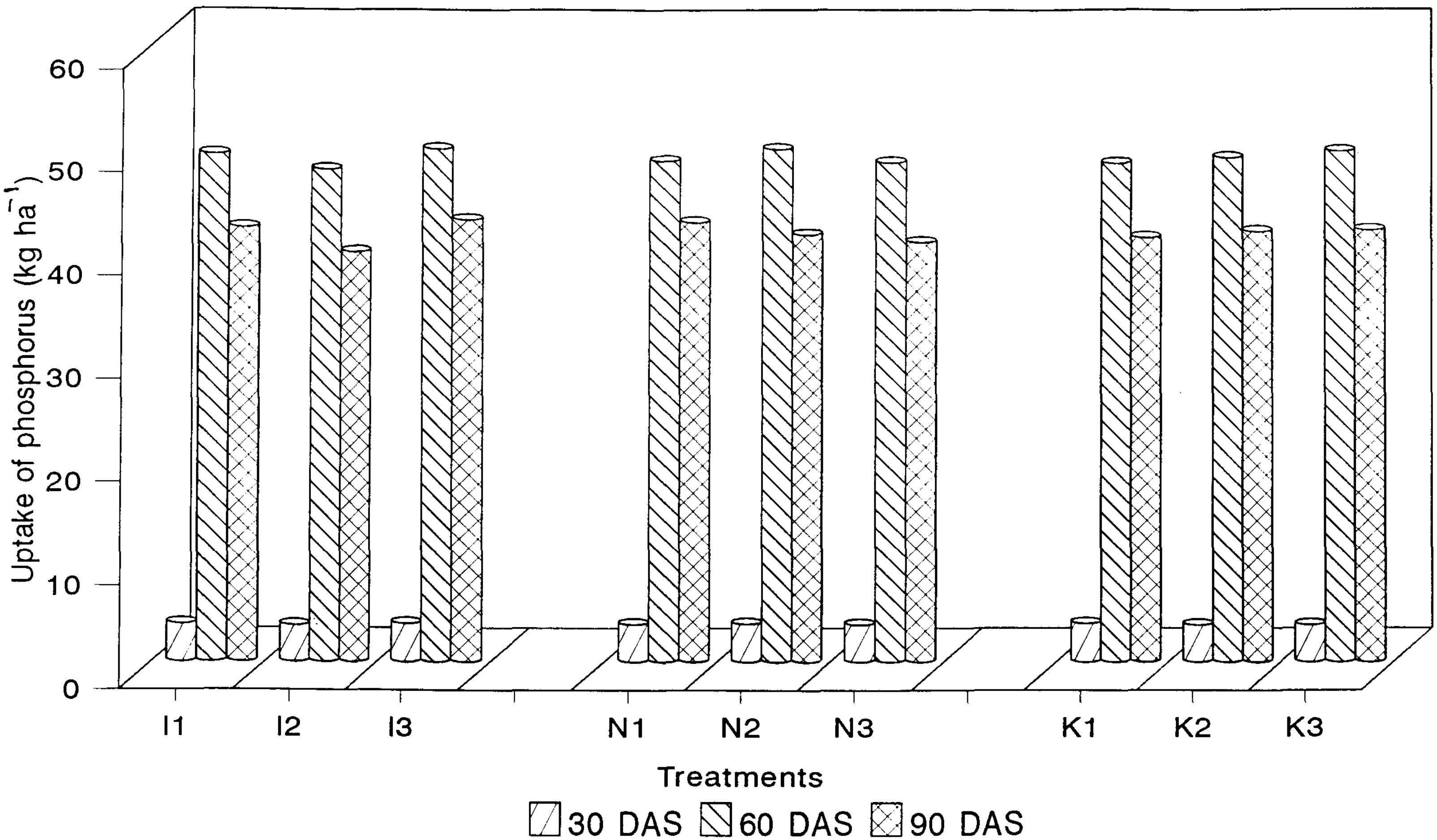

Fig. 8. Effect of irrigation, nitrogen and potassium on uptake of phosphorus (kg ha^{-1})

