THE EFFECT OF PHENOPHASED IRRIGATION ON VEGETABLE COWPEA(*Vigna sesquipedalis*) UNDER GRADED DOSES OF NITROGEN AND PHOSPHORUS.

By

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THESIS

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

Department Of Agronomy
COLLEGE OF AGRICULTURE
Vellayani - Thiruvananthapuram
1995

Dedicated to my beloved parents and sister

DECLARATION

I hereby declare that this thesis entitled "**The effect of phenophased irrigation on vegetable cowpea (*Vigna sesquipedalis*) under graded doses of nitrogen and phosphorus**" 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 "The effect of phenophased irrigation on vegetable cowpea (Vigna sesquipedalis) under graded doses of nitrogen and phosphorus" is a record of research work done independently by **Jyothi. K.I.** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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ACKNOWLEDGEMENT

I wish to express my deep sense of gratitude and sincere thanks to

Dr. Kuruvilla Varughese, Associate Professor of Agronomy, College of Agriculture, Vellayani and Chairman of Advisory Committee for his valuable guidance, critical suggestions and constant encouragement during the course of research work and preparation of the thesis,

Prof. P. Chandrasekharan, Professor and Head of Agronomy, College of Agriculture, Vellayani for his expert advice and valuable suggestions at all stages of work,

Dr. V. Muraleedharan Nair, Professor of Agronomy and P.H. Latheef, Associate Professor, College of Agriculture, Vellayani for their helpful suggestions and advice rendered in the preparation of the thesis,

Dr. P. Saraswathy, Professor and Head of Agricultural Statistics, College of Agriculture, Vellayani for the expert advice and valuable guidance in the statistical analysis of the data,

Sri. C.E. Ajithkumar, Junior Programmer, Computer Centre, College of Agriculture, Vellayani for analysing the experimental data, My friends, Kalarani and Vineetha for their friendly co-operation and assistance rendered at various stages of the work,

The Librarian and staff of the library, Tamil Nadu Agricultural University, Coimbatore for providing necessary facilities to collect literature in connection with the thesis work,

The teaching and non-teaching staff of the Department of Agronomy, College of Agriculture, Vellayani for their sincere co-operation and assistance rendered during the course of this investigation,

Smt. S. Sreelatha, for neatly executing the typing of this thesis,

The Kerala Agricultural University for the award of fellowship for the Post graduate programme,

Above all the God Almighty in enabling me to undertake this venture successfully.

JYOTHI. K.I.

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LIST OF ABBREVIATIONS

mm	-	millimetre
cm	-	centimetre
cc	-	cubic centimetre
m	-	metre
mg	-	milli gram
g	-	gram
kg	-	Kilogram
q	-	quintal
t	-	tonnes
ha	-	hectare
N	-	Nitrogen
P	-	Phosphorus
K	-	Potassium
FYM	-	Farmyard manure
DAS	-	Days after sowing
ASM	-	Available Soil Moisture
MEP	-	Moisture extraction pattern
WUE	-	Water use efficiency
Cu	-	Consumptive use
SMP	-	Soil matric potential
KPa	-	Kilo Pascal
MPa	-	Mega Pascal
IW	-	Irrigation water
CPE	-	Cumulative pan evaporation
DMP	-	Dry matter production
LAI	-	Leaf area index
CGR	-	Crop growth rate
RBD	-	Randomised block design
cv.	-	Cultivar
var.	-	Variety
Fig.	-	Figure
BCR	-	Benefit-cost ratio
Mo	-	Molybdenum

INTRODUCTION

INTRODUCTION

The food and nutrition situation in many developing countries will not present a pleasant picture when the human race steps into the 21st century. This is especially true with reference to India, where the food production can hardly keep pace with the ever increasing population. To meet this challenge, it is necessary to get maximum returns from the cultivated area. The catch crops like summer vegetables normally give higher yields per unit area. Importance of vegetables for the maintenance of normal health is well being realized in all parts of the world. Hence the need for the improvement of different vegetable crops and development of new technology to increase their production have been the major considerations of agricultural scientists.

In Kerala, vegetable crops occupy an area of 1.43 lakh hectares with a production of 1.62 lakh tonnes. It is estimated that about 3 lakh tonnes of vegetables are consumed in Kerala per year. However, it is only one-third of the vegetable requirement for the entire state. Hence it is imperative to get a considerable quantity of vegetables from the neighbouring states.

In Kerala, the extent of cultivable land is limited and hence the vegetable production can be enhanced only through intensive multiple cropping practices giving more emphasis to the efficient management of different resources viz. land, water, nutrients etc. It is estimated that in Kerala, about 1.85 lakh hectares of summer rice fallows are available. Vegetable cultivation can be popularised in these summer rice fallows with limited irrigation facilities.

Among the various vegetable crops grown in Kerala, vegetable cowpea occupies a prime position. It is a highly nutritious leguminous vegetable crop. It can be cultivated either as an upland crop during the rainy season or as an irrigated crop in the summer rice fallows. At present, Kerala Agricultural University has evolved varieties of vegetable cowpea suitable for both upland and lowland conditions.

In the intensification of summer vegetable cultivation, availability of irrigation water is a major constraint. Though the crop can fix atmospheric nitrogen, a starter dose of N may boost the early growth and establishment of Rhizobium (Russel, 1961). Being a pulse crop, it responds well to P also. At present, only a general recommendation of irrigation and nutritional requirement of grain cowpea is available. Since the prolonged harvesting period of vegetable cowpea varies considerably from grain cowpea, the response pattern to different inputs mainly water and nutrients may also vary.

Taking into consideration of these aspects, the present investigation was undertaken with the following objectives:

1. To determine the optimum soil moisture level and to find out an optimum irrigation schedule with maximum water-use efficiency for vegetable cowpea grown in summer rice fallows.

2. To find out the effect of irrigation at different growth stages of the crop under varying levels of nitrogen and phosphorus.

3. To determine the N and P requirements of vegetable cowpea under different irrigation treatments.

4. To work out the economics of various irrigation treatments and NP ratios to vegetable cowpea in the summer rice fallows.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Water is one of the most essential inputs for crop production and is often a limiting factor in extending crop acreage. Hence the best use of available water must be made for efficient crop production. Due to uncertainty and insufficiency of rainfall, irrigation is essential to obtain higher yields of crops. To derive full benefit, there is an urgent need to increase the water-use efficiency through suitable agronomic practices. Fertilizer application has been proved to be an efficient tool in increasing productivity, facilitating better use of resources like land, labour, water etc. The impact of the response of irrigation and nutrients on crops are also important for scientific crop management. The current state of knowledge on these aspects is reviewed here.

Criteria of irrigation scheduling

The objectives of efficient irrigation management are high yield with good quality, high water-use efficiency, least damage to soil productivity and low irrigation cost. These objectives can be achieved by following optimum irrigation schedules for different crops. Scientific irrigation schedules must be based on a thorough understanding of soil-water-plant-atmosphere relationships. During the past 50 years, numerous efforts have been made by researchers to develop suitable criteria for scheduling irrigation to crops and have suggested a variety of approaches (Prihar *et al*., 1975). Transpiration ratio, depth-interval and yield, physiological stage, soil moisture depletion and climatological are the various approaches used in scheduling irrigation. The soil moisture depletion approach and climatological approach are quite common and fairly accurate in determining the irrigation requirement of crop.

2.1 Effect of irrigation

2.1.1 Effect of irrigation on growth characters

2.1.1.1 Plant height

Singh and Lamba (1971) reported that higher available soil moisture (ASM) in the root zone enhanced the plant height in cowpea. Similar increase in plant height in cowpea due to irrigation at 75 per cent ASM over 50 per cent and 25 per cent ASM was reported by Ahlawat *et al*. (1979). Farghaly *et al*. (1990) from an experiment with 5 cowpea cultivars observed that lengthening the irrigation interval from 1 week to 3 weeks reduced the plant height. Increased plant height due to frequent irrigation was noticed in other pulse crops also. viz., greengram (Ishii, 1969; Ali and Alam, 1973), redgram (Ramshe and Surve, 1984), pea (Yadav *et al*., 1990), blackgram (Singh and Tripathi, 1992) and groundnut (Bhoi *et al*., 1993). Pritoni *et al*. (1990)

noticed that withholding irrigation during the pod filling stage reduced the plant height and length of internodes in soybean. In greengram, Prasad et al. (1991) noted that two irrigations each at flowering and pod development stages recorded the maximum plant height. Similar results were obtained by Rao et al. (1991) in blackgram also.

2.1.1.2 Number of leaves

Singh and Lamba (1971) stated that in cowpea, irrigation at higher ASM in the root zone enhanced the number of leaves per plant. Soil moisture stress was found to reduce the number of leaves per plant and leaf area in greengram. (Ali and Alam, 1973). A reduction in leaf number and leaf area due to moisture stress was also reported by Manning et al. (1977) in peas, Henrique et al. (1978) in soybean and Kuhad et al. (1988) in chickpea.

2.1.1.3 Leaf area index (LAI) and crop growth rate (CGR)

Increased LAI and CGR were obtained in french bean by Hegde and Srinivas (1989) by irrigating the crop at the soil matric potential (SMP) of -45 Kpa at 15 cm depth over -65 and -85 Kpa. Enhanced LAI and CGR were noticed in greengram by irrigating at 300 mm CPE over 400 mm CPE (Pannu and Singh, 1993).

2.1.1.4 Number of branches

Ramshe and Surve (1984) in redgram and Pani and Srivastava (1990) in pea observed that the number of branches per plant was not influenced by irrigation, whereas, Pal and Jana (1991) in an experiment with summer greengram recorded an appreciable increase in number of branches per plant by two irrigations each at vegetative and pod development stage. Prasad et al. (1991) from an experiment with a greengram cv. Pusa 105 also concluded that two irrigations given at flowering and pod formation stages significantly increased the number of primary branches. In summer blackgram, higher number of branches per plant was noticed at an IW/CPE ratio of 0.8 as compared to the ratios of 0.4 and 0.6 (Singh and Tripathi, 1992).

2.1.2 Effect of irrigation on flowering

Hiler et al. (1972) observed that flowering stage was the most susceptible stage to moisture stress in grain cowpea. Ali and Alam (1973) reported that soil moisture stress reduced the initiation and retention of floral buds in greengram. According to Sionit and Kramer (1977), soybean was more sensitive to water stress at the post-flowering than at the pre-flowering period. Ramshe and Surve(1984) observed in redgram that days to 50 per cent flowering was not influenced by irrigation.

2.1.3. Effect of irrigation on yield attributes

In an experiment conducted at IARI, New Delhi with cowpea, Ahlawat et al. (1979) observed that irrigation at 75 per cent ASM at 0-30 cm depth recorded the maximum number of pods per plant over 50 per cent and 25 per cent ASM. Studies conducted on a summer vegetable cowpea revealed that the soil moisture regime of 100-80 per cent of ASM favourably influenced the number and weight of green pods per plant over regimes of 100-60, 100-40, 100-20 per cent of ASM (Patel, 1979). In cowpea, protective irrigations on 27th and 55th days after sowing (DAS) recorded the maximum number of pods per plant (Ramamurthy et al., 1990). 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.

Singh and Tripathi (1972) noticed that moisture stress during flower induction and flowering in soybean reduced pod and seed production and also grain test weight. In beans, moisture stress during vegetative or flowering or pod development stages reduced the pod number per plant and test weight of seeds (Miranda and Belmer, 1978). Sadasivam et al. (1988) noted that in greengram, stress significantly influenced the cluster number and pod number when it was induced at vegetative phase followed by stress at flowering phase. Pal and Jana (1991) noticed in summer greengram that scheduling irrigation at vegetative and pod development stages significantly increased the number of pods per plant and test weight. Prasad et al. (1991) also observed that in greengram, the maximum number of pods per plant, number of seeds per pod and test weight of seeds were observed when two irrigations were given at flowering and pod development stages compared to no irrigation and one irrigation either at flowering or pod formation stage.

Pal et al. (1991) from an experiment with blackgram stated that 3 irrigations each at branching, flowering and pod development stages recorded maximum values for yield attributes, whereas, Rao et al. (1991) working with rabi blackgram concluded that two irrigations each at flowering and pod development stages recorded the maximum number of pods per plant, number of seeds per pod, and test weight of seeds.

2.1.4 Effect of irrigation on yield

Singh and Lamba (1971) reported that higher ASM in the root zone enhanced the drymatter production (DMP) in cowpea. In an experiment conducted at IARI, New Delhi, with cowpea, Ahlawat et al. (1979) observed that irrigation at 75 per cent ASM at 0-30 cm depth recorded the maximum grain yield over 50 and 25 per cent ASM. In studies conducted on summer vegetable cowpea, Patel (1979) observed that the soil moisture regime 100-80 per cent of ASM gave 12.87, 29.15 and 84.18 per cent higher yield of green pods compared to moisture regimes of 100-60, 100-40, 100-20 per cent of ASM respectively.

Barrios et al. (1986) could obtain the maximum grain yield in cowpea when last irigation was given at maturation stage compared to irrigation given before flowering, at flowering, at pod formation or pod filling and the lowest yield was obtained when it was given before flowering. Farghaly et al. (1990) from an experiment with 5 cowpea cultivars observed that lengthening the irrigation interval from 1 week to 3 weeks reduced the seed yield. Maximum yield was recorded with an interval of 1 week and the lowest yield with an interval of 3 weeks. Ramamurthy et al. (1990) noticed that in cowpea, protective irrigations at 27th and 55th days after sowing recorded higher DMP, green stalk yield and seed yield compared to no irrigation. In an experiment on a vegetable cowpea cv. CO-2 at ARS, Bhavanisagar, it was noticed that irrigation at frequent intervals (0.8 IW/CPE) enhanced the DMP over wider intervals (0.6 IW/CPE). At very frequent intervals (1.0 IW/CPE), there was reduction in drymatter. But the maximum yield was recorded by irrigation at 1.0 IW/CPE which was on a par with the IW/CPE ratio of 0.8 and significantly superior to wider intervals (0.6 IW/CPE) (Subramanian et al., 1993).

Singh and Bharadwaj (1975) stated that irrigating greengram at 40 per cent ASM during pre-flowering and at

20 per cent ASM at post-flowering phases was the optimum irrigation scheduling for getting higher yield. Scheduling irrigation at flowering and pod development stages in greengram produced 15.5 per cent and 33.3 per cent increase in yield compared to one irrigation at flowering and pod development stages respectively (Agarwal *et al*., 1976). Similar results were obtained by Prasad *et al*. (1991). Khade *et al*. (1986) from an experiment with greengram concluded that the maximum grain yield was obtained by scheduling irrigation at 48 mm CPE compared to irrigation at 24,72 and 96 mm CPE. Pal and Jana (1991) noticed in summer greengram that scheduling irrigation at vegetative and pod development stages significantly increased the seed yield. Irrigation scheduled as per 100 mm CPE gave significantly more seed and haulm yield and harvest index than irrigation at 50,75 mm CPE and at critical growth stages in greengram (Bachchhav *et al*., 1993). The maximum DMP and seed yield were recorded by irrigating greengram at 300 mm CPE followed by irrigation at 400 mm CPE (Pannu and Singh, 1993).

According to Varughese *et al*. (1986), irrigating blackgram at an IW/CPE ratio of 0.5 was found to be the best. Irrigating the crop at ratios higher than 0.5 did not influence the yield. Pal *et al*. (1991) noticed in blackgram that three irrigations each at branching, flowering and pod development stages produced maximum pod and seed yields, whereas, Rao *et al*. (1991) observed that two irrigations each at flowering and pod development stages recorded the maximum DMP and grain yield in blackgram. Singh and Tripathi (1992) from an experiment with summer blackgram observed that maximum DMP was obtained by irrigating the crop at an IW/CPE ratio of 0.8 compared to 0.4 and 0.6 ratios. According to Vijayalakshmi and Aruna (1994), irrigating blackgram at an IW/CPE ratio of 0.6 resulted in higher grain yield over 0.75 and 0.9 ratios.

2.1.5 Effect of moisture stress on yield

Summerfield et al. (1976) observed in cowpea that moisture stress during the vegetative stage caused significant yield decline. Ferreira et al. (1991) reported that water stress during both vegetative and reproductive stages of 2 cowpea cultivars did not cause any significant reduction in yield because of drought avoidance mechanism in these cultivars. Tewolda et al. (1991) in an experiment on reproductive abscission and yield of irrigated and drought stressed cowpea observed that drought stress did not affect abscission and pod retention in the top one-third of the plant but increased abscission at nodes in the middle and lower parts from 82 per cent in well irrigated plants to 93 per cent in non-irrigated plants and caused 60 per cent reduction in pod retention. The number of peduncles per plant, DM and seed yield were also decreased, but did not affect harvest index.

In an experiment with greengram, Sadasivam et al. (1988) noticed that stress significantly influenced the pod yield per plant and seed yield when it was induced at vegetative phase followed by stress at flowering phase. Shashidharan (1988) observed in summer greengram that irrigation at 50 per cent ASM gave maximum seed yield and severe stress at flowering and pod formation stages significantly reduced seed and haulm yields. It was also observed that early flowering, early pod formation and pod development stages were found to be most critical for moisture stress.

Uprety and Bhatia (1989) observed in greengram that stress before flowering caused the smallest yield reduction. Harvest index was reduced by drought after flowering. Maximum plant height, pods per plant, length of pods, seeds per pod, seed yield per hectare, DM yield and harvest index were recorded by a low moisture stress given throughout the growth period in greengram (Varughese and Iruthayaraj, 1993).

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

The maximum Cu and WUE were recorded by irrigating cowpea at 75 per cent ASM over irrigation at 50 per cent and 25 per cent ASM (Ahlawat et al., 1979). Field experiment conducted to find out the optimum soil moisture regime for summer vegetable cowpea revealed that the WUE increased with increasing availability of soil moisture levels from 100-20 per cent of ASM to 100-80 per cent of ASM (Patel, 1979). In an experiment with greengram at IARI in a sandy loam soil, it was noted that the crop extracted most of its moisture requirement (54.4 per cent) from 0-30 cm depth. Irrigation given at an IW/CPE ratio of 0.2 resulted in greater soil moisture extraction from lower soil depths (>45 cm) and maximum WUE over ratios of 0.4 and 0.6 (Arya and Sharma, 1990). In greengram, better water use and WUE were recorded by two irrigations given at vegetative and pod development stages (Pal and Jana, 1991). The lowest Cu was observed by irrigating greengram at critical growth stages (seedling, branching, flowering, post-flowering and pod development stages) and the maximum Cu was recorded by irrigating the crop at 50 mm CPE, whereas, the maximum WUE was recorded at 100 mm CPE and least at 50 mm CPE (Bachchhav et al., 1993). 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 200 mm CPE and lowest by unirrigated treatment, whereas, the maximum WUE was recorded by unirrigated plot and the lowest by irrigation at 300 mm CPE in greengram (Pannu and Singh, 1993).

For obtaining higher WUE under limited availability of water, blackgram should be irrigated at branching stage alone and at higher availability of moisture, irrigation may be given at flowering and pod development stages also (Pal et al., 1991). Sinha and Pal (1991) reported that in blackgram, WUE increased with number of irrigations and was maximum by irrigation at 0.7 atmosphere soil moisture tension and lowest in rainfed treatment. In blackgram, maximum Cu of water (455.6 mm) was recorded with 0.8 IW/CPE ratio. It was also noted that the crop utilised more moisture from upper layers (0-30 cm) than 30-60 cm at this ratio (Singh and Tripathi, 1992). Irrigating blackgram at an IW/CPE ratio of 0.6 resulted in higher WUE over 0.75 and 0.9 ratios (Vijayalakshmi and Aruna, 1994).

2.1.7 Effect of irrigation on nutrient composition and uptake

In cowpea, the highest uptake of 121.7 kg nitrogen, 11.2 kg phosphorus and 53.8 kg potassium ha^{-1} were recorded for irrigation applied at an IW/CPE ratio of 0.8 and was significantly superior to IW/CPE ratio of 0.4 (Singh and Tripathi, 1992). Subramanian et al. (1993) found that in cowpea, there was no significant difference due to irrigation on P content, but P uptake was maximum by scheduling irrigation at frequent intervals (0.8 IW/CPE ratio) over wider intervals (0.6 IW/CPE ratio). At very frequent intervals (1.0 ratio), there was reduction in P uptake by the crop.

Bains and Bharadwaj (1976) observed better growth and higher yields of blackgram receiving two irrigations at flowering and pod development stages which could be attributed to enhanced availability of nutrients. Rao et al. (1991) observed in blackgram 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 irigation and one irrigation at flowering or pod development stages. In greengram, the N uptake by seed and haulm was appreciably higher for irrigation scheduled at higher levels of CPE (100 mm CPE) over lower levels (50 and 75 mm CPE) (Bachchhav et al., 1993).

2.1.8 Effect of irrigation on quality

Fajeria and Bajpal (1971) recorded decreased protein content in beans when moisture stress was imposed during pod formation stage. However, Sionit and Kramer (1977) reported that irrigation had little effect on protein content of soybean. Pritoni et al. (1990) observed that withholding irrigation during pod filling stage reduced protein and oil yields in soybean. The seed protein content was significantly more when irrigation was scheduled at critical growth stages than 50 and 75 mm CPE in greengram (Bachchhav et al., 1993).

2.2. Effect of nitrogen

Nitrogen plays a key role for proper growth and development of all cultivated crops. It is important in protein synthesis in legumes. Cowpea, an important pulse crop of Kerala is found to respond to moderate application of nitrogen (Patel (1979) and Raj and Patel (1991). Even though it meets part of its nitrogen requirement through N fixation by Rhizobium, it requires a starter dose of N for their proper growth and development. Some of the works conducted in India and abroad on the influence of N on growth, yield, quality and nutrient uptake of vegetable cowpea are briefly reviewed here. Since published works on the response of this crop to nitrogen are meagre, it has become necessary to include works on similar legumes also in this review.

2.2.1. Effect of nitrogen on growth characters

In an experiment conducted at G.K.V.K., Bangalore on cowpea, Ramamurthy et al. (1990) found that application of 25 kg N ha^{-1} recorded the maximum leaf area.

Experiments conducted on a greengram cv. Pusa Baisakhi revealed that increasing the level of nitrogen from 0 to 60 kg ha^{-1} significantly increased the plant height from 27.6 cm to 30.4 cm and number of branches per plant from 3.5 to 4.0

respectively (Panda, 1972). However, according to Lenka and Satpathy (1976), application of 20 or 40 kg N ha^{-1} increased vegetative growth, height and number of branches per plant in redgram.

Hathcock (1975) reported that nitrogen levels from 0 to 24 kg ha^{-1} did not influence the fresh weight, dry weight and plant height in soybean. In a french bean cv. Arkakomal, an increase in N level upto 80 kg ha^{-1} increased LAI and CGR (Hegde and Srinivas, 1989).

2.2.2. Effect of nitrogen on yield attributing characters

Malik et al. (1972) found that application of 20 to 40 kg N ha^{-1} to cowpea had no effect on 100 seed weight. Experiments conducted at KAU by Kumar and Pillai (1979) recorded that 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. Patel (1979) observed that application of 20 kg N ha^{-1} to cowpea significantly influenced the yield attributes like number and weight of green pods per plant, whereas, 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 at GAU, Navsari, Raj and Patel (1991) concluded that application of 20 kg N ha^{-1} significantly improved the pod length and number of grains per pod.

Venugopal and Morachan (1974) observed in greengram that N at 20 and 30 kg ha^{-1} significantly increased the 1000 grain weight. Singh et al. (1975) obtained significant improvement in the number of pods per plant, number of grains per pod and 1000 grain weight in greengram by increased supply of N.

