RESPONSE OF VEGETABLE COWPEA (*Vigna sesquipedalis* (L.) Fruw.) TO PHOSPHORUS UNDER VARYING MOISTURE LEVELS AND PLANT DENSITY

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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

1997

DECLARATION

I hereby declare that this thesis entitled "Response of vegetable cowpea (*Vigna sesquipedalis* (L.) Fruw.) to phosphorus under varying moisture levels and plant density" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

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CERTIFICATE

Certified that this thesis entitled "Response of vegetable cowpea (*Vigna sesquipedalis* (L.) Fruw.) to phosphorus under varying moisture levels and plant density" is a record of research work done independently by Ms. MINI [illegible] 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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ACKNOWLEDGEMENTS

I wish to place on record my deep sense of gratitude and indebtedness to:

Dr.Kuruvilla Varughese, Associate Professor of Agronomy, College of Agriculture, Vellayani and Chairman of Advisory Commitee for his valuable guidance, timely advice and constant encouragement throughout the course of investigation and preparation of the thesis.

Dr.G.Raghavan Pillai, Professor and Head, Department of Agronomy, College of Agriculture, Vellayani for going through the thesis and offering valuable suggestions.

Dr.(Mrs) S.Pushkala, Associate Professor of Soil Science & Agricultural Chemistry, College of Agriculture, Vellayani for her valuable suggestions regarding the conduct of the experiment and critical scrutiny of the manuscript.

Dr.(Mrs) P.Saraswathy, Professor and Head, Department of Agricultural Statistics, College of Agriculture, Vellayani for her valuable guidance in connection with the designing of the experiment and interpretation of the experimental data.

Sri. P. Chandrasekharan, Professor and Head (Retd.), Department of Agronomy, College of Agriculture, Vellayani for his valuable suggestions in writing of the thesis.

Sri. K.K.Raveendran Nair, Professor (Academic), College of Agriculture, Vellayani for his paternal guidance throughout the course of work.

Sri.C.E. Ajithkumar, Junior Programmer, Computer Centre, College of Agriculture, Vellayani for the valuable help in analysing the experimental data.

The teaching and non-teaching staff of the Department of Agronomy, the Instructional Farm, College of Agriculture, Vellayani and all my friends for their whole-hearted co-operation and help rendered from time to time.

My beloved mother, in-laws, husband and sister for their moral support, inspiration and encouragement throughout the course of this work.

And above all to 'The God Almighty' in enabling me to successfully complete this venture.

MINI.C.L.

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INTRODUCTION

The present day population pressure on land has necessitated maximum exploitation of each and every available cent for agricultural production. In developing countries where small farms and labour intensive operations predominate, to get best results in agriculture a desired agronomic information and a rational approach is needed so that productivity can be maximised.

Cultivating vegetables in summer rice fallow is a common practice throughout the developing tropics because of several advantages especially under limited moisture availability. It is estimated that the vegetable production in Kerala is only one third of the vegetable requirement for the state. Hence it is imperative to get a considerable quantity from the neighbouring states. Since the availability of cultivable land is limited in the state, summer rice fallows offers new vistas for vegetable production. Among the various vegetable crops grown in Kerala cowpea occupies a prime position. It can be cultivated either as an upland crop during rainy season or as an irrigated crop in the summer rice fallows. The recent varieties of vegetable cowpea released from Kerala Agricultural University are suitable for both the situations.

The high cost of fertilizers and timely scheduling of supplemental irrigation are the major constraints in the intensification of vegetable cowpea cultivation in the summer rice fallows. The new improved varieties have considerable variations in yield and growth characters under different management conditions. Being a pulse crop, it responds well to the application of phosphorus. For the proper establishment of rhizobium a sufficient quantity of available phosphorus is required in the soil. Cultivation of leguminous crops results in improvement of nitrogen status of the soil due to rhizobium fixation of nitrogen, which helps in increasing the yield of base as well as succeeding crop. Vegetable cowpea varieties branches profusely and hence it is necessary to find out the optimum densities of plant under varying situations. At present, only a general recommendation of irrigation, nutritional aspects and plant density of grain cowpea is available. Since the growth habits and prolonged harvest period of vegetable cowpea varies from grain cowpea, the response pattern of applied inputs may also vary. The productivity of vegetable cowpea can be maximised only by optimum level of irrigation, fertilizers and plant density.

Taking the above points into consideration the present study was conducted with the objectives of studying the effect of phosphorus on vegetable cowpea variety Malika under varying moisture levels and plant densities and also to work out the economics of different treatment combinations.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

The results of the experiments conducted in India and elsewhere on the growth, yield, yield attributing components, nutrient uptake and contents, soil moisture studies and economic analysis of cowpea and related crops as influenced by graded levels of irrigation, plant density and phosphorus and their interaction effects are reviewed here.

2.1 Effect of irrigation

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

2.1.1 Effect of irrigation on growth characters

2.1.1.1 Plant height

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

Increase in plant height due to higher levels of irrigation has been reported in other pulse crops viz., green-gram (Ali and Alam,1973 ,Prasad et al.,1991, Trivedi et al., 1994),blackgram (Rao et al.,1991, Singh and Tripathi, 1992, Jeyaraman, 1994), redgram (Ramshe and Surve, 1984), pea (Yadav et al., 1990) and cluster bean (Meena et al.,1991).

2.1.1.2 Number of leaves

In cowpea, Singh and Lamba (1971) observed that irrigation at a higher ASM in the root zone enhanced the number of leaves per plant. According to Ali and Alam (1973), soil moisture stress reduced the number of leaves per plant in green-gram. Significantly higher number of leaves was documented in summer cowpea irrigated at an IW/CPE ratio of 0.5 as compared to lower levels of moisture (Balakumaran, 1981). Kumar et al.(1992) learned that in lentil the number of leaves for plants irrigated at an IW/CPE ratio of 0.6 was higher as compared to lower levels of irrigation. A decrease in leaf number due to lower levels of moisture was also reported by Manning et al.(1977) in peas, Henrique et al. (1978) in soybean and Kuhad et al. (1988) in chickpea. In a recent study Jyothi(1995) observed that in vegetable cowpea the number of leaves was appreciably increased by irrigating the crop at 75 per cent ASM in summer season.

2.1.1.3 Number of branches

Summer cowpea grown in rice fallows showed significantly lower level of branching in early stages with increase in moisture supply (Balakumaran, 1981). In another experiment conducted with a green gram variety K 851, irrigation at an IW/CPE ratio of 0.7 recorded significantly more number of primary branches per plant compared to irrigation at an IW/CPE ratio 0.5 (Trivedi et al.,1994). An appreciably higher number of branches per plant was noticed in summer black gram given frequent irrigations at an IW/CPE ratio of 0.8 as compared to the ratio of 0.4 and 0.6 as observed by Singh and Tripathi (1992). Similarly in summer vegetable cowpea, Jyothi(1995) noticed a significant reduction in branching with lower levels of moisture supply.

Unlike the above observations, Ramamurthy et al. (1990) in cowpea and Pani and Srivastava (1990) in pea opined that the number of branches per plant was not significantly influenced by irrigation.

2.1.2 Effect of irrigation on yield attributing characters

2.1.2.1 Flowering

In most of the pulse crops it was observed that the retardation of growth and yield was most drastic due to lack of soil moisture at the flowering stage, especially in grain cowpea (Hiler *et al*.,1972). Ali and Alam (1973) reported that Soil Moisture Stress (SMS) reduced the initiation and retention of floral buds in green gram. In summer planted moongbean, irrigation, at an IW/CPE ratio of 1.0 significantly delayed 50 per cent flowering by six days as compared to irrigations at IW/CPE ratios of 0.4 and 0.6 and by two days as compared to an IW/CPE ratio of 0.8 (Yadav and Warsi, 1988). Chandrakar *et al*.(1994) observed in an experiment with sesamum that lesser number of flowers were formed and maximum flower abortion was observed when irrigation was given only twice, i.e.,at branching and pod forming stages in comparison with plants irrigated at an IW/CPE ratio of 0.5 upto pod formation and 0.7 thereafter and plants irrigated at an IW/CPE ratio of 0.7 throughout the crop growth. In summer vegetable cowpea early flowering was noticed when moisture availability was higher during the early growth stages (Jyothi, 1995).

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

2.1.2.2 Other yield attributing characters

Ahlawat *et al*. (1979) observed in spring cowpea that a higher level of ASM in the root zone during the cropping season by irrigating at 75 per cent ASM resulted in a significant improvement in the number of pods per plant over 50 and 25 per cent ASM. Increased wetness significantly increased the number and weight of pods in summer cowpea (Balakumaran, 1981) and an

IW/CPE ratio of 0.5 was the optimum. A field experiment conducted on summer vegetable cowpea revealed that the soil moisture regime of 80-100 per cent ASM appreciably increased the number and weight of green pods per plant as compared to 60-100,40-100 and 20-100 per cent ASM (Patel, 1979). But Subramanian et al. (1993) noted a significant influence of irrigation on pod length and number of seeds per pod in vegetable cowpea. In a field trial with vegetable cowpea during the summer season an increase in the number and length of pods and number of seeds per pod was noted with increase in soil wetness (Jyothi, 1995).

Irrigation at an IW/CPE ratio of 0.8 favoured the formation of maximum number of pods and grains per pod as against wetter and drier regimes in summer mung (Yadav and Warsi.,1988). Prasad and Yadav (1990) refers to a decline in the yield attributes like pod number per plant and 1000 grain weight in green gram and black gram when irrigation was given at an IW/CPE ratio of 0.6 and 0.4 as compared to 0.8. A significantly more number of pods per plant, pod length, grains per pod and test weight was reported by Trivedi et al. (1994) in green gram when irrigated at an IW/CPE ratio 0.7 as compared to a ratio of 0.5. An increase in the pods per plant and test weight in summer black gram irrigated at an IW/CPE ratio of 0.8 over the ratios 0.6 and 0.4 was reported by Singh and Tripathi (1992). In another experiment with rice fallow black gram, Jeyaraman (1994) reported significantly higher values for number of pods per plant and pod length for plants irrigated at an IW/CPE ratio of 0.7 over plants irrigated at IW/CPE ratios of 0.5 and 0.3.

2.1.3 Effect of irrigation on yield

In cowpea , a higher level of ASM in the root zone increased the dry matter production (DMP) per plant (Singh and Lamba,1971). Ahlawat et al.(1979) also noted that maximum grain yield was obtained by irrigating cowpea at 75 per cent ASM at 0-30cm depth over 50 and 25 per cent ASM. In another experiment conducted on summer vegetable cowpea, Patel (1979) learned that a soil moisture regime of 80 to 100 per cent of ASM gave 12.87 per cent higher yield of green pods compared to a moisture regime of 60 to 100 per cent ASM. Grain yield was significantly higher with wetter soils in summer cowpea and an IW/CPE ratio of 0.5 was recorded optimum (Balakumaran, 1981). Farghaly et al. (1990) from an experiment with 5 cowpea cultivars opined that lengthening the irrigation interval from one week to 3 weeks reduced the seed yield. In another experiment conducted with vegetable cowpea cv CO-2 at Bhavanisagar, it was reported that irrigation at an IW/CPE ratio of 1.00 gave maximum vegetable yield and was on par with 0.8 IW/CPE and was also significantly superior to 0.6 IW/CPE (Subramanian et al., 1993). In summer cowpea, maximum grain and fodder yield was recorded under IW/CPE ratio of 0.8 which was significantly superior over the ratios of 0.6 and 0.4 as noticed by Kher et al.,1994. In a recent study on summer vegetable cowpea, Jyothi (1995) noticed an increasing trend in pod and haulm yields as well as dry matter production towards wetter regimes.

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

Varughese et al.(1986) concluded that irrigating black gram at an IW/CPE ratio of 0.5 was adequate since higher ratios did not influence the yield. From an experiment with summer black gram, Singh and Tripathi (1992) noted that maximum DMP and grain yield was got by irrigating the crop at an IW/CPE ratio of 0.8 as compared to 0.4 and 0.6 ratios. In another experiment with rice fallow black gram, Jeyaraman (1994) found that irrigation at 0.7 IW/CPE in comparison with 0.5 and 0.3 ratios gave significantly higher grain yield. But Vijayalakshmi and

Aruna (1994) reported that irrigating blackgram at an IW/CPE ratio of 0.6 resulted in higher grain yield over 0.75 and 0.9 ratios.

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

Ahlwat et al.,(1979) found that the Cu and WUE of cowpea increased with increasing levels of irrigation. The maximum values were recorded by irrigating at 75 per cent ASM as compared to 50 and 25 per cent ASM. Another trial conducted on a summer crop of vegetable cowpea revealed that the WUE increased with increasing levels of soil moisture regimes, ie., from 20 to 100 per cent ASM to 80 to 100 per cent ASM (Patel, 1979). Subramanian et al.,(1993) observed that the vegetable cowpea crop irrigated at an IW/CPE ratio of 1.0 consumed more water than those irrigated at 0.6 and 0.8 ratios. In summer cowpea scheduling of irrigation based on an IW/CPE ratio of 0.8 gave significantly higher Cu of water over rest of the levels of IW/CPE ratios, i.e.,0.4 and 0.6 while different ratios did not exert any significant influence on WUE (Kher et al., 1994).

Mohanty and Sharma(1985) observed that the Cu of water and WUE were higher under two irrigations at 30 and 45 DAS as compared to one irrigation at any one stage in green gram during the summer season. A field trial on mungbean variety PS-16 with various irrigation schedules (IW/CPE ratios of 0.2,0.4 and 0.6) revealed that IW/CPE ratio of 0.2 gave higher water use efficiency over the other treatments along with greater soil moisture extraction from lower soil layers, i.e., more than 45 cm depth (Arya and Sharma,1990). Bachchhav et al. (1993) reported that in summer green gram, the lowest Cu of water was observed with irrigation at critical growth stages (seedling, branching,flowering,post-flowering and pod development stages) and the highest with scheduling of irrigation at 50mm CPE. However WUE was highest with irrigation at 100mm CPE and least with 50mm CPE. In another study on mungbean, soil moisture contents and moisture use from the top 45cm increased with the frequency of irrigation. The maximum water use was recorded by irrigation at 200mm CPE and lowest by unirrigated treatment, whereas the maximum WUE was recorded by unirrigated plot and the lowest by irrigation at 200mm CPE (Pannu and Singh, 1993).

Singh and Tripathi (1992) opined that in summer black gram Cu of water was maximum when irrigated at an IW/CPE ratio of 0.8 compared to 0.4 and 0.6 IW/CPE. This crop receiving maximum number of irrigations utilized more moisture from the upper layers (0-30cm) than the lower ones (30 - 60 cm). But a reverse phenomenon was observed when frequency of irrigation was low. For rice fallow blackgram, irrigation at an IW/CPE ratio of 0.3 recorded maximum WUE compared to irrigation at 0.5 and 0.7 IW/CPE (Jeyaraman, 1994). Similarly, Vijayalakshmi and Aruna (1994) reported that irrigating blackgram at an IW/CPE ratio of 0.6 resulted in higher WUE over 0.75 and 0.9 ratios.

2.1.5 Effect of irrigation on nutrient composition and uptake

Subramanian et al.(1993) observed that in cowpea, there was no significant difference in P content due to irrigation but uptake of P was maximum by scheduling irrigation at an IW/CPE ratio of 0.8 compared to both lower and higher levels of 0.6 and 1.00 IW/CPE ratios.

Bachchhav *et al.* (1993) found that the nitrogen uptake in the seed and straw of green gram was significantly more with irrigation scheduled at 100mm CPE and critical growth stages than with 50 and 75mm CPE. Singh and Tripathi (1992) reported that the highest uptake of 121.7 kg nitrogen/ha,11.2 kg phosphorus/ha and 5.8 kg potassium/ha were recorded for irrigation application at an IW/CPE ratio of 0.8 and was significantly superior to the uptake at an IW/CPE ratio of 0.4 in black gram.

Parihar and Tripathi (1989) observed that in chickpea, there was no significant effect of irrigation treatment on the nitrogen content of the grain but its phosphorus and potassium content increased with the increase in moisture level when irrigation was given at IW/CPE ratios of 0.4,0.6 and 0.8. But total nitrogen uptake was significantly reduced when irrigation water was supplied at an IW/CPE of 0.8, whereas the uptake of P and K was not appreciably affected by the different irrigation schedules.

2.1.6 Effect of irrigation on the economics of cultivation

In a study conducted on summer vegetable cowpea, Patel (1979) learned that the highest net profit (4165 Rs/ha) was obtained by maintaining the crop at 80-100 per cent ASM, while, the lowest net profit (Rs. 1426/ha) was obtained by maintaining at 20-100 per cent ASM. Patel and Patel (1994) in an experiment with redgram observed that the highest net realization of Rs.

5104/ha was obtained for the treatment with an irrigation schedule of 0.25 IW/CPE ratio compared to 0.50 and 0.75 IW/CPE ratios. In lentil, Lal et al., 1995 noted highest net return per hectare (Rs. 6905) and return per rupee invested (Rs 4.04) with 2 irrigations at 45 and 80 days. The treatment combination of 20 percent ASMD with 60kg P_2O_5/ha produced the maximum pod yield and net realization in clusterbean (Bhatt, 1983). The net profit (Rs/ha) and benefit-cost relationship (Rs/Re investment) increased due to different water regimes in groundnut on the order of 1.2 IW/CPE >0.9 IW/CPE > 0.6 IW/CPE (Katre et al.,1988) Geethalakshmi et al. (1994) also observed that optimum number of irrigations for irrigated summer groundnut is nine giving maximum net returns.

2.2 Effect of plant density

With the introduction of short duration and high yielding varieties of cowpea there is wide scope for obtaining high yields of a new variety given optimum spacing and manuring (Subramanian et al., 1977). Closer spacing between and within the rows increased the yields of cowpea (Ezodinma, 1974). This response may be attributed to the optimum exploitation of space, moisture, light and nutrients. The growth habit of the new varieties may be another reason for the response to optimum plant densities.

2.2.1 Effect of plant density on growth characters

In blackgram, Saharia (1988) noted an increase in plant height at a spacing of 30cm compared to 40cm row spacing. In black gram, the maximum values of primary root length and root: shoot ratio were obtained at a row spacing of 15cm followed by 20cm in an experinment with row spacings 15,20,25 and 30cm as treatments (Kumar and Sharma, 1989). The number of primary branches per plant in summer blackgram was minimum at a row spacing of 30cm compared to 15 and 22.5cm (Singh and Yadav, 1994). But Thakuria and Saharia (1990) noted that the effect of plant density on plant height in summer greengram was non significant. A significant improvement in the plant height and number of branches per plant was also noted in red gram by Padhi (1995) at a closer spacing of 30cm compared to 45cm.

2.2.2 Effect of plant density on yield attributing characters.

Saharia (1988) reported that in blackgram a wider row spacing of 40cm produced more number of pods per plant compared to a narrower row spacing of 30cm, but the effect on the number of seeds per pod and 100 seed weight was non-significant. In greengram and blackgram all the yield contributing characters including pod number per plant and 1000 grain weight exhibited increasing trend with decrease in the inter-row spacing from 30 to 15cm except grain number per pod which was not affected by inter-row spacing (Prasad and Yadav, 1990). In summer blackgram, maximum number of pods per plant, 1000-seed weight and seed weight per plant was attained with 30cm row spacing compared to 22.5 and 15cm (Singh and Yadav, 1994).