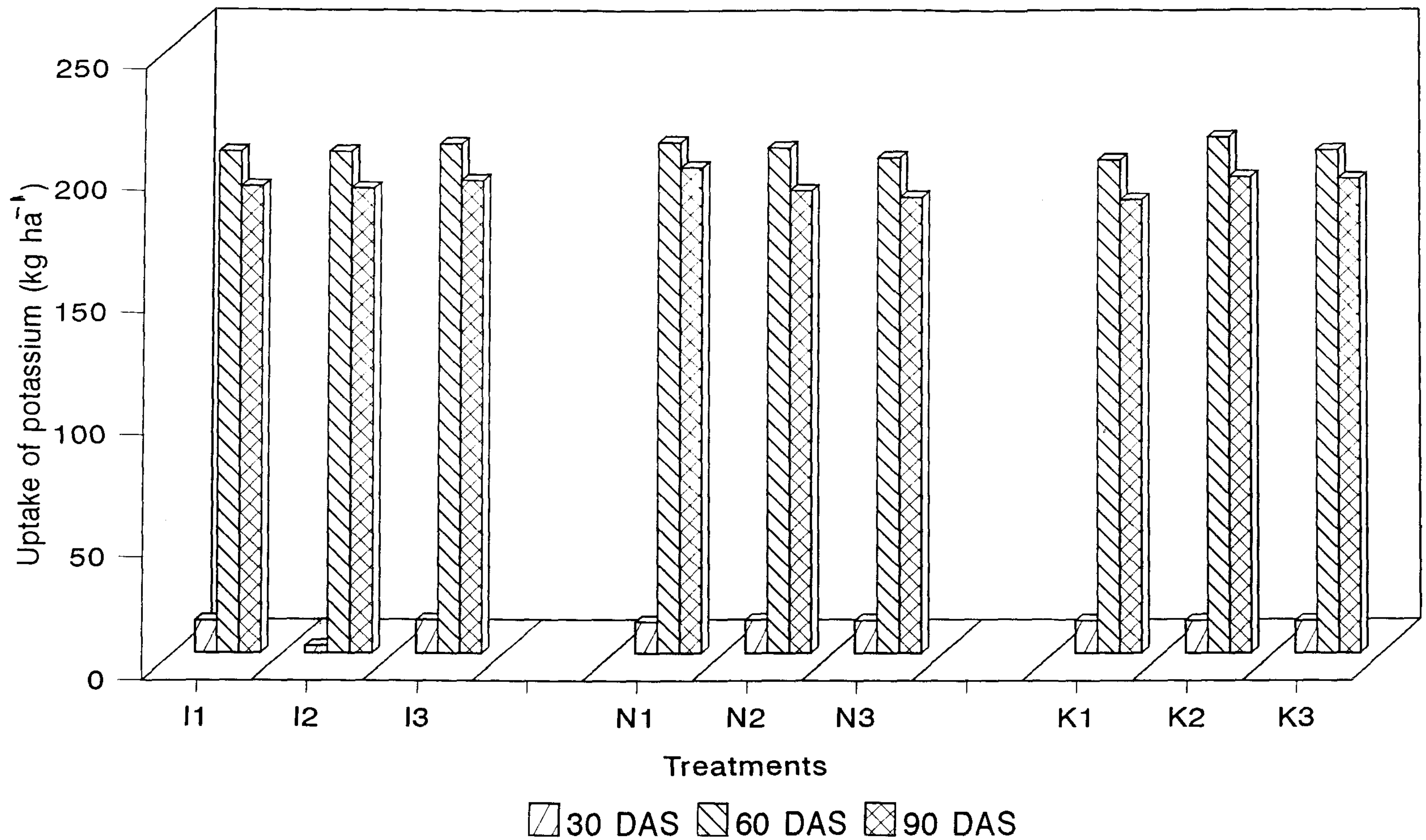

Fig. 9. Effect of irrigation, nitrogen and potassium on uptake of potassium (kg ha^{-1})

maximum uptake. This also might be due to increased nutrient availability in the soil, nutrient absorption power of roots and increased growth of roots in the fertilized zone as reported by Thomas (1984), Subbarao(1989) and Lakshmi(1997).