Panwar et al. (1977) observed an increase in the number of pods per plant by N application up to 15 kg ha^{-1}. Further increase in N level had no marked effect on any of the yield contributing characters in blackgram. However, 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 blackgram compared to 12.5 and 37.5 kg N ha^{-1} in blackgram.

2.2.3 Effect of nitrogen on yield

Malik et al. (1972) found that application of 20 to 40 kg N ha^{-1} to cowpea had no effect on yield. But Nangju (1976) recorded the 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 an experiment at Pattambi, Viswanathan et al. (1978)

observed that in cowpea, an increase in N level from 0 to 40 kg N ha^{-1} progressively increased the yield. Kumar and Pillai (1979) and Kumar et al. (1979) observed from an expt at Vellanikkara 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. Application of 25 kg N ha^{-1} produced significantly higher yield in cowpea (Ramamurthy et al., 1990, Gandhi et al., 1991). From a study on summer cowpea, Raj and Patel (1991) concluded that application of 20 kg N ha^{-1} recorded significantly higher grain yield over no nitrogen.

Increasing the level of nitrogen significantly increased the grain yield in greengram and the maximum yield was recorded with 60 kg N ha^{-1}. But from the economic point of view, most profitable level was 30 kg N ha^{-1} (Panda, 1972). Venugopal and Morachan (1974) observed that the different levels of nitrogen did not influence the yield in greengram. However, Singh et al. (1975) found that an increased application of nitrogen significantly increased the grain yield in greengram. The yield increased with an increase in nitrogen level upto 20 kg ha^{-1} and decreased with a further increase from 20 to 30 kg ha^{-1}, whereas, Bachchhav et al. (1993) noticed that application of 30 kg N ha^{-1} recorded significantly more seed and haulm yield in greengram.

According to Rajendran *et al*. (1974), N at 60 kg ha^{-1} was superior to control and 30 kg ha^{-1}, which were on a par for seed yield in blackgram. However, Sawhney *et al*. (1975) in a trial with blackgram found that N @ 17 and 34 kg ha^{-1} increased yield significantly over control and were on par. Panwar *et al*. (1977) observed that the optimum dose of N for blackgram was 15 kg ha^{-1}. But Khade *et al*. (1986) reported that the highest grain yield was obtained by the application of 25 kg N ha^{-1} compared to 12.5 kg and 37.5 kg ha^{-1} in blackgram.

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 (0-23 cm) was more and from the deeper layers was less without nitrogen application compared to 20 and 40 kg ha^{-1}. Application of 25 kg N ha^{-1} recorded the maximum consumptive use efficiency (CUE) in greengram compared to 12.5 kg and 37.5 kg N ha^{-1} (Khade *et al*., 1986).

The maximum values for Cu and CUE 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 greengram compared to control, 15 and 45 kg ha^{-1} (Bachchhav *et al*., 1993).

2.2.5 Effect of nitrogen on protein content

Malik *et al*. (1972) in a trial with cowpea showed that application of N with or without P had no effect on seed protein content. Similarly, Kurdikeri *et al*. (1973) also reported that application of N did not influence the protein content in cowpea.

Rajendran *et al*. (1974) observed that in blackgram, the crude protein content of seeds varied from 22.8 to 28.0 per cent with increasing level of N from 0 to 60 kg ha^{-1}. Bachchhav *et al*. (1993) observed a significant increase in protein content of seeds with an increase in N level from 0 to 45 kg ha^{-1} in greengram.

Singh (1970) noticed that in chickpea, application of 22.5 kg N ha^{-1} increased the protein content to 16.3 per cent compared to 14.73 per cent in the control plot. Arvadia and Patel (1987) could observe the maximum protein content and protein yield in chickpea by the application of 25 kg N ha^{-1} compared to control.

Singh *et al*. (1969) observed that protein content in grains increased progressively with an increase in level of N from 0 to 22 kg ha^{-1} in peas. Borcean *et al*. (1977) noted that the highest seed crude protein content of 28.2 per cent was obtained with 16 kg N ha^{-1} in peas.

2.3 Effect of phosphorus

The potential usefulness of P application to leguminous crops is unanimously accepted by many workers. Cowpea, being a pulse crop respond well to the application of phosphorus. P is very essential for nodulation, growth and development of reproductive phase, energy relations, protein synthesis etc. Experiments on vegetable cowpea in general revealed that the crop responded to levels from 30 to 50 kg P_2O_5 ha^{-1} (Sharma, 1977; Ramamurthy et al., 1990 and Gandhi et al., 1991). Some of the works conducted in India and abroad on the influence of P on growth, yield, quality and nutrient uptake of vegetable cowpea are reviewed here. However, literature on nutrient requirement of this crop is scanty. So, wherever sufficient information is lacking, relevant literature on similar pulse crops are also reviewed here.

2.3.1 Effect of phosphorus on growth characters

In cowpea, the highest leaf area was noticed by the application of 25 kg P_2O_5 ha^{-1} (Ramamurthy et al., 1990). The maximum plant height and branches per plant in summer blackgram were recorded by the application of 40 kg P_2O_5 ha^{-1} (Singh and Tripathi, 1992).

An increase in P level upto 60 kg ha^{-1} appreciably increased the plant height in greengram (Deshpande and Bathkal, 1965; Panda , 1972). However, Gill and Cheema (1976) reported that there was no response to added P with respect to vegetative growth and plant height in summer greengram.

Yadav et al. (1990) concluded from their experiment on pea that P application did not exert any significant influence on plant height and branches per plant. However, Yadav et al. (1993) observed that in pea, application of P significantly improved the leaf area per plant and LAI compared with control.

Dashora and Jain (1994) noticed that in soybean, LAI was increased by 9.4 and 16.2 per cent respectively over 40 and 20 kg P_2O_5 ha^{-1} by the application of 60 kg P_2O_5 ha^{-1}. Yadav et al. (1994) observed in chickpea that an increase in P level from 0 to 26.4 kg ha^{-1} increased the LAI from 2.58 to 3.02.

2.3.2 Effect of phosphorus on yield attributing characters

Subramanian et al. (1977) reported that application of 25 kg P_2O_5 ha^{-1} in cowpea exerted significant influence in increasing the number of pods per plant and number of grains per pod. In an experiment conducted at KAU on a cowpea cv. P.118, Kumar and Pillai (1979) found that application of P upto 40 kg P_2O_5 ha^{-1} profoundly influenced the number of pods per plant, number of seeds per pod and length of pods. Patel (1979) observed that application of 60 kg P ha^{-1} significantly influenced the number and weight of green pods per plant compared to control, 20 and 40 kg ha^{-1} in summer vegetable cowpea. Geetha Kumari and Kunju (1984) noticed that cowpea responded upto 50 kg P_2O_5 ha^{-1} and influenced all the yield contributing characters viz. number of pods per plant, seeds per pod and 100 grain weight. A further increase in dose upto 62.5 kg P_2O_5 ha^{-1} caused a reduction in all these yield attributes. However, Jain et al. (1986) noted that in cowpea, application of 40 kg P_2O_5 ha^{-1} recorded the maximum number of pods per plant and number of seeds per pod. Ramamurthy et al. (1990) observed that in cowpea, application of 50 kg P_2O_5 ha^{-1} recorded the maximum number of pods, pod weight per plant and seed yield per plant. Subramanian et al. (1993) noted that in cowpea, application of P had no significant influence on pod length and number of seeds per pod.

Deshpande and Bathkal (1965) pointed out that an increase in P level upto 60 kg P_2O_5 ha^{-1} significantly increased the number and weight of pods per plant in greengram. Panda (1972) observed that length of pods and weight of seeds per plant increased with an increase in P level from 0 to 90 kg P_2O_5 ha^{-1} in greengram. Singh et al. (1975) also noted that increasing the P_2O_5 rate from 0 to 60 kg P_2O_5 ha^{-1} favourably influenced the number of pods per plant, number of grains per pod and 100 grain weight in greengram.

2.3.3 Effect of phosphorus on yield

Sundaram et al. (1974) noticed in cowpea that application of P had no significant influence on green matter and dry matter yield. Addy (1975) also observed that application of P to cowpea in the wet season did not influence the seed yield. However, Nangju (1976) recorded the maximum grain yield by the application of 30 kg P_2O_5 ha^{-1} in cowpea, whereas, Viswanathan et al. (1978) obtained the highest grain yield in cowpea by the application of 40 kg P_2O_5 ha^{-1} which was on a par with 20 kg P_2O_5 ha^{-1}. Sharma (1977) reported that application of 30 kg P_2O_5 ha^{-1} to cowpea gave the highest grain yield, but it did not differ significantly with 60 kg P_2O_5 ha^{-1}. According to Subramanian et al. (1977), application of 25 kg P_2O_5 ha^{-1} recorded the maximum grain yield in cowpea and was on a par with 50 kg P_2O_5 ha^{-1}. Kumar and Pillai (1979) found that application of 40 kg P_2O_5 ha^{-1} recorded the maximum grain yield in cowpea. Patel (1979) observed that application of 60 kg P ha^{-1} significantly influenced the pod yield in summer vegetable cowpea compared to control, 20 and 40 kg ha^{-1}. Geethakumari and Kunju (1984) from their experiment on a grain cowpea cv. Kanakamony found that the grain yield increased linearly from 12.5 kg to 50 kg P_2O_5 ha^{-1}, but the yield decreased by further increasing the dose to 62.5 kg P_2O_5 ha^{-1}. Ramamurthy et al. (1990) observed in cowpea that the highest grain yield was recorded at 50 kg P_2O_5 ha^{-1}. Gandhi et al. (1991) also reported significantly higher yield was obtained when cowpea was fertilized with 50 kg P_2O_5 ha^{-1} and a higher dose of 75 kg P_2O_5 ha^{-1} could not produce any significant effect on yield. Raj and Patel (1991) reported the maximum grain yield in summer cowpea with 80 kg P_2O_5 ha^{-1}. But Subramanian et al. (1993) observed in cowpea that the maximum vegetable yield and DMP were recorded by the application of 100 kg P_2O_5 ha^{-1} which was on a par with 50 kg P_2O_5 ha^{-1}.

Moolani and Jana (1965) noted that on an acidic laterite soil, an yield increase of 34.5 percentage was obtained by the application of 100 kg P_2O_5 ha^{-1} over the control in greengram. Behl et al. (1969) noted that the grain yield increased progressively from 1140 to 1382 kg ha^{-1} with an increase in the rate of appllied P from 0 to 34 kg ha^{-1} in greengram. But a further increase in the rate of P upto 68 kg P_2O_5 ha^{-1} did not influence the yield. Panda (1972) found that in greengram, grain yield increased from 5.65 q ha^{-1} in control to 8.39 q ha^{-1} at 90 kg P_2O_5 ha^{-1}. Venugopal and Morachan (1974) noticed in greengram that P had significant influence on seed yield. P applied at 20 kg P_2O_5 ha^{-1} had given an yield increase of 83 kg ha^{-1} over the control. Singh et al. (1975) reported an yield increase of 51.7 per cent by an increase in rate of P from 0 to 60 kg P_2O_5 ha^{-1} in greengram. Agarwal et al. (1976) in trials with greengram reported that yield was increased from 0.77 t with 25 kg P_2O_5 ha^{-1} to 0.93 t with 50 kg P_2O_5 ha^{-1} and decreased thereafter with 75 kg P_2O_5 ha^{-1}, whereas, Kaul and Sekhon (1976) noted that application of P increased grain yield significantly in greengram, the increase being significant only upto 40 kg P_2O_5 ha^{-1} and did not further increased with 60-80 kg P_2O_5 ha^{-1}.

Thakur and Negi (1985) reported an increase in grain yield in blackgram with P application upto 60 kg P_2O_5 ha^{-1}, whereas, Singh and Tripathi (1992) could obtain the maximum grain yield and dry matter yield by the application at 40 kg P_2O_5 ha^{-1} in blackgram.

Experiments on cowpea in general revealed that the crop responded upto 30 to 50 kg P_2O_5 ha^{-1}. However, in some cases it responded even upto a higher level of 60 kg P_2O_5 ha^{-1}. The study related to P response on vegetable cowpea indicated a requirement of a much higher level of 100 kg P_2O_5 ha^{-1}. In other crops also, an increased level of P up to 125 kg P_2O_5 ha^{-1} favourably influenced the yield.

2.3.4 Effect of phosphorus on moisture-extraction pattern (MEP), consumptive use (Cu) and water-use efficiency (WUE)

Ahlawat et al. (1979) noticed that an increase in P application increased the Cu of water and WUE in cowpea. Subramanian et al. (1993) also reported that P application increased the WUE in vegetable cowpea in both kharif and summer season.

Chandrasekharaiah et al. (1986) observed in chickpea that P levels either at 50 kg or 100 kg P_2O_5 ha^{-1} had no marked influence on MEP. Siag et al. (1990) in an experiment with chickpea noticed that P application had favourable effect on Cu and WUE of the crop. Maximum Cu of water (187.5 mm) and WUE (14.29 kg ha^{-1} mm^{-1}) were reported with 60 kg P_2O_5 ha^{-1}. Prabhakar and Saraf (1991) also observed that P fertilization resulted in higher soil moisture depletion in chickpea. Yadav et al. (1994) noticed that in chickpea, the plant made more efficient use of water with an increase in P rate from 8.8 to 26.4 kg ha^{-1}.

2.3.5 Effect of phosphorus on protein content

Malik et al. (1972) noticed that P application had no effect on seed protein content in cowpea. However, Ravankar and Badhe (1975) reported that application of 120 kg P_2O_5 ha^{-1} in blackgram increased the protein content of seeds. Singh and Tripathi (1992) observed that application of 60 kg P_2O_5 ha^{-1} increased the crude protein content from 20.31 per cent in control to 24.11 per cent in blackgram.

Kesavan and Morachan (1973) observed that in soybean, protein content increased with an increase in the rate of applied P upto 150 kg P_2O_5 ha^{-1}. However, Ravankar and Badhe (1975) in an experiment with greengram and soybean observed that the protein content increased only upto 80 kg P_2O_5 ha^{-1}.

An increase in protein content was observed in groundnut also by the application of P upto 90 kg P_2O_5 ha^{-1} (Kumar and Venkatachari (1971), 67.2 kg P_2O_5 ha^{-1} (Bhuiya and Chowdhury (1974) and 100 kg P_2O_5 ha^{-1} (Punnoose and George (1974) and Saini and Tripathi (1975).

2.4. Uptake studies

2.4.1 Uptake of nitrogen

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. In an experiment with greengram, 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}. Bachchhav et al. (1993) noticed in greengram 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}.

Singh and Jain (1968) reported that plant nitrogen content increased significantly by the application of P to cowpea upto 60 kg P_2O_5 ha^{-1}, but increased only slightly with a further increase in dose of P to 100.5 kg P_2O_5 ha^{-1}. However, in a pot culture study, Kadwe and Badhe (1973) observed that in blackgram, application of 50 kg P_2O_5 ha^{-1} with 1-2 kg Mo ha^{-1} appreciably increased the plant uptake of nitrogen. Singh and Tripathi (1992) noticed that P application accelerated the uptake of N significantly upto 40 kg P_2O_5 ha^{-1} in blackgram.

2.4.2 Uptake of phosphorus

Singh and Jain (1968) noticed that plant P content increased markedly in cowpea with an increase in the rate of applied P upto 67 kg P_2O_5 ha^{-1}. But Sharma et al. (1974) noticed that application of 50 kg P_2O_5 ha^{-1} increased the plant uptake of P. The maximum P uptake in cowpea was observed with the application of 20 kg N ha^{-1} and 40 kg P_2O_5 ha^{-1} (Kumar et al. 1979). In a grain cowpea cv. Kanakamony, Geetha Kumari and Kunju (1984) observed that the uptake of P was positively influenced by P application. Subramanian et al. (1993) also observed that P uptake increased upto 100 kg P_2O_5 ha^{-1} in vegetable cowpea which was on a par with 50 kg P_2O_5 ha^{-1}, but significantly superior to control.

Rajendran et al. (1974) noticed that in blackgram, the total P content of grains was significantly influenced by P levels and at 90 kg P_2O_5 ha^{-1}, maximum P content was observed. Badanur et al. (1976) in trials with blackgram on red sandy loam soils reported that application of 1 t of lime and 96 kg P_2O_5 ha^{-1} increased the P uptake. However, Singh and Tripathi (1992) reported that in blackgram, P application upto 40 kg P_2O_5 ha^{-1} accelerated the uptake of P.

2.4.3 Uptake of potassium

Kumar et al. (1979) observed that application of 20 kg N ha^{-1} to cowpea recorded the highest uptake of K. But it was also noted that application of P did not exert any influence on K uptake in grain cowpea.

Kadwe and Badhe (1973) in a pot culture study with blackgram observed that application of 50 kg P_2O_5 ha^{-1} with 1-2 kg Mo ha^{-1} increased plant uptake of K. Singh and Tripathi (1992) reported that P application upto 40 kg P_2O_5 ha^{-1} increased the uptake of K in blackgram.

Walker (1973) observed that K content of groundnut was unaffected by rate of P application. Deshpande (1974) also noticed that the per cent of K in various plant parts of groundnut at harvest was not influenced by P fertilization. However, Dashora and Jain (1994) noticed that application of 60 kg P_2O_5 ha^{-1} increased the K uptake by 54.7 per cent over the control in soybean.

2.5 Combined effect of nitrogen and phosphorus on growth and yield

Ezedinma (1965) found that plant height and number of leaves per plant of cowpea were increased by 20 kg N ha^{-1} and 40 kg P_2O_5 ha^{-1}. But Malik et al.(1972) observed that application of 20 kg N + 60 kg P_2O_5 ha^{-1} produced the highest yield of 1350 kg ha^{-} in cowpea, whereas, Kurdikeri et al. (1973) from field trials with cowpea concluded that the highest yield of 1580 kg ha^{-1} was noticed with 11 kg N + 44 kg P_2O_5 ha^{-1}. In an experiment conducted at RRS, Pattambi, Viswanathan et al. (1978) found that the optimum doses of nutrients for maximum grain yield of cowpea were 31.6 kg N and 37.67 kg P_2O_5 ha^{-1}. Kumar and Pillai (1979) observed that the treatment combination of 20 kg N and 40 kg P_2O_5 ha^{-1} recorded the maximum number of pods per plant, number of seeds per pod, grain yield and grain-haulm ratio in cowpea. Patel (1979) reported from an experiment at GAU that the treatment combination of 20:60 kg NP ha^{-1} gave the highest green pod yield which was 18.66, 10.05 and 2.93 per cent higher than 20:0, 20:20 and 20:40 kg NP ha^{-1} respectively in summer vegetable cowpea. Singh (1991) reported that in a cowpea cv. Pusa Barsathi, a combination of 50 kg N + 75 kg P_2O_5 ha^{-1} recorded the maximum pod yield followed by a combination of 75 kg N +50 kg P_2O_5 ha^{-1}.

Venugopal and Morachan (1974) reported that in greengram, the treatment combination of 30+20, 20+60 and 30+40 kg N and P_2O_5 ha^{-1} respectively gave significantly higher seed yield per hectare than the combination of 30+60 kg N and P_2O_5 ha^{-1} and control and were on a par with each other. It was also noted that the treatment combination of 30+20 kg N and P_2O_5 ha^{-1} was the most economical. However, Reddy (1986) observed in greengram that the treatment combination of 15 kg N + 100 kg P_2O_5 ha^{-1} gave significantly higher yield and maximum N uptake which was on a par with the combination of 15 kg N + 50 kg P_2O_5 ha^{-1}.

Rajagopalan *et al*. (1970) reported that application of 2 t of compost in combination with 20 kg P_2O_5 and 10 kg N ha^{-1} gave increased yield over control in blackgram, whereas, Singh (1976) observed that a treatment combination of 30 kg N + 40 kg P_2O_5 ha^{-1} recorded the highest grain yield in greengram.

MATERIALS AND METHODS

MATERIALS AND METHODS

The present investigation was carried out to study the effect of phenophased irrigation on vegetable cowpea under graded doses of nitrogen and phosphorus. The field experiment was conducted during the summer season of 1993. The materials used and the methods adopted for the study are briefly described below:

3.1 MATERIALS

3.1.1 Experimental site:

The field experiment was conducted in the summer rice fallows at the Instructional Farm attached to the College of Agriculture, Vellayani. The location is situated at $8.5^{O}N$ latitude and $76.9^{O}E$ longitude at an altitude of 29 meter above the mean sea level.

3.1.2 Soil

The soil of the experimental site was sandy clay loam in texture. The important physical and chemical properties of the soil are summarised in Table 3.1.

3.1.3 Cropping history of the field

A continous bulk rice crop under uniform package of practices was cultivated during the previous two seasons.

Table 3.1 Physical and chemical properties of soil

A. Mechanical composition

Constituent	Content in soil (per cent)	Method used
Coarse sand	13.80	Bouyoucos Hydrometer method (Bouyoucos, 1962)
Fine sand	33.50	
Silt	28.00	
Clay	24.00	

Textural class - Sandy clay loam

B. Important physical constants of soil

Particulars	Depth of soil layer (0-45cm)			Method used
	0-15	15-30	30-45	
Field capacity (per cent)	22.5	20.0	24.0	Core sampler method (Dastane, 1967)
Bulk density (gcc^{-3})	1.30	1.33	1.35	(Dakshinamurthy and Gupta, 1968)

C. Chemical composition before the experiment

Constituent	Content in soil	Rating	Method used
Available nitrogen ($kg\ ha^{-1}$)	420	Medium	Alkaline - Potassium permanganate method (Subbiah and Asija, 1956)
Available P_2O_5 ($kg\ ha^{-1}$)	40	High	Bray Colorimetric method (Jackson, 1973)
Available K_2O ($kg\ ha^{-1}$)	187	Medium	Ammonium acetate method (Jackson, 1973)
pH	4.6	Acidic	pH meter with glass electrode (Jackson, 1973)

3.1.4 Season

The crop was raised during the summer season of 1993 (March to June).

3.1.5 Weather conditions

The weekly averages of temperatures, evaporation, relative humidity and weekly totals of rainfall during the cropping period were collected from the Agrometeorological observatory attached to the College of Agriculture, Vellayani and the data are given in Table 3.2 and Fig 1.

3.1.6 Cowpea variety

The vegetable cowpea cv. Malika was selected for the study. It was evolved from the College of Agriculture, Vellayani and found suitable for the summer rice fallows. The particulars of the variety are given in Table 3.3.

3.1.7 Source of seed material

The seeds for the experiment were obtained from the Instructional Farm, College of Agricutlture, Vellayani.