Padhi (1995) also noted significant decrease in the number of pods per plant in red gram by increasing the row spacing from 30 to 45cm but the effect on other yield attributes was not remarkable. The relationship between optimum plant density and yield attributing characters were also reported in

French bean (Dwivedi et al., 1994), cluster bean (Bhadoria and Chauhan, 1994), Indian butter bean (Patel et al., 1994) and rice bean (Prasad et al., 1994).

2.2.3 Effect of plant density on yield

In cowpea, Subramanian et al. (1977) observed that the effect of differential spacing on yield was significant. A closer spacing of 60 X 15cm (1,11000 pts/ha) recorded the highest grain yield and was superior compared to other spacings, 60 X 20cm (86,000 pts/ha) and 60 X 25 cm (67,000 pts/ha). Jain and Chauhan (1988) noted a significantly high grain yield and harvest index at a spacing of 30cm, compared to higher and lower spacings of 15, 22.5 and 37.5 cms in mungbean. In green gram genotypes Thakuria and Saharia (1990) opined that grain yield was significantly higher at a plant density of 330×10^3 compared to a lower density of 220×10^3. In summer green gram, Dwangan et al. (1992) learned that a closer spacing (20cm) significantly increased the seed yield compared with wider row (30cm) spacing. Kumar and Sharma (1989) noted in blackgram a significantly high grain yield per plant as well as dry weight of roots and shoots at 30cm row spacing compared to closer spacings. In both greengram and blackgram, Prasad and Yadav (1990) observed significantly high grain yield and biological yield at an inter-row spacing of 22.5cm compared to closer spacing of 15cm and wider spacing of 30cm. In summer blackgram, the seed and straw yields recorded at 22.5cm and 30cm row spacings were statistically on par but showed significant increase over 15cm spacing (Singh and Yadav, 1994).

Significant influence of plant density on yield has been reported in other crops also like redgram (Nivedita and Reddy, 1990, Tripathy and Chauhan, 1990), french bean (Haldavanekar et al., 1992, Dwivedi et al.,1994), cluster bean (Bhadoria and Chauhan, 1994), Indian butter bean (Patel et al.,1994), rice bean (Prasad et al., 1994), lentil (Watt and Singh, 1992), pea (Yadav et al.,1990, Yadav et al.,1993).

2.2.4 Effect of plant density on moisture - extraction pattern (MEP), consumptive use (Cu) and water-use efficiency (WUE)

Not much work has been done regarding this aspect. However, in summer green gram, Dwangan et al., 1992 observed that a closer row spacing of 20cm showed a higher WUE compared to a wider spacing of 30cm. Also the crop planted at a closer spacing extracted more moisture from the upper layers of 0-30 cm.

2.2.5 Effect of plant density on nutrient composition and uptake

Jain and Chauhan (1988) observed a higher protein content in green gram cultivars spaced at 22.5cm over 15cm but was on par with 30cm which was attributed to more uptake of nitrogen at a wider spacing. The protein content was maximum at the medium (111.1 X 10^3 pts/ha) than at the lowest (83.3 X 10^3 pts/ha) and the highest (166.7 X 10^3 pts/ha) plant densities in pigeonpea as reported by Tripathi and Chauhan (1990). In Indian butter bean, Patel et al. (1994) observed that the maximum grain protein content was got when the crop was sown 60 cm apart than at a closer spacing. Chavan and Kalra (1983) in groundnut variety TG-1 reported that wider rows of 45cm, recorded higher content of N,P,K while uptake of these nutrients was higher at a closer spacing of 30cm as the DMP was higher in this spacing. In soybean, Rajput et al. (1991) observed that there was a significant increase in the N,P and K contents of grain and straw with every increase in row width except P content of straw. But the total uptake of nutrient significantly decreased with the increasing row width in both grain and straw since there is a corresponding decrease in yield also. Prasad et al. (1993) also reported a higher protein content in soybean seed due to better availabitlity and uptake of nutrients at the lowest level of population of 167,000 pts/ha compared to 200,000, 250,000 and 333,000 pts/ha.

2.2.6 Effect of plant density on the economics of cultivation

Singh et al. (1978) reported that in pigeonpea, the net return was higher at 50cm (Rs.3965.65/ha) than at 75 cm of row spacing. In french bean, net returns was significantly higher with 400,000 pts/ha (30 cm row spacing) compared to 286,000 pts/ha (45 cm row spacing) and 200,000 pts/ha (60 cm row spacing) as reported by Dwivedi et al. (1994). In Indian butter bean, Patel et al. (1994) noted maximum a net return of Rs. 3092/ha under 45cm spacing. Both the net return and return per rupee invested decreased markedly due to reduction in plant density from 333,000 to 1,67,000/ha in summer sesamum (Ghosh and Patra, 1994).

2.3 Effect of phosphorus

The significance of judicious application of phosphorus to legumes has been recognised by different workers from different parts of the world. Application of phosphorus to pulses has improved the growth, yield and quality of the crops and fixed varying quantities of atmospheric nitrogen resluting in restoration of soil fertility. Differential response of P can be attributed to its uptake efficiency and its utilization, which in turn is greatly influenced by environmental factors (Abbas et al., 1994).

2.3.1 Effect of phosphorus on growth characters

Phosphorus is a major constituent of plant cell nucleus and growing root tips which helps to absorb more plant nutrients and water from the deeper layers of the soil and ultimately results in better growth of the plant.

Application of phosphorus had significant influence on plant height only at the early growth stages in summer cowpea as reported by Balakumaran (1981). Singh (1985) also observed an increase in plant height in summer cowpea when the level of applied phosphorus was higher (60kg P_2O_5/ha) compared to lower levels (20 and 40 kg/ha). But no clear trend was noted in the number of branches per plant.

A better value for the length of main shoot in cowpea with a phosphorus level of 40kg/ha compared to 20 and 60 kg/ha and no phosphorus was noted by Jain et al. (1986) but the difference due to different levels of applied phosphorus was non significant. But with respect to the number of branches, the highest was with 60kg which was on a par with 40kg but both levels gave significantly higher values compared to lower levels. An exactly similar trend was noticed with the number of leaves per plant also. Kher et al.(1994) recorded that phosphorus at 40 and 80kg/ha did not differ practically with respect to growth parameters (plant height and plant spread) in cowpea but was apparently higher over the control. In summer cowpea fertilizing with P_2O_5 @ 50kg/ha improved the growth attributes like plant height, leaves per plant, canopy area significantly compared to 0 and 25kg and was on a par with 75kg/ha (Rajput, 1994).

Plant height was found to be significantly increased with 50kg P_2O_5/ha over other treatments (0,25 and 75kg/ha) in green gram (Arya and Kalra, 1988). A phosphorus level of 30kg/ha was found to increase the plant height and number of branches per plant compared to control by Singh and Chowdhary (1992) in green gram. A significant increase in the plant height and number of branches per plant by the application of phosphorus upto 60kg/ha was reported by Singh and Tripathi (1992) in black gram. Plant height at 45 DAS and at harvest and primary branches per plant in blackgram showed significant response to application of 30 and 60kg P_2O_5/ha compared with the control. The two levels were found to be on a par (Shah et al., 1994).

2.3.2 Effect of phosphorus on yield attributing characters

Kumar and Pillai (1979) reported that the application of phosphorus upto 40kg P_2O_5/ha profoundly influenced the number of pods per plant, number of seeds per pod and the length of pods in cowpea. The highest number and weight of green pods per plant was noted by the application of 60kg P_2O_5/ha in summer vegetable cowpea by Patel (1979) in comparsion with lower levels of 0,20 and 40kg/ha. Jayaram and Ramiah (1980) reported that the application of phosphorus in cowpea increased the number of pods per plant and the number of grains per pod in both summer and kharif seasons upto 37.5 kg and 25kg P_2O_5/ha respectively.

It was found that cowpea responded to phophorus upto 50kg P_2O_5/ha and influenced all the yield contributing characters, viz., the number of pods per plant, seeds per pod and 100 grain weight (Geethakumari and Kunju, 1984). A further increase in dose upto 62.5 kg/ha caused a reduction in all these yield contributing attributes. The maximum weight of pods and the total green pod weight per plant in cowpea was noted with the application of 60kg P_2O_5/ha, but the increase in the number of seeds per pod was significant only upto 40 kg/ha (Jain et al., 1986). In cowpea, maximum number of pods, pod weight per plant and seed yield was recorded by the application of 50kg P_2O_5/ha (Ramamurthy et al., 1990). Subramanian et al. (1993) reported that in vegetable cowpea the application of graded levels of phosphorus had no significant effect on the pod length and number of seeds per pod. In another study on the response of summer cowpea to phosphorus Kher et al. (1994) noted that the application of 40 and 80kg/ha phosphorus did not differ practically in respect of yield attributes like the number of grains per pod, length of the pod and test weight but was apparently higher over the control. In cowpea, Rajput (1994) also found significant effect of P on yield attributes like the number of pods per plant and seeds per pod upto 50kg/ ha which was on par with a higher level of 75kg/ha.

In summer green gram, Gupta and Rai (1989) pointed out that the yield attributes like the number of effective pods per plant and seeds per pod were significantly improved by P application upto 15 kg/ha and upto 30 kg/ha for 1000 grain weight. In another experiment with summer green gram it was found that the yield attributes like the pod number, pod length, grains per pod and 1000 grain weight were significantly influenced by P application upto 80kg/ha (Sarkar, 1992). Mishra (1993) also reported a significant increase in yield attributes like the pods per plant, seeds per pod and 1000 grain weight upto 60 kg/ha in black gram.

2.3.3 Effect of phosphorus on yield

Application of 60kg P_2O_5 /ha markedly increased the seed yield in cowpea whereas higher doses decreased the yields (Malik et al., 1972). Maximum grain yield in cowpea was got by the application of 40kg P_2O_5/ha but the difference with 20kg/ha was not significant (Viswanathan et al.,1978). Ahlawat et al., (1979) also found that the highest grain yield was got by applying phosphorus @ 60kg/ha compared to 30kg and no phosphorus but the increase over 30kg was not significant. In summer vegetable cowpea, Patel (1979) noted that application of P @ 60kg/ha gave significantly higher pod yield over 20 and 40kg/ha. From a field experiment conducted at TNAU, Jayaram and Ramiah (1980) concluded that a linear increase in grain yield was observed in cowpea upto 37.5kg P_2O_5/ha in summer and 25kg/ha in kharif. The grain yield increased linearly in grain cowpea from 12.5 kg to 50kg P_2O_5/ha (Geethakumari and Kunju,1984). Muthuswamy et al.(1986) from another experiment on rainfed cowpea pointed out that there is a significant positive response in the grain yield for P application compared to no phosphorus but the difference between the effects of different levels were insignificant. In cowpea, Ramamurthy et al. (1990) observed highest yield at a P level of 50kg/ha. Gandhi et al.(1991) also reported significantly higher yield when cowpea was fertilized with 50kg P_2O_5/ha. In summer cowpea, maximum grain and fodder yield was obtained by applying P @ 80 kg/ha (Raj and Patel., 1991). Better expression of yield was got in cowpea with higher level of P (30kg/ha) compared to 15kg (Philip,1993). In vegetable cowpea, maximum DMP and vegetable yield was obtained at an applied P level of 100kg/ha which was on par with 50kg/ha (Subramanian et al., 1993). Kher et al. (1994) noted that in summer cowpea application of phosphorus at 40 and 80kg/ha did not differ practically with respect to yield but was significantly higher over the control. Highest seed and stover yield of cowpea was obtained by P application @ 75kg/ha which was on par with 50kg/ha (Rajput,1994).

In green gram genotypes, Thakuria and Saharia (1990) observed the highest grain yield with 20kg P_2O_5/ha which was on par with higher doses. But Dubey et al. (1992) noted no significant effect of applied P on green gram yield, whereas Dwangan et al.(1992) observed that phosphorus @ 60kg/ha gave significantly higher yield. Sarkar (1992) reported linear increase in grain yield of green gram upto 80kg P_2O_5/ha. Application of 30kg P_2O_5/ha recorded significantly higher yield over the control but was on par with 60kg/ha (Singh and Chaudhary, 1992). Sharma et al.(1994) observed that dry matter partitioning indicated significant response of crop to P for dry matter of leaf and stem upto 60kg P_2O_5/ha. Singh et al.(1994) also observed significant increase in seed yield by P application

@ 30kg/ha in comparison with the control but the effect of a higher dose was not significant.

Rao et al. (1990) also observed a positive relationship between yield and phosphorus application in blackgram upto 60kg/ha beyond which it decreased. An increase in yield and DMP of summer black gram by the application of phosphorus upto 60kg/ha was also reported by Singh and Tripathi (1992). Mishra (1993) also found that grain yield increased progressively with an increase in the level of P and the maximum response was at 60kg/ha in black gram. Phosphorus application was reported to increase the grain, straw and biological yields as well as the DMP at harvest in blackgram upto 30kg/ha beyond which the increase was not significant (Shah et al., 1994).

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

In spring cowpea, an increase in the Cu of water and WUE was observed with the application of phosphorus by Ahlawat et al. (1979). However, the differences between 30 and 60kg P_2O_5/ha were not perceptible. But, Subramanian et al.(1993) reported that phosphorus application linearly accentuated the water use efficiencies of cowpea in both kharif and summer season. In another experiment with summer cowpea, application of phosphorus at 40 and 80kg/ha did not differ practically in respect of Cu of water and WUE but was apparently higher over the control (Kher et al.,1994).

In summer green gram, phosphorus @ 60kg P_2O_5/ha showed maximum WUE (Dwangan et al., 1992). The Cu of water was reported to increase by 31.4mm with increase in level of phosphorus from 0 to 60kg /ha in summer black gram (Singh and Tripathi, 1992). A favourable influence of P on moisture use in chickpea upto 45kg/ha was noted by Joseph and Varma (1994).

2.3.5 Effect of phosphorus on nutrient composition and uptake

In summer cowpea, N content significantly decreased with increase in P but P content showed a positive response to applied P whereas K content was not influenced by graded P application (Balakumaran, 1981). In grain cowpea, uptake of P was significantly influenced by P application (Geethakumari and Kunju,1984). Muthuswamy et al. (1986) observed an increasing trend in the uptake of P in cowpea with the increasing levels of applied P from 0 to 40kg/ha. Available P status of the soil was also higher after the experiment with the highest level of P. A significant decrease in N content with increasing levels of P was noted in cowpea along with a positive response in P content with applied P. But uptake of N and K did not show any significant relationship whereas P uptake increased with applied P (Philip, 1993). Subramanian et al., (1993) also observed that P uptake increased with increase in applied P upto 100 kg/ha which was on par with 50kg/ha in vegetable cowpea.

Uptake of N by green gram was significantly high at a P level of 100kg which was on par with 50kg (Reddy, 1986). In green gram, a significant increase in the N uptake of grain and straw and P uptake of grain was noted with 30kg P_2O_5/ha compared to control but the effect of a higher dose was non-significant whereas the P uptake of straw and total P uptake was significantly high at 60kg P_2O_5/ha (Singh et al., 1994). A significant increase in the total N,P and K uptake was noted due to application of P upto 60kg/ha in black gram (Shah et al.,1994)

2.3.6 Effect of phosphorus on the economics of cultivation

In summer vegetable cowpea, Patel (1979) reported that the highest net profit of Rs.4577/ha was obtained by the application of highest level of phosphorus i.e.,60kg/ha. From another study on cowpea, Jayaram and Ramiah (1980) reported that the economic optimum dose of P was 26.9 kg/ha. Among the different treatments, application of 25 kg P_2O_5/ha gave comparatively higher net return in both summer and kharif seasons. Among the different levels of P tried in cowpea, 75 kg/ha gave the highest gross, net returns and benefit-cost ratio of Rs.19,216, Rs.7832/ha and 1.69 respectively owing to higher yields (Rajput,1994). In summer mung, Arya and Kalra (1988) calculated the economically optimum dose of P from response curve as 43.63kg/ha and 44.20kg/ha for two consecutive years. Pal and Jana (1991) found that the benefit-cost ratio was maximum (5.47) at 30kg P_2O_5/ha and diminished to 1.51 at 60kg P_2O_5/ha in green gram.

MATERIALS AND METHODS

MATERIALS AND METHODS

The investigation was carried out with the objective of assessing the effect of phosphorus on vegetable cowpea var. Malika under varying moisture regimes and plant densities and to work out the economics of different treatment combinations. The materials used and the methods adopted for the study are briefly described below.

3.1 MATERIALS

3.1.1 Experimental site

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

3.1.2 Soil

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

3.1.3 Cropping histroy of the field

During the previous two seasons,bulk crop of rice was cultivated in the experimental area.

3.1.4 Season

The study was conducted during the summer season (period extending from the second fortnight of December to the first week of April of 1994-95).

Table3.1 Physico-Chemical properties of soil

A. Mechanical Composition

Sl no	Constituent	Content in soil (%)	Method used
1.	Coarse Sand	13.82	Bouyoucos Hydrometermethod (Bouyoucos, 1962)
2.	Fine Sand	32.75	
3.	Silt	28.25	
4.	Clay	24.88	

Textural Class - Sandy clay loam

B. Important Soil Physical Constants

Particulars	Depth of Soil layer (0-45cm)			Method used
	0-15	15-30	30-45	
Field capacity (per cent)	23.5	20.5	25.0	Core sampler method (Dasthane, 1967)
Bulk density (Mg/m^3)	1.30	1.33	1.35	(Dakshinamurthy and Gupta, 1968)

C. Chemical Composition

Sl No	Parameters	Content	Rating	Method used
1.	Available N (Kg/ha)	430	Medium	Alkaline potassium permanganate method (Subbiah and Asija, 1956)
2.	Available P_2O_5 (Kg/ha)	34	Medium	Bray colorimetric method(Jackson,1973)
3.	Available K_2O (Kg/ha)	197	Medium	Ammonium acetate method(Jackson,1973)
4.	P^H	4.3	Acidic	P^H meter with glass electrode (Jackson, 1973)

3.1.5 Weather data

The meteorological data including weekly averages of temperature, evaporation, relative humidity and weekly totals of rainfall during the cropping period was collected from the Agrometeorological observatory attached to the Department of Agronomy, COA, Vellayani and are presented in Table 3.2 and Fig.1.

3.1.6 Crop and variety

Vegetable cowpea cv. Malika was selected for the study. This variety was released from COA, Vellayani and found suitable for cultivation in the red sandy clay loam soils of Kerala, especially during the summer rice fallows. The morphological characters of the variety are given in Table 3.3.

3.1.7 Source of seed material

The seeds for the experiment was obtained from the IF, COA, Vellayani.