5.7 Economics of cultivation.

5.7.1. Net returns

The main effects of irrigation, nitrogen and potassium didnot excert any influence on net returns(Fig 10). The interaction between I x N exerted a significant influence on net returns and the treatment $I_2 N_3$ recorded the maximum net returns of Rs. 63529. This might be due to the highest yield of pods recorded by the same interaction, as shown in table 4.8.1, due to which the net returns was maximum.

5.7.2 Benefit cost ratio (BCR)

The main effects of irrigation , nitrogen and potassium exerted no variation on BCR. However, the interaction between Ix N exerted a significant influence on BCR and the treatment $I_1 N_2$ recorded the maximum value. This might be due to the less labour wages incured in surface method of irrigation (Fig. 10).

The superiority of sprinkler irrigation in terms of water economy and better crop response has been discussed in 5.3.2.· However, a technically feasible proportion should also be financially viable for its successful adoption in the field . One of the main constraints under sprinkler is its high initial investment in the form of plastic pipes, micro sprinklers and accessories to design the unit.

However the high initial cost of over Rs 24,614 ha^{-1} for installation of the system appears to be the major bottleneck in adoption of sprinkler method. But sprinkler assumes greater importance at limited water supply considering water as an important economic input.

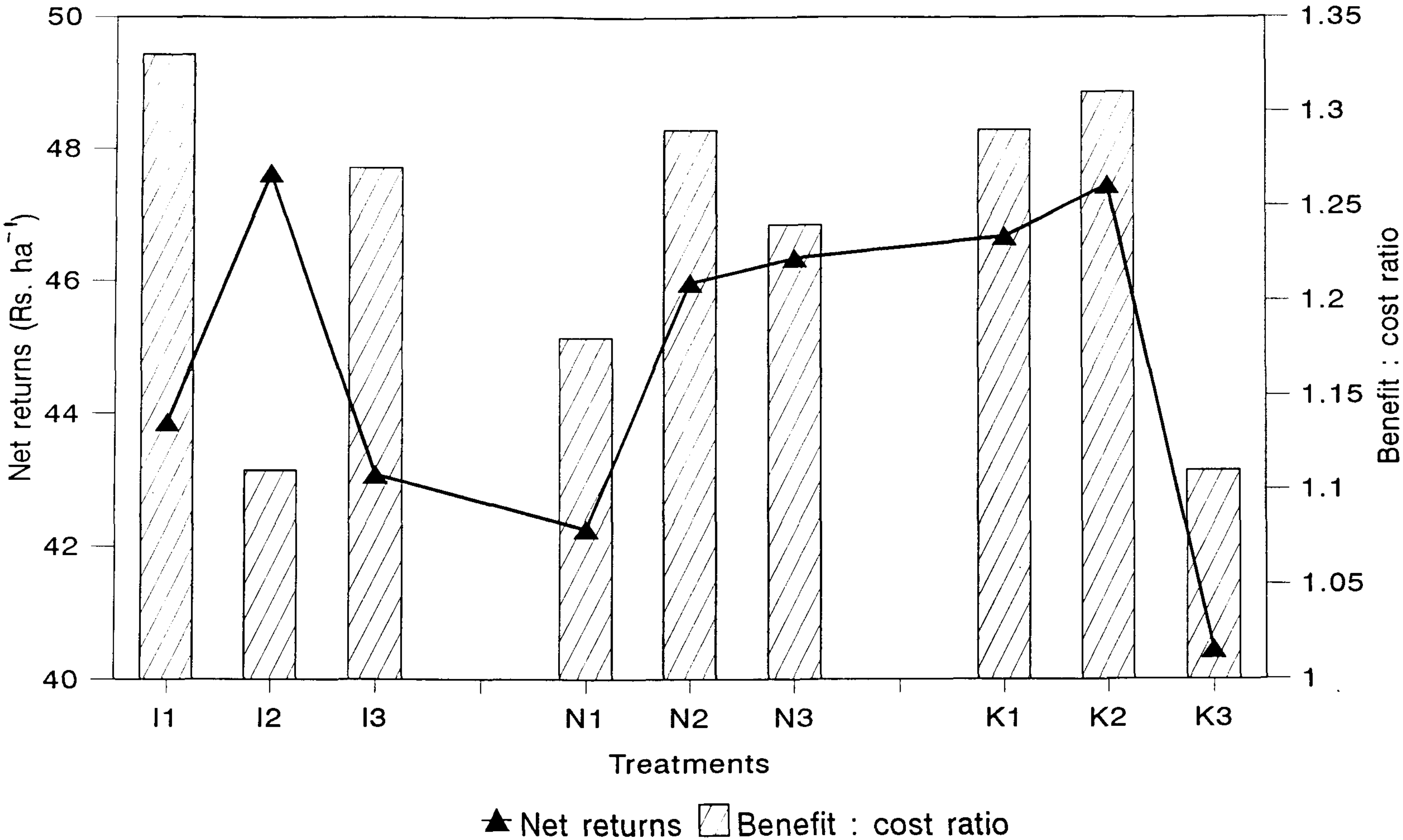

Fig. 10. Effect of irrigation, nitrogen and potassium on net returns (Rs. ha^{-1}) and benefit : cost ratio

Besides sprinklers could provide irrigation for additional area by way of water saving. Eventhough a high installation cost occurs for sprinklers it will be economically feasible for the succeeding crop as it can be reused for a minimum of 5 to 6 years.