3.1.8 Manures and fertilizers

Well decomposed and dried farm yard manure (FYM) obtained from the Instructional Farm was used in the study. Urea (46 per cent N), single super phosphate (16 per cent P_2O_5) and

Table 3.2 Weather data during the cropping period

Period	Standard week	Maximum temp. (°C)	Minimum temp. (°C)	Rainfall (mm) (weekly total)	Evaporation (mm)	Relative humidity (per cent)
1993	12	32.3	23.7	36.3	4.6	74.6
	13	32.2	24.0	8.0	4.9	75.7
	14	31.9	24.6	12.7	4.5	81.6
	15	32.3	24.4	--	4.8	81.6
	16	32.7	24.6	12.5	5.0	81.7
	17	33.2	25.1	6.4	5.0	83.5
	18	33.3	25.8	47.4	4.3	84.6
	19	32.9	25.9	51.0	4.1	86.7
	20	32.2	25.0	1.40	4.4	78.8
	21	31.6	24.0	74.4	3.8	83.7
	22	30.3	24.1	121.3	2.9	85.1
	23	28.7	23.2	207.8	2.8	87.6
	24	30.0	24.2	41.8	2.8	85.7
	25	30.5	25.1	29.0	3.9	84.2
	26	29.8	23.7	93.5	2.9	88.2

Fig.1. Weather data during the cropping period

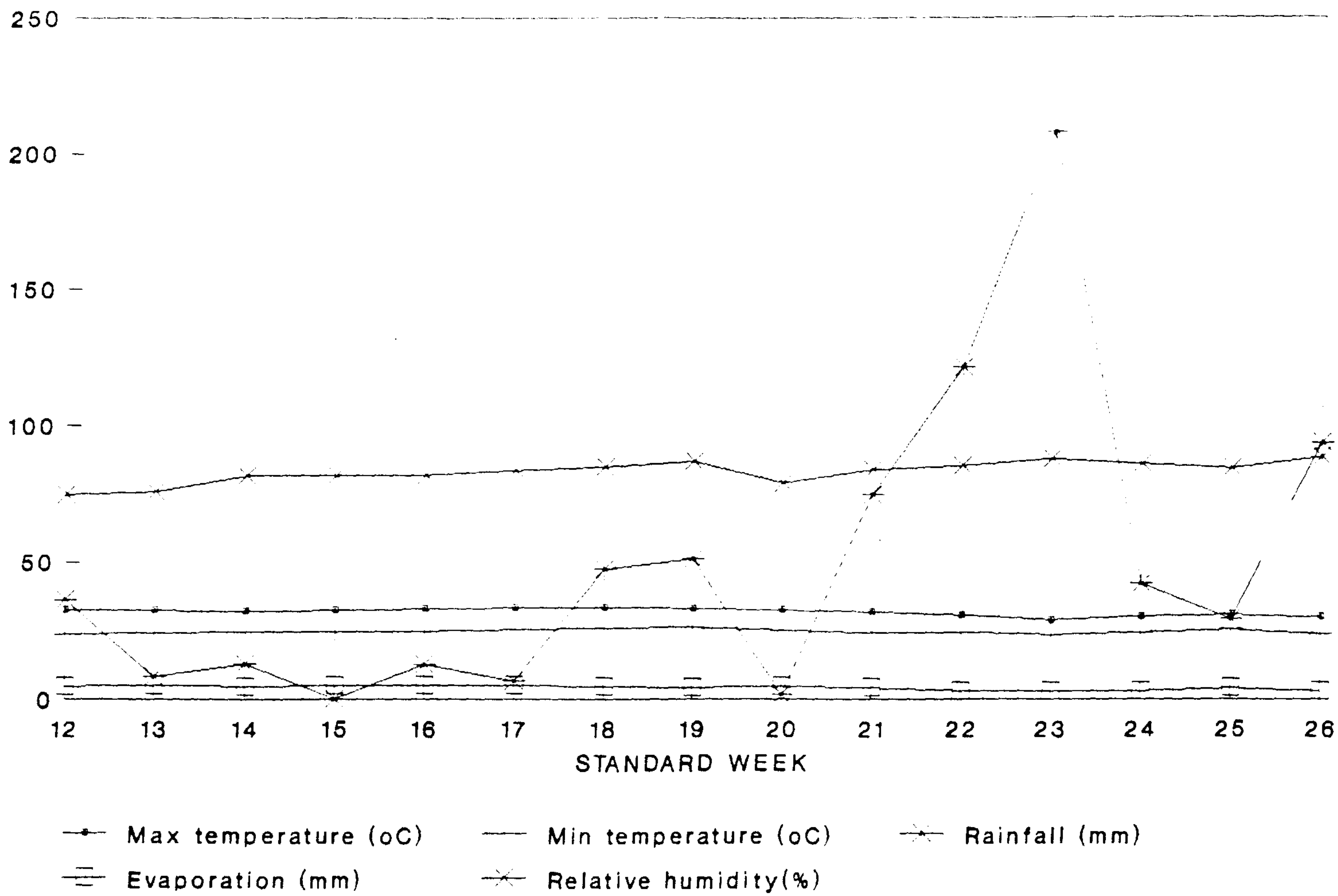


Table 3.3 Particulars of vegetable cowpea cv. Malika

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 attachement to peduncle	: Pendent
Immature pod colour	: Light green
Dry pod colour	: Straw
Seed shape	: Kidney - shaped
Seed colour	: Brown coloured with a white speck of irregular shape at one end.
Days to 50 per cent flowering	: 45 to 50
Number of pods per plant	: 36.9
Length of pod	: 43.5 cm
Number of seeds per pod	: 17.1
Weight of 100 seeds	: 16.1 g.
Productivity	: 9.8 t ha^{-1}
Duration	: 100 days

Muriate of potash (60 per cent K_2O) were used as the sources of nitrogen (N), phosphorus (P) and potassium (K) respectively.

3.2 METHODS

3.2.1 Details of the experiment

3.2.1.1 Design and layout

The field experiment was laid out in Factorial Randomised Block design (RBD) with a combination of five irrigation and three combinations of N and P replicated thrice. The layout of the experiment is presented in Fig. 2.

3.2.1.2 Treatment details

Treatment combinations (15) - Combination of five irrigation treatments (I) and three combinations of N and P.

Irrigation treatments

I_1 - Irrigating the crop at 75 per cent of field capacity (-0.03 MPa) throughout the crop growth.

I_2 - Irrigating the crop at 50 per cent field capacity during 0-33 days and irrigating at 75 per cent of field capacity (-0.03 Mpa) during the remaining period of crop growth.

I_3 - Irrigating the crop at 50 per cent of field capacity during 34-66 days and irrigating the crop at 75 per cent of field capacity. (-0.03 Mpa) during the early phase (0-33 days) and remaining period of the crop growth (67-100 days).

Fig.2. LAYOUT PLAN

Design - Factorial RBD

Treatments - 15

Replication	-	3	Irrigation (5)	-	I_1, I_2, I_3, I_4 and I_5
Gross plot size	-	4 m x 3.6 m			
Net plot size	-	2 m x 2.4 m	NP ratio (3)	-	F_1, F_2 and F_3
Border row	-	1			

I_3F_3	I_5F_2	I_1F_1
I_5F_3	I_4F_3	I_2F_2
I_2F_3	I_2F_1	I_1F_2
I_4F_2	I_1F_3	I_3F_2
I_4F_1	I_5F_1	I_3F_1

REPLICATION - 1

I_4F_1	I_5F_3	I_5F_1
I_1F_1	I_4F_3	I_1F_2
I_2F_3	I_1F_3	I_3F_1
I_4F_2	I_2F_1	I_3F_2
I_3F_3	I_5F_2	I_2F_2

REPLICATION - 2

I_4F_2	I_5F_3	I_4F_3
I_2F_3	I_5F_2	I_2F_2
I_1F_2	I_3F_1	I_2F_1
I_4F_1	I_1F_1	I_3F_3
I_3F_2	I_5F_1	I_1F_3

REPLICATION - 3

I_4 - Irrigating the crop at 50 per cent of field capacity during 67-100 days, irrigating the crop at 75 per cent of field capacity (-0.03 MPa) during the early phase of the crop growth (0-66 days).

I_5 - Farmer's practice. (daily light irrigation at a depth of 1 cm).

Depth of irrigation for I_1 to I_4 - 3 cm.

N and P combinatiions (kg ha^{-1})

F_1 - 20:30 N and P_2O_5 (Package of Practices Recommendations, KAU, 1992).

F_2 - 30:45 N and P_2O_5

F_3 - 40:60 N and P_2O_5

Total number of plots	- 45
Spacing	- 100 x 60 cm
Gross plot size	- 4 m x 3.6 m
Net plot size	- 2 m x 2.4 m
Number of plants per plot	- 24

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 laid out into blocks and plots.

3.3.2 Manures and fertilizers

Farm yard manure (FYM) at the rate of 20 t ha^{-1} was applied uniformly to all the plots and mixed well with the top soil. N and P were applied to the plots in the form of urea and single super phosphate respectively. A uniform dose of potash (K) at the rate of 10 kg ha^{-1} was applied basally along with entire quantity of P and 50 per cent of N. The remaining quantity of N was applied as top dressing at 20 days after sowing (DAS).

3.3.3 Sowing

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

3.3.4 After cultivation

Gap filling and thinning were done 5 DAS. The plants were trailed on the standards. Regular weeding operations were done by hand weeding to keep the plots weed free for the entire cropping period. Earthing up was also done after top dressing of N.

3.3.5 Irrigation

The differential irrigations according to the treatments were started one week after sowing. Soil samples were taken periodically from each plot and moisture content was calculated by gravimetric method and whenever the moisture content was depleted 25 or 50 per cent , measured quantity of irrigation water was given to the plots according to the treatments, at 3 cm depth in treatments I_1 to I_4. In the I_5 treatment (farmer's practice), pot watering was done daily to a depth of 1 cm. Details of irrigation are given in Table 3.4.

3.3.6 Plant protection

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. Soil drenching with Thiride at 0.2 per cent was also done as a preventive measure against Rhizoctonia rot.

3.3.7 Harvesting

First picking of green pods was done at 53 DAS. Subsequent harvests were made on alternate days uniformly from all the treatments upto 100 DAS.

3.4 BIOMETRIC OBSERVATIONS

3.4.1 Height of the plant

The height of the plant was recorded from five randomly selected observational plants at five stages of growth viz. 30th, 45th, 60th, 75th and 90th DAS. The height was measured from the

Table 3.4 Details of irrigation given

Sl No.	I_1	I_2	I_3	I_4	I_5
1.	13-4-93	25-4-93	13-4-93	13-4-93	
2.	23-4-93	2-5-93	23-4-93	23-4-93	
3.	2-5-93	20-5-93		2-5-93	Daily irrigation
4.	20-5-93			20-5-93	
Total number of irrigations	4	3	2	4	38
Quantity of water applied (mm)	120	90	60	120	380
Effective rainfall received (mm)	155.5	155.5	184.9	155.5	155.5
Total quantity of water received (mm)	275.5	245.5	244.9	275.5	535.5

ground level to the top-most leaf bud of all observational plants, mean values were computed and expressed in centimetre.

3.4.2 Number of branches per plant

Simultaneously with observations on the height of the plants, number of branches per plant were also counted and the mean number of branches worked out for each plant at 30th, 45th and 60th DAS.

3.4.3 Number of leaves per plant

Total number of leaves in each observational plant were counted and the mean leaves per plant at five stages of growth viz., 30th, 45th, 60th, 75th and 90th DAS were recorded.

3.4.4 Leaf Area Index (LAI)

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

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

3.4.5 Dry Matter Production per plant (DMP)

Dry matter production was recorded during five growth stages. viz. 30^{th}, 45^{th}, 60^{th}, 75^{th} and 90^{th} DAS. One plant was uprooted from the destructive row at each stage carefully without damaging the roots and separated into plant parts viz. leaves, stem and roots. These were dried under shade separately and then dried in the oven at 80$\pm$5^{o}C till two consecutive weights coincided. The final weights were totalled and expressed in gram per plant (g plant^{-1}).

3.4.6 Crop Growth Rate (CGR)

CGR during the growth period was calculated as per the equation by Hunt (1978) and expressed in mg^{-2} day^{-1}.

$$CGR = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{1}{p}$$

where W_2 and W_1 are DMP at time t_2 and t_1 respectively and p is the ground area.

3.4.7 Days for 50 per cent flowering

Days taken by 50 per cent of plants for emergence of flowers in each treatment were noted and recorded.

3.4.8 Number of pods per plant

The number of pods harvested from the five observation plants were counted and average worked out.

3.4.9 Length of the pod

Length of pods harvested from the five observation plants was measured and the average was worked out and expressed in centimetre.

3.4.10 Number of seeds per pod

Number of seeds per pod harvested from the five observation plants were counted and average worked out.

3.4.11 Pod yield in kg ha^{-1}

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

3.4.12 Haulm yield

Weight of haulm from each plot was recorded and expressed in kilogram per hectare.

3.5 Moisture studies

3.5.1 Moisture depletion pattern

The average relative soil moisture depletion from each soil layer in the root zone was worked out for each irrigation interval. The total loss from each layer was determined on percentage basis at the end of the cropping period.

3.5.2 Water-use efficiency (WUE)

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

3.5.3 Yield response factor (Doorenbos and Kassam, 1986)

Yield response factor was calculated by using the relationship.

$$\left(1 - \frac{Ya}{ym}\right) = Ky \left(1 - \frac{ET_a}{ET_m}\right)$$

Ya - Actual harvested yield

Ym - Maximum harvested yield

Ky - Yield response factor

ETa- Actual evapo-transpiration

ETm- Maximum evapo-transpiration

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, available P_2O_5 and available K_2O contents. Available N content was determined by alkaline potassium permanganate method (Subbiah and Asija, 1956). Available P_2O_5 content was estimated by Bray colorimetric method

(Jackson, 1973) and available potash by ammonium acetate method (Jackson, 1973).

3.6.2 Plant analysis

The plant samples were analysed for N, P and K at three stages of crop growth viz. 30th, 60th and 90th DAS. The samples were chopped and dried in an air oven at $80 \pm 5^{o}C$ 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 a physical balance and used for chemical analysis. Analysis of fruits was carried out with composite samples collected from different harvests.

3.6.2.1 Uptake studies

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

3.6.2.2 Crude protein content of pods

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

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:-

Net income(Rs ha^{-1}) = Gross income - Total cost of cultivation

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

3.8 Statistical analysis

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

RESULTS

RESULTS

A field experiment was conducted at Instructional Farm attached to the College of Agriculture, Vellayani during the summer season of 1993 to study the influence of phenophased irrigation on vegetable cowpea cv. Malika under graded doses of nitrogen and phosphorus. The results of the experiment are presented below:

4.1 Growth characters

Plant growth as influenced by irrigation and NP ratios was measured as plant height, number of leaves and number of branches at fortnightly intervals from 30 DAS.

4.1.1 Plant height

Data on plant height as influenced by irrigation and NP ratios are given in Table 4.1 and Table 4.1.1.

In general, plant height increased progressively upto 90 DAS. The treatments did not give any marked difference in plant height upto 30 DAS. Thereafter, the plant height was significantly influenced by irrigation, NP ratios and their interaction.

The irrigation treatments at I_1 and I_5 profoundly increased the plant height over other treatments and the response from I_1 and I_5 were found to be the same. This trend

Table 4.1 Effect of irrigation and NP ratios on plant height (cm)

Treatments	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
Irrigation					
I_1	100.7	187.2	248.9	299.6	364.6
I_2	92.8	169.6	235.4	295.2	358.7
I_3	90.3	141.6	207.9	268.6	323.2
I_4	102.3	168.0	233.3	289.7	347.6
I_5	111.3	187.8	251.2	307.7	369.8
$F_{(4,28)}$	1.77^{ns}	35.68^{**}	17.62^{**}	37.14^{**}	34.57^{**}
SE	-	3.15	4.12	2.42	3.14
CD (0.05)	-	9.1	11.9	7.0	9.0
NP ratios					
F_1	104.1	175.9	240.3	296.7	356.8
F_2	94.3	156.9	221.9	279.6	338.7
F_3	100.0	179.7	243.8	300.2	368.9
$F_{(2,28)}$	1.04^{ns}	25.11^{**}	13.68^{**}	34.56^{**}	26.90^{**}
SE	-	2.44	3.19	1.87	2.43
CD (0.05)	-	7.0	9.2	5.4	7.0

Table 4.1.1 Interaction effect of irrigation and NP ratios on plant height (cm)

Treatments	45 DAS	60 DAS	75 DAS	90 DAS
I_1F_1	178.5	247.0	294.0	357.8
I_1F_2	162.7	222.0	289.0	354.8
I_1F_3	220.2	277.7	315.9	381.1
I_2F_1	184.0	260.1	316.1	383.4
I_2F_2	144.1	202.9	269.7	325.4
I_2F_3	180.7	243.1	299.8	367.4
I_3F_1	142.3	201.8	268.4	319.9
I_3F_2	130.9	197.3	247.3	300.7
I_3F_3	151.5	224.5	289.9	349.1
I_4F_1	152.5	208.8	274.5	330.9
I_4F_2	168.1	237.8	286.5	343.4
I_4F_3	183.3	253.2	308.2	368.5
I_5F_1	222.2	283.7	330.5	391.9
I_5F_2	178.3	249.3	305.5	368.9
I_5F_3	162.7	220.6	287.1	348.5
$F_{(8, 28)}$	16.06^{**}	13.11^{**}	19.55^{**}	14.73^{**}
SE	5.46	7.13	4.19	5.44
CD (0.05)	15.8	20.6	12.1	15.7

was noticed upto 90 DAS. A significant reduction in plant height was observed in I_3.

The NP ratios at F_1 and F_3 showed no significant variation in plant height and these ratios resulted in an enhanced plant height and was significantly superior to F_2. This trend was noticed upto 75 DAS. However, at 90 DAS, the plant height was significantly high with F_3 in comparison with F_1.

The interaction effect between I and F was also significant. A significant increase in plant height was observed with I_1F_3 and I_4F_3 combinations in comparison with other interactions and I_1F_3 was markedly superior to I_4F_3. But with farmer's practice (I_5), maximum plant height was observed with F_1 ratio (I_5F_1) which was on a par with I_1F_3 and this trend was observed at 60, 75 and 90 DAS.

4.1.2 Number of branches per plant

The influence of the different irrigation treatments and NP ratios on the number of branches per plant from 30 DAS to 60 DAS are presented in Table 4.2.

In general, the number of branches per plant increased progressively upto 60 DAS. No significant variation in the number of branches per plant was observed upto 45 DAS, while, at 60 DAS, a significant reduction in the number of branches

Table 4.2 Effect of irrigation and NP ratios on number of branches per plant

Treatments	30 DAS	45 DAS	60 DAS
Irrigation			
I_1	2.6	3.8	5.2
I_2	2.2	3.6	5.2
I_3	2.5	3.4	4.7
I_4	3.1	4.1	5.5
I_5	2.7	4.0	5.2
$F_{(4,28)}$	1.83^{ns}	1.64^{ns}	2.91^{*}
SE	-	-	0.17
CD (0.05)	-	-	0.48
NP ratios			
F_1	2.7	3.9	5.2
F_2	2.5	3.5	5.0
F_3	2.7	3.9	5.3
$F_{(2,28)}$	0.31^{ns}	1.48^{ns}	1.86^{ns}
CD (0.05)	-	-	-

per plant was noticed with I_3, the other irrigation treatments resulting in the same response.

The NP ratios and its interaction with irrigation did not produce any significant difference in the number of branches per plant during the entire period of crop growth.

4.1.3 Number of leaves per plant

Data on number of leaves per plant as influenced by irrigation and NP ratios are presented in Table 4.3.

Generally, the number of leaves increased progressively upto 60 DAS and the rate of increase declined at 75 DAS. Thereafter, a reduction in the number of leaves per plant was observed.

The irrigation treatments significantly increased the number of leaves per plant during all the growth stages. The I_4 treatment produced the highest number of leaves per plant and it was minimum with I_2. It has also been noted that I_4 was significantly superior to other treatments which were on a par with each other during the initial period. But from 60 DAS, I_4 was on a par with I_1.

The NP ratios and its interaction with irrigation levels did not exert any influence on the production of leaves per plant.

Table 4.3 Effect of irrigation and NP ratios on number of leaves per plant

Treatments	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
<u>Irrigation</u>					
I_1	13.0	32.4	71.2	77.2	65.9
I_2	12.0	30.8	69.0	75.2	63.3
I_3	12.6	31.7	69.7	75.9	64.1
I_4	16.6	35.5	73.6	79.6	67.8
I_5	13.5	32.4	70.5	76.7	65.0
$F_{(4,28)}$	3.00^*	3.63^*	3.43^*	3.17^*	3.73^*
SE	1.05	0.93	0.95	0.94	0.91
CD (0.05)	3.0	2.6	2.7	2.7	2.6
<u>NP ratios</u>					
F_1	14.1	33.0	71.3	77.3	65.7
F_2	13.3	32.5	70.5	76.7	65.0
F_3	13.2	32.2	70.6	76.8	65.0
$F_{(2,28)}$	0.39^{ns}	0.36^{ns}	0.31^{ns}	0.19^{ns}	0.26^{ns}
CD (0.05)	-	-	-	-	-

4.1.4 Leaf Area Index (LAI)

Data on LAI recorded at different growth stages are presented in Table 4.4.

In general, LAI attained the maximum values at 60 DAS and declined thereafter upto 90 DAS.

From the table, it is clear that the irrigation treatments significantly influenced the LAI at all the growth stages. I_1 recorded the highest LAI at all the growth stages followed by I_4 and was superior to other treatments. The lowest LAI was recorded in I_3 at all the growth stages.

The maximum LAI was recorded in F_2 followed by F_3 and F_1 at all stages of growth studied.

The interaction effect between irrigation and NP ratios did not exert any appreciable influence on the LAI at any of the growth stages.

4.1.5 Days for 50 per cent flowering

The mean number of days taken for 50 per cent flowering are given in Table 4.5.

The irrigation treatments significantly influenced the days for 50 per cent flowering. The days taken for 50 per cent flowering was minimum in I_1 which was superior to other treatments except I_4. Delayed flowering was noticed in I_2 and I_3.

Table 4.4 Effect of irrigation and NP ratios on LAI

Treatments	30 DAS	60 DAS	90 DAS
Irrigation			
I_1	0.405	1.500	1.477
I_2	0.367	1.442	1.422
I_3	0.355	1.425	1.403
I_4	0.392	1.480	1.458
I_5	0.377	1.463	1.442
$F_{(4, 14)}$	33.40**	514.50**	213.02**
SE	0.003	0.001	0.002
CD (0.05)	0.010	0.004	0.006
NP ratios			
F_1	0.365	1.442	1.421
F_2	0.394	1.482	1.458
F_3	0.378	1.462	1.442
$F_{(2,14)}$	29.93**	386.47**	145.55**
SE	0.003	0.001	0.002
CD (0.05)	0.008	0.003	0.005

Table 4.5 Effect of irrigation and NP ratios on days for 50 per cent flowering

Treatments	NP ratios			
	F_1	F_2	F_3	Mean
<u>Irrigation</u>				
I_1	44.67	42.67	45.33	44.22
I_2	45.33	44.67	45.67	45.22
I_3	45.33	45.33	45.00	45.22
I_4	45.00	46.67	42.67	44.78
I_5	45.00	43.67	46.33	45.00
Mean	45.07	44.60	45.00	

$F_{(4, 28)}$ (I) - 4.50^{**} $F_{(2, 28)}$ (F) - 2.77^{ns} $F_{(8, 28)}$ (IF) - 16.73^{**}

SE - 0.196 SE - 0.340

CD (0.05) - 0.56 CD (0.05) - - CD (0.05) - 0.98

The NP levels had no influence on days for 50 per cent flowering. But early flowering was noticed in F_2 and it was maximum in F_1.

The interaction effect significantly influenced the days for 50 per cent flowering. None of the irrigation treatments produced significant difference in days for 50 per cent flowering with F_1 ratio. But with F_2 ratio, it was noticed that I_4 took more days for 50 per cent flowering which was significantly high in comparison with other irrigation treatments and minimum number of days was taken by I_1. But, when F_3 was combined with irrigation treatments, early flowering was observed with I_4 and it was maximum with I_5 and no significant difference was observed with I_1, I_2 and I_3.

4.1.6 Total dry matter production (DMP)

The data on total DMP at different growth stages are presented in Table 4.6 and Table 4.6.1.

In general, total DMP increased progressively upto 90 DAS with the maximum rate of increase from 45-60 DAS.

The data clearly showed that irrigation had a significant influence on the total DMP at all the growth stages. The maximum DMP was recorded in I_1 followed by I_4 and was superior to all other irrigation treatments. The least DMP was noticed in I_3 at all the growth stages.