3.1.8 Manures and Fertilizers

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

Urea - 46 per cent N

Mussoriephos - 22 per cent P_2O_5

Muriate of potash - 60 per cent K_2O

Fig. 1 Weather data during the cropping period(1994-1995)

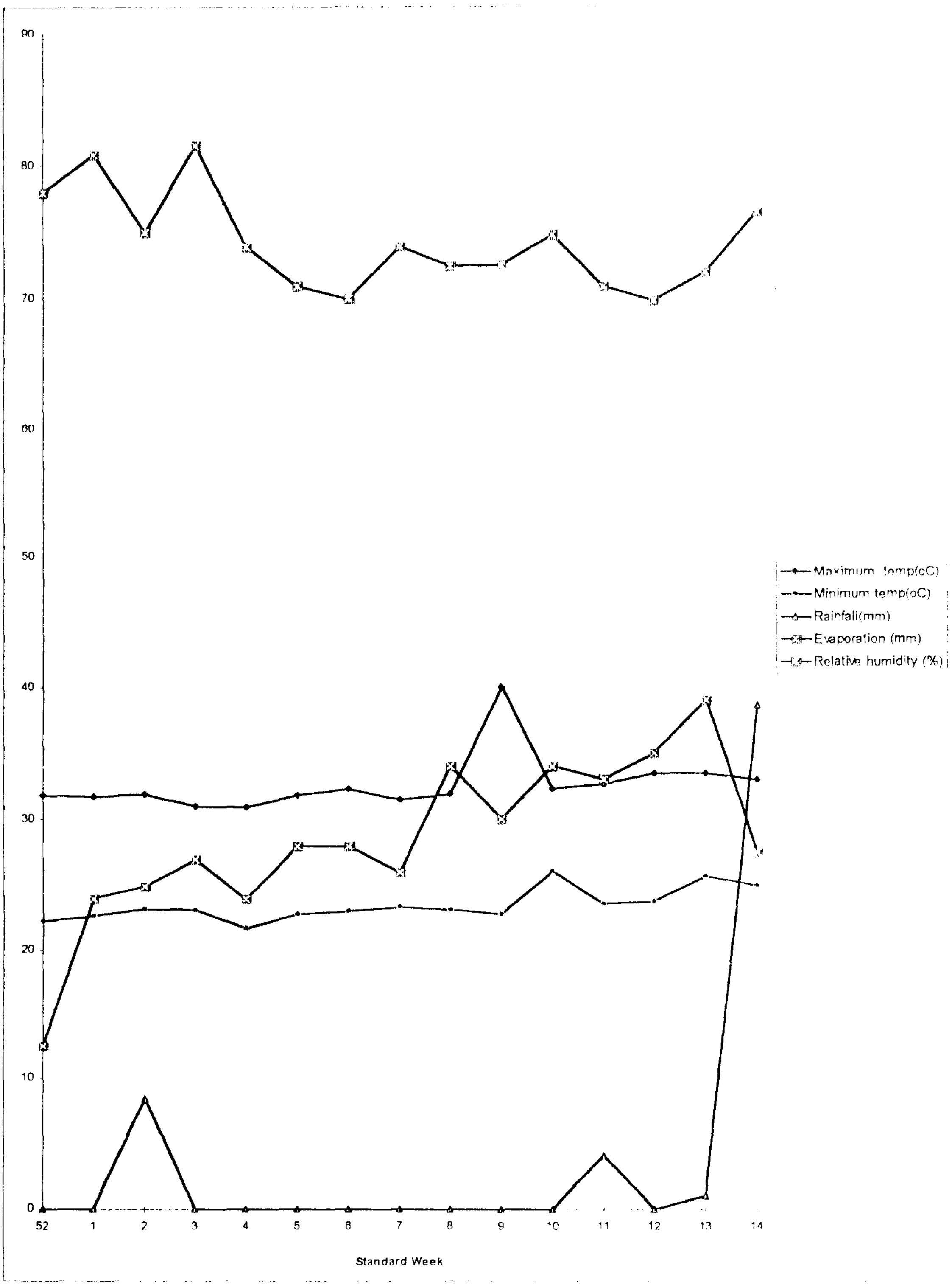


Table 3.2 Weather data during cropping period

Period	Standard week	Maximum temperature (°C)	Minimum temperature (°C)	Rainfall (mm) (weekly total)	Evaporation (mm) (weekly total)	Relative humidity (%)
1994-	52	31.8	22.2	0	12.5	77.93
95	1	31.7	22.6	0	24.0	80.79
	2	31.9	23.2	8.4	25.0	74.93
	3	31.0	23.1	0	27.0	81.43
	4	30.9	21.6	0	24.0	73.79
	5	31.8	22.8	0	28.0	70.93
	6	32.3	23.0	0	28.0	69.93
	7	31.5	23.3	0	26.0	73.79
	8	31.9	23.1	0	34.0	72.36
	9	40.0	22.8	0	30.0	72.43
	10	32.3	23.1	0	34.0	74.71
	11	32.6	23.6	4.0	33.0	70.79
	12	33.4	23.7	0	35.0	69.79
	13	33.4	25.7	1.0	39.0	71.86
	14	32.9	25.0	38.6	27.5	76.42

Table 3.3 Morphological characters of vegetable cowpea cv.Malika

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

Fig. 2 Layout plan of the experimental plot

I - Irrigation levels(3)

I_1 - Irrigating at 10 mm CPE value

I_2 - Irrigating at 15 mm CPE value

D -Plant density levels(3)

D_1 - 22,222 pts/ha (0.75X0.6 m)

D_2 - 16,667 pts/ha (1X0.6 m)

D_3 - 13,333 pts/ha (1.25X0.6m)

P - Phosphorus levels(4)

P_0 - No phosphorus

P_1 - 30 kg/ha P_2O_5

P_2 - 45 kg/ha P_2O_5

P_3 - 60 kg/ha P_2O_5

$I_2D_1P_0$	$I_2D_1P_2$	$I_3D_1P_1$	$I_3D_1P_3$	$I_1D_1P_2$	$I_1D_1P_0$
$I_2D_1P_1$	$I_2D_1P_3$	$I_3D_1P_0$	$I_3D_1P_2$	$I_1D_1P_3$	$I_1D_1P_1$
$I_2D_3P_3$	$I_2D_3P_0$	$I_3D_3P_0$	$I_3D_3P_1$	$I_1D_3P_3$	$I_1D_3P_1$
$I_2D_3P_1$	$I_2D_3P_2$	$I_3D_3P_3$	$I_3D_3P_2$	$I_1D_3P_0$	$I_1D_3P_2$
$I_2D_2P_0$	$I_2D_2P_1$	$I_3D_2P_1$	$I_3D_2P_2$	$I_1D_2P_0$	$I_1D_2P_2$
$I_2D_2P_3$	$I_2D_2P_2$	$I_3D_2P_3$	$I_3D_2P_0$	$I_1D_2P_1$	$I_1D_2P_3$
$I_2D_3P_1$	$I_2D_3P_0$	$I_1D_3P_2$	$I_1D_3P_3$	$I_3D_3P_3$	$I_3D_3P_2$
$I_2D_3P_3$	$I_2D_3P_2$	$I_1D_3P_1$	$I_1D_3P_0$	$I_3D_3P_1$	$I_3D_3P_0$
$I_2D_2P_3$	$I_2D_2P_1$	$I_1D_2P_1$	$I_1D_2P_2$	$I_3D_2P_1$	$I_3D_2P_0$
$I_2D_2P_2$	$I_2D_2P_0$	$I_1D_2P_0$	$I_1D_2P_3$	$I_3D_2P_2$	$I_3D_2P_3$
$I_2D_1P_2$	$I_2D_1P_3$	$I_1D_1P_1$	$I_1D_1P_0$	$I_3D_1P_2$	$I_3D_1P_1$
$I_2D_1P_0$	$I_2D_1P_1$	$I_1D_1P_2$	$I_1D_1P_3$	$I_3D_1P_0$	$I_3D_1P_3$
$I_3D_1P_1$	$I_3D_1P_3$	$I_1D_1P_3$	$I_1D_1P_2$	$I_2D_1P_0$	$I_2D_1P_1$
$I_3D_1P_0$	$I_3D_1P_2$	$I_1D_1P_1$	$I_1D_1P_0$	$I_2D_1P_3$	$I_2D_1P_2$
$I_3D_2P_3$	$I_3D_2P_1$	$I_1D_2P_0$	$I_1D_2P_2$	$I_2D_2P_2$	$I_2D_2P_3$
$I_3D_2P_0$	$I_3D_2P_2$	$I_1D_2P_1$	$I_1D_2P_3$	$I_2D_2P_1$	$I_2D_2P_0$
$I_3D_3P_3$	$I_3D_3P_1$	$I_1D_3P_2$	$I_1D_3P_0$	$I_2D_3P_2$	$I_2D_3P_0$
$I_3D_3P_2$	$I_3D_3P_0$	$I_1D_3P_3$	$I_1D_3P_1$	$I_2D_3P_1$	$I_2D_3P_3$

Strip-Split plot design

Gross plot size - 6 x 4.8m

Net plot size - 4 x 3.6m

3.2 METHODS

3.2.1 Design and layout

The field experiment was laidout in Strip-split plot design with three replications. The layout is presented in Fig.2.

3.2.2 Treatment details

Treatment combinations- 36

Main plot combinations (9) - Combinations of three levels of irrigation and three levels of plant density in horizontal and vertical strips.

Sub plot treatments (4) - Four levels of phosphorus in the subplots (split plots) within the cross-section plots.

Irrigation levels

I_1 - Irrigating the crop at 10mm CPE value

I_2 - Irrigating the crop at 15mm CPE value

(Depth of irrigation 20mm for I_1 and I_2)

I_3 - Farmer's practice (Light irrigation of 10mm everyday)

Plant density levels

D_1 - 22,222 plants/ha (0.75 X 0.6m)

D_2 - 16,667 plants/ha (1 X 0.6m)

D_3 - 13,333 plants/ha (1.25 X 0.6m)

Phosphorus levels

P_0 - No phosphorus

P_1 - 30 kg/ha P_2O_5

P_2 - 45 kg/ha P_2O_5

P3 - 60 kg/ha P_2O_5

3.2.3 Size of the plot

Gross plot size - 6 X 4.8m

Net plot size - 4 X 3.6m

3.3 FIELD CULTURE

3.3.1 Land preparation

The experimental field was ploughed with a power tiller, stubbles were removed and levelled properly. The field was then laid out into blocks and plots. Liming was done to neutralize the acidity of the field @ 250 kg/ha.

3.3.2 Manures and fertilizers

FYM @ 20 t/ha was applied uniformly to all the plots and mixed well with the top soil. A common dose of 30 kg/ha N and 10 kg/ha K_2O was given to all the treatments. Phosphorus was applied in the form of Rock phosphate. Full dose of phosphorus and potash and half of nitrogen was applied basally one week after sowing and the remaining half of nitrogen in three equal split doses 20, 30 and 40 DAS as soil application.

3.3.3 Sowing

Furrows of width 30cm were taken along the length of the plot at 1, 1.25 or 0.75m distance according to treatment and seeds were dibbled at the rate of three per hole at a depth of 5cm in the furrows and at a spacing of 60cm between plants.

3.3.4 Aftercultivation

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

3.3.5 Irrigation

The differential irrigations according to the treatments were started 10 DAS. Soil samples were taken periodically from each plot and moisture content was calculated by gravimetric method and also by using Sentry 200 AP, an instrument giving values of soil moisture content at varying depths based on the high dielectric constant of water and the moisture depletion pattern was studied. Measured quantities of water was given to the plots according to the treatments at a CPE value of 10 and 15mm respectively in treatments I_1 and I_2 at a depth of 20mm and daily irrigation treatment given to I_3 at a depth of 10mm.

3.3.6 Plant protection

BHC 10% dust was applied along the furrows and also around each individual plot after sowing to prevent the attack of ants feeding on seeds and also grasshoppers cutting the young seedlings at the collar region. Dusting was repeated every week till one month. Quinalphos at 0.3% and Phosphamidon at 0.1% were sprayed at 20 and 30 DAS as a prophylactic measure against aphids and shoot borer. Spraying of Neem kernel suspension was given thrice from flowering stage to about 80 days stage to protect the plant from the American leaf miner found serious in the field.

Soil drenching with Fytolan 0.3% was done 2-3 days before sowing as a prophylactic measure against pre-emergence damping off. Regular spraying of the fungicide was repeated at intervals of two weeks upto 45 DAS.

3.3.7 Harvesting

Vegetable picking commenced 50 DAS. Subsequent harvests of immature pods from the net plot area was done in alternate days uniformly from all the treatments upto 100 DAS and fresh weight and dry weight recorded seperately. After the crop period when the vegetable yield had fallen well below the economic level, the plants were pulled out from the net area and bhusa yield recorded. After that the same was sundried and ovendried and dry weight was recorded.

3.4 BIOMETRIC OBSERVATIONS

3.4.1 Height of the plant

The mean value of the height of 5 randomly selected observational plants from each net plot were computed at 30, 45, 60, 75 and 90 DAS and recorded. The height was taken from the base of the plant to the terminal leaf bud and expressed in centimetres.

3.4.2 Number of branches

The mean values of number of branches per plant were computed from 5 observational plants at 30, 45 and 60 DAS and recorded.

3.4.3 Number of leaves

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

3.4.4 Drymatter production (DMP)

DMP was recorded during five growth stages viz., 30, 45,60,75 and 90 DAS. One plant was uprooted from the destructive row at each stage carefully without damaging the roots and seperated into leaves, stem and roots. These were dried under shade seperately and then oven dried at 65^0C for 10 hours till two consecutive weights coincided. The final weights were totalled and expressed in gram per plant.

3.4.5 Days for 50 per cent flowering

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

3.4.6 Number of pods per plant

Pods collected from 5 observational plants per net plot were counted seperately and averages were worked out.

3.4.7 Pod yield in kg/ha

Yield of vegetable obtained from each net plot was recorded seperately and totalled up at the end of the cropping season and expressed in kg/ha

3.4.8 Earliness of harvest

Observations on the day of first harvest, protracted pattern of maturity of pods for early harvest treatmentwise were done.

3.4.9 Haulm yield

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

3.4.10 Number of picking

Number of vegetable pickings from each net plot during the total crop period was recorded treatmentwise.

3.5 SOIL 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 an interval of 15days for each treatment. The total loss from each layer was determined on percentage basis at the end of the cropping period.

3.5.2 Water use efficiency (WUE)

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

3.6 ANALYTICAL PROCEDURES

3.6.1 Soil analysis

Soil samples were taken from the experimental area before and after the experiment. The air dried soil samples were analysed for available N, P_2O_5 and K_2O content. Available N content was determined by Alkaline KM_nO_4 method (Subbiah and Asija, 1956), available P_2O_5 content by Bray Colorimetric method (Jackson, 1973) and available K_2O by Ammonium acetate method (Jackson, 1973).

3.6.2 Plant analysis

Plant samples were analysed for N,P and K content at 3 stages of crop growth viz, 30, 60 and 90 DAS. Samples were chopped and dried in an oven at 80 $\pm$ 5^{0}C till constant weights were obtained. Samples were ground and sieved through 60 mesh sieve. The required quantity of samples were then weighed out accurately in an electronic balance and used for chemical analysis.

3.6.3 Uptake studies

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

3.7 ECONOMIC ANALYSIS

The economics of cultivation of the crop was worked out and the net income and Benefit- Cost ratio(BCR) were calculated as follows:-

$$BCR = \frac{\text{Gross Income}}{\text{Total Cost of Cultivation}}$$

3.8 STATISTICAL ANALYSIS

Data relating to each character was analysed by applying the Analysis of Variance technique (ANOVA) (Gomez and Gomez, 1984).

RESULTS

RESULTS

A field experiment was conducted at the Instructional Farm attached to the College of Agriculture, Vellayani during the summer season of 1995 to study the response of vegetable cowpea cv.Malika to phosphorus under varying moisture levels and plant densities. The experimental data collected were statistically analysed to find out the effects of graded levels of irrigation, plant density and phosphorus as well as their interaction effects. The results obtained are presented below.

4.1 Growth characters

Plant growth was measured in terms of plant height, number of leaves and branches per plant at fortnightly intervals commencing from 30 DAS.

4.1.1 Plant height

Plant height as influenced by irrigation, plant density and phosphorus are presented in Table 4.1, 4.1.1, 4.1.2, 4.1.3 and 4.1.4.During all the different stages of crop growth, plant height was significantly influenced by irrigation, plant density and phosphorus and their interactions.

The irrigation treatments, I_1 and I_3 gave a marked increase in plant height over I_2. I_3 was also significantly superior to I_1. The same trend was noticed upto 90 DAS. A plant density level of D_2 recorded a significantly higher plant height over D_1 and D_3 during all the growth stages. A marked reduction in plant height was also noted with D_1 compared to the other plant density levels. The phosphorus level of P_2 was significantly superior to all the other levels with respect to the height of plants. The trend remained the same throughout the crop growth. With a no phosphorus level (P_o) a significant reduction in plant height was noted compared to all other levels. In general, a significant increase was noted in plant height with increase in the level of phosphorus upto P_2 whereas a further higher level P_3 showed a significant reduction.

The interactions of irrigation and plant density, irrigation and phosphorus and density and phosphorus exerted remarkable influence on plant height. The combinations I_3D_2, I_3P_2 and D_2P_2 gave appreciably taller plants than other two factor combinations.

The combined interaction of the three factors, viz.,irrigation, plant density and phosphorus was also significant with respect to the plant height. The treatment combination $I_3D_2P_2$ was superior to all other treatment combinations during all the stages of crop growth except at 30 DAS when I_1 was on a par with I_3 at the same level of density and phosphorus, D_2P_2.