The management practices should be tailored to maintain high yield potential or otherwise the additional returns obtained under sprinkler can be lower and in turn result in lower BCR.

5.8 Biochemical studies.

5.8.1. Proline content of leaves.

The data revealed that the differential irrigation levels exerted significant influence on the proline content of the leaves during all the stages of crop growth (Fig11). It is found that I_2 recorded the highest proline content through out the crop growth period. Many researchers are of the view that proline accumulation occurs under mild stress conditions in the plants to reduce the adverse effect of drought on plant metabolism. It acts as a storage form for the otherwise injurious ammonia released during protein breakdown and increase the bound water in the cells due to the hygroscopic nature. Thus the varieties showing accumulation of proline during stress will be drought tolerant and high yielding. (Anitha, 1989). This is in confirmity with the results of Mehkri *et al* .(1977) in ground nut and Elmore and Micheal(1981). Mukherjee *et al*.(1982) concluded that plants having and inherent capacity to accumulate proline during moisture stress can also acquire the property of drought resistence under such conditions.

Nitrogen application excerted a slight influence on proline content only at 45 DAS (Fig11) . Potassium excerted a significant influence on the proline content. In the present study it was found that with the enhanced application of K an increase in proline content was noted (Fig 11). This result is in confirmity with that of Umar *et al.* (1991). Potassium plays a major