Table 4.6 Effect of irrigation and NP ratios on total DMP ($kg\ ha^{-1}$)

Treatments	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
Irrigation					
I_1	187.8	1183.7	2373.0	3456.81	4451.2
I_2	166.0	1069.3	2171.5	3079.0	3900.8
I_3	153.1	1047.8	2097.4	2989.8	3790.8
I_4	183.0	1128.0	2292.1	3319.8	4269.9
I_5	176.7	1099.9	2231.7	3221.2	4124.6
$F_{(4,14)}$	86.92**	740.86**	213.70**	150.21**	63.81**
SE	1.49	1.95	7.28	15.19	33.58
CD (0.05)	4.5	5.9	22.0	46.0	101.8
NP ratios					
F_1	166.4	1038.5	2143.6	3053.4	3895.8
F_2	180.2	1161.4	2334.2	3352.7	4277.2
F_3	173.4	1117.4	2221.7	3233.9	4149.3
$F_{(2,14)}$	35.73**	1697.33**	288.81**	164.07**	55.69**
SE	1.16	1.51	5.64	11.77	26.01
CD (0.05)	3.5	4.5	17.1	35.7	78.9

Table 4.6.1 Interaction effect of irrigation and NP ratios on total DMP (kg ha^{-1})

Treatments	45 DAS	60 DAS
I_1F_1	1086.5	2257.7
I_1F_2	1280.1	2515.0
I_1F_3	1184.5	2346.3
I_2F_1	1016.1	2096.1
I_2F_2	1110.3	2244.4
I_2F_3	1081.6	2173.9
I_3F_1	996.2	2028.9
I_3F_2	1083.0	2183.7
I_3F_3	1064.3	2079.7
I_4F_1	1055.4	2191.4
I_4F_2	1182.4	2402.3
I_4F_3	1146.1	2282.6
I_5F_1	1038.1	2144.0
I_5F_2	1151.1	2325.3
I_5F_3	1110.5	2225.9
$F_{(8, 14)}$	42.57^{**}	3.73^{*}
SE	3.38	12.60
CD (0.05)	10.2	38.2

The NP ratios also appreciably influenced the DMP at all the growth stages. F_2 registered the maximum DMP followed by F_3.

The interaction effect between irrigation levels and NP ratios was significant only at 45 and 60 DAS. The rate of change in total DMP with respect to various irrigation treatments under each NP ratio was not similar.

4.1.7 Crop Growth Rate (CGR)

The influence of irrigation and NP ratios on CGR are given in Table 4.7 and Table 4.7.1.

Generally, CGR increased upto 60 DAS and showed a declining trend thereafter upto 90 DAS.

It is seen from the table that irrigation exerted a profound influence on the CGR. I_1 registered the maximum CGR followed by I_4. The lowest value was recorded in I_3. I_1 was superior to other treatments at all growth stages except at 75-90 DAS. At 75-90 DAS, I_1 and I_4 were on a par with each other.

The NP ratios also significantly influenced the CGR at all the growth stages. F_2 registered the maximum CGR at all the growth stages and was superior to F_1 and F_3 except at 75-90 DAS. At 75-90 DAS, F_2 and F_3 were on a par with each other. At 45-60 DAS, F_1 and F_3 were on a par with each other.

Table 4.7 Effect of irrigation and NP ratios on CGR (mg^{-2} day^{-1})

Treatments	30-45 DAS	45-60 DAS	60-75 DAS	75-90 DAS
Irrigation				
I_1	0.663	0.792	0.722	0.662
I_2	0.605	0.733	0.602	0.550
I_3	0.597	0.702	0.577	0.505
I_4	0.632	0.775	0.685	0.633
I_5	0.617	0.753	0.655	0.602
$F_{(4,14)}$	166.45**	57.91**	124.71**	39.17**
SE	0.002	0.005	0.005	0.010
CD (0.05)	0.006	0.014	0.016	0.031
NP ratios				
F_1	0.582	0.737	0.604	0.562
F_2	0.656	0.781	0.677	0.616
F_3	0.630	0.735	0.663	0.593
$F_{(2,14)}$	566.81**	52.40**	88.63**	12.00**
SE	0.002	0.004	0.004	0.008
CD (0.05)	0.005	0.011	0.012	0.024

Table 4.7.1 Interaction effect of irrigation and NP ratios on CGR (mg^{-2} day^{-1})

Treatments	30-45 DAS	60-75 DAS
I_1F_1	0.600	0.710
I_1F_2	0.725	0.735
I_1F_3	0.665	0.720
I_2F_1	0.575	0.530
I_2F_2	0.630	0.640
I_2F_3	0.610	0.635
I_3F_1	0.565	0.500
I_3F_2	0.615	0.625
I_3F_3	0.610	0.605
I_4F_1	0.590	0.660
I_4F_2	0.665	0.705
I_4F_3	0.640	0.690
I_5F_1	0.580	0.620
I_5F_2	0.645	0.680
I_5F_3	0.625	0.665
$F_{(8, 14)}$	19.35^{**}	7.44^{**}
SE	0.004	0.009
CD (0.05)	0.011	0.028

The interaction effect between irrigation and NP ratios was significant only at 30-45 and 60-75 DAS. I_1F_2 registered the highest CGR at all the growth stages and was superior to all other treatments. With F_1 ratio, no significant difference between I_4 and I_5 and I_2 and I_3 was noticed at 30-45 DAS. But at 60-75 DAS, CGR showed a contradictory effect with F_2 ratio. Here no significant difference in CGR was detected with I_2 and I_3 and also with I_4 and I_5.

4.2 Yield and yield attributes

4.2.1 Number of pods per plant

The data on mean number of pods per plant are presented in Table 4.8.

Irrigation remarkably increased the number of pods per plant. I_1 gave a significant increase in the number of pods per plant than other irrigation treatments. I_1 gave a 21.63 per cent increase in number of pods per plant over I_3. The other irrigation treatments also recorded a marked variation in the number of pods per plant in the order of I_4, I_5, I_2 and I_3.

The NP ratios also appreciably influenced the pod production. F_2 showed a significant increase in the number of pods per plant over F_3 and F_1. F_1 recorded the least number of pods per plant. F_2 showed a 6.76 per cent and a 3.85 per cent increase in the number of pods per plant over F_1 and F_3 respectively.

Table 4.8 Effect of irrigation and NP ratios on yield attributes

Treatments	Number of pods per plant	Length of the pods (cm)	Number of seeds per pod
<u>Irrigation</u>			
I_1	47.8	31.9	16.9
I_2	42.6	29.5	14.9
I_3	39.3	28.9	14.3
I_4	46.6	31.5	16.2
I_5	45.2	30.4	15.5
$F_{(4,28)}$	243.25**	333.03**	496.89**
SE	0.22	0.07	0.05
CD (0.05)	0.6	0.2	0.1
<u>NP ratios</u>			
F_1	42.9	29.8	14.9
F_2	45.8	31.1	16.3
F_3	44.1	30.3	15.5
$F_{(2,28)}$	73.14**	143.62**	395.00**
SE	0.17	0.05	0.04
CD (0.05)	0.4	0.1	0.1

The interaction effect between irrigation and NP ratios was not significant with regard to the number of pods per plant.

4.2.2 Length of the pods

The data on mean length of pods revealed the significant influence of irrigation (Table 4.8). The mean length of the pods was higher in I_1 than I_2, I_3, I_4 and I_5 and was superior to other treatments. In I_3, the length of the pods was drastically reduced as compared to other irrigation treatments.

The length of the pods was also significantly influenced by NP ratios. Among the three combinations tried, F_2 gave lengthy pods than the other two combinations. F_2 produced 4.36 per cent and a 2.64 per cent increase in the length of the pods over F_1 and F_3 respectively.

There was no significant variation in pod length due to the interaction effect between irrigation and NP ratios.

4.2.3 Number of seeds per pod

The data on mean number of seeds per pod are presented in Table 4.8.

The effect of irrigation on number of seeds per pod was significant. The maximum number of seeds per pod was noticed in I_1 and was superior to other treatments. I_4 also gave an increase in number of seeds per pod over other irrigation treatments and the minimum number of seeds per pod was observed in I_3.

The NP ratios also profoundly influenced the number of seeds per pod. Like other yield attributing characters, F_2 showed an increase in number of seeds per pod over F_3 and F_1. F_2 recorded a 9.40 per cent and a 5.16 per cent increase in the number of seeds per pod over F_1 and F_3 respectively.

The interaction effect due to irrigation and NP ratios was not significant with respect to the number of seeds per pod.

4.2.4 Green pod yield

The data pertaining to green pod yield are presented in Table 4.9.

The different irrigation treatments did not produce any variation in marketable green pod yield.

The NP ratios significantly influenced the green pod yield. The maximum pod yield of 4429.5 kg ha^{-1} was obtained in F_2, but was on a par with F_3. The F_3 ratio also showed a positive response over F_1. F_2 ratio recorded a 6.36 per cent increase in green pod yield over F_1.

The interaction effect due to irrigation and NP ratios with respect to green pod yield was not significant.

4.2.5 Haulm yield

The data on haulm yield in kg ha^{-1} are presented in Table 4.9.

Table 4.9 Effect of irrigation and NP ratios on yield of pod and haulm (kg ha^{-1})

Treatments	Pod yield	Haulm yield
Irrigation		
I_1	4374.2	16834
I_2	4304.2	16194
I_3	4279.1	15983
I_4	4329.1	16583
I_5	4305.4	16390
$F_{(4,28)}$	1.07^{ns}	35.38^{**}
SE	-	55.64
CD (0.05)	-	161.1
NP ratios		
F_1	4164.6	15989
F_2	4429.5	16855
F_3	4361.2	16347
$F_{(2,28)}$	26.28^{**}	102.05^{**}
SE	26.83	43.10
CD (0.05)	77.7	124.8

Unlike pod yield, irrigation showed a significant influence on haulm yield. I_1 registered the maximum haulm yield followed by I_4 and was significantly superior to other treatments. The lowest haulm yield was recorded in I_3.

The NP ratios also markedly influenced the haulm yield. F_2 gave a significant increase in haulm yield over F_3 and F_1.

The interaction due to irrigation and NP ratios was not significant with regard to haulm yield.

4.3 Nutrient uptake

4.3.1 Uptake of nitrogen by the plant

The data on N uptake at 30th, 60th and 90th DAS are presented in Table 4.10 and Table 4.10.1.

Irrigation treatments profoundly influenced the N uptake at all the growth stages. I_1 registered the maximum uptake followed by I_4 and was significantly superior to other irrigation treatments. The lowest uptake was recorded in I_3 at all the growth stages.

The NP ratios also remarkably influenced the N uptake at all stages of growth. The maximum uptake was noticed in F_2 which was followed by F_3 and F_1.

Interaction effect on the uptake of N at different growth stages was also significant. It was observed that

Table 4.10 Effect of irrigation and NP ratios on uptake of nitrogen by the crop (kg ha^{-1})

Treatments	30 DAS	60 DAS	90 DAS
<u>Irrigation</u>			
I_1	13.42	54.59	51.00
I_2	13.15	38.46	34.57
I_3	12.24	33.85	30.64
I_4	13.35	48.58	44.30
I_5	13.28	43.10	37.28
$F_{(4, 14)}$	1263.39**	1065.29**	948.87**
SE	0.01	0.25	0.26
CD (0.05)	0.04	0.76	0.80
<u>NP ratios</u>			
F_1	12.89	39.58	36.34
F_2	13.29	47.82	42.90
F_3	13.09	43.74	39.43
$F_{(2,14)}$	369.25**	451.79**	259.61**
SE	0.01	0.19	0.20
CD (0.05)	0.03	0.59	0.62

Table 4.10.1 Interaction effect of irrigation and NP ratios on uptake of nitrogen (kg ha^{-1})

Treatments	30 DAS	60 DAS	90 DAS
I_1F_1	13.3	50.8	48.3
I_1F_2	13.6	58.1	53.8
I_1F_3	13.4	54.9	50.8
I_2F_1	12.9	33.4	30.4
I_2F_2	13.3	42.9	38.3
I_2F_3	13.2	39.1	35.0
I_3F_1	11.8	31.5	27.9
I_3F_2	12.6	37.4	33.9
I_3F_3	12.3	32.6	30.1
I_4F_1	13.2	43.2	39.9
I_4F_2	13.5	52.4	48.4
I_4F_3	13.3	50.1	44.6
I_5F_1	13.1	39.0	35.2
I_5F_2	13.4	48.2	40.1
I_5F_3	13.3	42.0	36.6
$F_{(8, 14)}$	26.09**	8.69**	3.79**
SE	0.024	0.43	0.46
CD (0.05)	0.07	1.32	1.38

whatever be the irrigation treatment. F_2 recorded the maximum uptake of N. Though the trend of response of I within F_1 and F_2 remained more or less similar, under F_3, no significant difference in N uptake was shown by I_4 and I_5 at 30th DAS. It has also been noted that the rate of change in N uptake with respect to various irrigation treatments under each NP ratio was not similar during all the growth stages.

4.3.2 Uptake of phosphorus by the plant

The data on P uptake at 30th, 60th and 90th DAS are presented in Table 4.11.

Irrigation significantly influenced the P uptake at all the growth stages. The highest P uptake was noticed in I_1 followed by I_4 and was significantly superior to other treatments at all the growth stages. The least P uptake was recorded in I_3.

The NP ratios also exerted a marked influence on P uptake at all the growth stages. Like the uptake of N, F_2 registered the maximum P uptake and was superior over F_3 and F_1.

The interaction effect due to irrigation and NP ratios was not significant at all the growth stages.

4.3.3 Uptake of potassium by the plant

The data on K uptake at 30th, 60th and 90th DAS are given in Table 4.12 and Table 4.12.1.

Table 4.11 Effect of irrigation and NP ratios on uptake of phosphorus by the crop (kg ha^{-1})

Treatments	30 DAS	60 DAS	90 DAS
Irrigation			
I_1	3.21	46.82	34.11
I_2	2.63	37.23	20.37
I_3	2.50	34.11	16.35
I_4	2.85	42.37	29.37
I_5	2.72	39.98	24.27
$F_{(4, 14)}$	223.27**	531.07**	118.24**
SE	0.02	0.21	0.65
CD (0.05)	0.06	0.64	1.97
NP ratios			
F_1	2.69	37.34	21.08
F_2	2.87	43.05	29.41
F_3	2.78	39.91	24.19
$F_{(2, 14)}$	41.52**	306.32**	70.25**
SE	0.01	0.16	0.50
CD (0.05)	0.04	0.50	1.52

Table 4.12 Effect of irrigation and NP ratios on uptake of potassium by the crop (kg ha^{-1})

Treatments	30 DAS	60 DAS	90 DAS
Irrigation			
I_1	12.86	213.85	200.75
I_2	8.44	190.51	172.34
I_3	7.87	182.44	165.11
I_4	11.33	207.05	192.29
I_5	9.65	199.69	181.85
$F_{(4, 14)}$	657.74**	891.82**	195.40**
SE	0.08	0.42	1.03
CD (0.05)	0.24	1.28	3.14
NP ratios			
F_1	8.81	191.39	175.74
F_2	11.28	205.63	189.47
F_3	10.00	199.11	182.19
$F_{(2,14)}$	394.33**	478.29**	73.61**
SE	0.06	0.33	0.80
CD (0.05)	0.19	0.99	2.43

Table 4.12.1 Interaction effect of irrigation and NP ratios on uptake of potassium (kg ha^{-1})

Treatments	30 DAS	60 DAS
I_1F_1	11.1	206.5
I_1F_2	15.4	221.9
I_1F_3	12.1	213.2
I_2F_1	7.0	184.8
I_2F_2	9.8	195.6
I_2F_3	8.6	191.1
I_3F_1	7.5	177.2
I_3F_2	8.3	187.1
I_3F_3	7.9	183.1
I_4F_1	10.1	198.6
I_4F_2	12.2	214.9
I_4F_3	11.7	207.7
I_5F_1	8.3	189.8
I_5F_2	10.8	208.8
I_5F_3	9.8	200.5
F(8, 14)	28.72**	7.41**
SE	0.14	0.73
CD (0.05)	0.4	2.2

It is evident from the table that irrigation had a significant influence on the uptake of K at all the growth stages. The maximum K uptake was noticed in I_1 at all the growth stages and was superior to all other treatments. The lowest uptake was recorded in I_3 at all stages of growth studied.

The NP ratios also exerted a significant influence on K uptake. F_2 showed a significant increase in K uptake over F_3 and F_1. F_1 registered the least uptake at all stages of growth.

Interaction effect was also significant at all growth stages except at 90 DAS. The maximum uptake was recorded in I_1F_2 followed by I_4F_2 and was superior to all other treatments. I_2 recorded the minimum K uptake in combination with F_1. But with F_2 and F_3, I_3 registered the least uptake. All irrigation treatments in combination with F_2 recorded the maximum K uptake. No significant difference in K uptake was noticed with F_1 and F_3 under I_3 at 30th DAS. But at 60th DAS, I_3 recorded the minimum K uptake with all NP ratios. But the rate of change in K uptake with respect to various irrigation treatments under each NP ratio was not similar at all stages of growth.

4.4 Quality aspect

4.4.1 Protein content of pods

The data on protein content of pods expressed in percentage are given in Table 4.13.

Table 4.13 Effect of irrigation and NP ratios on protein content of pods (per cent)

Treatments	Protein content
Irrigation	
I_1	23.9
I_2	23.2
I_3	23.1
I_4	23.8
I_5	23.6
F (4, 14)	543.77**
SE	0.02
CD (0.05)	0.05
NP ratios	
F_1	23.4
F_2	23.7
F_3	23.5
F (2,14)	173.09**
SE	0.01
CD (0.05)	0.04

The protein content of pods was markedly influenced by irrigation. The maximum protein content of pods was recorded in I_1 and was superior to all other treatments. The other irrigation treatments also showed a remarkable variation in protein content in the order of I_4, I_5, I_2 and I_3.

The NP ratios also appreciably influenced the protein content of pods. F_2 registered a significant increase in protein content over F_3 and F_1. The lowest protein content was noticed in F_1.

Interaction effect due to irrigation and NP ratios did not exert any appreciable influence on the protein content.

4.5 Moisture studies

4.5.1 Water-use efficiency (WUE)

The data on WUE expressed in kg ha^{-1} mm^{-1} are presented in Table 4.14.

It is evident from the table that irrigation treatments profoundly influenced the WUE. The highest WUE was recorded in I_2 and was on a par with I_3, but significantly superior I_1 and I_4 which inturn were on a par. A marked reduction in WUE was noticed in I_5. I_2 recorded a 118 per cent increase in WUE over I_5 (farmer's practice).

Table 4.14 Effect of irrigation and NP ratios on water use efficiency (WUE)

Treatments	WUE ($kg\ ha^{-1}\ mm^{-1}$)
Irrigation	
I_1	15.88
I_2	17.53
I_3	17.47
I_4	15.71
I_5	8.04
F (4, 28)	851.87**
SE	0.14
CD (0.05)	0.39
NP ratios	
F_1	14.41
F_2	15.32
F_3	15.05
F (2,28)	19.70**
SE	0.10
CD (0.05)	0.30

The NP ratios also appreciably influenced the WUE. The maximum WUE was noticed in F_2 and was on a par with F_3, but superior to F_1.

The interaction effect due to irrigation and NP ratios had no effect on WUE.

4.5.2 Moisture-extraction pattern (MEP)

Moisture extraction pattern from different soil layers are presented in Table 4.15. It was not statistically analysed.

The results revealed that the 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. On an average, 67.29, 23.05 and 9.66 per cent of moisture is extracted from 0-15, 15-30 and 30-45 cm soil depth respectively.

There was appreciable variation in the MEP due to NP ratios also. The results showed that the per cent depletion of moisture decreased from 0-15 cm soil depth with an increase in ratio from F_1 to F_3 and increased from 15-45 cm soil depth with higher ratios.

4.5.3 Yield response factor (Ky)

The Ky factor of the irrigation treatments are presented in Table 4.16. The Ky was vitiated due to the frequent

Table 4.15 Effect of irrigation and NP ratios on moisture extraction pattern (MEP)

Treatments	Soil depth (cm) 0-15	15-30	30-45
<u>Irrigation</u>			
I_1	72.00	18.40	9.60
I_2	62.27	27.00	10.73
I_3	60.70	27.87	11.43
I_4	66.60	23.37	10.03
I_5	74.87	18.60	6.53
<u>NP ratios</u>			
F_1	70.14	22.04	7.82
F_2	68.24	22.98	8.78
F_3	63.48	24.12	12.40

Table 4.16 Yield response factor (Ky) as influenced by irrigation

Treatments	Total water applied: Irrigation (mm)	Total water applied: Effective rain fall (mm)	Total (mm)	Yield (kg ha^{-1})	$1 - \frac{ETa}{ETm}$	$1 - \frac{Ya}{Ym}$	Ky
I_2	90	155.5	245.5	4304.2	0.109	0.016	0.147
I_3	60	184.9	244.9	4279.1	0.111	0.022	0.198
I_1	120	155.5	275.5	4374.2	-	-	-
I_4	120	155.5	275.5	4329.1	-	-	-
I_5	380	155.5	535.5	4305.4	-	-	-

Table 4. 17 Effect of irrigation and NP ratios on soil nutrient status after the experiment

Treatments	Available N content ($kg\ ha^{-1}$)	Available P_2O_5 content ($kg\ ha^{-1}$)	Available K_2O content ($kg\ ha^{-1}$)
Irrigation			
I_1	528.2	44.0	74.0
I_2	629.2	49.0	78.6
I_3	647.3	51.6	81.2
I_4	573.8	45.7	75.4
I_5	602.5	47.1	76.5
F (4, 14)	801.45**	213.32**	415.20**
SE	1.66	0.20	0.14
CD (0.05)	5.0	0.6	0.4
NP ratios			
F_1	625.0	50.9	80.5
F_2	568.4	44.6	72.4
F_3	595.3	47.0	78.5
F (2,14)	483.45**	406.76**	1549.68**
SE	1.29	0.16	0.11
CD (0.05)	3.9	0.4	0.3

Table 4.17.1 Interaction effect of irrigation and NP ratios on available potassium content of the soil after the experiment (kg ha^{-1})

Treatments	NP ratios			
	F_1	F_2	F_3	Mean
<u>Irrigation</u>				
I_1	76.7	69.4	76.0	74.0
I_2	82.3	73.9	79.5	78.6
I_3	85.3	76.4	81.9	81.2
I_4	78.4	70.9	77.1	75.4
I_5	79.8	71.6	78.2	76.5
Mean	80.5	72.4	78.5	
$F_{(8, 14)}$	5.71**			
SE	0.239			
CD (0.05)	0.7			

4.7 Economics of cultivation

Economics of different treatments presented in Table 4.18 indicated that net returns and BCR increased with an increase in the frequency of irrigation even though irrigation effect was not significant on the net returns and BCR. I_1 recorded the maximum values followed by I_4, I_5, I_2 and I_3.

Among the NP ratios tried, the highest value for net returns and BCR were recorded in F_2 and was superior to other treatments. But F_1 and F_3 were on a par with each other.

Interaction effect due to irrigation and NP ratios on net returns and BCR was not significant.

Table 4. 18 Effect of irrigation and NP ratios on economics of cultivation

Treatments	Net returns (Rs ha^{-1})	Benefit-cost ratio
<u>Irrigation</u>		
I_1	2317.15	1.15
I_2	2037.14	1.13
I_3	1936.61	1.13
I_4	2136.83	1.14
I_5	2041.97	1.14
$F_{(4,\ 28)}$	1.07^{ns}	0.97^{ns}
CD (0.05)	-	-
<u>NP ratios</u>		
F_1	1846.77	1.12
F_2	2538.22	1.17
F_3	1896.83	1.12
$F_{(2,\ 28)}$	12.91^{**}	13.18^{**}
SE	107.3	0.007
CD (0.05)	310.9	0.02

DISCUSSION

DISCUSSION

Results obtained from the investigation to study the effect of phenophased irrigation on vegetable cowpea under graded doses of nitrogen (N) and phosphorus (P) presented in Chapter IV are discussed under the following sections:

5.1 Growth characters

In general, plant height increased progressively upto 90 DAS. The irrigation treatments did not give any marked variation in plant height upto 30 DAS. Thereafter, it was significantly influenced by irrigation treatments.