4.1.2 Number of leaves per plant

The mean number of leaves per plant as influenced by irrigation, plant density and phosphorus are presented in Table 4.2 , 4.2.1 , 4.2.2, 4.2.3 and 4.2.4. Generally the number of leaves increased progressively upto 75 DAS. Thereafter a reduction in the number of leaves per plant was observed. The

Table 4.1 **Effect of irrigation, plant density and phosphorus on plant height(cm)**

Treatments	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
Irrigation					
I_1	103.03	175.71	237.23	296.24	356.09
I_2	92.35	151.61	217.79	278.70	333.38
I_3	103.69	177.02	238.70	297.00	357.68
$F_{2,4}$	11667**	58974**	13074**	5141.33**	**
SE	0.059	0.059	0.102	0.144	0.0
CD (0.05)	0.231	0.231	0.401	0.567	0.0
Plant density					
D_1	97.86	164.69	228.12	287.28	345.43
D_2	101.18	171.21	234.58	293.84	352.70
D_3	100.02	168.43	231.03	290.82	349.03
$F_{2,4}$	1639.00**	1230.80**	**	1556.00**	**
SE	0.042	0.093	0.0	0.083	0.0
CD (0.05)	0.164	0.366	0.0	0.327	0.0
Phosphorus					
P_0	94.50	157.29	222.01	280.67	338.71
P_1	97.20	164.63	227.28	286.56	344.59
P_2	104.26	176.11	238.92	298.95	357.70
P_3	102.79	174.43	236.74	296.40	355.21
$F_{3,54}$	6036.59**	10793.57**	14210.31**	17685.00**	**
SE	0.059	0.085	0.067	0.064	0.0
CD (0.05)	0.168	0.240	0.189	0.181	0.0

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

Treatments	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
I_1 D_1	100.64	171.31	233.35	291.77	351.63
I_1 D_2	105.14	179.69	241.53	300.48	360.56
I_1 D_3	103.30	176.14	236.48	296.47	356.09
I_2 D_1	91.58	150.11	216.68	277.46	331.75
I_2 D_2	92.59	153.09	218.80	279.78	334.98
I_2 D_3	92.88	151.62	217.89	278.88	333.43
I_3 D_1	101.36	172.67	234.33	292.60	352.90
I_3 D2	105.82	180.85	243.40	301.28	362.56
I_3 D_3	103.88	177.53	238.38	297.12	357.58
$F_{4,8}$	112.57**	**	348.00**	**	42.00**
SE	0.095	0.0	0.102	0.0	0.270
CD (0.05)	0.311	0.0	0.333	0.0	0.881

Table 4.1.2 Interaction effect of irrigation and phophorus on plant height (cm)

Treatments	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
I_1P_0	96.53	162.20	226.54	284.44	343.07
I_1P_1	99.77	171.12	231.70	289.76	350.62
I_1P_2	108.76	185.64	246.58	306.97	367.03
I_1P_3	107.06	183.89	244.08	303.79	363.66
I_2P_0	90.24	146.22	212.10	272.56	328.47
I_2P_1	91.42	150.06	216.87	279.27	331.02
I_2P_2	94.63	155.31	221.59	281.90	337.56
I_2P_3	93.09	154.83	220.61	281.09	336.49
I_3P_0	96.72	163.43	227.40	285.00	344.61
I_3P_1	100.40	172.70	223.28	290.67	352.11
I_3P_2	109.39	187.37	248.60	307.99	368.52
I_3P_3	108.23	184.57	245.53	304.33	365.48
$F_{6,54}$	544.39**	712.29**	825.92**	1497.00**	**
SE	0.103	0.147	0.116	0.111	0.0
CD(0.05)	0.290	0.416	0.327	0.314	0.0

Table 4.1.3 Interaction effect of plant density and phosphorus on plant height (cm)

Treatments	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
D_1P_0	93.52	155.23	220.28	279.28	336.66
D_1P_1	96.10	161.27	226.59	284.64	342.64
D_1P_2	101.52	172.11	233.94	294.01	352.40
D_1P_3	100.29	170.17	231.67	291.17	350.01
D_2P_0	95.34	159.16	223.61	281.94	340.81
D_2P_1	98.49	167.47	228.27	288.42	346.89
D_2P_2	106.01	180.07	244.07	304.02	362.90
D_2P_3	104.89	178.16	242.36	300.99	360.19
D_3P_0	94.63	157.47	222.16	280.78	338.68
D_3P_1	97.00	165.14	226.99	286.62	344.22
D_3P_2	105.24	176.14	238.76	298.82	357.81
D_3P_3	103.20	174.97	236.20	297.06	355.42
$F_{6,54}$	66.29**	45.43**	401.54**	315.00**	**
SE	0.103	0.147	0.116	0.111	0.0
CD(0.05)	0.290	0.416	0.327	0.314	0.0

Table 4.1.4 Interaction effect of irrigation, plant density and phosphorus on plant height (cm)

Treatments	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
$I_1D_1P_0$	95.20	159.47	224.80	283.30	340.77
$I_1D_1P_1$	98.37	167.13	230.83	287.53	348.73
$I_1D_1P_2$	105.53	180.07	240.53	299.93	360.00
$I_1D_1P_3$	103.47	178.57	237.23	296.30	357.03
$I_1D_2P_0$	97.57	164.53	228.03	285.60	345.10
$I_1D_2P_1$	101.23	174.97	233.23	292.37	353.07
$I_1D_2P_2$	111.73	190.73	253.13	313.93	373.93
$I_1D_2P_3$	110.03	188.53	251.70	310.03	370.13
$I_1D_3P_0$	96.83	162.60	226.80	284.43	343.33
$I_1D_3P_1$	99.70	171.27	231.03	289.37	350.07
$I_1D_3P_2$	109.00	186.13	246.07	307.03	367.17
$I_1D_3P_3$	107.67	184.57	243.30	305.03	363.80
$I_2D_1P_0$	89.90	145.23	210.63	270.63	327.20
$I_2D_1P_1$	91.17	148.63	217.03	278.30	330.00
$I_2D_1P_2$	92.80	153.63	219.90	280.80	335.60
$I_2D_1P_3$	92.43	152.93	219.17	280.10	334.20
$I_2D_2P_0$	90.70	147.17	213.10	274.13	329.70
$I_2D_2P_1$	91.80	151.30	215.97	279.80	332.00
$I_2D_2P_2$	94.20	157.17	223.57	283.03	339.63
$I_2D_2P_3$	93.67	156.73	223.57	282.13	338.57
$I_2D_3P_0$	90.13	146.27	212.57	272.90	328.50
$I_2D_3P_1$	91.30	150.23	217.60	279.70	331.07
$I_2D_3P_2$	96.90	155.13	221.30	281.87	337.43
$I_2D_3P_3$	93.17	154.83	220.10	281.03	336.70

Treatments	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
$I_3D_1P_0$	95.47	161.00	225.40	283.90	342.00
$I_3D_1P_1$	98.77	168.03	231.90	288.10	349.20
$I_3D_1P_2$	106.23	182.63	241.40	301.30	361.60
$I_3D_1P_3$	104.97	179.00	238.60	297.10	358.80
$I_3D_2P_0$	97.77	165.77	229.70	286.10	347.63
$I_3D_2P_1$	102.43	176.13	235.60	293.10	355.60
$I_3D_2P_2$	112.01	192.30	255.50	315.10	375.13
$I_3D_2P_3$	110.97	189.20	252.80	310.80	371.87
$I_3D_3P_0$	96.93	163.53	227.10	285.00	344.20
$I_3D_3P_1$	100	173.93	232.33	290.80	351.53
$I_3D_3P_2$	109.83	187.17	248.90	307.57	368.83
$I_3D_3P_3$	108.77	185.50	245.20	305.10	365.77
$F_{12,54}$	18.00**	5.25**	50.19**	96.75**	**
SE	0.178	0.255	0.200	0.192	0.0
CD(0.05)	0.503	0.720	0.567	0.544	0.0

irrigation treatments influenced the number of leaves per plant during all the growth stages. The I_3 treatment produced the highest number of leaves per plant and it was minimum with I_2. The differences between the irrigation treatments were significant except I_3 and I_1 which were on par only at 90 DAS. A plant density level of D_2 gave significantly higher leaf number as compared to D_3 which was also significantly superior to D_1. The trend remained the same upto 90 DAS. The graded levels of phosphorus also gave an appreciable increase in the number of leaves upto P_2 but a significant reduction in the character was noted with a higher dose of phosphorus, P_3.

The interaction between irrigation and plant density was significant with respect to the number of leaves from 45 to 90 DAS. A higher leaf number was noted with the I_3 treatment at a plant density level D_2. But at the same density level D_2, I_1 and I_3 levels of irrigation were found to be on a par with each other with respect to the leaf number during all the growth stages expect at 75 DAS when I_3D_2 was significantly superior to I_1D_2.

The interaction effect of irrigation and phosphorus was also significant. The irrigation treatment I_3 gave the highest number of leaves per plant at a phosphorus level of P_2 during all the growth stages except at 45 DAS when I_1 was superior at the same level of phosphorus. But I_3P_2 was found to be an a par with I_1P_2 during all the stages except 45 DAS, with I_3P_3 at 30,75 and 90 DAS and with I_1P_3 at 30 and 90 DAS.

The interaction effect of plant density and phosphorus on the leaf number was significant. The phosphorus level P_2 at a plant density of D_2 gave the highest leaf number at 30,45 and 75 DAS whereas P_3 was superior at 60 and 90DAS at the same plant density. But the two combinations were on par with each other during all the growth stages except 45 DAS and also with D_3P_3 at 75 DAS. So, the P levels P_2 and P_3 were on par at the density level D_2 during all the stages except 45 DAS.

The interaction of all the three factors, irrigation, plant density and phosphorus was also significant in case of number of leaves per plant upto 90 DAS. The irrigation levels I_1 and I_3 and phosphorus levels P_2 and P_3 at a plant density of D_2 were on par and superior to other combinations and recorded higher leaf number at 30, 60, 75 and 90 DAS. $I_1D_2P_2$ was significantly superior to all other treatment combinations at 45 DAS. At 75 DAS, the combinations $I_1D_3P_3$, $I_3D_3P_3$ and $I_3D_3P_2$ were found to be on par with the superior combinations.

4.1.3 Number of branches

The influence of differential levels of irrigation,plant density and phosphorus and their interactions on the number of branches per plant from 30 to 60 DAS is presented in Table 4.3,4.3.1,4.3.2,4.3.3 and 4.3.4. During all the three stages of crop growth observed the number of branches was significanty influenced by irrigation, plant density and phosphorus and their interactions.

Table 4.2 Effect of irrigation, plant density and phosphorus on number of leaves per plant

Treatments	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
Irrigation					
I_1	18.95	39.54	73.88	80.88	67.46
I_2	15.12	34.95	71.09	78.04	64.89
I_3	19.16	39.65	73.97	81.01	67.50
$F_{2,4}$	11214.12**	22058.00**	6176.00**	**	5154.00**
SE	0.021	0.018	0.021	0.0	0.021
CD(0.05)	0.084	0.071	0.082	0.0	0.082
Plant density					
D_1	17.34	37.39	72.52	79.73	66.28
D_2	18.24	38.78	73.40	80.21	66.96
D_3	17.64	37.97	73.02	79.98	66.59
$F_{2,4}$	708.18**	**	**	**	**
SE	0.017	0.0	0.0	0.0	0.0
CD (0.05)	0.068	0.0	0.0	0.0	0.0
Phosphorus					
P_0	16.23	36.33	71.79	78.84	65.60
P_1	17.59	37.50	72.50	79.68	66.23
P_2	18.63	39.31	73.92	80.74	67.36
P_3	18.51	39.05	73.71	80.64	67.26
$F_{3,54}$	751.47**	5515.09**	2390.40**	1339.71**	1671.30**
SE	0.04	0.019	0.021	0.024	0.021
CD(0.05)	0.114	0.053	0.059	0.069	0.059

Table 4.2.1 Interaction effect of irrigation and plant density on number of leaves per plant

TreatmentS	45 DAS	60 DAS	75 DAS	90 DAS
I_1D_1	38.86	73.32	80.58	67.07
I_1D_2	40.37	74.42	81.18	67.83
I_1D_3	39.39	73.91	80.88	67.47
I_2D_1	34.43	70.81	77.86	64.71
I_2D_2	35.48	71.31	78.19	65.13
I_2D_3	34.95	71.15	78.06	64.82
I_3D_1	38.88	73.44	80.73	67.08
I_3D_2	40.50	74.47	81.28	67.93
I_3D_3	39.57	73.99	81.01	67.49
$F_{4,8}$	11.33**	40.00**	4.00**	12.67**
SE	0.049	0.026	0.026	0.031
CD (0.05)	0.161	0.083	0.083	0.102

Table 4.2.2 Interaction effect of irrigation and phosphorus on number of leaves per plant

Treatments	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
I_1P_0	17.37	37.69	72.39	79.42	66.22
I_1P_1	18.79	38.81	73.37	80.58	67.03
I_1P_2	19.87	40.93	75.03	81.80	68.32
I_1P_3	19.77	40.72	74.73	81.72	68.24
I_2P_0	13.53	33.28	70.42	77.39	64.23
I_2P_1	14.90	34.64	70.77	77.81	64.58
I_2P_2	16.10	36.20	71.61	78.54	65.42
I_2P_3	15.93	35.69	71.56	78.40	65.31
I_3P_0	17.80	38.02	72.54	79.70	66.36
I_3P_1	19.08	39.03	73.37	80.64	67.07
I_3P_2	19.91	40.79	75.11	81.88	68.33
I_3P_3	19.83	40.74	74.84	81.80	68.23
$F_{6,54}$	2.90^{*}	42.00^{**}	107.10^{**}	57.21^{**}	44.55^{**}
SE	0.070	0.033	0.036	0.042	0.036
CD(0.05)	0.198	0.092	0.101	0.120	0.101

Table 4.2.3 Interaction effect of plant density and phosphorus on number of leaves per plant

Treatments	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
D_1P_0	15.70	35.83	71.52	78.57	65.34
D_1P_1	17.31	37.28	72.26	79.49	66.02
D_1P_2	18.21	38.34	73.26	80.56	66.90
D_1P_3	18.13	38.10	73.06	80.29	66.87
D_2P_0	16.73	36.76	72.03	79.13	65.90
D_2P_1	18.00	37.77	72.78	79.90	66.43
D_2P_2	19.20	40.49	74.34	80.96	67.74
D_2P_3	19.03	40.11	74.43	80.87	67.78
D_3P_0	16.27	36.40	71.80	78.81	65.57
D_3P_1	17.46	37.44	72.47	79.64	66.22
D_3P_2	18.47	39.09	74.16	80.71	67.43
D_3P_3	18.37	38.94	73.64	80.77	67.14
$F_{6,54}$	2.44*	166.09**	46.80**	3.86**	13.05**
SE	0.070	0.033	0.036	0.042	0.036
CD (0.05)	0.198	0.092	0.101	0.120	0.101

Table 4.2.4 Interaction effect of irrigation, plant density and phosphorus on number of leaves per plant

Treatments	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
$I_1D_1P_0$	16.60	37.30	72.00	79.10	65.90
$I_1D_1P_1$	18.50	38.73	73.10	80.40	66.77
$I_1D_1P_2$	19.50	39.80	74.20	81.57	67.90
$I_1D_1P_3$	19.20	39.60	73.97	81.27	67.70
$I_1D_2P_0$	18.00	38.17	72.80	79.87	66.53
$I_1D_2P_1$	19.20	39.00	73.70	80.80	67.30
$I_1D_2P_2$	20.50	42.30	75.57	82.03	68.67
$I_1D_2P_3$	20.50	42.00	75.60	82.00	68.83
$I_1D_3P_0$	17.50	37.60	72.37	79.30	66.23
$I_1D_3P_1$	18.67	38.70	73.30	80.53	67.03
$I_1D_3P_2$	19.60	40.70	75.33	81.80	68.40
$I_1D_3P_3$	19.60	40.57	74.63	81.90	68.20
$I_2D_1P_0$	13.00	32.73	70.27	77.17	64.10
$I_2D_1P_1$	14.60	34.50	70.63	77.80	64.60
$I_2D_1P_2$	15.70	35.50	71.27	78.37	65.03
$I_2D_1P_3$	15.80	35.00	71.07	78.10	65.10
$I_2D_2P_0$	14.00	33.60	70.60	77.43	64.43
$I_2D_2P_1$	15.50	34.90	70.77	77.87	64.63
$I_2D_2P_2$	16.60	37.10	71.87	78.87	65.80
$I_2D_2P_3$	16.20	36.30	72.00	78.60	65.67
$I_2D_3P_0$	13.60	33.50	70.40	77.57	64.17
$I_2D_3P_1$	14.60	34.53	70.90	77.77	64.50
$I_2D_3P_2$	16.00	36.00	71.70	78.40	65.43

Treatments	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
$I_2D_3P_3$	15.80	35.77	71.60	78.50	65.17
$I_3D_1P_0$	17.50	37.47	72.30	79.43	66.03
$I_3D_1P_1$	18.83	38.60	73.03	80.27	66.70
$I_3D_1P_2$	19.43	39.73	74.30	81.73	67.77
$I_3D_1P_3$	19.40	39.70	74.13	81.50	67.80
$I_3D_2P_0$	18.20	38.50	72.70	80.10	66.73
$I_3D_2P_1$	19.30	39.40	73.87	81.03	67.37
$I_3D_2P_2$	20.50	42.07	75.60	81.97	68.77
$I_3D_2P_3$	20.40	42.03	75.70	82.00	68.83
$I_3D_3P_0$	17.70	38.10	72.63	79.57	66.30
$I_3D_3P_1$	19.10	39.10	73.20	80.63	67.13
$I_3D_3P_2$	19.80	40.57	75.43	81.93	68.47
$I_3D_3P_3$	19.70	40.50	74.70	81.90	68.07
$F_{12,54}$	2.36*	11.46**	4.95**	4.50**	2.03*
SE	0.121	0.056	0.062	0.073	0.062
CD(0.05)	0.342	0.160	0.176	0.208	0.176

The number of branches per plant showed significant variations due to differential irrigation. I_3 treatment gave significantly higher value compared to I_1 which was again superior to I_2. The varying levels of plant density was also found to influence the number of branches. D_2 gave the highest number and was significantly superior to D_3 which was again superior to D_1. Additional increase in P was found to result in an additional number of branches upto P_2 whereas a higher level P_3 resulted in a reduction in branching. The differences were significant.

The number of branches was significantly influenced by the interaction of irrigation and density. At the density level D_2. I_1 and I_3 levels of irrigation were on par with each other at 30 DAS whereas I_3 dominated during all other stages.

The interaction of irrigation and phosphorus was also found to influence the number of branches. At a phosphorus level P_2. irrigation level I_3 gave the highest number of branches at 30 DAS and I_1 at 45 and 60 DAS. But at a phosphorus level P_2.I_1 and I_3 were on par with each other at 30 and 45 DAS and also with the combination I_3P_3 at 45 DAS.

The number of branches per plant was also significantly influenced by the interaction of plant density and phosphorus. At a plant density of D_2. phosphorus at a level P_2 showed superiority from 30 to 60 DAS. At 45 DAS, P_2 was observed to be on par with P_3 at the density level I_2 with respect to the number of branches.

Table 4.3 Effect of irrigation, plant density and phosphorus on number of branches per plant

Treatments	30 DAS	45 DAS	60 DAS
Irrigation			
I_1	3.89	5.88	7.83
I_2	2.34	4.28	6.17
I_3	3.95	5.93	7.90
$F_{2,4}$	23293.86**	10202.27**	8562.79**
SE	0.006	0.009	0.011
CD (0.05)	0.023	0.037	0.042
Plant density			
D_1	3.24	5.20	7.10
D_2	3.58	5.54	7.47
D_3	3.36	5.34	7.33
$F_{2,4}$	145.01**	166.32**	274.53**
SE	0.014	0.013	0.011
CD (0.05)	0.055	0.051	0.045
Phosphorus			
P_0	2.80	4.75	6.66
P_1	3.20	5.17	6.98
P_2	3.84	5.79	7.84
P_3	3.74	5.74	7.73
$F_{3,54}$	1056.01**	2121.40**	2802.61**
SE	0.015	0.011	0.011
CD (0.05)	0.042	0.031	0.030

Table 4.3.1 Interaction effect of irrigation and plant density on number of branches per plant.