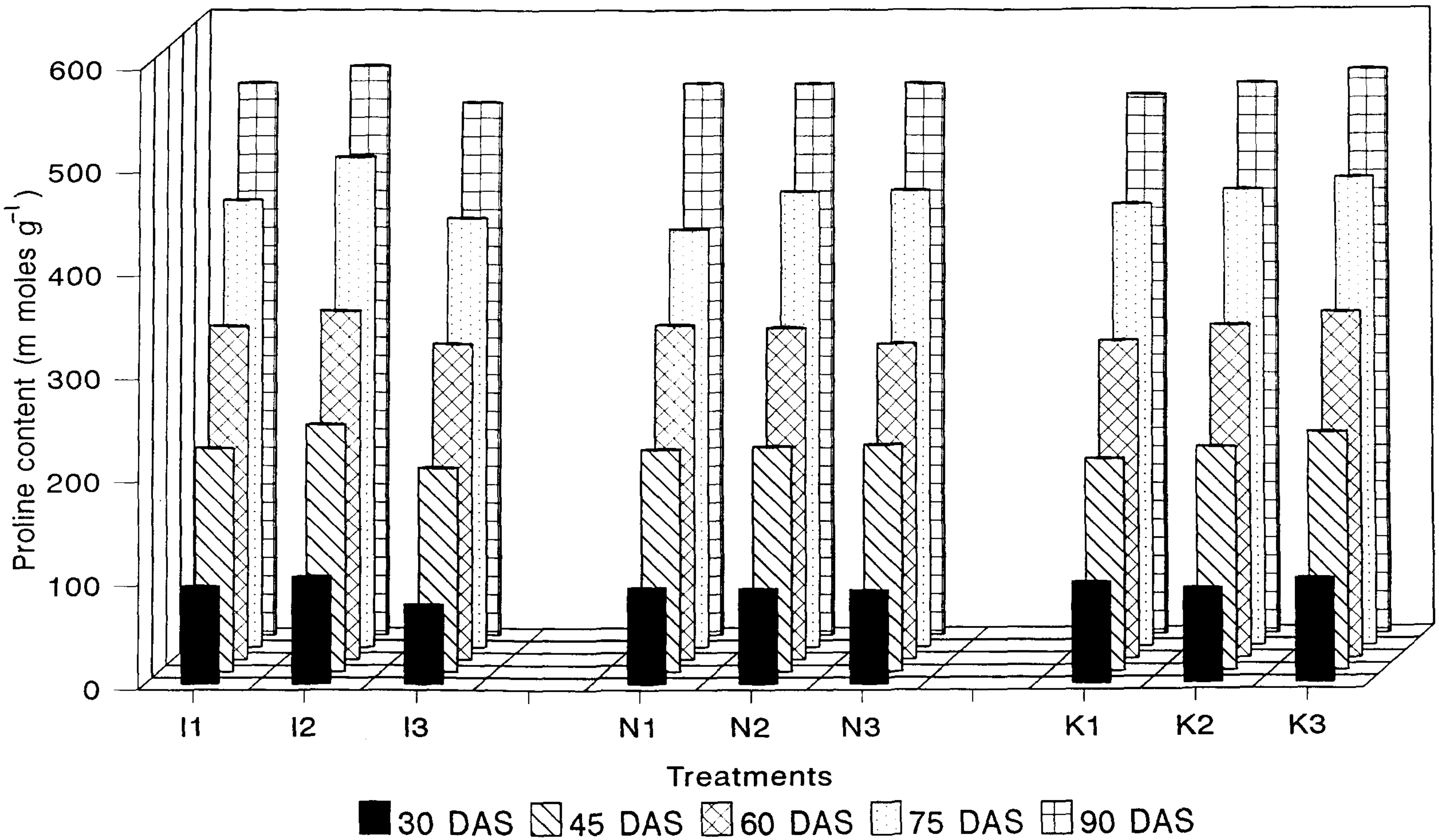

Fig. 11. Effect of irrigation, nitrogen and potassium on proline content (m moles g^{-1}) of the leaves

role in transpirational loss of water in cultivated crops during moisture stress period Maintenance of plant turgor is essential for the proper functioning of photosynthetic and metabolic processes. The opening of stomata occurs when there is an increase of turgor pressure of the gaurd cells surrounding each stoma, which is brought about by an influx of potassium. Malfunctioning of stomata due to deficiency of this nutrient has been related to lower rates of photosynthesis and less efficent use of water (Tisdale *et al.*, 1993). Stomata with adequate K are more sensitive under such conditions . By reducing transpiration during high evaporative demand, better plant water status is obtained and drought injury is minimised. (Balasubramanian, 1982). Krishnasastry (1985) reported that K increased proline in fingermillet and groundnut under water stress condition as a result of promotion of proline biosynthesis via potassium mediated arginase activity. In cowpea increasing levels of KCl had a marked effect on proline accumulation both under normal and stress conditions (Udayakumar *et al.* 1976; Balasubramanian,1982 and Thomas ,1998).Reports are available on potassium induced proline accumulation in maize leaf discs (Mukherjee,!974) and in cucumber cotyledon (Udayakumar *et al.*,1976).