Among the various irrigation treatments tested, I_1 and I_5 remarkably increased the plant height over other treatments and they were on a par with each other.

The number of leaves were also increased progressively upto 60 DAS and the rate of increase declined at 75 DAS. Thereafter, a reduction in the number of leaves was noticed. The irrigation treatments markedly increased the number of leaves per plant during all the growth stages. I_4 produced the highest number of leaves per plant, which was on a par with I_1 at 60th, 75th and 90th DAS.

The increased plant height and number of leaves in the frequently irrigated treatments might be due to uniform moisture supply. The increased growth of plants was due to increased soil moisture availability which in turn increased the turgidity of cells favouring cell enlargement and cell division. But low available soil moisture adversely affected the above processes and retarded growth (Begg and Turner, 1976). The reduction in the rate of leaf initiation and cell division might have caused the production of lesser number of leaves under water stress. 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. An enhancement in plant height and number of leaves due to irrigation at higher ASM in the rootzone was reported by Singh and Lamba (1971) in cowpea. Similar increase in plant height in cowpea due to irrigation at 75 per cent ASM over 50 per cent and 25 per cent ASM was reported by Ahlawat et al. (1979). Increased plant height due to frequent irrigation was noticed in other pulse crops also viz. redgram, greengram, blackgram and peas by Ishii (1969), Ali and Alam (1973), Ramshe and Surve (1984), Yadav et al. (1990) and Singh and Tripathi (1992).

In general, the number of branches per plant increased progressively upto 60 DAS. No significant variation in the number of branches per plant was observed upto 45th DAS, while at 60th DAS, a significant reduction in the number of branches per plant was noticed with I_3.

The NP ratios also exerted a profound influence on plant height from 45th DAS onwards. The trend continued upto the final stages of the crop growth. The F_3 treatment recorded taller plants than F_2 and F_1 at 90th DAS. The increase in plant height might be due to the increased supply of N and P in F_3. The enhanced supply of N promoted the vegetative growth in different crops (Tisdale et al., 1985). In green gram also, an increase in N supply resulted in an increase in plant height (Savithri, 1980). Unlike plant height, NP ratios did not influence the production of leaves and branches of the crop. This finding is in confirmity with the results obtained by Rao and Rajan (1960) in groundnut and Shukla (1964) in chickpea.

The interaction effect due to irrigation and NP ratios significantly influenced the plant height at all stages of crop growth, except upto 30th DAS. A significant increase in plant height was observed with I_1F_3 and I_4F_3 in comparison with other interactions and I_1F_3 was significantly superior over I_4F_3. But with farmer's practice, maximum plant height was observed with F_1 ratio which was on a par with I_1F_3 and this trend was observed at 60th, 75th and 90th DAS. But the interaction effect was non-significant with respect to the production of leaves and branches.

5.2 Days for 50 per cent flowering

The irrigation treatments significantly influenced the days for 50 per cent flowering. Early flowering was noticed in

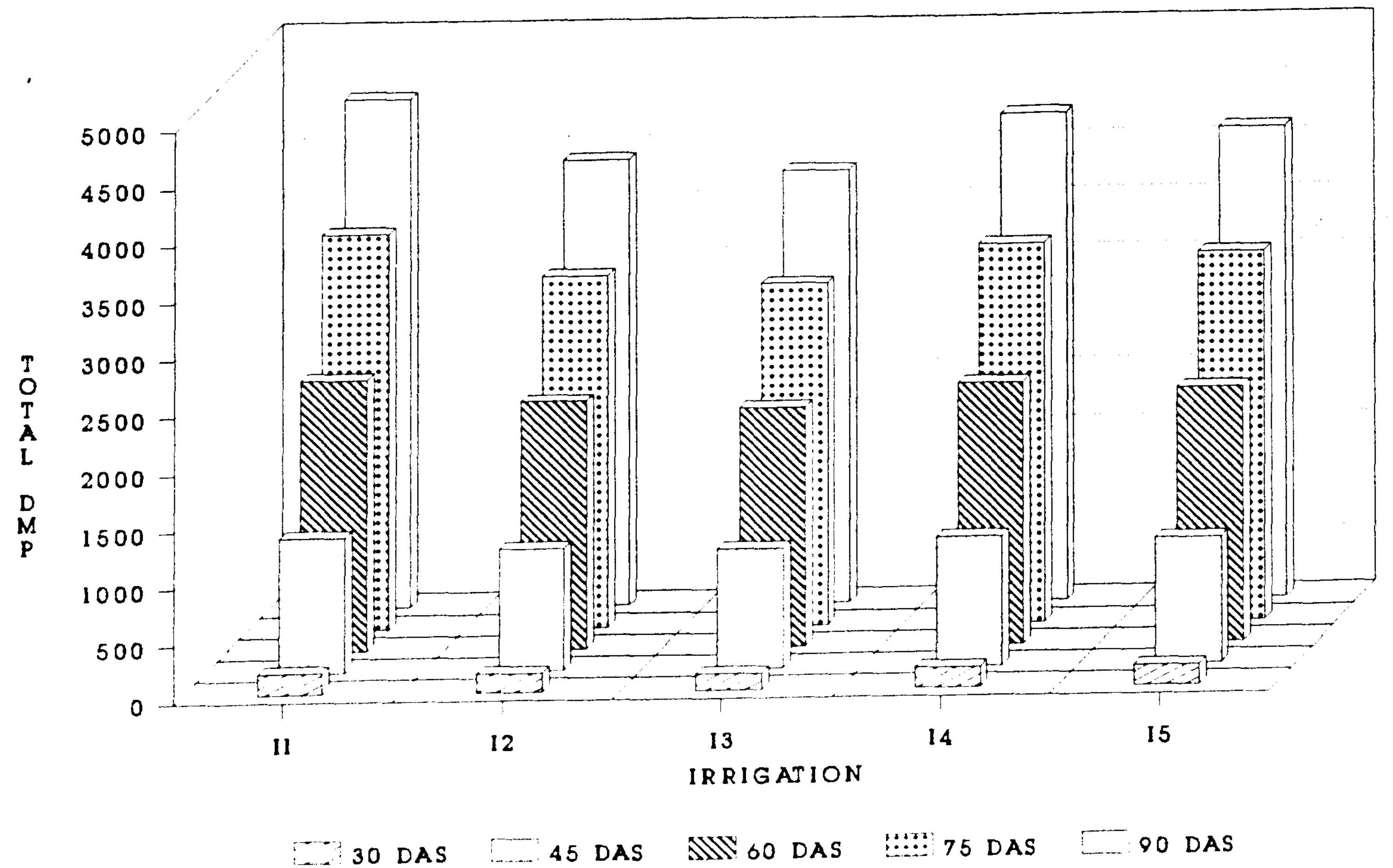
I_1 and I_4 and a significant difference was noticed in I_2 and I_3. Stress during early vegetative stage and flowering period in I_2 and I_3 might have resulted in delayed flowering in these two treatments. Hiler et al. (1972) observed that flowering stage was the most susceptible stage to moisture stress for cowpea. Similar results were also reported in groundnut by Golakiya and Patel (1992). This might be due to the fact that soil moisture stress reduced the initiation and retention of floral buds (Ali and Alam, 1973).

The days for 50 per cent flowering was not influenced by NP ratios. The interaction effect between NP ratios and irrigation treatments significantly influenced the days for 50 per cent flowering. None of the irrigation treatments produced significant difference in days for 50 per cent flowering with F_1 ratio. With F_2 ratio, early flowering was noticed in I_1. But when F_3 ratio was combined with irrigation treatments, I_4 is required for early flowering. Because of frequent rainfall received during the later period of crop growth, I_1 and I_4 became more or less same treatments.

5.3 Total dry matter production (DMP)

In general total DMP increased progressively upto 90 DAS with the maximum rate of increase from 45-60 DAS. Irrigation profoundly influenced the DMP at all the growth stages. The

Fig.3. Effect of irrigation on total DMP at various growth stages (kg per hectare)



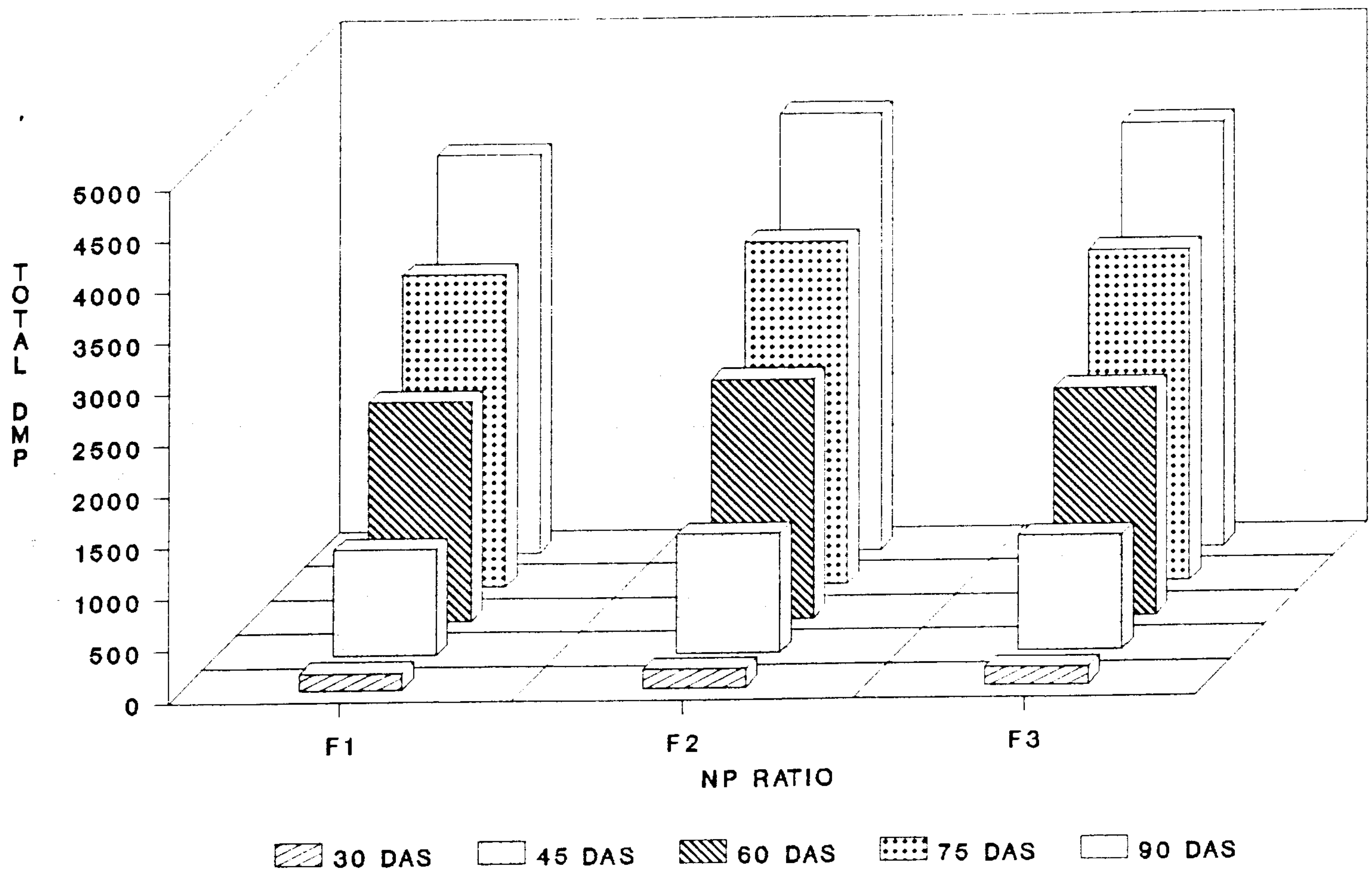
maximum DMP was noticed in I_1 followed by I_4 and was significantly superior to other irrigation treatments. The least DMP was recorded in I_3 at all the growth stages (Fig. 3). The increase in DMP noticed at enhanced levels of irrigation might be due to the better moisture availability, which helped the plants to absorb more nutrients from soil. The higher levels of irrigation might also have favourably influenced the cell elongation, turgidity and promoted various physiological processes including the uptake of nutrients, leading to improved plant growth (Murari, 1982). Efficient utilisation of nutrients in the frequently irrigated treatments (I_1 and I_4) as evident from Tables 4.10, 4.11 and 4.12 has increased the plant growth which is evident from the plant height, leaf production and LAI (Tables 4.1, 4.3 and 4.4) and thereby DMP. Similar trend of positive correlation between total DMP and uptake of N, P and K was reported by Savithri (1980) in greengram. More leaf area and leaf area duration to intercept more solar radiation usually help in increasing the rate of photosynthesis under good soil moisture conditions (Turner and Begg, 1981). But under moisture stress conditions, the size of the photosynthetic apparatus was also reduced due to reduction in LAI. The leaves are the actual sites of photosynthesis and the photosynthetic efficiency depends on size and thickness of leaves, number of leaves and their lifespan. The LAI is the best measure to study the ability of a crop to produce dry matter. Higher DMP due to frequent irrigation has been reported by Singh and Lamba (1971) and

Subramanian *et al.* (1993) in cowpea. Similar increase in DMP in frequently irrigated plots was also reported by Hegde and Srinivas (1989) in french bean, Singh and Tripathi (1992) in blackgram and Pannu and Singh (1993) in greengram.

The NP ratios had a marked influence on the total DMP at all the growth stages. The NP ratio at F_2 (30:45) recorded an appreciable increase in DMP over both lower and higher ratios (Fig. 4). This might be due to the increased LAI noticed in F_2 at all the growth stages. Nitrogen also helps in better assimilation resulting in higher DMP (Lal and Pundrik, 1971). Chandran (1987) also observed that application of N upto 30 kg ha^{-1} produced a significant influence on the total DMP in vegetable cowpea. Increased DMP with an increase in the rate of N have been reported by Brillin (1984) in winged bean and Saradhi *et al*. (1990) in groundnut. Increased DMP due to an increase in the level of P upto 45-50 kg P_2O_5 ha^{-1} was reported by Subramanian *et al*. (1993) in vegetable cowpea. A reduction in dry weight per plant beyond 50 kg P_2O_5 ha^{-1} was also reported by Kumar and Agarwal (1993) in lentil. This might be due to nutrient imbalance in soil-plant system.

The interaction effect between irrigation and NP ratios was significant only at 45th and 60th DAS. But the rate of change in DMP with respect to various irrigation treatments under each NP ratio was not similar during all the growth stages.

Fig.4. Effect of NP ratios on total DMP at various growth stages (kg per hectare)



5.4 Growth analysis

Growth analysis is an important aspect in studying the various interactions between plant growth and the environment. Growth analysis parameters viz. LAI and CGR were measured at fixed intervals to study the influence of treatments and their interaction on plant growth and the results are discussed below:

5.4.1 Leaf Area Index (LAI)

Generally, LAI attained the maximum values at 60 DAS and declined thereafter upto 90 DAS.

Irrigation treatments profoundly influenced the LAI at all the growth stages. I_1 recorded the highest LAI at all the growth stages followed by I_4 and was superior to other treatments. The lowest LAI was noticed in I_3 at all the growth stages. A reduction in leaf area due to moisture stress was reported by Ali and Alam (1973) in greengram, Manning et al. (1977) in peas, Henrique et al. (1978) in soybean and Kuhad et al. (1988) in chick pea. 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. Increased LAI was obtained in french bean by Hegde and Srinivas (1989) by irrigating the crop at the SMP of -45 KPa at 15 cm depth over -65 and -85 KPa. Enhanced LAI was also noticed in greengram 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 which was evident in I_3 level of irrigation.

The LAI was influenced by the NP ratios and the highest value was noticed in F_2 over F_3 and F_1. The result revealed that the dose 30:45 kg N and P_2O_5 ha^{-1} was optimum over higher and lower NP ratios. An increase in LAI at medium to higher levels of N was reported by Hegde and Srinivas (1989) in frenchbean. This might be due to the favourable influence of N on expansion of leaves which in turn increased the LAI. Russel (1973) noticed that extra protein produced as a result of increase in 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 bittergourd by Thomas (1984) and Rajan (1991) in amaranthus. Increased LAI at higher levels of P was also reported by Yadav et al. (1993) in pea and Dashora and Jain (1994) in soybean. The favourable influence of P on the production of leaves and leaf area might have resulted in increased LAI.

The interaction effect due to irrigation and NP ratios did not exert any appreciable influence on the LAI at any of the growth stages.

5.4.2 Crop Growth Rate (CGR)

The CGR increased upto 60 DAS and showed a declining trend thereafter upto 90 DAS.

Irrigation treatments remarkably influenced the CGR. The maximum CGR was registered in I_1 followed by I_4 and was superior to other irrigation treatments. The lowest CGR was noticed in I_3 at all the growth stages. The better CGR in I_1 and I_4 might be due to increased plant height, leaf production, LAI and DMP as evident from Tables 4.1, 4.3, 4.4 and 4.6. A restriction in irrigation may result in poor canopy development and reduced CGR through its adverse effects on various morphophysiological processes (Phogat et al., 1984a and b) and Sinclair et al. (1987). Water deficit can also influence partitioning of dry matter from vegetative parts to grain (Singh et al. 1988). Increased CGR was noticed in french bean by Hegde and Srinivas (1989) by irrigating the crop at the SMP of -45 KPa at 15 cm depth over -65 and -85 K Pa. Similar enhancement in CGR was also reported in greengram by irrigating the crop at 300 mm CPE over 400 mm CPE (Pannu and Singh, 1993).

The NP ratios significantly influenced the CGR at all the stages of observation. The maximum CGR was recorded in F_2 and was superior to F_1 and F_3 at all the growth stages except at 75-90 DAS. At 75-90 DAS, F_2 and F_3 were on a par with each other. The increase in CGR is a reflection of the increased LAI and DMP noticed at F_2 ratio. Enhanced CGR due to higher levels of N was reported by Hegde and Srinivas (1989) in french bean and Rao and Raikhelkar (1993) in sesamum. The beneficial effect of N and P application on CGR was also reported by Chakraborty et al. (1984) and Deshmukh (1988) in sesamum.

The interaction effect between irrigation levels and NP ratios was significant only at 30-45 and 60-75 DAS. With F_1 ratio, no significant difference betweeen I_4 and I_5 and I_2 and I_3 was noticed at 30-45 DAS. But at 60-75 DAS, no significant difference in CGR was detected with I_2 and I_3 and also with I_4 and I_5 with F_2 ratio.

5.5 Yield and yield attributes

5.5.1 Yield attributes

As the soil wetness increased, the yield attributes viz. number of pods per plant, length of the pods and number of seeds per pod were significantly increased. The maximum values for these yield attributes were noticed in I_1 followed by I_4 and was superior to other treatments. The increase in these yield attributes might be a reflection of better growth characters viz. plant height, leaf production, LAI, DMP and CGR (Tables 4.1, 4.3, 4.4, 4.6 and 4.7). Ahlawat et al. (1979) reported higher number of pods per plant in cowpea by irrigation at 75 per cent ASM at 0-30 cm soil depth over 50 and 25 per cent ASM. In summer vegetable cowpea, irrigation at 100-80 per cent of ASM favourably influenced the number and weight of green pods per plant over irrigation regimes of 100-60, 100-40 and 100-20 per cent of ASM

(Patel, 1979). Similar trend was also noticed in greengram by Khade et al. (1986). Increase in pod length due to frequent irrigation could be attributed to continuing cell division, progressive initiation of tissues and on the differentiation and enlargement of cells (Fischer, 1973). The results are in agreement with the finding of Thomas (1984) in bittergourd. The treatment subjected to a moisture stress at the flowering and pod development stages (I_3) recorded the lowest values for these yield attributes. According to Hiler et al. (1972), flowering stage was found to be the most susceptible stage to moisture stress in cowpea. Singh and Tripathi (1972) noticed that moisture stress during flower induction and flowering reduced pod and seed production in soybean. According to Kaufman (1972), water deficit induces retardation of floral primordia development, flower production, fruit set and induces flower and fruit abscission leading to decrease in fruit production. According to M'Ribu (1985), the pod development stage was the most critical stage for irrigation in french bean. A watering regime of 2 days interval during pod development stage produced maximum length of the pods.

The NP ratios also appreciably influenced the yield attributes viz. number of pods per plant, length of the pod and number of seeds per pod. The maximum values for these yield attributes were noticed in F_2, which was significantly superior to F_3 and F_1. The increase in yield attributes with N fertilization was due to the increased supply of photosynthates as well as a direct consequence of better growth characters like LAI, DMP and CGR (Tables 4.4, 4.6 and 4.7) and also better uptake of nutrients (Tables 4.10, 4.11 and 4.12). The present results are in agreement with the results obtained by Chandran (1987) who observed that application of 30 kg N ha^{-1} recorded the maximum number of pods per plant and number of seeds per pod in vegetable cowpea. It was reported that an increase in N supply significantly increased the number of pods per plant and number of grains per pod in greengram (Singh et al., 1975 and Khade et al., 1986). An adverse effect on yield attributes by the application of N beyond 30 kg N ha^{-1} was reported by Sarnaik et al. (1984) in winged bean. This is in corroboration with the present findings. An increase in P level also favourably influenced yield attributes. Kumar and Pillai (1979) and Jain et al. (1986) found that P application upto 40 kg P_2O_5 ha^{-1} profoundly influenced the number of pods per plant, number of seeds per pod and length of the pods in cowpea. However, according to Geethakumari and Kunju (1984) and Ramamurthy et al. (1990), application of 50 kg P_2O_5 ha^{-1} favourably influenced the yield attributes. Phosphorus, a major constituent of plant cell nucleus and growing root tips which helps in cell division and root elongation, might have helped the plant to absorb more plant nutrients from the deeper soil layers. Moreover, P might have also involved in the basic reaction of photosynthesis and this tended to increase the number of pods per plant, length of the pods and number of seeds per pod.

The interaction effect due to irrigation and NP ratios was not significant with regard to the yield attributes.

5.5.2 Green pod yield

The data on pod yield revealed that irrigation treatments did not influence the green pod yield. The reasons for the treatment differences in the pod yield being not significant could be attributed to the total amount of rainfall received and its distribution over the crop growth period during the season. The rainfall amounting to 513.3 mm with 30 rainy days was received during the harvest period of one and a half months. The frequent rainfall received during this period might have nullified the pod yield differences due to different irrigation treatments. Similar effect was also observed by Dhonde et al. (1985) during their experiment with groundnut. However, a marginal increase in green pod yield in frequently irrigated plots (I_1 and I_4) (Fig. 5) might be a reflection of the enhanced yield attributes (Table 4.8) and also better uptake of nutrients (Tables 4.10 - 4.12). Similar effect on pod yield was observed by Savithri (1980) in greengram. Increased pod yield due to frequent irrigation was reported by Ahlawat et al. (1979), Patel (1979) and Subramanian et al. (1993) in cowpea, Khade et al. (1986), Bachchhav et al. (1993) and Pannu and Singh (1993) in greengram. A marginal reduction in pod yield in I_3 might be due to the adverse effect of moisture stress during the early flowering period. Similar reduction in yield due to moisture stress at flowering stage was noticed by Shashidharan (1988) in greengram, Pahalwan and Tripathi (1984) and Kpoghomou et al. (1990) in soybean. But the staggered flowering habit of the crop coupled with well distributed rainfall might have nullified the trend.