Treatments	30 DAS	45 DAS	60 DAS
I_1D_1	3.75	5.73	7.58
I_1D_2	4.10	6.08	8.04
I_1D_3	3.82	5.83	7.88
I_2D_1	2.24	4.13	6.01
I_2D_2	2.47	4.40	6.31
I_2D_3	2.33	4.31	6.20
I_3D_1	3.74	5.75	7.71
I_3D_2	4.17	6.13	8.07
I_3D_3	3.95	5.89	7.93
$F_{4,8}$	10.71 **	11.72**	6.83**
SE	0.018	0.013	0.016
CD(0.05)	0.059	0.044	0.051

Table 4.3.2 Interaction effect of irrigation and phosphorus on number of branches per plant

Treatments	30 DAS	45 DAS	60 DAS
I_1P_0	3.13	5.09	6.88
I_1P_1	3.69	5.72	7.43
I_1P_2	4.40	6.42	8.62
I_1P_3	4.33	6.30	8.40
I_2P_0	2.00	4.03	6.01
I_2P_1	2.12	3.99	5.99
I_2P_2	2.70	4.56	6.37
I_2P_3	2.56	4.53	6.32
I_3P_0	3.27	5.12	7.10
I_3P_1	3.80	5.79	7.52
I_3P_2	4.41	6.40	8.52
I_3P_3	4.33	6.39	8.46
$F_{6,54}$	35.17^{**}	132.64^{**}	326.88^{**}
SE	0.026	0.019	0.019
CD (0.05)	0.073	0.053	0.053

Table 4.3.3 Interaction effect of plant density and phosphorus on number of branches per plant

Treatments	30 DAS	45 DAS	60 DAS
D_1P_0	2.68	4.70	6.54
D_1P_1	3.00	5.01	6.86
D_1P_2	3.69	5.60	7.57
D_1P_3	3.61	5.50	7.43
D_2P_0	2.93	4.86	6.74
D_2P_1	3.49	5.36	7.06
D_2P_2	4.02	5.99	8.14
D_2P_3	3.87	5.96	7.94
D_3P_0	2.79	4.69	6.70
D_3P_1	3.12	5.13	7.03
D_3P_2	3.80	5.79	7.80
D_3P_3	3.74	5.77	7.80
$F_{6,54}$	6.10**	14.69**	33.90**
SE	0.026	0.019	0.019
CD(0.05)	0.073	0.053	0.053

Table 4.3.4 Interaction effect of irrigation, plant density and phosphorus on number of branches per plant

Treatments	30 DAS	45 DAS	60 DAS
$I_1D_1P_0$	3.00	5.03	6.57
$I_1D_1P_1$	3.47	5.47	7.27
$I_1D_1P_2$	4.30	6.27	8.47
$I_1D_1P_3$	4.23	6.17	8.03
$I_1D_2P_0$	3.37	5.27	7.03
$I_1D_2P_1$	4.03	6.03	7.57
$I_1D_2P_2$	4.53	6.57	8.93
$I_1D_2P_3$	4.47	6.47	8.63
$I_1D_3P_0$	3.03	4.97	7.03
$I_1D_3P_1$	3.57	5.67	7.47
$I_1D_3P_2$	4.37	6.43	8.47
$I_1D_3P_3$	4.30	6.27	8.53
$I_2D_1P_0$	2.03	4.03	6.03
$I_2D_1P_1$	2.00	4.03	5.97
$I_2D_1P_2$	2.50	4.27	5.97
$I_2D_1P_3$	2.43	4.17	6.07
$I_2D_2P_0$	1.97	4.03	5.97
$I_2D_2P_1$	2.23	3.97	6.03
$I_2D_2P_2$	3.00	4.83	6.67
$I_2D_2P_3$	2.67	4.77	6.57
$I_2D_3P_0$	2.00	4.03	6.03
$I_2D_3P_1$	2.13	3.97	5.97
$I_2D_3P_2$	2.60	4.57	6.47

Treatments	30 DAS	45 DAS	60 DAS
$I_2D_3P_3$	2.57	4.67	6.33
$I_3D_1P_0$	3.00	5.03	7.03
$I_3D_1P_1$	3.53	5.53	7.33
$I_3D_1P_2$	4.27	6.27	8.27
$I_3D_1P_3$	4.17	6.17	8.20
$I_3D_2P_0$	3.47	5.27	7.23
$I_3D_2P_1$	4.20	6.07	7.57
$I_3D_2P_2$	4.53	6.57	8.83
$I_3D_2P_3$	4.47	6.63	8.63
$I_3D_3P_0$	3.33	5.07	7.03
$I_3D_3P_1$	3.67	5.77	7.67
$I_3D_3P_2$	4.43	6.37	8.47
$I_3D_3P_3$	4.37	6.37	8.53
$F_{12,54}$	6.36**	15.68**	15.89**
SE	0.045	0.032	0.032
CD (0.05)	0.127	0.092	0.091

The interaction of all the three factors, irrigation, plant density and phosphorus together was also found to influence the growth character significantly. The combination $I_1D_2P_2$ and $I_3D_2P_2$ was observed to give maximum branching at 30 DAS and $I_3D_2P_3$ alone at 45 DAS where as at 60 DAS $I_1D_2P_2$ alone gave maximum number of branches. However at 45 DAS I_1 and I_3 was found to be on par with each other at a density and phosphorus level D_2P_2. Also these combinations were on par with $I_3D_2P_3$. But at 30 DAS, P_2 and P_3 levels at I_1D_2 and I_3D_2 combinations and D_2 and D_3 at I_3P_2 were found to be on par, i.e., $I_1D_2P_2$, $I_1D_2P_3$, $I_3D_2P_2$, $I_3D_2P_3$ and $I_3D_3P_2$ gave similar response in branching effect.

4.1.4 Days for 50 per cent flowering

The mean number of days taken for attaining 50 percent flowering is given in Table 4.4. It was noted that differential irrigation exerted significant influence in attaining 50 percent flowering. The number of days taken for 50 percent flowering was minimum for I_3 treatment which was on par with I_1 However, the plant density did not influence in attaining of 50 percent flowering. Phosphorus application at all levels induced early flowering than no application of phosphorus. P_3 was the earliest to flower. The interaction effect of different treatment combinations was not seen with respect to the character.

4.1.5 Total dry matter production (DMP)

The data on total DMP at different growth stages as influenced by the treatments and their interactions is summarized in Table 4.5, 4.5.1, 4.5.2, 4.5.3 and 4.5.4. The data clearly revealed that irrigation, phosphorus, plant density and the interaction of these factors significantly influenced the total DMP. The DMP was found to increase progressively upto 90 DAS.

The irrigation level of I_3 recorded maximum DMP at all the growth stages and was superior to other levels except I_1 at 45 DAS. A plant density level of D_2 was observed to give maximum DMP and was significantly superior to the other treatments uniformly upto 90 DAS. A significant increase in the total DMP was manifested throughout the crop growth with increase in the level of P upto P_2 but thereafter a significant reduction was noted.

The interaction between irrigation and plant density had a significant influence on the DMP throughout the crop. At the plant density level D_2, I_3 gave maximum value for the attribute and was significantly superior to all other combinations except at 45 DAS when I_1 was found to be on a par with I_3 at the density level D_2.

The irrigation treatment I_3 at P_2 level of phosphorus recorded maximum DMP and was remarkably superior to all other combinations upto 90 DAS establishing the interaction effect of irrigation and phosphorus on the total DMP. The significance of the interaction of plant density and phosphorus was clearly established by the data showing superiority in the total DMP by the plant density level D_2 at P_2 level of phosphorus above all other combinations upto 90 DAS. However the response to P_2 and P_3 at the density level D_2 was similar at 45 DAS.

Table 4.4 Effect of irrigation, plant density and phosphorus on days for 50 percent flowering.

Treatments	Days for 50 percent flowering
Irrigation	
I_1	42.41
I_2	43.99
I_3	42.38
$F_{2,4}$	23.21**
SE	0.192
CD (0.05)	0.752
Plant density	
D_1	43.11
D_2	42.75
D_3	42.92
$F_{2,4}$	2.98
SE	0.104
CD(0.05)	0.409
Phosphorus	
P_0	43.57
P_1	42.99
P_2	42.57
P_3	42.58
$F_{3,54}$	13.80**
SE	0.127
CD (0.05)	0.358

Table 4.5 Effect of irrigation, plant density and phosphorus on total DMP (kg/ha)

Treatments	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
Irrigation					
I_1	179.46	1987.90	2268.75	3352.58	4421.18
I_2	160.60	1885.06	2134.55	3116.91	4129.54
I_3	180.72	1989.96	2277.34	3366.78	4436.08
$F_{2,4}$	18285.50**	8092.00**	9616.67**	**	16805.00**
SE	0.083	0.667	0.816	0.0	1.333
CD (0.05)	0.327	2.617	3.205	0.0	5.234
Plant density					
D_1	170.53	1899.53	2205.381	3244.23	4285.66
D_2	176.64	1983.67	2248.03	3313.73	4377.88
D_3	173.61	1979.72	2227.23	3278.32	4330.26
$F_{2,4}$	1787.33**	**	**	1358.00**	511.50**
SE	0.072	0.0	0.0	0.943	1.886
CD (0.05)	0.283	0.0	0.0	3.701	7.403
Phosphorus					
P_0	164.21	1865.68	2164.47	3173.48	4203.29
P_1	170.50	1974.64	2200.93	3247.23	4291.61
P_2	180.86	1989.64	2278.39	3357.93	4423.49
P_3	178.80	1987.28	2263.73	3336.38	4397.34
$F_{3,54}$	49281.43**	80514.00**	18612.00**	6327.69**	8352.00**
SE	0.035	0.210	0.392	1.068	1.109
CD (0.05)	0.098	0.593	1.109	3.022	3.136

Table 4.5.1 **Interaction effect of irrigation and plant density on total DMP (kg/ha)**

Treatments	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
I_1D_1	175.58	1981.56	2240.48	3314.98	4373.63
I_1D_2	183.40	1993.65	2295.15	3391.15	4469.58
I_1D_3	179.39	1988.50	2270.63	3351.60	4420.33
I_2D_1	159.29	1733.18	2125.58	3089.23	4096.28
I_2D_2	161.76	1961.93	2143.15	3144.25	4160.35
I_2D_3	160.75	1960.08	2134.93	3117.25	4132.00
I_3D_1	176.73	1983.85	2250.08	3328.48	4387.08
I_3D_2	184.75	1995.44	2305.80	3405.78	4482.73
I_3D_3	180.68	1990.58	2276.13	3366.10	4438.45
$F_{4,8}$	**	7956.00**	360.00**	10.00**	29.00**
SE	0.0	0.816	0.577	2.00	1.633
CD (0.05)	0.0	2.663	1.883	6.522	5.325

Table 4.5.2 Interaction effect of irrigation and phosphorus on total DMP (kg/ha)

Treatments	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
I_1P_0	167.53	1969.79	2188.07	3237.43	4286.27
I_1P_1	175.50	1981.11	2234.97	3315.37	4378.30
I_1P_2	188.84	2001.77	2337.03	3441.63	4525.33
I_1P_3	185.94	1998.95	2314.93	3415.87	4494.80
I_2P_0	156.37	1655.81	2109.20	3031.03	4025.00
I_2P_1	159.06	1957.96	2124.57	3098.53	4104.10
I_2P_2	163.88	1963.70	2155.01	3175.40	4204.50
I_2P_3	163.10	1962.79	2149.43	3162.67	4184.57
I_3P_0	168.73	1971.43	2196.13	3251.97	4298.60
I_3P_1	176.94	1984.84	2243.27	3327.80	4392.43
I_3P_2	189.86	2003.46	2343.11	3456.77	4540.63
I_3P_3	187.34	2000.10	2326.83	3430.60	4512.67
$F_{6,54}$	3621.86**	50157.00**	1674.00**	81.69**	78.43**
SE	0.060	0.363	0.679	1.850	1.920
CD (0.05)	0.170	1.026	1.920	5.234	5.431

Table 4.5.3 Interaction effect of plant density and phosphorus on total DMP (kg/ha)

Treatments	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
D_1P_0	162.61	1663.92	2153.47	3146.37	4171.53
D_1P_1	168.36	1971.13	2186.27	3224.87	4262.23
D_1P_2	176.59	1983.50	2248.02	3314.13	4367.57
D_1P_3	174.58	1979.57	2233.77	3291.53	4341.30
D_2P_0	166.03	1967.96	2174.63	3200.20	4233.67
D_2P_1	172.58	1977.45	2215.37	3270.30	4318.47
D_2P_2	184.98	1994.96	2308.97	3401.10	4477.57
D_2P_3	182.96	1994.33	2293.17	3383.3	4453.83
D_3P_0	163.99	1965.16	2165.30	3173.87	4204.67
D_3P_1	170.57	1975.33	2201.17	3246.53	4294.13
D_3P_2	181.01	1990.47	2278.17	3358.57	4425.33
D_3P_3	178.86	1987.93	2264.27	3334.30	4396.90
$F_{6,54}$	492.43**	54702.00**	228.86**	40.15**	61.71**
SE	0.060	0.363	0.679	1.850	1.920
CD (0.05)	0.170	1.026	1.920	5.234	5.431

Table 4.5.4 Interaction effect of irrigation, plant density and phosphorus on total DMP (kg/ha)

Treatments	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
$I_1D_1P_0$	165.90	1967.43	2172.60	3211.30	4253.40
$I_1D_1P_1$	172.80	1976.60	2214.40	3293.50	4347.30
$I_1D_1P_2$	183.10	1993.40	2298.80	3391.80	4461.60
$I_1D_1P_3$	180.50	1988.80	2276.10	3363.30	4432.20
$I_1D_2P_0$	169.70	1972.17	2201.30	3262.10	4317.80
$I_1D_2P_1$	178.10	1985.43	2252.20	3337.90	4408.10
$I_1D_2P_2$	194.50	2008.90	2374.00	3492.40	4591.90
$I_1D_2P_3$	191.30	2008.10	2353.10	3472.20	4560.50
$I_1D_3P_0$	167.00	1969.77	2190.30	3238.90	4287.60
$I_1D_3P_1$	175.60	1981.30	2238.30	3314.70	4379.50
$I_1D_3P_2$	188.93	2003.00	2338.30	3440.70	4522.50
$I_1D_3P_3$	186.03	1999.93	2315.60	3412.10	4491.70
$I_2D_1P_0$	155.43	1055.23	2104.10	3001.10	3999.70
$I_2D_1P_1$	158.03	1957.10	2118.80	3075.50	4077.50
$I_2D_1P_2$	162.30	1960.60	2142.13	3147.40	4165.50
$I_2D_1P_3$	161.40	1959.80	2137.30	3132.90	4142.40
$I_2D_2P_0$	157.10	1956.50	2113.60	3059.30	4052.10
$I_2D_2P_1$	159.97	1959.00	2130.40	3120.50	4127.50
$I_2D_2P_2$	165.30	1966.30	2167.40	3203.40	4240.10
$I_2D_2P_3$	164.67	1965.90	2161.20	3193.80	4221.70
$I_2D_3P_0$	156.57	1955.70	2109.90	3032.70	4023.20
$I_2D_3P_1$	159.17	1957.77	2124.50	3099.60	4107.30

Treatments	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
$I_2D_3P_2$	164.03	1964.20	2155.50	3175.40	4207.90
$I_2D_3P_3$	163.23	1962.67	2149.80	3161.30	4189.60
$I_3D_1P_0$	166.50	1969.10	2183.70	3226.70	4261.50
$I_3D_1P_1$	174.23	1979.70	2225.60	3305.60	4361.90
$I_3D_1P_2$	184.37	1996.50	2303.13	3403.20	4475.60
$I_3D_1P_3$	181.83	1990.10	2287.90	3378.40	4449.30
$I_3D_2P_0$	171.30	1975.20	2209.00	3279.20	4331.10
$I_3D_2P_1$	179.67	1987.90	2263.50	3352.50	4419.80
$I_3D_2P_2$	195.13	2009.67	2385.50	3507.50	4600.70
$I_3D_2P_3$	192.90	2009.00	2365.20	3483.90	4579.30
$I_3D_3P_0$	168.40	1970.00	2195.70	3250.00	4303.20
$I_3D_3P_1$	176.93	1986.93	2240.70	3325.30	4395.60
$I_3D_3P_2$	190.07	2004.20	2340.70	3459.60	4545.60
$I_3D_3P_3$	187.30	2001.20	2327.40	3429.50	4509.40
$F_{12,54}$	69.43**	57613.50**	23.14**	6.92**	5.79**
SE	0.104	0.629	1.176	3.205	3.326
CD (0.05)	0.294	1.778	3.326	9.065	9.407

Significant interaction between irrigation, plant density and phosphorus was recorded throughout the crop growth. The combination $I_3D_2P_2$ produced maximum dry matter, and was superior to all other levels except at 45 DAS when P_2 and P_3 and I_1 and I_3 were on a par with each other and their combinations at the density level D_2. Also at 90 DAS, I_1 recorded a response similar to I_3 at the density and phosphorus level D_2P_2.

4.2 Yield and yield attributes

4.2.1 Number of pods per plant

The data on the mean number of pods per plant are recorded in Table 4.6,4.6.1 and 4.6.2. The irrigation,plant density and phosphorus treatments and their interactions significantly influenced this character.

Irrigation levels had a profound influence on the number of pods per plant. I_3 treatment gave maximum number of pods which was significantly superior to all other levels. A notable reduction in this character could also be observed with the I_2 treatment. A plant density level of D_2 significantly increased the number of pods per plant than D_1 and D_3. An appreciable increase in pod number was noted with increasing levels of applied P upto P_2, but a higher dose resulted in a decline in pod number. A significantly lower pod number was obtained with no phosphorus as compared to all other levels.

The significance of interactions betwen irrigation and plant density, irrigation and phosphorus and density and phosphorus in effecting the number pods per plant was confirmed from the data. The combinations I_3D_2, I_3P_2 and D_2P_2 retained

Table 4.6 Effect of irrigation, plant density and phosphorus on the number of pods per plant

Treatments	Number of pods
Irrigation	
I_1	98.58
I_2	77.45
I_3	100.39
$F_{2,4}$	**
SE	0.0
CD(0.05)	0.0
Plant density	
D_1	87.92
D_2	96.68
D_3	91.83
$F_{2,4}$	**
SE	0.0
CD (0.05)	0.0
Phosphorus	
P_0	80.70
P_1	86.36
P_2	102.19
P_3	99.31
$F_{3,54}$	615537.00**
SE	0.013
CD (0.05)	0.037

Table 4.6.1 **Interaction effects of irrigation and plant density, irrigation & phosphorus & plant density & phosphorus on the number of pods per plant**

Treatments	Number of pods	Treatments	Number of pods
I_1D_1	92.85	I_3P_3	110.78
I_1D_2	104.55	$F_{6,54}$	92351.25**
I_1D_3	98.34	SE	0.023
I_2D_1	76.34	CD (0.05)	0.064
I_2D_2	78.63	D_1P_0	79.37
I_2D_3	77.39	D_1P_1	84.54
I_3D_1	94.57	D_1P_2	95.29
I_3D_2	106.85	D_1P_3	92.49
I_3D_3	99.74	D_2P_0	82.60
$F_{4,8}$	4062.67**	D_2P_1	88.78
SE	0.044	D_2P_2	108.77
CD (0.05)	0.144	D_2P_3	106.56
I_1P_0	83.49	D_3P_0	80.14
I_1P_1	90.74	D_3P_1	85.76
I_1P_2	111.97	D_3P_2	102.52
I_1P_3	108.12	D_3P_3	98.88
I_2P_0	74.46	$F_{6,54}$	16715.25**
I_2P_1	76.66	SE	0.023
I_2P_2	79.68	CD(0.05)	0.064
I_2P_3	79.02		
I_3P_0	84.17		
I_3P_1	91.68		
I_3P_2	114.93		

Table 4.6.2 Interaction effect of irrigation, plant density and phosphorus on the number of pods per plant

Treatments	Number of pods	Treatments	Number of pods
$I_1D_1P_0$	81.90	$I_2D_3P_3$	78.73
$I_1D_1P_1$	88.27	$I_3D_1P_0$	82.63
$I_1D_1P_2$	102.77	$I_3D_1P_1$	89.17
$I_1D_1P_3$	98.47	$I_3D_1P_2$	105.07
$I_1D_2P_0$	85.57	$I_3D_1P_3$	101.43
$I_1D_2P_1$	93.93	$I_3D_2P_0$	86.70
$I_1D_2P_2$	120.50	$I_3D_2P_1$	95.30
$I_1D_2P_3$	118.20	$I_3D_2P_2$	124.70
$I_1D_3P_0$	83.00	$I_3D_2P_3$	120.70
$I_1D_3P_1$	90.03	$I_3D_3P_0$	83.17
$I_1D_3P_2$	112.63	$I_3D_3P_1$	90.57
$I_1D_3P_3$	107.70	$I_3D_3P_2$	115.03
$I_2D_1P_1$	73.57	$I_3D_3P_3$	110.20
$I_2D_1P_1$	76.20	$F_{12,54}$	2983.50^{**}
$I_2D_1P_2$	78.03	SE	0.039
$I_2D_1P_3$	77.57	CD (0.05)	0.111
$I_2D_2P_0$	75.53		
$I_2D_2P_1$	77.10		
$I_2D_2P_2$	81.10		
$I_2D_2P_3$	80.77		
$I_2D_3P_0$	74.27		
$I_2D_3P_1$	76.67		
$I_2D_3P_2$	79.90		

their superiority with respect to this character throughout the growth of the crop. Also among the interactions of all the three factors together, $I_3D_2P_2$ gave a remarkably higher pod number.