SUMMARY

SUMMARY

A field experiment was conducted in the summer season at the Instructional Farm attached to the College of Agriculture, Vellayani during 1999 to study the response of vegetable cowpea to nitrogen and potassium under varying levels of irrigation. The soil of the experimental field was sandy clay loam in texture with a bulk density ranging from 1.32 to 1.37 kg m^{-3},acidic in reaction, low in available nitrogen and potassium and medium in available phosphorus. The experiment was laid out in a 3^3 confounded factorial design confounding INK in replication I and INK^2 in replication II. The treatments comprised of three levels of irrigation (I_1-Irrigating the crop at 20mm CPE value with a depth of 40mm water through surface method, I_2- Irrigating the crop at 10mm CPE value with a depth of 20mm water through micro sprinkler, I_3-Farmer's practice (light irrigation with 10mm water everyday by pot watering)), three levels of nitrogen (N_1-0 kg ha^{-1}, N_2-20 kg ha^{-1}, N_3- 40 kg ha^{-1}), three levels of potassium (K_1- 0 kg ha^{-1}, K_2- 20 kg ha^{-1}, K_3- 40 kg ha^{-1}). Observations were made on growth, yield attributing and yield characters of the crop, nutrient and moisture uptake, water use efficency and economics of the treatments. The data were statistically analysed and the results of the study are summarised below:-

During all the different stages of crop growth plant height increased progressively upto 90 DAS, though the main effects and their interactions were not significant. The other growth characters like number of leaves and leaf area index also followed the same trend.

The total DMP increased with increase in plant growth, the irrigation treatments influenced the DMP at 45 DAS. The highest DMP was recorded in I_1 and was on par with I_3. Nitrogen had a significant influence on DMP at 75 DAS and N_1 recorded the maximum DMP which was on par with N_3. The influence of K on DMP was not observed at any stage of the crop growth.

It was found that differential irrigation significantly influenced the days for 50 per cent flowering . The number of days taken for 50 per cent flowering was minimum for I_2 which was significantly superior to the other two irrigation levels. However, N and K did not have any marked influence on the days for 50 per cent flowering.

Irrigation levels had a profound influence on number of pods per plant. The treatment at I_2 gave the maximum number of pods per plant and was remarkably higher than I_1 and I_3. Eventhough, N and K did not excert a significant influence on pod number per plant, the treatments N_2 and K_2 showed a trend of increase in this vital yield attributing character. In the case of pod yield per plant also the same trend was noticed.

Differential levels of irrigation excerted a significant influence on green pod yield (economic yield). The irrigation level at I_2 registered an appreciable increase of pod yield over the other two levels. Nitrogen and potassium also induced a profound influence on green pod yield. Higher pod yield was noticed at N_2 and K_2 levels and was on par with N_3 and K_1. The interaction between IxN was also significant and I_2N_3 recorded the maximum pod yield. However, the I, N and K main effects was not noticed in case of haulm yield.

Considering the moisture depletion pattern it was noted that the percentage depletion of moisture from the top layer(0-15cm) was higher under micro sprinkler method of irrigation (I_2). However, in the deeper layers more depletion of moisture was noticed with surface method of irrigation(I_1). The moisture depletion was not influenced by variation in nitrogen. Potassium, on the other hand influenced the moisture depletion pattern significantly. At the surface layer ie., 0-15cm depth K_3 recorded the highest per cent depletion of the moisture followed by K_1 and K_2.