The marketable green pod yield was significantly influenced by NP ratios. The highest pod yield was obtained in F_2 and was on a par with F_3, but significantly superior to F_1 (Fig. 6). The F_2 ratio recorded an increase in pod yield of 264.9 kg ha^{-1} (6.36 per cent) and 68.3 kg ha^{-1} (1.57 per cent) over F_1 and F_3 ratios respectively. Singh (1976) also observed that a treatment combination of 30 kg N + 40 kg P_2O_5 ha^{-1} recorded the highest grain yield in greengram. According to Viswanathan et al. (1978), the optimum doses of nutrients for maximum grain yield of cowpea were 31.67 kg N and 37.3 kg P_2O_5 ha^{-1}. However, due to staggered harvesting during the period of one and a half to two months, the N and P requirement might be higher with vegetable cowpea. The increased green pod yield in F_2 is a reflection of the enhanced level of yield attributes viz. number of pods per plant, length of the pods and number of seeds per pod. Kumar et al. (1976) reported that pod yield in cowpea was intimately associated with the number of pods per plant, length of the pods, number of seeds per pod and 100 seed weight.

Fig.5. Effect of irrigation on yield of pod and haulm (kg per hectare)

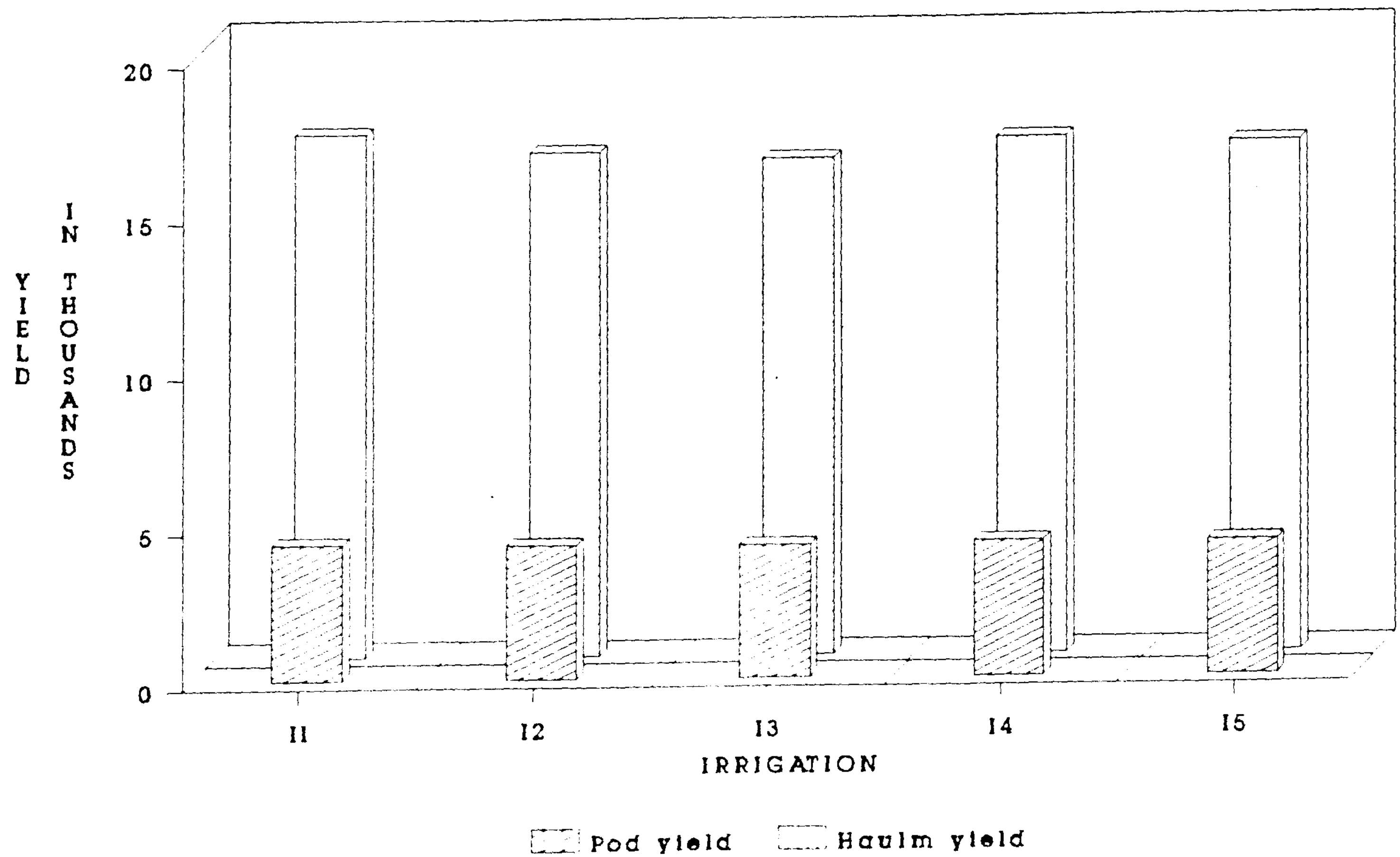
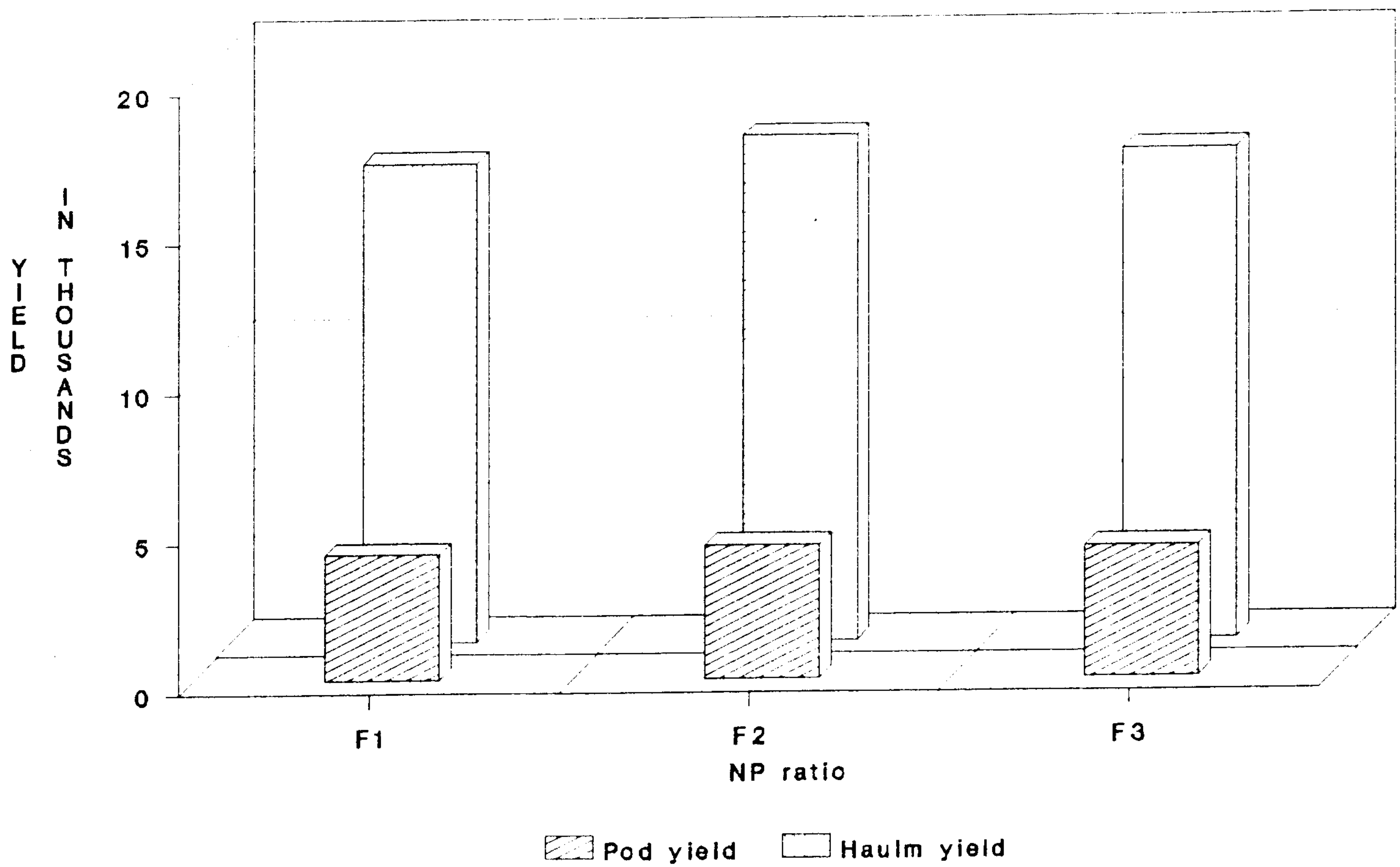


Fig.6. Effect of NP ratios on yield of pod and haulm (kg per hectare)



Similar observations were reported by Rao and Patel (1975) and Savithri (1980) in greengram. Increase in yield with an increase in N level upto 30 kg N ha^{-1} was reported by Nangju (1976), Viswanathan et al. (1978), Ramamurthy et al. (1990) and Gandhi et al. (1991) in cowpea. The reduction in yield at higher doses of nitrogen might be attributed to the excessive vegetative growth at the expense of pod production. An increase in yield upto 40 kg P_2O_5 ha^{-1} was observed by Kumar and Pillai (1979) in cowpea, Kaul and Sekhon (1976) in greengram and Singh and Tripathi (1992) in blackgram. A reduction in yield beyond 50 kg P_2O_5 ha^{-1} was observed by Ahlawat et al. (1979) and Geethakumari and Kunju (1984) in cowpea. The increase in yield with the application of P might be due to its beneficial effect on root development, flower primordia initiation and seed formation. The increased pod yield in F_2 can also be attributed to the increased uptake of nutrients (Tables 4.10 - 4.12). Similar trend was observed in greengram by Savithri (1980).

The interaction effect due to irrigation and NP ratios was non-significant with respect to pod yield.

5.5.3 Haulm yield

Irrigation treatments remarkably influenced the pod yield. The maximum haulm yield was registered in I_1 followed by I_4 and was superior to other treatments (Fig. 5). This might be a reflection of increased growth characters viz. plant height, number of leaves, LAI, DMP and CGR and also better uptake of nutrients. Furthermore, increased LAI at higher levels of irrigation might have also helped in increased haulm production by increasing the rate of assimilation by photosynthesis. This result is in agreement with the findings of Krishnaswamy et al. (1964), Lenka and Misra (1973) and Gopalaswamy et al. (1974) in groundnut. Increased haulm yield due to frequent irrigation was reported by Prasad et al. (1991) in greengram also. The reduced haulm yield in I_3 subjected to a moisture stress during flowering and pod development stages might be due to the adverse effect of moisture stress on plant height, number of leaves, LAI, DMP and CGR. Similar reduction in haulm yield due to severe stress at flowering and pod formation stages was also observed by Shashidharan (1988) in greengram.

Haulm yield was also significantly influenced by NP ratios. Like green pod yield, haulm yield was significantly higher in F_2 (Fig. 6). This might be due to better expression of growth characters like LAI, DMP and CGR (Tables 4.4, 4.6 and 4.7) and also higher uptake of nutrients (Tables 4.10 - 4.12). Efficient utilisation of nutrients has promoted vegetative growth and thereby haulm yield. Moreover, enhanced LAI noticed in F_2 might have increased the rate of assimilation by photosynthesis which in turn increased the haulm yield. Chandran (1987) observed that application of 30 kg N ha^{-1} recorded significantly more haulm yield in vegetable cowpea. Khade et al. (1986) and Bachchhav et al. (1993) also observed similar results in greengram. An increase in stover yield in soybean at higher levels of P was noticed by Dashora and Jain (1994). Application of higher levels of P resulted in elongated root system which might have helped the plant to absorb more plant nutrients and resulted in better growth characters viz. LAI, DMP and CGR, which ultimately reflected in increased haulm yield.

The interaction effect due to irrigation and NP ratios did not influence the haulm yield.

5.6 Nutrient uptake

Irrigation treatments markedly influenced the uptake of N, P and K at all the growth stages. The maximum uptake was noticed in I_1 followed by I_4 and was superior to other treatments (Fig. 7, Fig. 9 and Fig. 11) This might be due to the increased total DMP recorded in frequently irrigated plots (I_1 and I_4). Similar trend was also observed by Savithri (1980) in greengram. In the farmer's practice of irrigation as given in I_5, the uptake of nutrients was lesser than I_1 and I_4 indicating the possibilities of leaching loss of nutrients. Increased nutrient uptake by frequent irrigation was observed in cowpea by

Fig.7. Effect of irrigation on uptake of nitrogen at various growth stages (kg per hectare)

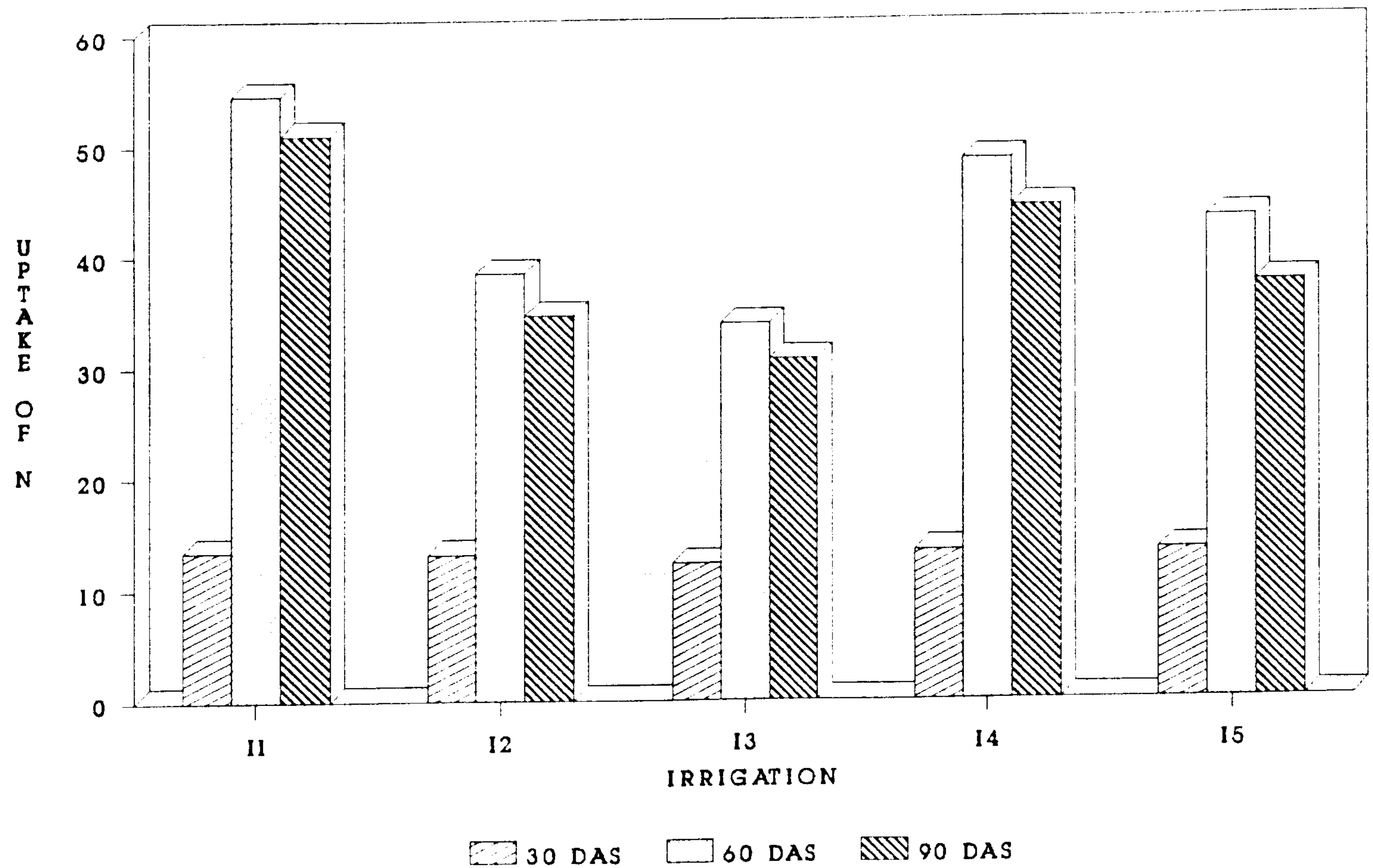
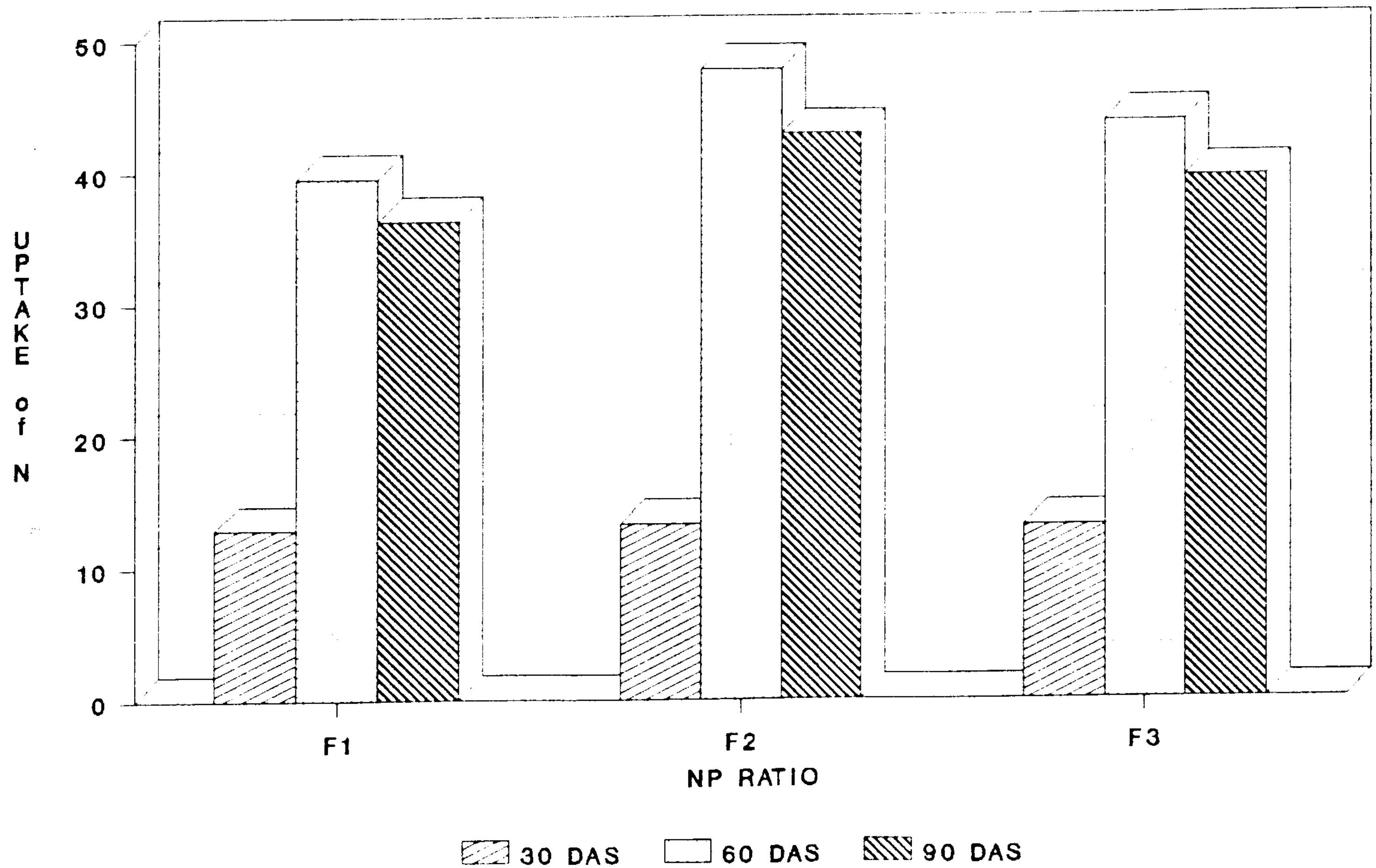


Fig.8. Effect of NP ratios on uptake of nitrogen at various growth stages (kg per hectare)



Singh and Tripathi (1992), Brown et al. (1960) and Rajput et al. (1991) in soybean. The reduction in nutrient uptake in treatments with moisture stress might be due to the fact that under unsaturated soil moisture environment, a vapour gap would be formed round the roots by their turgor pressure, which will reduce the availability of nutrients to the roots, probably due to lesser contact between roots and water particle causing drastic reduction in DMP and uptake of nutrients (Philips, 1966).