4.2.2 Pod yield

Data pertaining to the green pod yield and haulm yield are presented in Table 4.7, 4.7.1, 4.7.2, 4.7.3 and 4.7.4. Varying levels of irrigation, plant density and phosphorus and their interactions exerted noticeable differences in pod and haulm yields.

Differential irrigation had significant influence on the green pod and haulm yields with I_3 giving superior values as compared to I_1 and I_2. I_2 recorded the lowest yields. The plant density level D_2 resluted in an appreciable increase in the pod and haulm yields as compared to D_1 and D_2. A marked reduction in the yields was also noted with D_1 in comparison with the other two. Similar to the number of pods per plant the green pod and haulm yields also increased with graded doses of P upto P_2 but a higher dose resulted in decreased yields.

The interaction effects of irrigation and plant density, irrigation and phosphorus and plant density and phosphorus on pod and haulm yields were also significant. The combinations I_3D_2, I_3P_2 and D_2P_2 gave better results. Also the three factor combination of $I_3D_2P_2$ was superior to all other combinations with respect to the green pod yield.

Table 4.7 Effect of irrigation, plant density and phosphorus on pod and haulm yield (kg/ha)

Treatments	Pod yield	Haulm yield
Irrigation		
I_1	8323.38	16668.75
I_2	7290.85	16189.06
I_3	8385.09	16694.42
$F_{2,4}$	15182.29**	**
SE	4.99	0.0
CD (0.05)	19.586	0.0
Plant density		
D_1	7882.77	16449.83
D_2	8114.41	16585.50
D_3	8002.14	16516.89
$F_{2,4}$	754.40**	161.00**
SE	4.216	5.333
CD (0.05)	16.553	20.938
Phosphorus		
P_0	7605.73	16305.74
P_1	7892.74	16445.89
P_2	8279.14	16681.56
P_3	8221.48	16636.45
$F_{3,54}$	3134.83**	10800.00**
SE	5.591	1.676
CD (0.05)	15.812	4.74

Table 4.7.1 Interaction effect of irrigation and plant density on pod and haulm yield (kg/ha)

Treatments	Pod yield	Haulm yield
I_1D_1	8186.55	16592.00
I_1D_2	8455.60	16745.00
I_1D_3	8327.98	16669.25
I_2D_1	7224.75	16140.50
I_2D_2	7356.71	16239.00
I_2D_3	7291.09	16187.67
I_3D_1	8237.02	16617.00
I_3D_2	8530.91	16772.50
I_3D_3	8387.34	16693.75
$F_{4,8}$	30.17**	**
SE	8.00	0.0
CD (0.05)	26.09	0.0

Table 4.7.2 Interaction effect of irrigation and phosphorus on pod and haulm yield (kg/ha)

Treatments	Pod yield	Haulm yield
I_1P_0	7809.67	16430.00
I_1P_1	8200.03	16583.33
I_1P_2	8668.17	16861.67
I_1P_3	8615.63	16800.00
I_2P_0	7136.21	16034.89
I_2P_1	7218.42	16147.67
I_2P_2	7425.73	16298.00
I_2P_3	7383.03	16275.67
I_3P_0	7871.30	16452.33
I_3P_1	8259.78	16606.67
I_3P_2	8743.51	16885.00
I_3P_3	8665.77	16833.67
$F_{6,54}$	256.85**	252.00**
SE	9.683	2.903
CD (0.05)	27.388	8.211

Table 4.7.3 Interaction effect of plant density and phosphorus on pod and haulm yeield (kg/ha)

Treatments	Pod yield	Haulm yield
D_1P_0	7513.23	16257.33
D_1P_1	7808.53	16394.33
D_1P_2	8137.02	16594.33
D_1P_3	8072.30	16553.33
D_2P_0	7701.05	16350.67
D_2P_1	7980.01	16502.00
D_2P_2	8402.20	16768.00
D_2P_3	8374.37	16721.33
D_3P_0	7602.90	16309.22
D_3P_1	7889.69	16441.33
D_3P_2	8298.19	16682.33
D_3P_3	8217.77	16634.67
$F_{6,54}$	11.23^{**}	58.50^{**}
SE	9.683	2.903
CD (0.05)	27.388	8.211

Table 4.7.4 Interaction effect of irrigation, plant density and phosphorus on pod yield (kg/ha)

Treatments	Pod yield	Treatments	Pod yield
$I_1D_1P_0$	7677.60	$I_2D_3P_3$	7371.30
$I_1D_1P_1$	8097.20	$I_3D_1P_0$	7741.40
$I_1D_1P_2$	8532.40	$I_3D_1P_1$	8134.60
$I_1D_1P_3$	8439.00	$I_3D_1P_2$	8573.87
$I_1D_2P_0$	7947.90	$I_3D_1P_3$	8498.20
$I_1D_2P_1$	8314.10	$I_3D_2P_0$	8002.70
$I_1D_2P_2$	8765.70	$I_3D_2P_1$	8383.03
$I_1D_2P_3$	8794.70	$I_3D_2P_2$	8907.60
$I_1D_3P_0$	7803.50	$I_3D_2P_3$	8830.30
$I_1D_3P_1$	8188.80	$I_3D_3P_0$	7869.80
$I_1D_3P_2$	8706.40	$I_3D_3P_1$	8261.70
$I_1D_3P_3$	8613.20	$I_3D_3P_2$	8749.07
$I_2D_1P_0$	7120.70	$I_3D_3P_3$	8668.80
$I_2D_1P_1$	7193.80	$F_{12,54}$	2.78**
$I_2D_1P_2$	7304.80	SE	16.772
$I_2D_1P_3$	7279.70	CD (0.05)	47.437
$I_2D_2P_0$	7152.53		
$I_2D_2P_1$	7242.90		
$I_2D_2P_2$	7533.30		
$I_2D_2P_3$	7498.10		
$I_2D_3P_0$	7135.40		
$I_2D_3P_1$	7218.57		
$I_2D_3P_2$	7439.10		

4.3 Nutrient uptake

The effect of varying levels of irrigation, plant density and phosphorus and their interactions on the uptake of nitrogen, phosphorus and potassium by the crop is summarised in Table 4.8, 4.8.1, 4.8.2, 4.8.3, 4.8.4, 4.9, 4.9.1, 4.9.2, 4.9.3, 4.9.4, 4.10, 4.10.1, 4.10.2, 4.10.3 and 4.10.4.

Irrigation levels profoundly influenced the nutrient uptake at all the stages of growth. I_3 registered maximum uptake and was significantly superior to I_1 and I_2. The lowest uptake was noted with I_2 constantly upto 90 DAS. The plant density treatments also resulted significant variations in the uptake of all the three nutrients. D_2 recorded highest and D_1 lowest for the uptake values from 30 to 90 DAS. The uptake of N, P and K was found to increase constantly with increase in applied P upto a level of P_2 and thereafter, a higher dose resulted in reduced uptake. The differences were analysed to be statistically significant at all the growth stages observed.

Among the different combinations of irrigation and plant density, irrigation and phosphorus and density and phosphorus, I_3D_2, I_3P_2 and D_2P_2 exhibited remarkably higher uptake of nutrients, except for K uptake at 60 DAS when I_1D_2 reached on par with I_3D_2 and also gave highest uptake. Also $I_3D_2P_2$, on comparing the different three factor combinations profoundly increased the nitrogen uptake, at 30 and 60 DAS. But at 90 DAS $I_1D_2P_2$ recorded maximum N uptake. However at 30 and 90 DAS, I_1 was on par with I_3 at the density and phosphorus combinations of D_2P_2 and was significantly superior to all other combinations. But for P uptake, the combination

$I_3D_2P_2$ showed higher uptake compared to other combinations only at 90 DAS. At 30 DAS the combination was also on a par with $I_3D_2P_3$. But at 45 DAS, $I_3D_2P_3$ was noted as significantly superior to all other combinations. In case of K uptake, however, $I_3D_2P_2$ gave profoundly higher uptake at 30 and 90 DAS. At 60 DAS $I_1D_2P_2$ was the combination resulting maximum K uptake. At 90 DAS, P_2 was found to be on a par with P_3 at an irrigation and density combination I_3D_2.

4.5 Soil analysis

The mean values of available N, P_2O_5 and K_2O contents of the soil after the experiment are presented in Table 4.11, 4.11.1, 4.11.2, 4.11.3 and 4.11.4.

It is revealed from the data that irrigation exert a significant influence on the soil nutrient status. I_2 recorded maximum content of available N,P_2O_5 and K_2O followed by I_1. The density levels also manifested appreciable effect on the nutrient status of the soil. D_1 recorded the highest N,P_2O_5 and K_2O contents in the soil followed by D_3. The nutrient content of the soil was found to decrease with increasing P levels upto P_2 after which there was a slight increase with P_3.

The soil nutrient status after the experiment was also found to be profoundly influenced by the interaction of irrigation and plant density, irrigation and phosphorus and density and phosphorus. The combinations I_2D_1, I_2P_0 and D_1P_0 recorded higher values of N, P_2O_5 and K_2O contents compared to other combinations. Similarly the combination $I_2D_1P_0$ recorded

Table 4.8 Effect of irrigation, plant density and phosphorus on the uptake of nitrogen by the crop (kg/ha)

Treatments	30 DAS	60 DAS	90 DAS
Irrigation			
I_1	13.30	48.25	44.96
I_2	12.54	38.81	35.34
I_3	13.33	48.77	45.48
$F_{2,4}$	**	289716.00**	27335.82**
SE	0.0	0.01	0.035
CD (0.05)	0.0	0.041	0.136
Plant density			
D_1	12.97	43.86	40.48
D_2	13.15	46.69	43.41
D_3	13.06	45.28	41.90
$F_{2,4}$	614.00**	6129.33**	6588.00**
SE	0.004	0.018	0.018
CD (0.05)	0.014	0.071	0.071
Phosphorus			
P_0	12.72	41.06	37.55
P_1	12.97	43.86	40.50
P_2	13.30	48.46	45.38
P_3	13.24	47.71	44.29
$F_{3,54}$	53802.00**	159310.30**	23123.42**
SE	0.001	0.009	0.024
CD (0.05)	0.003	0.024	0.067

Table 4.8.1 Interaction effect of irrigation and plant density on the uptake of nitrogen by the crop (kg/ha)

Treatments	30 DAS	60 DAS	90 DAS
I_1D_1	13.20	46.50	43.15
I_1D_2	13.39	49.99	46.82
I_1D_3	13.30	48.25	44.92
I_2D_1	12.46	37.99	34.51
I_2D_2	12.63	39.66	36.15
I_2D_3	12.55	38.77	35.36
I_3D_1	13.24	47.09	43.78
I_3D_2	13.43	50.41	47.25
I_3D_3	13.33	48.81	45.42
$F_{4,8}$	**	**	383.60**
SE	0.0	0.0	0.029
CD (0.05)	0.0	0.0	0.093

Table 4.8.2 Interaction effect of irrigation and phosphorus on the uptake of nitrogen by the crop (kg/ha)

Treatments	30 DAS	60 DAS	90 DAS
I_1P_0	12.92	43.21	39.68
I_1P_1	13.19	46.48	43.12
I_1P_2	13.57	52.01	49.22
I_1P_3	13.51	51.28	47.83
I_2P_0	12.27	36.31	32.84
I_2P_1	12.47	38.03	34.64
I_2P_2	12.73	40.72	37.23
I_2P_3	12.70	40.18	36.64
I_3P_0	12.97	43.67	40.13
I_3P_1	13.23	47.07	43.72
I_3P_2	13.59	52.67	49.67
I_3P_3	13.53	51.67	48.39
$F_{6,54}$	558.00**	6797.57**	1138.33**
SE	0.002	0.015	0.041
CD (0.05)	0.006	0.042	0.116

Table 4.8.3 Interaction effect of plant density and phosphorus on the uptake of nitrogen by the crop (kg/ha)

Treatments	30 DAS	60 DAS	90 DAS
D_1P_0	12.65	40.08	36.63
D_1P_1	12.89	42.88	39.48
D_1P_2	13.20	46.69	43.38
D_1P_3	13.12	45.80	42.42
D_2P_0	12.80	42.01	38.46
D_2P_1	13.05	44.83	41.45
D_2P_2	13.39	50.16	47.52
D_2P_3	13.36	49.75	46.19
D_3P_0	12.71	41.10	37.57
D_3P_1	12.96	43.88	40.55
D_3P_2	13.31	48.55	45.22
D_3P_3	13.26	47.59	44.24
$F_{6,54}$	153.00**	1229.14**	218.42**
SE	0.002	0.015	0.041
CD (0.05)	0.006	0.042	0.116

Table 4.8.4 Interaction effect of irrigation, plant density and phosphorus on the uptake of nitrogen by the crop (kg/ha)

Treatments	30 DAS	60 DAS	90 DAS
$I_1D_1P_0$	12.87	42.08	38.73
$I_1D_1P_1$	13.10	45.34	41.73
$I_1D_1P_2$	13.47	49.82	46.63
$I_1D_1P_3$	13.36	48.76	45.52
$I_1D_2P_0$	12.98	44.29	40.60
$I_1D_2P_1$	13.28	47.62	44.28
$I_1D_2P_2$	13.66	54.01	52.21
$I_1D_2P_3$	13.64	54.03	50.19
$I_1D_3P_0$	12.91	43.26	39.71
$I_1D_3P_1$	13.19	46.49	43.35
$I_1D_3P_2$	13.59	52.19	48.82
$I_1D_3P_3$	13.52	51.06	47.78
$I_2D_1P_0$	12.20	35.56	32.03
$I_2D_1P_1$	12.41	37.42	34.17
$I_2D_1P_2$	12.64	39.71	36.24
$I_2D_1P_3$	12.59	39.28	35.59
$I_2D_2P_0$	12.35	36.97	33.52
$I_2D_2P_1$	12.53	38.65	35.21
$I_2D_2P_2$	12.83	41.78	38.20
$I_2D_2P_3$	12.80	41.23	37.68
$I_2D_3P_0$	12.27	36.39	32.97
$I_2D_3P_1$	12.48	38.01	34.55

Treatments	30 DAS	60 DAS	90 DAS
$I_2D_3P_2$	12.74	40.66	37.26
$I_2D_3P_3$	12.70	40.03	36.64
$I_3D_1P_0$	12.89	42.59	39.13
$I_3D_1P_1$	13.16	45.87	42.54
$I_3D_1P_2$	13.49	50.53	47.27
$I_3D_1P_3$	13.41	49.36	46.16
$I_3D_2P_0$	13.07	44.77	41.25
$I_3D_2P_1$	13.33	48.21	44.87
$I_3D_2P_2$	13.67	54.68	52.16
$I_3D_2P_3$	13.63	53.99	50.71
$I_3D_3P_0$	12.95	43.65	40.02
$I_3D_3P_1$	13.21	47.13	43.76
$I_3D_3P_2$	13.62	52.79	49.59
$I_3D_3P_3$	13.56	51.67	48.31
$F_{12,54}$	27.00^{**}	146.57^{**}	30.89^{**}
SE	0.003	0.026	0.071
CD (0.05)	0.010	0.073	0.200

Table 4.9 **Effect of irrigation, plant density and phosphorus on the uptake of phosphorus by the crop (kg/ha)**

Treatments	30 DAS	60 DAS	90 DAS
Irrigation			
I_1	3.01	43.31	30.10
I_2	2.70	36.78	21.44
I_3	3.04	43.78	30.50
$F_{2,4}$	16532.04**	8298.35**	161046.00**
SE	0.001	0.43	0.013
CD (0.05)	0.006	0.169	0.05
Plant density			
D_1	2.81	40.42	26.42
D_2	2.97	42.13	28.36
D_3	2.92	41.33	27.25
$F_{2,4}$	2916.00**	**	1455.83**
SE	0.001	0.0	0.026
CD(0.05)	0.004	0.0	0.10
Phosphorus			
P_0	2.77	38.69	23.63
P_1	2.86	40.39	26.40
P_2	3.03	43.22	30.01
P_3	3.01	42.86	29.34
$F_{3,54}$	11022.35**	30575.57**	11204.81**
SE	0.001	0.012	0.028
CD	0.003	0.035	0.078

Table 4.9.1 Interaction effect of irrigation and plant density on the uptake of phosphorus by the crop (kg/ha)

Treatments	30 DAS	60 DAS	90 DAS
I_1D_1	2.95	42.24	29.00
I_1D_2	3.08	44.21	31.21
I_1D_3	3.01	43.48	30.09
I_2D_1	2.68	36.34	20.66
I_2D_2	2.72	37.23	22.16
I_2D_3	2.70	36.78	21.48
I_3D_1	2.97	42.67	29.61
I_3D_2	3.10	44.96	31.71
I_3D_3	3.04	43.73	30.17
$F_{4,8}$	215.60**	222.50**	54.93**
SE	0.002	0.026	0.035
CD (0.05)	0.006	0.083	0.114

Table 4.9.2 Interaction effect of irrigation and phosphorus on the uptake of phosphorus by the crop (kg/ha)

Treatments	30 DAS	60 DAS	90 DAS
I_1P_0	2.83	40.14	25.57
I_1P_1	2.93	42.24	28.88
I_1P_2	3.16	45.69	33.17
I_1P_3	3.13	45.17	32.77
I_2P_0	2.64	35.44	19.16
I_2P_1	2.68	36.37	20.81
I_2P_2	2.75	37.81	23.14
I_2P_3	2.75	37.52	22.63
I_3P_0	2.85	40.50	26.16
I_3P_1	2.96	42.56	29.49
I_3P_2	3.19	46.17	33.71
I_3P_3	3.15	45.91	32.62
$F_{6,54}$	925.15**	1873.29**	420.92**
SE	0.002	0.021	0.048
CD (0.05)	0.006	0.060	0.136

Table 4.9.3 Interaction effect of plant density and phosphorus on the uptake of phosphorus by the crop (kg/ha)

Treatments	30 DAS	60 DAS	90 DAS
D_1P_0	2.75	38.08	22.67
D_1P_1	2.83	39.76	25.54
D_1P_2	2.96	42.24	29.19
D_1P_3	2.93	41.59	28.29
D_2P_0	2.79	39.18	24.53
D_2P_1	2.88	41.01	27.27
D_2P_2	3.10	44.21	31.25
D_2P_3	3.09	44.14	30.39
D_3P_0	2.77	38.83	23.69
D_3P_1	2.86	40.40	26.38
D_3P_2	3.04	43.22	29.58
D_3P_3	3.00	42.86	29.34
$F_{6,54}$	205.15**	258.43**	19.45**
SE	0.002	0.021	0.048
CD (0.05)	0.006	0.060	0.136

Table 4.9.4 Interaction effect of irrigation, plant density and phosphorus on the uptake of phosphorus by the crop (kg/ha)