The WUE was more when irrigation was given through micro sprinkler than the other two methods tried in the experiment. Nitrogen levels at N_2 and potassium level at K_2 recorded enhanced WUE compared to other levels.

It is evident from the results that the main effects of N alone influenced the uptake of N at 60 DAS. The treatment N_2 excerted a remarkable influence on the uptake of nitrogen and was on par with N_3. The data reveals that I,N and K increased the uptake of nitrogen till 60 DAS and thereafter a decreasing trend was seen. In the case of phosphorus, irrigation treatments significantly influenced the uptake of phosphorus only at 90 DAS. The effect of N and K levels on the uptake of P was not noticed at any stages of crop growth. The uptake of K was significantly influenced by N and K treatments, while irrigation treatments failed in influencing the K uptake. At 30 DAS, N_2 recorded the maximum uptake of K and was on par with N_3. At 90 DAS, N_1 and K_2 recorded the highest value for the uptake of potassium.

The soil nutrient status after the experiment was influenced by the effect of nitrogen alone. Nutrient status at N_3 recorded the highest available soil N content after the experiment. While the N levels did not influence the available soil P_2O_5 and K_2O content.

The main effects failed to influence the net returns and BCR. The highest net returns of Rs. 47633 ha^{-1} with a BCR of 1.11 was noticed at I_2. While I_1 recorded the maximum BCR of 1.33 over the other two treatments. Among the different levels of nitrogen, N_2 recorded a BCR of 1.29. Comparing the different levelsof potassium, K_2 resulted in maximum net returns of Rs. 47452 $ha^{-1}$and BCR of 1.31.

The differential levels of I and K significantly influenced the proline content of the leaves at all the stages of crop growth. The irrigation level at I_2 recorded the highest proline content at all the stages of crop growth. Among the different levels of potassium K_3 recorded the maximum proline content at all the stages of crop growth followed by K_2 and K_1. Nitrogen influenced the proline content of leaves only at 45 DAS and N_2 gave the maximum proline content.

In conclusion, it is evident from the experiment that irrigating the vegetable cowpea through micro sprinkler is more effective and a nitrogen and potassium level of 20 kg ha^{-1} showed better response in expressing the growth, yield attributing characters and yield.

Future line of study

The present study is a follow up study of the two earlier trails on vegetable cowpea. The best treatment of the three experiments may be tested for future verification and general recommendation .

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* Originals not found

Appendix I

Data on daily evaporation during the crop growth period

Date	Evaporation (mm)	Date	Evaporation (mm)	Date	Evaporation (mm)
15-1-99	3.3	21-2-99	2.6	30-3-99	3.5
16-1-99	3.5	22-2-99	3.9	31-3-99	4.0
17-1-99	4.0	23-2-99	5.2	1-4-99	5.0
18-1-99	3.5	24-2-99	4.0	2-4-99	4.6
19-1-99	3.7	25-2-99	3.6	3-4-99	3.2
20-1-99	3.6	26-2-99	4.0	4-4-99	4.7
21-1-99	3.8	27-2-99	4.0	5-4-99	3.7
22-1-99	3.6	28-2-99	3.5	6-4-99	4.4
23-1-99	3.0	1-3-99	4.3	7-4-99	2.2
24-1-99	3.2	2-3-99	4.3	8-4-99	4.9
25-1-99	2.5	3-3-99	4.2	9-4-99	6.0
26-1-99	3.6	4-3-99	5.2	10-4-99	3.5
27-1-99	4.0	5-3-99	4.0	11-4-99	4.9
28-1-99	3.8	6-3-99	4.3	12-4-99	4.3
29-1-99	3.7	7-3-99	4.0	13-4-99	5.3
30-1-99	2.9	8-3-99	4.5	14-4-99	3.9
31-1-99	2.2	9-3-99	4.0	15-4-99	4.5
1-2-99	4.3	10-3-99	4.0	16-4-99	4.0
2-2-99	3.8	11-3-99	3.9	17-4-99	4.8
3-2-99	3.9	12-3-99	4.0	18-4-99	4.0
4-2-99	3.4	13-3-99	4.4	19-4-99	4.1
5-2-99	3.4	14-3-99	4.0	20-4-99	3.1
6-2-99	6.2	15-3-99	5.7	21-4-99	4.0
7-2-99	3.7	16-3-99	4.4	22-4-99	3.2
8-2-99	3.3	17-3-99	4.8	23-4-99	2.0
9-2-99	3.9	18-3-99	5.5	24-4-99	1.5
10-2-99	3.6	19-3-99	4.7	25-4-99	2.4
11-2-99	3.3	20-3-99	4.0	26-4-99	2.0
12-2-99	3.7	21-3-99	4.0	27-4-99	4.0
13-2-99	3.9	22-3-99	4.0		
14-2-99	4.0	23-3-99	4.6		
15-2-99	4.0	24-3-99	4.0		
16-2-99	3.9	25-3-99	4.0		
17-2-99	3.7	26-3-99	3.9		
18-2-99	3.8	27-3-99	4.0		
19-2-99	3.6	28-3-99	4.9		
20-2-99	3.6	29-3-99	3.9		