The NP ratios also profoundly influenced the nutrient uptake at all the growth stages. The treatment combination F_2 registered the maximum nutrient uptake and was superior to F_1 and F_3 (Fig. 8, Fig. 10 and Fig. 12). Kumar et al. (1979) could also observe that application of 20 kg N ha^{-1} in combination with 40 kg P_2O_5 ha^{-1} recorded the maximum uptake of N and P in cowpea. This might be due to increased total DMP in F_2. Similar trend was noticed by Savithri (1980) in greengram. An increase in N and P uptake by the application of N upto 30 kg ha^{-1} was observed by Chandran (1987) in vegetable cowpea and Brillin (1984) in winged bean. A growth stimulation under high N levels might have resulted in better proliferation of root system and increased the intake efficiency of plants. Increased K uptake upto the application of 30 kg N ha^{-1} was also reported by Savithri (1980) in greengram. Higher levels of N increased the LAI and DMP, which might have increased the photosynthetic efficiency. It is

Fig.9. Effect of irrigation on uptake of phosphorus at various growth stages (kg per hectare)

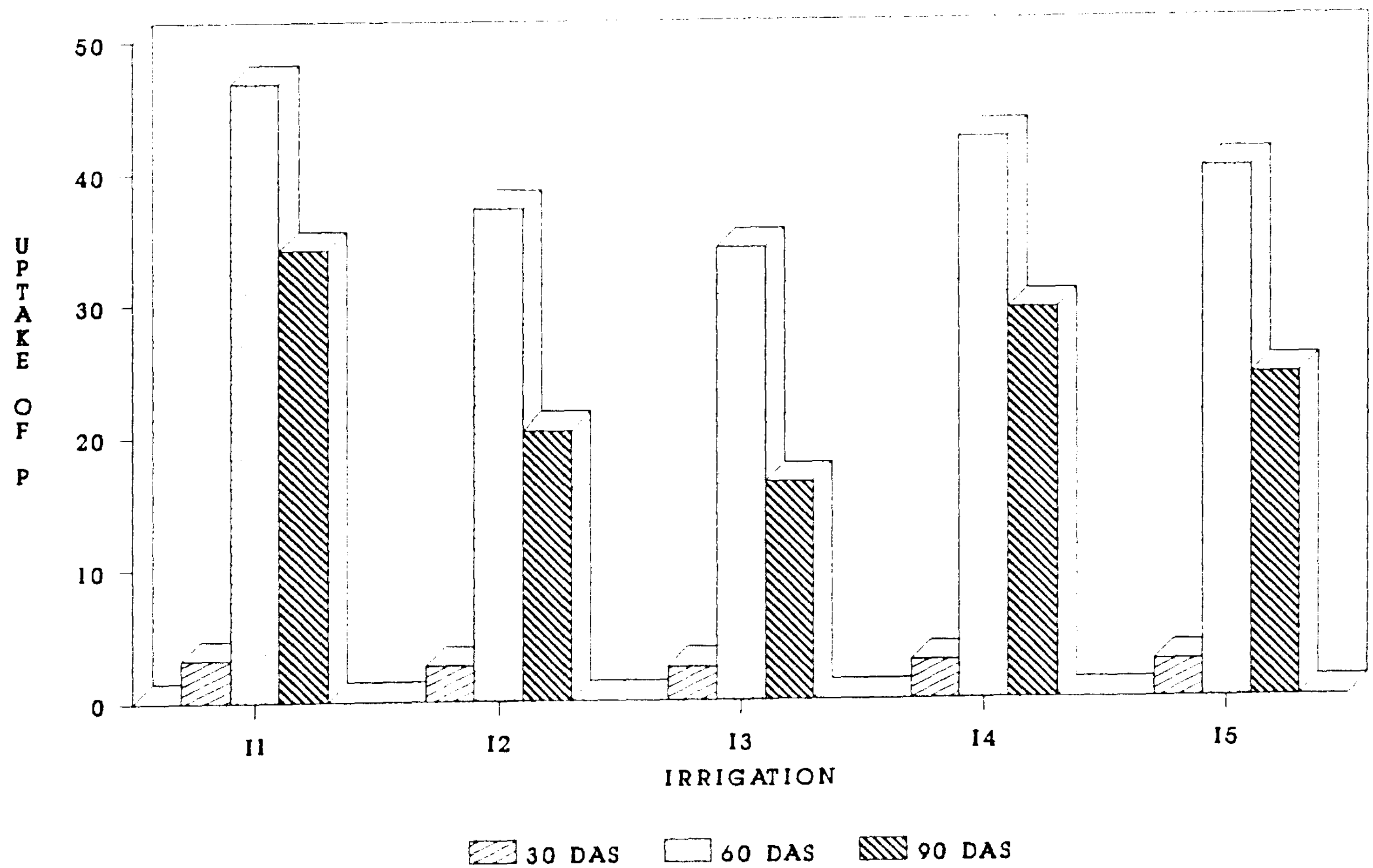
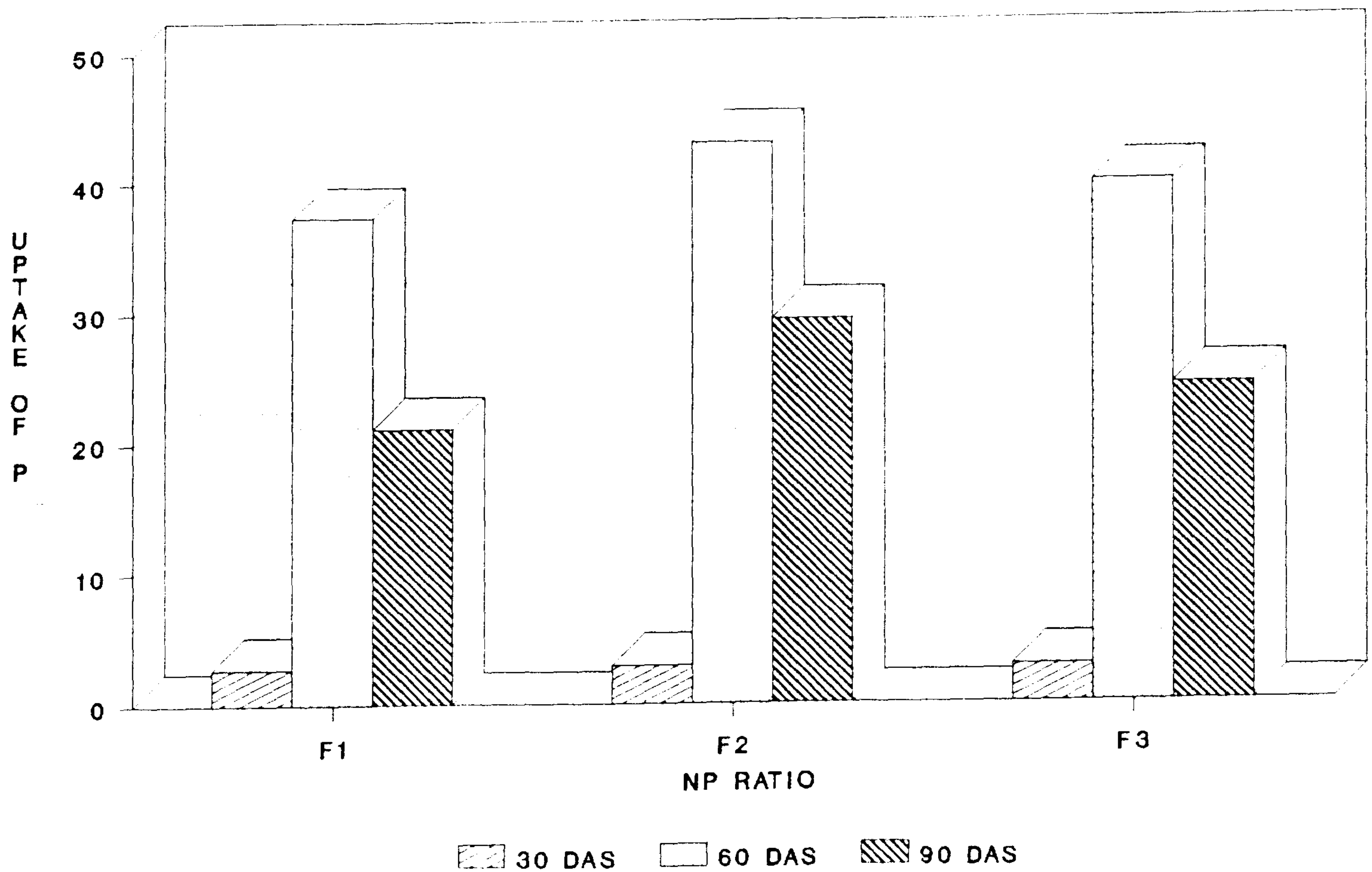


Fig.10. Effect of NP ratios on uptake of phosphorus at various growth stages (kg per hectare)



considered that increased photosynthetic activity increased the uptake of K. An increase in N and K uptake due to higher levels of P upto 50 kg P_2O_5 ha^{-1} was reported by Kadwe and Badhe (1973) in blackgram, whereas, Singh and Tripathi (1992) observed the maximum uptake of N, P and K by the application of 40 kg P_2O_5 ha^{-1} in blackgram. The favourable influence on nutrient uptake due to higher levels of P could be attributed to the better development of root system which might have helped the crop to absorb more nutrients from deeper layers.

The interaction effect due to irrigation and NP ratios profoundly influenced the N uptake at all the growth stages. It was also noticed that whatever be the irrigation treatment, F_2 recorded the maximum uptake of N. Though the trend of response of I within F_1 and F_2 remained more or less similar, under F_3, no significant difference in N uptake was shown by I_4 and I_5 at 30th DAS. The rate of charge in N uptake with respect to various irrigation treatments under each NP ratio was not similar during all the growth stages.

The interaction effect due to irrigation and NP ratios did not influence the P uptake at any of the growth stages.

The interaction effect significantly influenced the K uptake at all the growth stages except at 90 DAS. I_2 recorded the minimum K uptake in combination F_1, but with F_2 and F_3, I_3

Fig.11. Effect of irrigation on uptake of potassium at various growth stages (kg per hectare)

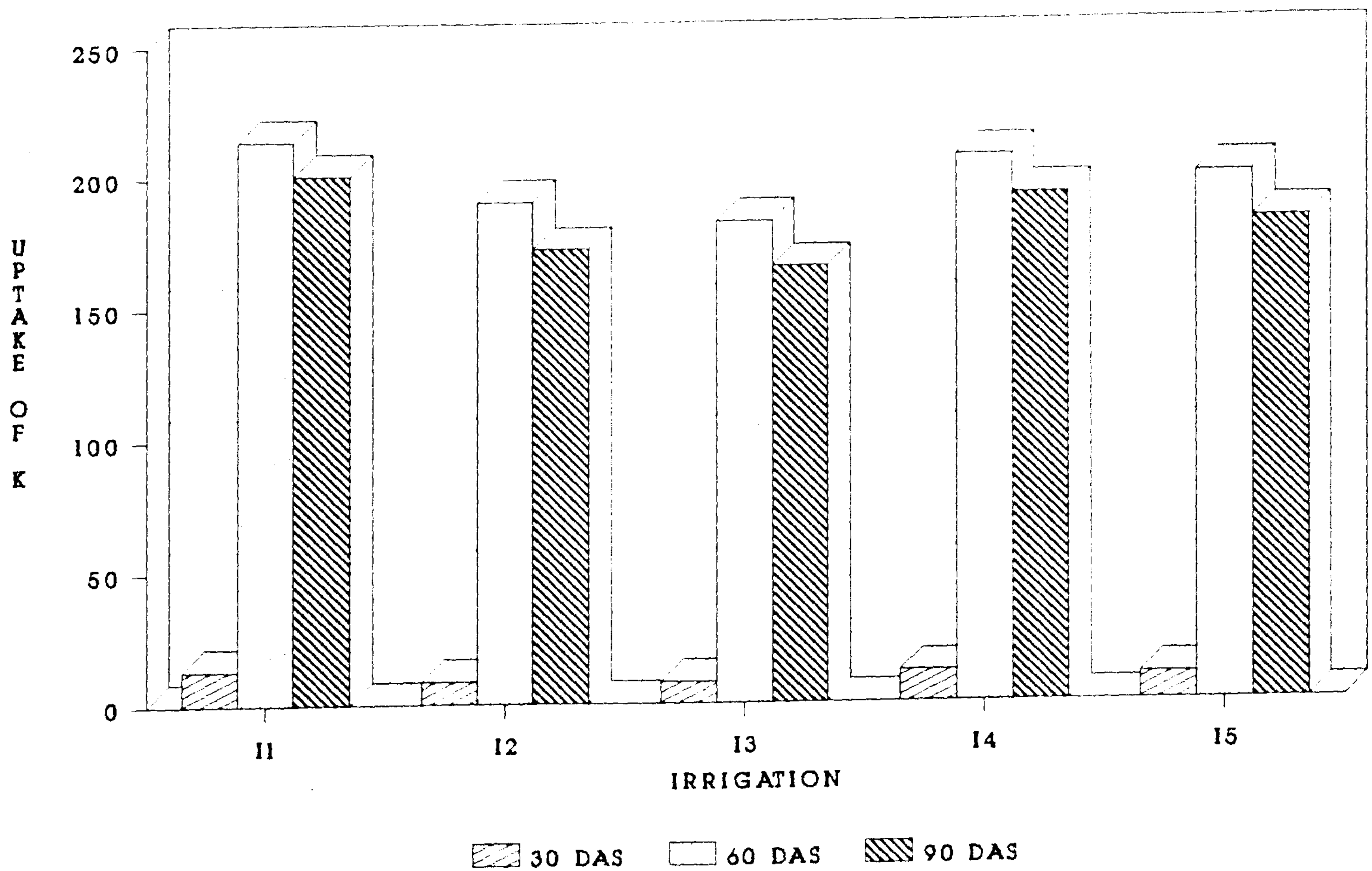
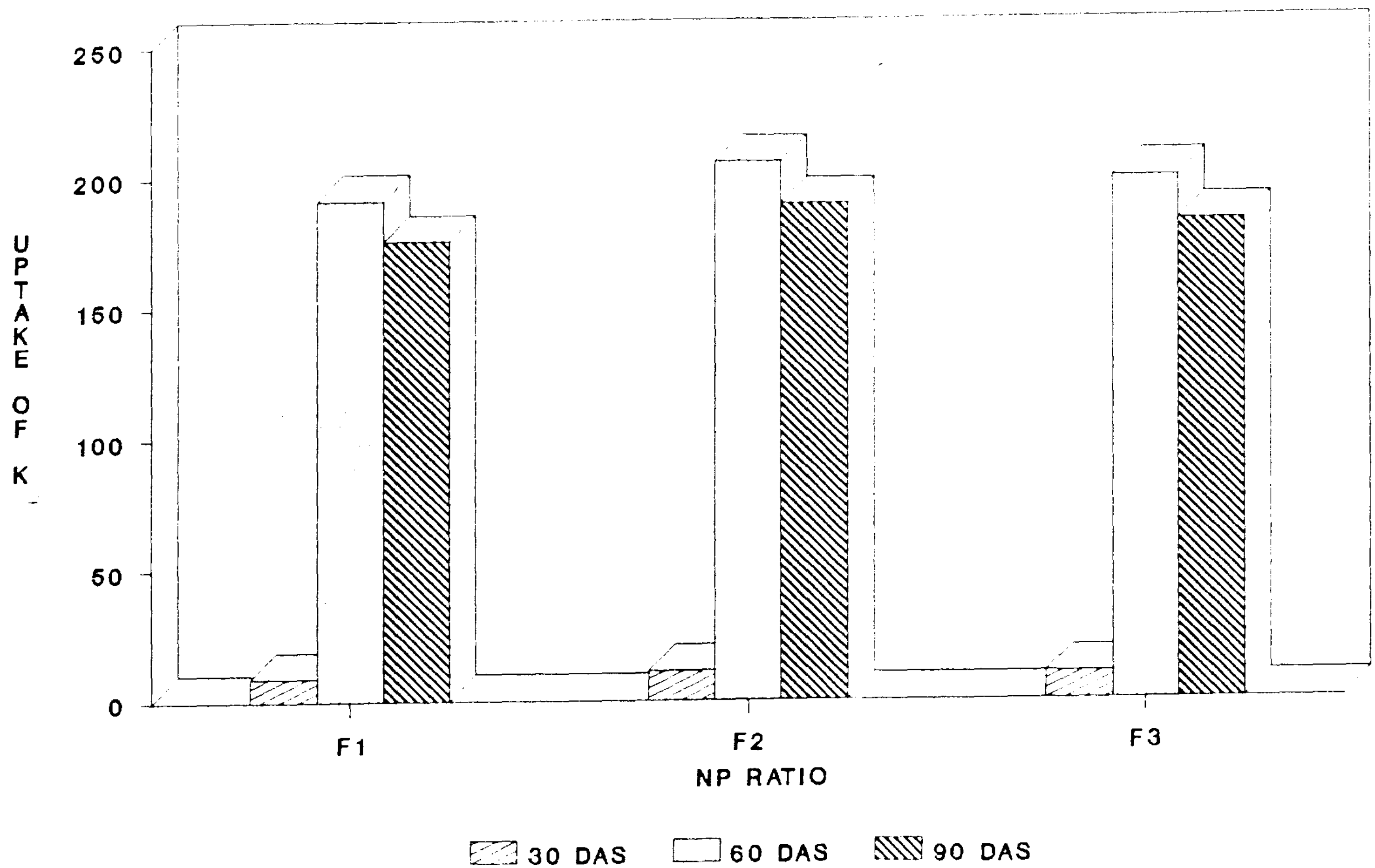


Fig.12. Effect of NP ratios on uptake of potassium at various growth stages (kg per hectare)



registered the least uptake. All irrigation levels in combination with F_2 recorded the maximum K uptake. No significant difference in K uptake was noticed with F_1 and F_3 under I_3 at 30th DAS. But at 60th DAS, I_3 recorded the minimum K uptake with all NP ratios. But the rate of change in K uptake with respect to various irrigation treatments under each NP ratio was not similar at all growth stages.

5.7 Protein content of pods

It is evident from the table that the protein content of pods was markedly influenced by irrigation treatments. The maximum protein content was noticed in I_1 and was superior to other irrigation treatments . The other irrigation treatments also showed a remarkable variation in protein content in the order of I_4, I_5, I_2 and I_3. The increased protein content in frequently irrigated treatments might be due to increased N uptake. An intimate association between protein content and total N uptake was also observed by Savithri (1980) in greengram. It is a well established fact that nitrogen plays an important role in protein synthesis of legume crops. The reduced protein content in I_3 might be due to the adverse effect of moisture stress on N uptake. Decreased protein content due to a moisture stress at pod formation stage was reported by Fajeria and Bajpal (1971) in beans and Pritoni et al. (1990) in soybean.

The NP ratios also remarkably influenced the protein content of pods. The treatment F_2 registered the maximum protein content and was superior to F_1 and F_3. This might be due to the increased N and P supply in F_2. It is a well known fact that N and P are very important in protein synthesis. A significant positive correlation between protein content and total N uptake was observed by Rajendran et al. (1974) in blackgram, Borcean et al. (1977) in peas and Savithri (1980) in greengram. Similar increase in protein content with increased rates of N application have been reported by George (1981) and Sheela (1985) in grain cowpea, Arvadia and Patel (1987) in chickpea, Chandran (1987) in vegetable cowpea and Bachchhav et al. (1993) in greengram. Enhanced protein content with increasing levels of P was also observed by Kesavan and Morachan (1973) in soybean, Panwar and Singh (1975) in greengram, Ravankar and Badhe (1975) in blackgram, green gram and soybean, Singh et al. (1987) in cluster bean and Singh and Tripathi (1992) in blackgram.

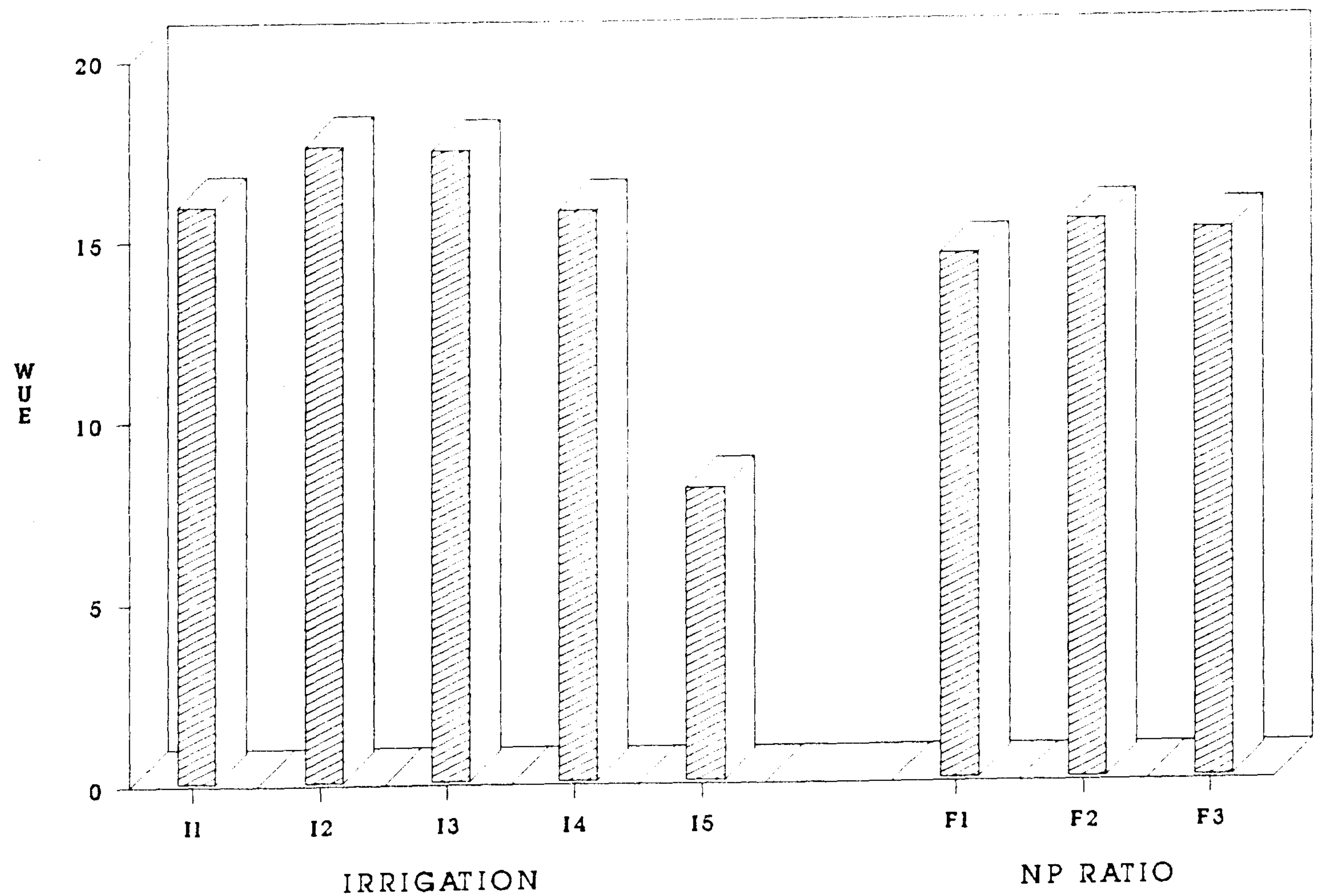
The interaction effect due to irrigation and NP ratios did not exert any significant influence on the protein content of pods.

5.8 Moisture studies

5.8.1 Water-use efficiency (WUE)

It is evident from the Table 4.14 that irrigation treatments profoundly influenced the WUE. The highest WUE was recorded in I_2 and was on a par with I_3, but significantly superior to other treatments. The least WUE was noticed in I_5 (Fig. 13). The results indicated that the WUE was higher in less frequent irrigation schedules. WUE is likely to increase with decrease in soil moisture supply until it reaches the minimum critical level because the plants may try to economise water loss in the range from minimum critical to optimum soil moisture level. Water above the optimum level may be lost in the form of excessive evaporation, transpiration or even as deep percolation. Moreover, the low LAI has mainly been responsible for the low evapo-transpiration from the moisture stressed plants and this might have reflected in higher WUE in I_2 and I_3, eventhough these two treatments recorded lower yields. Increased WUE due to less frequent irrigation was also reported by Kumar et al. (1992), Bachchhav et al. (1993), Dubey (1993), Vijayalakshmi and Aruna (1994) and Yadav 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 corroborated the findings of Grewal et al. (1984). Slatyer (1967) reported that evapo-transpiration is always at near-potential rate when water is adequate, whereas, yield which is a complex phenomenon depending on several other factors may not be optimal. The present finding clearly indicated the wastage of irrigation water and time as practised by the farmer's of the locality.