Treatments	30 DAS	60 DAS	90 DAS
$I_1D_1P_0$	2.80	39.23	24.46
$I_1D_1P_1$	2.90	41.47	27.77
$I_1D_1P_2$	3.07	44.54	32.43
$I_1D_1P_3$	3.03	43.72	31.32
$I_1D_2P_0$	2.85	40.82	26.65
$I_1D_2P_1$	2.97	42.98	29.96
$I_1D_2P_2$	3.25	46.62	34.63
$I_1D_2P_3$	3.24	46.43	33.59
$I_1D_3P_0$	2.83	40.37	25.59
$I_1D_3P_1$	2.93	42.27	28.92
$I_1D_3P_2$	3.17	45.91	32.46
$I_1D_3P_3$	3.12	45.35	33.39
$I_2D_1P_0$	2.63	35.13	18.44
$I_2D_1P_1$	2.66	35.94	20.32
$I_2D_1P_2$	2.72	37.25	22.18
$I_2D_1P_3$	2.71	37.03	21.71
$I_2D_2P_0$	2.65	35.70	19.76
$I_2D_2P_1$	2.68	36.77	21.30
$I_2D_2P_2$	2.78	38.44	24.03
$I_2D_2P_3$	2.77	38.00	23.57
$I_2D_3P_0$	2.63	35.48	19.29

Treatments	30 DAS	60 DAS	90 DAS
$I_2D_3P_1$	2.69	36.40	20.81
$I_2D_3P_2$	2.74	37.73	23.21
$I_2D_3P_3$	2.75	37.52	22.62
$I_3D_1P_0$	2.82	39.87	25.10
$I_3D_1P_1$	2.92	41.86	28.52
$I_3D_1P_2$	3.09	44.93	32.96
$I_3D_1P_3$	3.06	44.02	31.84
$I_3D_2P_0$	2.88	41.01	27.19
$I_3D_2P_1$	3.00	43.27	30.56
$I_3D_2P_2$	3.27	47.57	35.09
$I_3D_2P_3$	3.26	47.98	34.01
$I_3D_3P_0$	2.84	40.63	26.20
$I_3D_3P_1$	2.96	42.54	29.40
$I_3D_3P_2$	3.20	46.01	33.07
$I_3D_3P_3$	3.14	45.72	32.02
$F_{12,54}$	25.15**	68.79**	16.71**
SE	0.004	0.037	0.083
CD (0.05)	0.010	0.104	0.235

Table 4.10 **Effect of irrigation, plant density and phosphorus on the uptake of potassium by the crop (kg/ha)**

Treatments	30 DAS	60 DAS	90 DAS
Irrigation			
I_1	11.63	203.10	190.78
I_2	9.32	185.96	171.05
I_3	11.76	203.76	191.69
$F_{2,4}$	**	**	**
SE	0.0	0.0	0.0
CD (0.05)	0.0	0.0	0.0
Plant density			
D_1	10.56	195.11	181.58
D_2	11.22	200.43	187.23
D_3	10.93	197.28	184.72
$F_{2,4}$	3272.40**	**	4610.00**
SE	0.006	0.0	0.042
CD (0.05)	0.023	0.0	0.164
Phosphorus			
P_0	9.83	190.23	175.78
P_1	10.55	194.54	181.62
P_2	11.71	203.33	190.97
P_3	11.51	202.32	189.66
$F_{3,54}$	127222.00**	115542.00**	297018.00**
SE	0.002	0.019	0.013
CD (0.05)	0.007	0.052	0.037

Table 4.10.1 Interaction effect of irrigation and plant density on the uptake of potassium by the crop (kg/ha)

Treatments	30 DAS	60 DAS	90 DAS
I_1D_1	11.19	199.69	187.68
I_1D_2	12.05	207.25	193.83
I_1D_3	11.65	202.37	190.83
I_2D_1	9.16	184.91	169.01
I_2D_2	9.48	186.96	172.71
I_2D_3	9.33	186.00	171.43
I_3D_1	11.33	200.73	188.05
I_3D_2	12.14	207.09	195.14
I_3D_3	11.81	203.47	191.89
$F_{4,8}$	2320.00**	426.00**	**
SE	0.003	0.072	0.0
CD (0.05)	0.010	0.235	0.0

Table 4.10.2 Interaction effect of irrigation and phosphorus on the uptake of potassium by the crop (kg/ha)

Treatments	30 DAS	60 DAS	90 DAS
I_1P_0	10.27	194.33	180.84
I_1P_1	11.20	198.60	186.90
I_1P_2	12.64	210.21	198.60
I_1P_3	12.41	209.26	196.76
I_2P_0	8.86	181.80	165.80
I_2P_1	9.10	184.88	169.27
I_2P_2	9.73	189.02	174.81
I_2P_3	9.59	188.13	174.33
I_3P_0	10.36	194.56	180.71
I_3P_1	11.37	200.14	188.68
I_3P_2	12.77	210.77	199.51
I_3P_3	12.54	209.59	197.88
$F_{6,54}$	9222.00**	6885.00**	12033.00**
SE	0.004	0.032	0.023
CD (0.05)	0.012	0.091	0.064

Table 4.10.3 Interaction effect of plant density and phosphorus on the uptake of potassium by the crop (kg/ha)

Treatments	30 DAS	60 DAS	90 DAS
D_1P_0	9.66	188.69	174.06
D_1P_1	10.27	192.75	179.41
D_1P_2	11.27	199.99	187.27
D_1P_3	11.03	199.01	185.58
D_2P_0	10.02	191.37	177.50
D_2P_1	10.82	196.35	183.38
D_2P_2	12.08	207.36	194.20
D_2P_3	11.98	206.65	193.82
D_3P_0	9.82	190.64	175.78
D_3P_1	10.57	194.51	182.07
D_3P_2	11.79	202.65	191.45
D_3P_3	11.53	201.32	189.57
$F_{6,54}$	1039.00**	1872.00**	2727.00**
SE	0.004	0.032	0.023
CD (0.05)	0.012	0.091	0.064

Table 4.10.4 Interaction effect of irrigation, plant density and phosphorus on the uptake of potassium by the crop (kg/ha)

Treatments	30 DAS	60 DAS	90 DAS
$I_1D_1P_0$	10.06	192.65	179.64
$I_1D_1P_1$	10.81	195.71	184.35
$I_1D_1P_2$	12.09	205.50	194.28
$I_1D_1P_3$	11.80	204.89	192.43
$I_1D_2P_0$	10.50	196.12	182.24
$I_1D_2P_1$	11.57	201.43	188.76
$I_1D_2P_2$	13.13	216.01	202.76
$I_1D_2P_3$	13.02	215.42	201.54
$I_1D_3P_0$	10.26	194.23	180.64
$I_1D_3P_1$	11.21	198.65	187.60
$I_1D_3P_2$	12.71	209.12	198.76
$I_1D_3P_3$	12.41	207.46	196.32
$I_2D_1P_0$	8.80	180.42	164.12
$I_2D_1P_1$	8.99	184.03	168.45
$I_2D_1P_2$	9.49	187.96	172.23
$I_2D_1P_3$	9.36	187.21	171.25
$I_2D_2P_0$	8.92	182.56	167.31
$I_2D_2P_1$	9.21	185.98	170.04
$I_2D_2P_2$	9.95	190.33	176.66
$I_2D_2P_3$	9.82	188.98	176.83
$I_2D_3P_0$	8.86	182.43	165.97
$I_2D_3P_1$	9.08	184.63	169.31

Treatments	30 DAS	60 DAS	90 DAS
$I_2D_3P_2$	9.75	188.76	175.55
$I_2D_3P_3$	9.60	188.19	174.90
$I_3D_1P_0$	10.13	192.99	178.43
$I_3D_1P_1$	11.02	198.50	185.42
$I_3D_1P_2$	12.22	206.52	195.29
$I_3D_1P_3$	11.94	204.92	193.06
$I_3D_2P_0$	10.63	195.43	182.96
$I_3D_2P_1$	11.68	201.65	191.33
$I_3D_2P_2$	13.17	215.73	203.18
$I_3D_2P_3$	13.09	215.55	203.10
$I_3D_3P_0$	10.34	195.25	180.73
$I_3D_3P_1$	11.40	200.26	189.30
$I_3D_3P_2$	12.92	210.07	200.05
$I_3D_3P_3$	12.59	208.30	197.48
$F_{12,54}$	53.50**	477.00**	283.50**
SE	0.007	0.056	0.039
CD (0.05)	0.021	0.157	0.111

Table 4.11 **Effect of irrigation, plant density and phosphorus on the soil nutrient status after the experiment**

Treatments	Available N content (kg/ha)	Available P_2O_5 content (kg/ha)	Available K_2O content (kg/ha)
Irrigation			
I_1	539.87	44.06	73.80
I_2	609.37	47.95	77.77
I_3	536.33	43.85	73.60
$F_{2,4}$	30532.00**	**	12734.00**
SE	0.236	0.0	0.021
CD (0.05)	0.925	0.0	0.082
Plant density			
D_1	571.02	45.86	75.58
D_2	553.09	44.73	74.55
D_3	561.45	45.27	75.03
$F_{2,4}$	1447.00**	1481.00**	614.00**
SE	0.236	0.015	0.021
CD (0.05)	0.925	0.058	0.082
Phosphorus			
P_0	590.62	46.90	76.79
P_1	571.04	45.81	75.65
P_2	540.33	44.03	73.72
P_3	545.43	44.40	74.06
$F_{3,54}$	**	23358.86**	11952.00**
SE	0.0	0.009	0.013
CD(0.05)	0.0	0.024	0.037

Table 4.11.1 **Interaction effect of irrigation and plant density on the soil nutrient status after the experiment**

Treatments	Available N content (kg/ha)	Available P_2O_5 content (kg/ha)	Available K_2O content (kg/ha)
I_1D_1	550.73	44.78	74.36
I_1D_2	529.75	43.33	73.24
I_1D_3	539.13	44.08	73.79
I_2D_1	615.30	48.21	78.19
I_2D_2	603.28	47.63	77.33
I_2D_3	609.53	48.00	77.78
I_3D_1	547.03	44.59	74.20
I_3D_2	526.25	43.23	73.09
I_3D_3	535.70	43.74	73.51
$F_{4,8}$	**	65.33**	**
SE	0.0	0.031	0.0
CD (0.05)	0.0	0.102	0.0

Table 4.11.2 Interaction effect of irrigation and phosphorus on the soil nutrient status after the experiment

Treatments	Available N content (kg/ha)	Available P_2O_5 content (kg/ha)	Available K_2O content (kg/ha)
I_1P_0	573.59	46.19	75.63
I_1P_1	549.94	44.69	74.51
I_1P_2	515.18	42.48	72.31
I_1P_3	520.77	42.89	72.73
I_2P_0	628.63	48.56	79.33
I_2P_1	616.57	48.28	78.18
I_2P_2	594.03	47.37	76.66
I_2P_3	598.23	47.59	76.90
I_3P_0	569.63	45.97	75.41
I_3P_1	546.60	44.48	74.26
I_3P_2	511.77	42.26	72.19
I_3P_3	517.30	42.71	72.54
$F_{6,54}$	**	1992.86**	63.00**
SE	0.0	0.015	0.023
CD (0.05)	0.0	0.042	0.064

Table 4.11.3 **Interaction effect of plant density and phosphorus on the soil nutrient status after the experiment**

Treatments	Available N content (kg/ha)	Available P_2O_5 content (kg/ha)	Available K_2O content (kg/ha)
D_1P_0	597.53	47.31	77.17
D_1P_1	577.77	46.16	75.98
D_1P_2	551.41	44.78	74.37
D_1P_3	557.37	45.20	74.82
D_2P_0	583.97	46.47	76.44
D_2P_1	563.98	45.44	75.30
D_2P_2	530.72	43.40	73.11
D_2P_3	533.70	43.60	73.36
D_3P_0	590.36	46.93	76.77
D_3P_1	571.37	45.84	75.67
D_3P_2	538.84	43.92	73.68
D_3P_3	545.23	44.39	74.00
$F_{6,54}$	**	216.00**	74.250**
SE	0.0	0.015	0.023
CD (0.05)	0.0	0.042	0.064

Table 4.11.4 Interaction effect of irrigation, plant density and phosphorus on the soil nutrient status after the experiment.

Treatments	Available N content (kg/ha)	Available P_2O_5 content (kg/ha)	Available K_2O content (kg/ha)
$I_1D_1P_0$	582.00	46.67	75.90
$I_1D_1P_1$	557.70	45.07	74.80
$I_1D_1P_2$	527.83	43.50	73.13
$I_1D_1P_3$	535.40	43.90	73.60
$I_1D_2P_0$	565.50	45.60	75.33
$I_1D_2P_1$	542.13	44.23	74.20
$I_1D_2P_2$	504.57	41.60	71.53
$I_1D_2P_3$	506.80	41.87	71.90
$I_1D_3P_0$	573.27	46.30	75.67
$I_1D_3P_1$	550.00	44.77	74.53
$I_1D_3P_2$	513.13	42.33	72.27
$I_1D_3P_3$	520.10	42.90	72.70
$I_2D_1P_0$	632.70	48.67	79.83
$I_2D_1P_1$	621.30	48.50	78.53
$I_2D_1P_2$	601.80	47.77	77.03
$I_2D_1P_3$	605.40	47.90	77.37
$I_2D_2P_0$	625.20	48.40	78.90
$I_2D_2P_1$	610.90	48.07	77.80
$I_2D_2P_2$	586.40	46.90	76.20
$I_2D_2P_3$	590.60	47.17	76.40
$I_2D_3P_0$	628.00	48.60	79.27
$I_2D_3P_1$	617.50	48.27	78.20

Treatments	Available N content (kg/ha)	Available P_2O_5 content (kg/ha)	Available K_2O content (kg/ha)
$I_2D_3P_2$	593.90	47.43	76.73
$I_2D_3P_3$	598.70	47.70	76.93
$I_3D_1P_0$	577.90	46.60	75.77
$I_3D_1P_1$	554.30	44.90	74.60
$I_3D_1P_2$	524.60	43.07	72.93
$I_3D_1P_3$	531.30	43.80	73.50
$I_3D_2P_0$	561.20	45.40	75.10
$I_3D_2P_1$	538.90	44.03	73.90
$I_3D_2P_2$	501.20	41.70	71.60
$I_3D_2P_3$	503.70	41.77	71.77
$I_3D_3P_0$	569.80	45.90	75.37
$I_3D_3P_1$	546.60	44.50	74.27
$I_3D_3P_2$	509.50	42.00	72.03
$I_3D_3P_3$	516.90	42.57	72.37
$F_{12,54}$	**	32.79**	19.13**
SE	0.0	0.026	0.039
CD (0.05)	0.0	0.073	0.111

maximum values for N, P_2O_5 and K_2O. But with respect to P_2O_5 content D_3 was found to be on par with D_1 at I_2P_0 level of irrigation and phosphorus.

4.6 Moisture studies

4.6.1 Water-use efficiency

The data on WUE as influenced by irrigation, plant density and phosphorus and their interactions is given in Table 4.12, 4.12.1 and 4.12.2. Significant effect of the treatments and their interactions is evident from the tables.

The highest WUE was recorded with I_2 and was found superior to all other treatments. A marked reduction in WUE was noticed with I_3. I_2 recorded 181.05% increase in WUE over I_3 (farmers practice). The density levels also exhibited significant influence on WUE. D_2 was efficient than the other two levels followed by D_3. In general, an increasing trend was noted in WUE with increase in P levels upto P_2 but a further higher dose resulted in a significant lowering of WUE.

Appreciably higher efficiency of water use was found with the combinations I_2D_2, I_2P_2 and D_2P_2 of irrigation and plant density, irrigation and phosphorus and density and phosphorus respectively revealing the significance of interaction effects on the character studied. Also, the three factor combination $I_2D_2P_2$ registered comparatively more efficiency of water use.

4.6.2 Moisture _ extraction pattern (MEP)

The moisture extraction pattern from the different soil layers is presented in Table 4.13, 4.13.1, 4.13.2, 4.13.3 and 4.13.4 which clearly reveals the effect of irrigation, plant density and phosphorus and their interaction effect on the character.

The percentage extraction of moisture from the top layer (0-15cm) was found to be higher with wetter regimes with a maximum at I_3 followed by I_1 and least with I_2. But from 15-30 and 30-45 cm depths, the percentage extraction increased with drier regimes. The plant density level D_2 resluted in the highest percentage extraction from the top layer while D_1 extracted more water from deeper layers compared to the other levels bringing out the significance of plant density in the MEP. Depletion of moisture from the top 15cm increased progressively with increasing levels of phosphorus upto P_2 but a higher dose decreased the extraction. However absence of P gave the highest percentage extraction from the lower layers.

Comparing the MEP from different depths by the crop treated with various coimbinations of irrigation and plant density, irrigation and phosphorus and density and phosphorus, remarkably higher percentage of moisture depletion from 0-15cm depth was noticed with I_3D_2, I_3P_2 and D_2P_2 while I_2D_1, I_2P_0 and D_1P_0 extracted more moisture from 15-45 cm depth. Also, the three factor combination $I_3D_2P_2$ was observed to extract most of the moisture from the top 15 cm soil layer while the deeper layers were more exploited by the combination $I_2D_1P_0$. The differences were statistically relevant except for the similar response of D_2 and D_1 at a combination level I_2P_0 for the 15-30 cm soil layer.