RESPONSE OF VEGETABLE COWPEA
(*Vigna unguiculata* subsp.*sesquipedalis (L)* verdcourt)
TO NITROGEN AND POTASSIUM UNDER VARYING LEVELS OF IRRIGATION.

By

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ABSTRACT OF THESIS

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ABSTRACT

An experiment was conducted at the Instructional Farm attached to the College of Agriculture, Vellayani in the summer season during 1999 to study the response of vegetable cowpea cv.*Malika* to nitrogen and potassium under varying levels of irrigation. The experiment was laid out in a 3^3 confounded factorial design confounding INK in replication I and INK^2 in replication II. The treatments included three levels each of irrigation,nitrogen and potassium.

The study revealed that the crop responded to irrigation,nitrogen and potassium levels. The growth characters like plant height,number of leaves per plant and LAI were not significantly influenced by the different treatments. But the earliness in flowering and the main yield attributing character viz., the number of pods per plant were favourably influenced when irrigation was given at a CPE value of 20mm with a depth of 10mm water through micro sprinkler method. The earliness in flowering and number of pods per plant were also influenced when nitrogen and potassium were applied at the rate of 20 kg ha^{-1} as compared to the other levels.

The maximum yield of green pods was obtained when the crop was irrigated through micro sprinklers at 20mm CPE with a depth of 10mm water. The nitrogen and potassium levels at 20 kg ha^{-1} also enhanced pod yield. The haulm yield was not influenced by any of the treatments or its combinations .

The uptake of nutrient was influenced by the treatments. The nitrogen uptake was influenced only by variation in N levels. Potassium uptake was affected by the influence of both N and K. Irrigation treatments influenced the uptake of P_2O_5 alone at a single growth stage.

Water use efficiency was highest whenirrigation was given through micro sprinkler. Nitrogen and potassium levels each at 20 kg ha^{-1} resulted in highest WUE compared to the other two levels. Moisture depletion was higher from the top 0-15 cm layer of the soil when the crop was irrigated at 10mm CPE with a depth of 20mm water through micro sprinkler. At 15-30cm and 30-45 cm depth surface method recorded the highest moisture depletion. Higher levels of potassium was found to influence the moisture depletion pattern.

The available soil nutrient status after the experiment was influenced by nitrogen alone. The application of 40kg N ha^{-1} resulted in the highest available soil nitrogen content after the experiment.

Irrigation and potassium exerted a remarkable influence on the proline content of the leaves. The maximum proline content was recorded when the crop was irrigated through micro sprinklers and potassium was applied at the rate of 40 kg ha^{-1}.

The results of economic analysis revealed that the net returns was maximum by irrigating the crop through micro sprinkler. However, the BCR was highest when irrigation was given by surface method and at a nitrogen and potassium level of 20 kg ha^{-1} each.