Fig.13. Effect of irrigation and NP ratios on water-use efficiency (kg per hectare per mm)



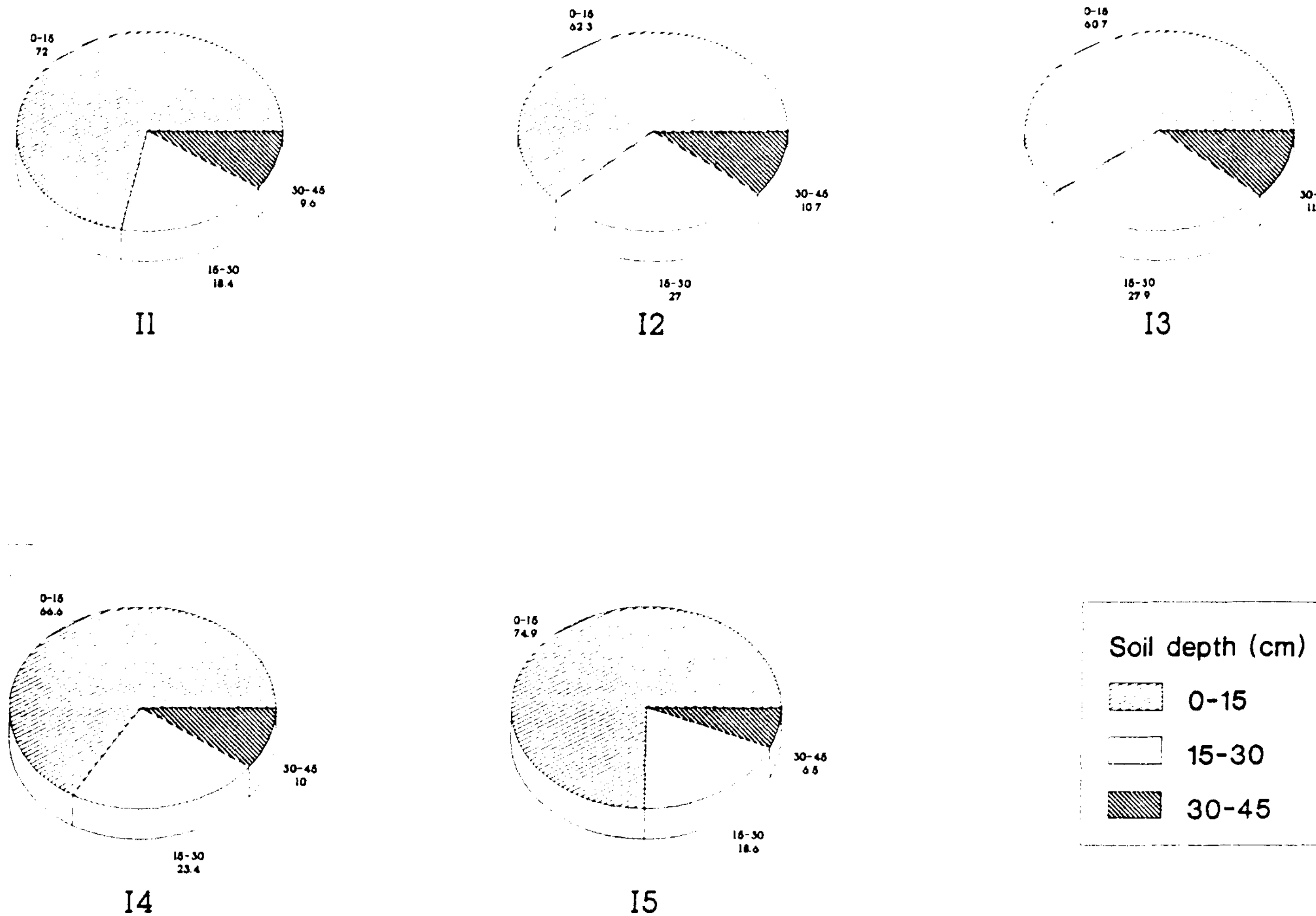
The NP ratios also remarkably influenced the WUE. The maximum WUE was registered in F_2 and was on a par with F_3, but superior to the lowest level (F_1) (Fig. 13). Bachchhav et al. (1993) noticed that the maximum WUE was obtained with 30 kg N ha^{-1} in green gram compared to lower and higher ratios. An increase in WUE due to P application was also reported by Ahlawat et al. (1979) and Subramanian et al. (1993) in cowpea, Siag et al. (1990) and Yadav et al. (1994) in chickpea. The present finding is in agreement with the above results.

The interaction effect due to irrigation and NP ratios was not significant with respect to WUE.

5.8.2 Moisture-extraction pattern

The results indicated that the percentage depletion of moisture decreased with moisture stress from 0-15 cm depth, but it increased with moisture stress from deeper soil depths (Fig. 14). This is in agreement with the findings of Arya and Sharma (1990) and Bachchhav et al. (1993) in greengram and Dubey (1993) in soybean. The reason might be that under irrigated treatment, moisture availability to plants in the upper layers increased with irrigation, while, in less frequent irrigation treatments, moisture availability in the upper layer reduced and upward movement of water from deeper layers was started which caused

Fig.14. Effect of irrigation on soil moisture extraction pattern



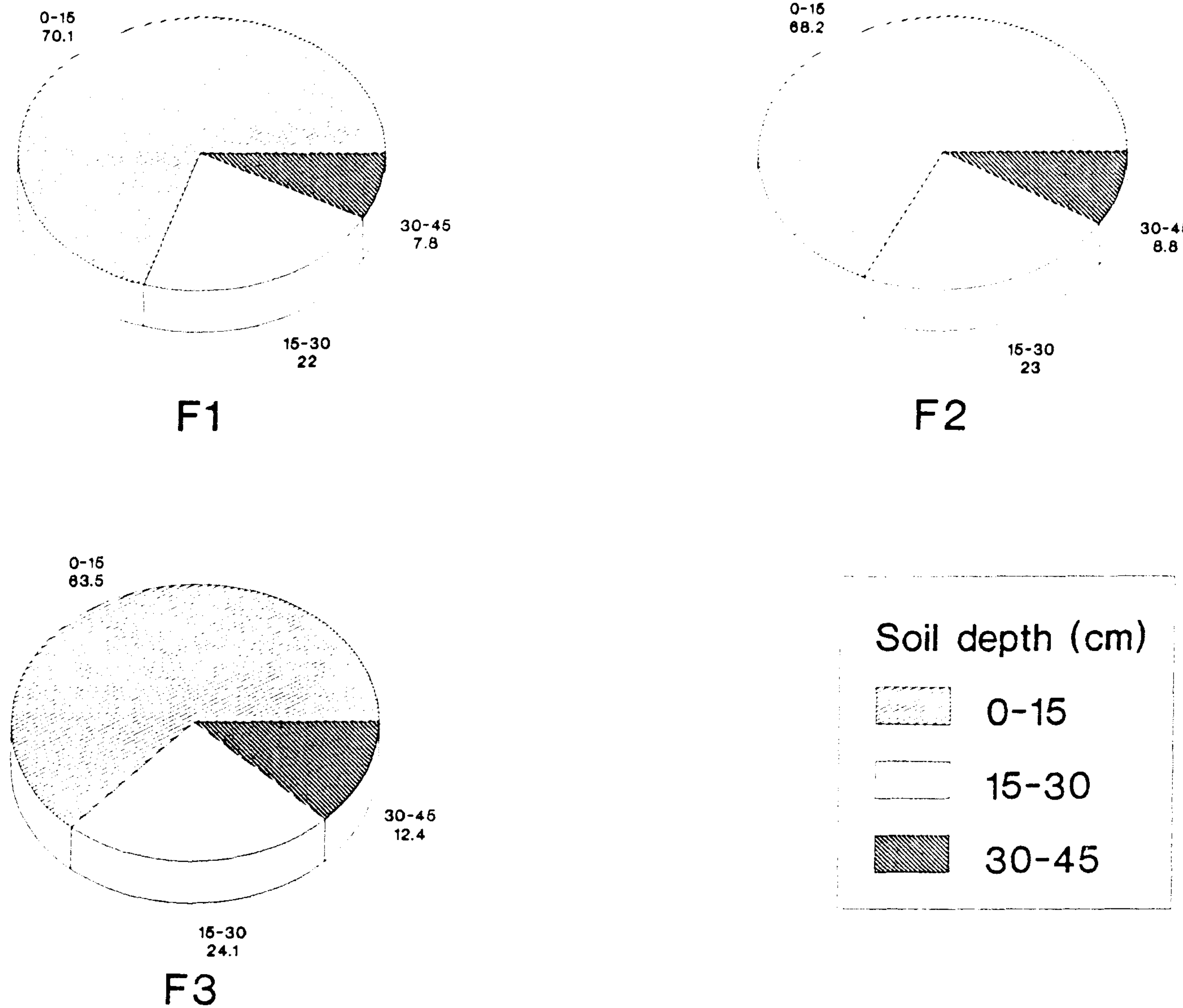
increased depletion in deeper layers with an increase in moisture stress. The non-availability of water in the surface layers might have caused the root to penetrate deeper resulting in higher moisture extraction from deeper layers of soil. Black (1973) has pointed out that root grows deeper into the soil in search of water when the moisture supply is not adequate in the surface layer of soil. It was also observed that the crop extracted most of its moisture requirement (67.29 per cent) from upper layer (upto 15 cm) (Table 4.15). This might be due to the additive effect of higher transpiration from the increased leaf area and more water loss from the soil surface through evaporation. This is in conformity with the findings of Nayar and Singh (1985) in chickpea. Khade et al. (1986) and Arya and Sharma (1990) in greengram and Sinha and Pal (1991) in blackgram also reported similar results.

The NP ratios also caused appreciable variation in moisture-extraction pattern. The per cent depletion of moisture decreased from 0-15 cm soil depth, but increased from 15-45 cm soil depth at higher ratios (Fig. 15). Varma and Kalra (1985) in lentil and Prabhakar and Saraf (1991) in chickpea also observed similar results. This might be due to an extensive proliferation of root system at higher ratios.

5.8.3 Yield response factor (Ky)

It is clear from Table 4.16 that Ky was vitiated due to the frequent rainfall received during the crop growth period.

Fig.15. Effect of NP ratios on soil moisture extraction pattern



However, a marginal response was noticed in I_3 over I_2 indicating that the crop was more susceptible to water stress at the flowering stage. The present finding is in agreement with Hiler *et al*. (1972) in cowpea.

5.9 Soil nutrient status after the experiment

The data revealed that irrigation treatments exerted a significant influence on soil nutrient status after the experiment. The treatment I_3 registered the maximum contents of available N, P and K followed by I_2 and was superior to other irrigation treatments. The least contents of available N, P and K were noticed in I_1 indicating that the soil nutrient status decreased as the frequency of irrigation increased. The higher water availability might have enhanced better uptake of N, P and K (Tables 4.10 - 4.12) which might have reduced the available N, P and K contents of soil in I_1 and I_4. Such a decreasing trend in available N and P contents of soil at higher irrigation levels was reported earlier by Thomas (1984) and Rajan (1991).

The NP ratios also markedly influenced the soil nutrient status after the experiment. The maximum available N, P and K contents were noticed in F_1 followed by F_3 and F_2. This might be due to the increased total DMP and uptake of N, P and K at higher ratios (F_2 and F_3). The reduced available N content of soil at the highest ratios might be due to the fact that at higher levels of N, the symbiotic fixation of N might have considerably reduced which resulted in more extraction of both applied and native N content of soil. However, a starter N dose in F_1 might have contributed to higher symbiotic fixation of N thereby reducing the use of native N from the soil.

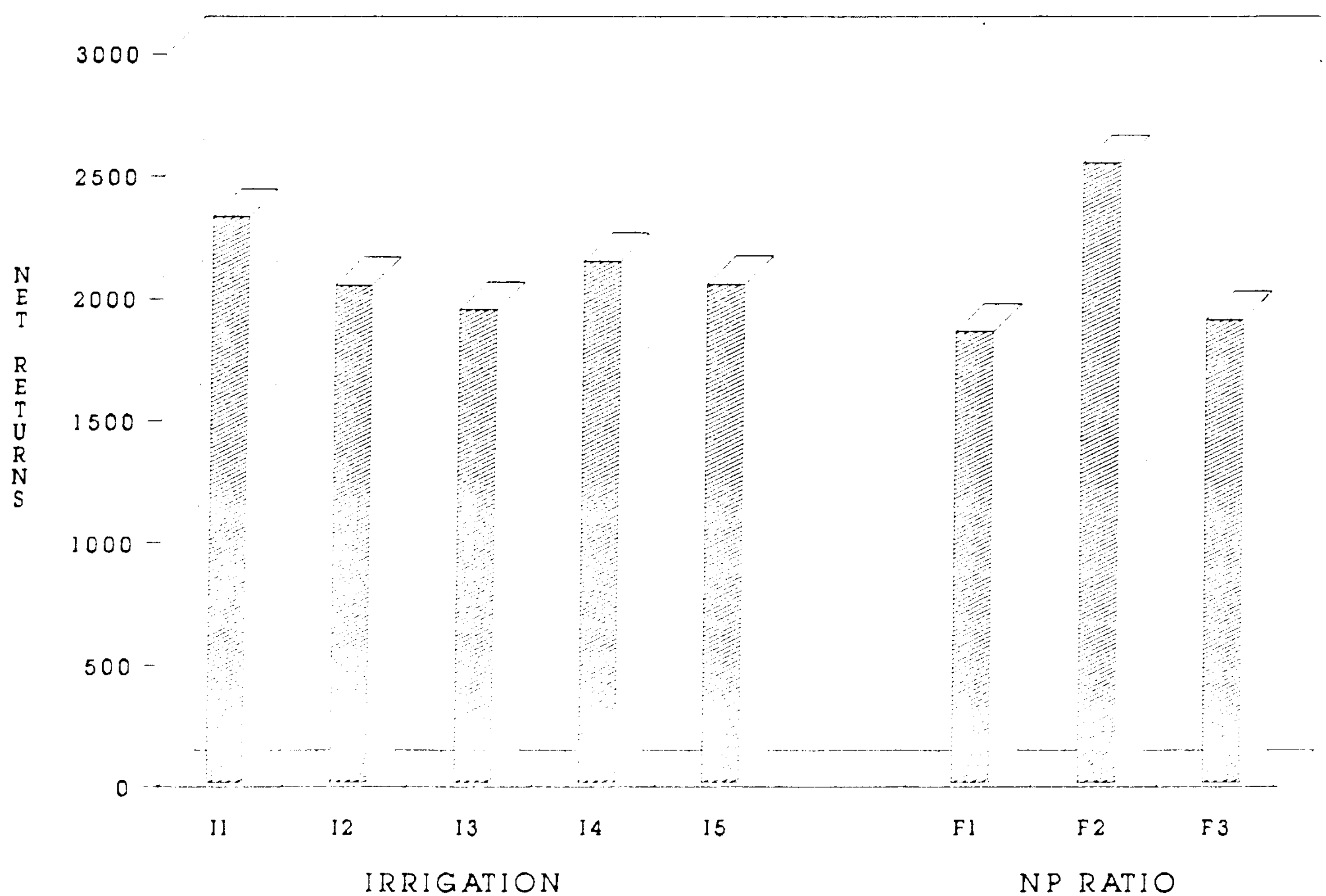
The interaction effect due to irrigation and NP ratios significantly influenced the available K content of soils, but did not influence the available N and P contents of soil. The rate of change in K content of soil with respect to various irrigation treatments under F_1 and F_2 remained more or less the same.

5.10 Economics of cultivation

The economic analysis revealed that the net returns and benefit cost ratio (BCR) increased with an increase in frequency of irrigation. The maximum net returns (Fig. 16) and BCR was recorded in I_1 followed by I_4, I_5, I_2 and I_3 (Table 4.18). Since there was linear increase in pod yield in frequent irrigation treatments, maximum net returns and BCR were obtained at higher levels of irrigation indicating that the crop should be irrigated at 75 per cent of field capacity for obtaining maximum net income as well as BCR.

The NP ratios also profoundly influenced the net returns and BCR. The maximum net returns and BCR was recorded in F_2. This could be attributed to the increased marketable green pod yield with an increase in NP ratio upto 30:45 kg ha^{-1}.

Fig.16. Effect of irrigation and NP ratios on net returns (Rupees per hectare)



However, an increase in NP ratio beyond F_2 did not give a corresponding increase in pod yield. The lowest level of N and P also gave comparatively lesser marketable green pod yield resulting in the lowest net returns.

The interaction effect due to irrigation and NP ratios did not influence the net returns and BCR.

SUMMARY

SUMMARY

A field experiment was conducted in the summer rice fallows at the Instructional Farm attached to the College of Agriculture, Vellayani during 1993 to study the effect of phenophased irrigation on vegetable cowpea cv. Malika under graded doses of nitrogen and phosphorus. The soil of the experimental field was sandy clay loam in texture with a bulk density ranging from 1.3 - 1.35 g cc^{-3}, acidic in reaction and medium in available nitrogen, phosphorus and potassium. The experimental field received appreciable amount of rainfall during the period of crop growth. The treatments were laid out as a 5x3 factorial experiment in randomised block design with three replications. The treatments comprised of five irrigation treatments (I_1 - Irrigating the crop at 75 per cent of field capacity throughout the crop growth period, I_2 - Irrigating the crop at 50 per cent of field capacity during 0 - 33 days and then irrigating at 75 per cent of field capacity during the remaining period of the crop, I_3 - Irrigating the crop at 50 per cent of field capacity during 34-66 days and irrigating the crop at 75 per cent of field capacity during the early phase (0 - 33 days) and the remaining period of the crop (67-100 days), I_4 - Irrigating the crop at 50 per cent of field capacity during 67 - 100 days and irrigating the crop at 75 per cent of field capacity during the early phase (0 -66 days) of the crop growth, I_5 - farmer's practice) and three ratios of N and P (F_1 - 20:30,

F_2 - 30:45 and F_3 - 40:60 kg N and P_2O_5 ha^{-1}). Observations were made on growth, yield and quality characters of the crop, data were statistically analysed and the results of the study are summarised below:-

1. In general, the plant height increased progressively upto 90 DAS. The treatments did not exert any influence on plant height upto 30 DAS. Thereafter, the plant height was significantly influenced by irrigation. I_1 and I_5 markedly increased the plant height over other treatments. An increase in NP ratio upto F_3 registered a remarkable increase in plant height at 90th DAS.

2. No significant variation in the number of branches per plant was observed upto 45th DAS, while at 60th DAS, a signi-icant reduction in the number of branches per plant was noticed with I_3. The number of branches per plant was not influenced by NP ratios.

3. The number of leaves per plant increased progressively upto 60 DAS and the rate of increase declined at 75 DAS. Thereafter a reduction in the number of leaves per plant was noticed. The number of leaves per plant was significantly increased in frequently irrigated treatments viz. I_1 and I_4. However, the number of leaves per plant was not influenced by NP ratios and its interaction with irrigation.

4. LAI was significantly influenced by irrigation treatments at all the stages of observation. The LAI increased with an increase in the number of irrigations and the maximum LAI was recorded in I_1. The effect of NP ratios on LAI was also significant and the maximum value was noticed in F_2.

5. The days for 50 per cent flowering was also influenced by irrigation treatments. Early flowering was noticed in I_1 and I_4. But the NP ratios did not influence the flowering.

6. The total DMP of the crop increased progressively upto 90th DAS. The total DMP was significantly increased in I_1 and the least DMP was noticed in I_3. An increase in NP ratio upto F_2 favourably influenced the total DMP.

7. The crop growth rate (CGR) was also significantly influenced by irrigation and NP ratios. The maximum CGR was observed at the irrigation level of I_1 and at the NP ratio of F_2.

8. The yield attributes viz. number of pods per plant, length of the pods and number of seeds per pod were substantially improved by frequent irrigation. The irrigation treatment at I_1 recorded maximum values for these yield attributes. The yield attributes were adversely affected by a moisture stress during

flowering and pod development stages. The NP ratio of F_2 favourably influenced the yield attributes over lower and higher ratios.

9. The marketable green pod yield was not influenced by irrigation due to frequent rainfall received during the later period of crop growth. However, a marginal increase in green pod yield was observed in I_1. The NP ratios significantly influenced the pod yield. The maximum pod yield was noticed in F_2 which was significantly higher than F_1, but was on a par with F_3.

10. Unlike pod yield, haulm yield was significantly influenced by irrigation. The maximum haulm yield was observed in I_1. An increase in NP ratio upto F_2 produced the maximum haulm yield over both lower and higher ratios.

11. The uptake of N, P and K by the plant was significantly increased in I_1 and a marked reduction in uptake of major nutrients was noticed in I_3. An increase in N, P and K uptake was noticed in F_2 over F_1 and F_3.

12. The protein content of pods was also favourably influenced by frequent irrigation schedules. The irrigation treatment at I_1 favourably influenced the protein content, whereas, a moisture stress during flowering and pod development stages considerably reduced the protein content of pods. The maximum protein content was noticed at the NP ratio of F_2.

13. Field water-use efficiency (WUE) was highest in less frequent irrigation schedules (I_2 and I_3) and lowest in I_5 (farmer's practice). The maximum WUE was recorded in F_2.

14. The data on moisture-extraction pattern showed that the per cent depletion of moisture from upper layers increased with an increase in the number of irrigations. But from deeper soil layers, the per cent depletion of moisture increased with moisture stress. The NP ratios also caused appreciable variation in moisture - extraction pattern. The per cent depletion of moisture increased from surface layers at lower ratio (F_1), but it increased from deeper layers with an increase in NP ratio.

15. Though the yield response factor (Ky) did not differ remarkably among irrigation treatments, better crop response to irrigation was noted at the flowering stage.

16. Irrigation treatments significantly influenced the soil nutrient status after the experiment. The maximum contents of N, P and K were observed in treatments with moisture stress. The lowest NP ratio (F_1) registered the maximum available N, P and K contents of soil.

17. Economics of different treatments indicated that the net returns and benefit-cost ratio (BCR) increased with an increase in the number of irrigations. The irrigation treatment at I_1

registered the highest net income of Rs.2317/- per hectare, with a BCR of 1.15. Thus in areas with limited water supply, it is remunerative to adopt irrigation at 75 per cent of field capacity throughout the crop growth period compared to the schedule of daily irrigation as practised by the local farmers. Among the NP ratios, the highest net income of Rs.2538 per hectare was recorded in F_2 compared to both lower and higher ratios.

The results of the experiment revealed that for optimising pod yield of vegetable cowpea cv. Malika in the summer rice fallows, an irrigation level of 75 per cent of field capacity (-0.03 MPa) during the entire crop growth period was most beneficial. The crop also responded to the application of nitrogen and phosphorus at the rate of 30 and 45 kg ha^{-1} respectively over higher and lower rates of N and P. The economic analysis also indicated that a treatment combination of irrigation at 75 per cent of field capacity throughout the crop growth period along with N and P at the rate of 30 and 45 kg ha^{-1} respectively gave higher benefit - cost ratio compared to other treatment combinations.

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THE EFFECT OF PHENOPHASED IRRIGATION ON VEGETABLE COWPEA(*Vigna sesquipedalis*) UNDER GRADED DOSES OF NITROGEN AND PHOSPHORUS.

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ABSTRACT OF THESIS

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

Department Of Agronomy
COLLEGE OF AGRICULTURE
Vellayani - Thiruvananthapuram
1995

ABSTRACT

An experiment was conducted at the Instructional Farm attached to the College of Agriculture, Vellayani in the summer rice fallows during 1993 to study the effect of phenophased irrigation on vegetable cowpea cv. Malika under graded doses of nitrogen and phosphorus. The trial was laid out as a 5x3 factorial experiment in randomised block design with 3 replications. The treatments comprised of five irrigation treatments and three ratios of N and P.

The study revealed that the crop responded to irrigation and application of N and P at the rate of 30 and 45 kg ha^{-1}. Biometric characters viz. plant height, number of leaves per plant, LAI, total DMP and CGR and yield attributing characters viz. number of pods per plant, length of the pods and number of seeds per pod were favourably influenced by maintaining a moisture regime of 75 per cent of field capacity throughout the crop growth period. The maximum LAI, total DMP, CGR and yield attributes viz. number of pods per plant, length of the pods and number of seeds per pod were significantly increased upto an NP ratio of 30:45 kg ha^{-1}.

Irrigation treatments could not produce any marked differences in green pod yield mainly due to the frequent rainfall received during the harvesting period of one and a half months. Unlike pod yield, haulm yield was appreciably influenced

by irrigation and the maximum haulm yield was noticed by irrigating the crop at 75 per cent of field capacity throughout the crop growth period. The maximum yield of green pods and haulm were noticed at an NP ratio of 30:45 kg ha^{-1}.

The uptake of major nutrients viz. N, P and K by the crop and the quality parameter (protein content of pods) significantly increased by irrigation at 75 per cent of field capacity throughout the crop growth period and at the NP ratio of 30:45 kg ha^{-1}.

The field water-use efficiency was higher in less frequently irrigated plots and at an NP ratio of 30:45 kg ha^{-1}. Soil moisture-extraction pattern showed that on an average, the crop extracted 67.29, 23.05 and 9.66 per cent of moisture from 0-15, 15-30 and 30-45 cm soil depths respectively. Drier regimes and an increase in NP ratio showed a tendency to extract more moisture from deeper layers. The yield response factor indicated a marginal response of the crop to moisture stress at the flowering stage.

Available N, P and K contents of the soil after the experiment indicated a decrease in soil nutrient status with an increase in the number of irrigations.

The results of economic analysis revealed that net income and benefit cost ratio increased by irrigating the crop at 75 per cent of field capacity throughout the crop growth period and at NP ratio of 30:45 kg ha^{-1}.