Table 4.12 Effect of irrigation, plant density and phosphorus on water use efficiency (WUE) (kg/ha/mm)

Treatments	WUE
Irrigation	
I_1	11.90
I_2	15.19
I_3	8.39
$F_{2,4}$	**
SE	0.0
CD(0.05)	0.0
Plant density	
D_1	11.66
D_2	11.99
D_3	11.82
$F_{2,4}$	**
SE	0.00
CD(0.05)	0.00
Phosphorus	
P_0	11.30
P_1	11.67
P_2	12.21
P_3	12.12
$F_{3,54}$	**
SE	0.0
CD (0.05)	0.0

Table 4.12.1 Interaction effects of irrigation and plant density, irrigation and phosphorus and plant density and phosphorus on water use efficiency (WUE) (kg/ha/mm)

Treatments	WUE	Treatments	WUE	Treatments	WUE
I_1D_1	11.70	I_1P_0	11.16	D_1P_0	11.18
I_1D_2	12.11	I_1P_1	11.72	D_1P_1	11.56
I_1D_3	11.90	I_1P_2	12.43	D_1P_2	11.99
I_2D_1	15.05	I_1P_3	12.31	D_1P_3	11.91
I_2D_2	15.33	I_2P_0	14.87	D_2P_0	11.42
I_2D_3	15.19	I_2P_1	15.04	D_2P_1	11.78
I_3D_1	8.24	I_2P_2	15.47	D_2P_2	12.42
I_3D_2	8.53	I_2P_3	15.38	D_2P_3	12.34
I_3D_3	8.39	I_3P_0	7.87	D_3P_0	11.29
$F_{4,8}$	**	I_3P_1	8.26	D_3P_1	11.67
SE	0.00	I_3P_2	8.74	D_3P_2	12.23
CD(0.05)	0.00	I_3P_3	8.67	D_3P_3	12.11
		$F_{6,54}$	**	$F_{6,54}$	**
		SE	0.00	SE	0.00
		CD(0.05)	0.00	CD (0.05)	0.00

Table 4.12.2 Interaction effect of irrigation, plant density and phosphorus on water use efficiency (WUE) (kg/ha/mm)

Treatments	WUE	Treatments	WUE
$I_1D_1P_0$	10.97	$I_2D_3P_2$	15.50
$I_1D_1P_1$	11.57	$I_2D_3P_3$	15.36
$I_1D_1P_2$	12.19	$I_3D_1P_0$	7.74
$I_1D_1P_3$	12.06	$I_3D_1P_1$	8.13
$I_1D_2P_0$	11.35	$I_3D_1P_2$	8.57
$I_1D_2P_1$	11.88	$I_3D_1P_3$	8.50
$I_1D_2P_2$	12.66	$I_3D_2P_0$	8.00
$I_1D_2P_3$	12.56	$I_3D_2P_1$	8.38
$I_1D_3P_0$	11.15	$I_3D_2P_2$	8.91
$I_1D_3P_1$	11.70	$I_3D_2P_3$	8.83
$I_1D_3P_2$	12.44	$I_3D_3P_0$	7.87
$I_1D_3P_3$	12.30	$I_3D_3P_1$	8.26
$I_2D_1P_0$	14.83	$I_3D_3P_2$	8.75
$I_2D_1P_1$	14.99	$I_3D_3P_3$	8.67
$I_2D_1P_2$	15.22	$F_{12,54}$	**
$I_2D_1P_3$	15.16	SE	0.0
$I_2D_2P_0$	14.90	CD (0.05)	0.0
$I_2D_2P_1$	15.09		
$I_2D_2P_2$	15.69		
$I_2D_2P_3$	15.62		
$I_2D_3P_0$	14.87		
$I_2D_3P_1$	15.04		

Table 4.13 Effect of irrigation, plant density and phosphorus on moisture extraction pattern (MEP)

Treatments	MEP (per cent)		
	Soil depth (cm)		
	0-15	15-30	30-45
Irrigation			
I_1	68.98	21.19	9.83
I_2	61.88	26.79	11.33
I_3	69.36	20.80	9.85
$F_{2,4}$	81820.00**	207161.00**	18243.00**
SE	0.015	0.007	0.006
CD (0.05)	0.058	0.029	0.025
Plant density			
D_1	65.57	23.79	10.64
D_2	67.94	22.01	10.04
D_3	66.70	22.97	10.33
$F_{2,4}$	2157.33**	5816.00**	285.09**
SE	0.026	0.012	0.018
CD (0.05)	0.100	0.046	0.069
Phosphorus			
P_0	63.67	25.61	10.72
P_1	65.67	23.96	10.37
P_2	69.19	20.72	10.09
P_3	68.43	21.41	10.16
$F_{2,4}$	100686.00**	35466.67**	371.85**
SE	0.008	0.012	0.015
CD (0.05)	0.023	0.034	0.042

Table 4.13.1 Interaction effect of irrigation and plant density on moisture extraction pattern (MEP)

Treatment	MEP (per cent) Soil depth (cm)		
	0 - 15	15 - 30	30 - 45
I_1D_1	67.60	22.29	10.11
I_1D_2	70.35	20.05	9.61
I_1D_3	69.00	21.23	9.77
I_2D_1	61.17	27.14	11.69
I_2D_2	66.64	26.43	10.93
I_2D_3	61.82	26.80	11.38
I_3D_1	67.95	21.94	10.11
I_3D_2	70.84	19.57	9.59
I_3D_3	69.29	20.88	9.84
$F_{2,4}$	**	2619.00**	17.80**
SE	0.0	0.009	0.020
CD (0.05)	0.0	0.029	0.065

Table 4.13.2 Interaction effect of irrigation and phosphorus on moisture extraction pattern (MEP)

Treatments	MEP (per cent)		
	Soil depth (cm)		
	0 - 15	15 - 30	30 - 45
I_1P_0	65.45	24.56	9.98
I_1P_1	67.70	22.56	9.74
I_1P_2	71.83	18.36	9.81
I_1P_3	70.94	19.27	9.79
I_2P_0	59.81	27.90	12.29
I_2P_1	61.32	27.18	11.50
I_2P_2	63.41	25.89	10.70
I_2P_3	62.98	26.18	10.84
I_3P_0	65.74	24.36	9.90
I_3P_1	68.00	22.12	9.88
I_3P_2	72.33	17.92	9.75
I_3P_3	71.37	18.77	9.86
$F_{6,54}$	3204.00**	3130.83**	228.07**
SE	0.014	0.021	0.026
CD (0.05)	0.039	0.059	0.073

Table 4.13.3 Interaction effect of plant density and phosphorus on moisture extraction pattern (MEP)

Treatments	MEP(Per cent)		
	Soil depth (cm)		
	0-15	15-30	30-45
D_1P_0	63.09	26.00	10.91
D_1P_1	64.97	24.52	10.52
D_1P_2	67.38	21.94	10.68
D_1P_3	66.86	22.71	10.44
D_2P_0	64.24	25.16	10.60
D_2P_1	66.34	23.30	10.35
D_2P_2	71.08	19.47	9.45
D_2P_3	70.12	20.12	9.76
D_3P_0	63.68	25.66	10.66
D_3P_1	65.72	24.05	10.24
D_3P_2	69.11	20.77	10.13
D_3P_3	68.31	21.40	10.29
$F_{6,54}$	2205.00*	450.83**	100.56**
SE	0.014	0.021	0.026
CD(0.05)	0.039	0.059	0.073

Table 4.13.4 Interaction effect of irrigation, plant density and phosphorus on moisture extraction pattern (MEP)

Treatments	MEP (per cent)		
	Soil depth (cm)		
	0 - 15	15 - 30	30 - 45
$I_1D_1P_0$	64.83	25.08	10.09
$I_1D_1P_1$	66.91	23.18	9.91
$I_1D_1P_2$	69.62	19.93	10.45
$I_1D_1P_3$	69.04	20.98	9.98
$I_1D_2P_0$	66.00	23.98	10.02
$I_1D_2P_1$	68.42	21.82	9.76
$I_1D_2P_2$	74.01	16.76	9.23
$I_1D_2P_3$	72.96	17.62	9.42
$I_1D_3P_0$	65.53	24.63	9.84
$I_1D_3P_1$	67.77	22.70	9.54
$I_1D_3P_2$	71.87	18.38	9.75
$I_1D_3P_3$	70.82	19.21	9.97
$I_2D_1P_0$	59.24	28.00	12.75
$I_2D_1P_1$	60.76	27.41	11.83
$I_2D_1P_2$	62.52	26.42	11.06
$I_2D_1P_3$	62.17	26.73	11.10
$I_2D_2P_0$	60.37	27.79	11.85
$I_2D_2P_1$	61.88	26.94	11.17
$I_2D_2P_2$	64.41	25.33	10.26
$I_2D_2P_3$	63.92	25.65	10.43

Treatments	MEP (per cent)		
	Soil depth (cm)		
	0 - 15	15 - 30	30 - 45
$I_2D_3P_0$	59.83	27.90	12.27
$I_2D_3P_1$	61.32	27.19	11.48
$I_2D_3P_2$	63.30	25.93	10.78
$I_2D_3P_3$	62.84	26.17	10.99
$I_3D_1P_0$	65.19	24.92	9.89
$I_3D_1P_1$	67.23	22.96	9.81
$I_3D_1P_2$	70.01	19.46	10.53
$I_3D_1P_3$	69.37	20.41	10.23
$I_3D_2P_0$	66.35	23.73	9.93
$I_3D_2P_1$	68.71	21.15	10.13
$I_3D_2P_2$	74.82	16.32	8.86
$I_3D_2P_3$	73.48	17.08	9.44
$I_3D_3P_0$	65.69	24.43	9.89
$I_3D_3P_1$	68.06	22.26	9.70
$I_3D_3P_2$	72.15	17.99	9.86
$I_3D_3P_3$	71.26	18.83	9.91
$F_{12,54}$	259.50**	32.08**	28.73**
SE	0.024	0.036	0.044
CD (0.05)	0.068	0.102	0.126

4.7 Economics of cultivation

Economics of different treatments presented in Table 4.14, 4.14.1, 4.14.2, 4.14.3 and 4.14.4 indicated that net returns and BCR were significanlty influenced by irrigation, phosphorus, plant density and their interactions.

The irrigation treatment I_1 gave the maximum net returns and the BCR and was significantly economic compared to other levels. A plant density level D_2 was observed to be most profitable with the highest net returns and BCR. An appreciable increase in net returns and BCR was recorded with increase in doses of P upto P_2 but a higher dose was found less economic.

Among the different combinations of irrigation and plant density, irrigation and phosphorus and density and phosphorus tried, I_1D_2, I_1P_2 and D_2P_2 were more profitable giving more net returns and higher BCR substantiating the significance of interaction effects on the economics of cultivation. Also comparing the different combinations of the three factors, $I_1D_2P_2$ was computed to be most economic while $I_3D_1P_0$ gave the lowest net returns and BCR.

Table 4.14 Effect of irrigation, plant density and phosphorus on economics of cultivation

Treatments	Net returns (Rs/ha)	Benefit-cost ratio
Irrigation		
I_1	19161.48	1.62
I_2	16414.57	1.60
I_3	10789.78	1.27
$F_{2,4}$	67394.43**	179962.00**
SE	16.438	0.0
CD (0.05)	64.535	0.002
Plant density		
D_1	14127.87	1.45
D_2	16421.91	1.53
D_3	15816.06	1.52
$F_{2,4}$	4731.91**	4630.00**
SE	17.282	0.001
CD (0.05)	67.847	0.003
Phosphorus		
P_0	13415.36	1.44
P_1	14805.41	1.48
P_2	17080.49	1.55
P_3	16519.86	1.53
$F_{2,4}$	8230.18**	39762.01**
SE	18.40	0.0
CD (0.05)	52.04	0.001

Table 4.14.1 Interaction effect of irrigation and plant density on the economics of cultivation

Treatments	Net returns (Rs/ha)	Benefit-cost ratio
I_1D_1	17672.50	1.56
I_1D_2	20318.85	1.66
I_1D_3	19493.10	1.64
I_2D_1	15427.75	1.55
I_2D_2	17018.17	1.63
I_2D_3	16797.78	1.62
I_3D_1	9283.35	1.23
I_3D_2	11928.70	1.30
I_3D_3	11157.30	1.29
$F_{4,8}$	136.88**	*
SE	26.128	0.0
CD (0.05)	85.208	0.0

Table 4.14.2 Interaction effect of irrigation and phosphorus on the economics of cultivation

Treatments	Net returns (Rs/ha)	Benefit-cost ratio
I_1P_0	16361.00	1.54
I_1P_1	18408.13	1.60
I_1P_2	21270.00	1.69
I_1P_3	20606.80	1.66
I_2P_0	15846.27	1.59
I_2P_1	15933.42	1.59
I_2P_2	17141.40	1.62
I_2P_3	16737.18	1.61
I_3P_0	8038.80	1.21
I_3P_1	10074.67	1.26
I_3P_2	12830.07	1.33
I_3P_3	12215.60	1.31
$F_{6,54}$	875.02**	4872.60**
SE	31.868	0.00
CD (0.05)	90.136	0.001

Table 4.14.3 Interaction effect of plant density and phosphorus on the economics of cultivation

Treatments	Net returns (Rs/ha)	Benefit_cost ratio
D_1P_0	12242.40	1.40
D_1P_1	13719.13	1.44
D_1P_2	15543.13	1.49
D_1P_3	15006.80	1.47
D_2P_0	14251.27	1.47
D_2P_1	15518.96	1.51
D_2P_2	18216.20	1.58
D_2P_3	17701.20	1.57
D_3P_0	13752.40	1.46
D_3P_1	15178.13	1.50
D_3P_2	17482.13	1.57
D_3P_3	16851.58	1.54
$F_{6,54}$	52.36**	442.80**
SE	31.868	0.00
CD (0.05)	90.136	0.001

Table 4.14.4 Interaction effect of irrigation, plant density and phosphorus on economics of cultivation

Treatments	Net returns	Benefit-cost ratio
$I_1D_1P_0$	14950.60	1.48
$I_1D_1P_1$	17173.00	1.55
$I_1D_1P_2$	19637.40	1.62
$I_1D_1P_3$	18929.00	1.60
$I_1D_2P_0$	17454.40	1.58
$I_1D_2P_1$	19356.60	1.63
$I_1D_2P_2$	22519.20	1.73
$I_1D_2P_3$	21945.20	1.71
$I_1D_3P_0$	16678.00	1.55
$I_1D_3P_1$	18694.80	1.61
$I_1D_3P_2$	21653.40	1.71
$I_1D_3P_3$	20946.20	1.68
$I_2D_1P_0$	15135.20	1.55
$I_2D_1P_1$	15278.80	1.55
$I_2D_1P_2$	15797.80	1.56
$I_2D_1P_3$	15499.20	1.55
$I_2D_2P_0$	16208.20	1.61
$I_2D_2P_1$	16122.07	1.61
$I_2D_2P_2$	18050.80	1.66
$I_2D_2P_3$	17691.60	1.65
$I_2D_3P_0$	16195.40	1.61
$I_2D_3P_1$	16399.40	1.61
$I_2D_3P_2$	17575.60	1.65

Treatments	Net returns (Rs/ha)	Benefit-cost ratio
$I_2D_3P_3$	17020.73	1.63
$I_3D_1P_0$	6641.40	1.17
$I_3D_1P_1$	8705.60	1.22
$I_3D_1P_2$	11194.20	1.28
$I_3D_1P_3$	10592.20	1.26
$I_3D_2P_0$	9091.20	1.23
$I_3D_2P_1$	11078.20	1.28
$I_3D_2P_2$	14078.60	1.36
$I_3D_2P_3$	13466.80	1.34
$I_3D_3P_0$	8383.80	1.22
$I_3D_3P_1$	10440.20	1.27
$I_3D_3P_2$	13217.40	1.34
$I_3D_3P_3$	12587.80	1.32
$F_{12,54}$	6.07**	49.50**
SE	55.197	0.001
CD (0.05)	156.121	0.002

DISCUSSION

DISCUSSION

The results of the experiment conducted to study the response of vegetable cowpea to phosphorus under varying moisture regimes and plant densities are discussed below.

5.1 Growth characters

Plant height increased progressively upto 90 DAS. Right from the beginning, the plant height was significantly influenced by the irrigation treatments. The irrigation levels I_1 and I_3 resulted in a marked increase in plant height over I_2. The trend remained the same upto the end of the cropping period indicating that frequent, light irrigation is more beneficial for crop growth.

In general, a progressive increase in the number of leaves per plant was noticed upto 60 DAS. Thereafter, a reduction in the number of leaves was noticed. The irrigation treatments showed an appreciable influence on the leaf number during all the growth stages. The I_3 treatment, i.e., daily light irrigation produced the highest number of leaves followed by I_1 and I_2 i.e., irrigaion at 10 and 15mm CPE.

The number of branches per plant also showed an increasing trend upto 60 DAS. Differential irrigation had its influence on the growth character with I_3 giving significantly higher extend of branching than I_1 and I_2 .

Better observations on growth parameters with frequently irrigated crop might be due to the uninterrupted moisture supply which might have helped in maintaining the turgidity of the cells favouring cell enlargement and cell division resulting in increased plant height (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 dry soil conditions. Leaf senescence was also accelerated by stress which leads to a fall in the leaf number (Balakumaran.1981). Frequent and better availability of water might have resulted in optimum and early availability of nutrients and moisture enhancing the growth and developmental characters(Mohanty and Sharma, 1985, Prasad et al., 1991). Absence of moisture stress at the critical stages might be another factor for better growth at higher moisture regimes (Chatterjee and Bhattacharya, 1986). In general, these results corroborated with the findings of Jeyaraman (1994) and Trivedi et al. (1994).

Throughout the crop growth the plant density level D_2 tried at a spacing of 1 X 0.6 m showed its superiority in plant height over its lower and higher densities. A marked reduction in plant height was also noticed at a spacing of 75 X 60 cm (D_1). The other growth characters, viz., number of leaves and branches per plant also indicated a similar trend.

Compared to a low density treatment (D_3) a higher level of competition for light might have made the plants taller in the medium density treatment D_2 (Chandler, 1969). But for the high density treatment D_1 it must be assumed that the competition was so severe that there was reduction in the growth characters of individual plants. Increased plant density limits the availability of space per plant and hence root configuration affecting crop growth (Ahuja, 1994).

The taller plants of the D_2 treatment might have made optimum use of the available resources like space, light, nutrients and moisture resulting in better expression of other growth characters. Higher level of evaporation from the soil surface which contributes the major part of moisture needed for crop growth and higher level of weed interference might be other possible reasons for depression of growth in the low density treatment with inadequate canopy coverage. The results are in agreement with the findings of Singh et al. (1981), Prasad et al.(1993), Dwivedi et al. (1994) and Padhi (1995).

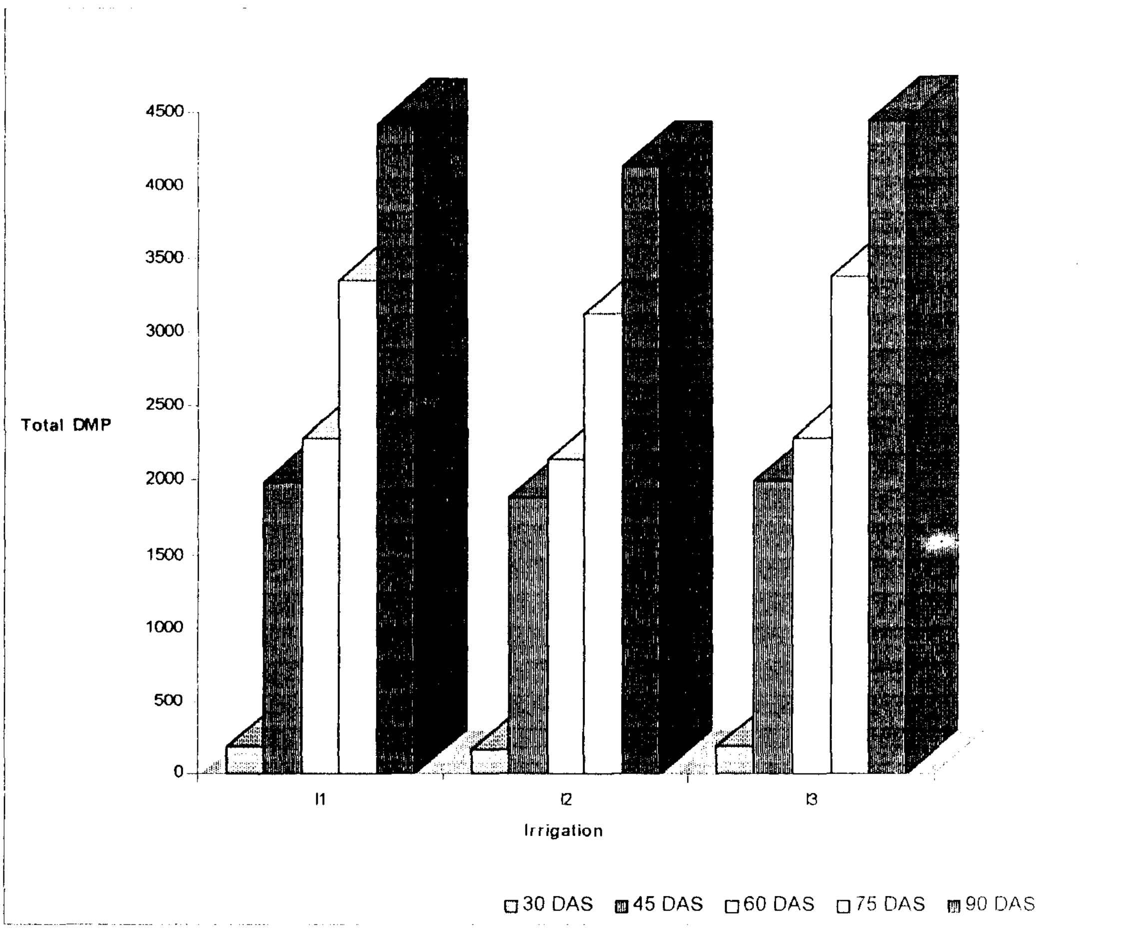
In general, the graded levels of phosphorus gave an appreciable increase in the growth attributes upto the level P_2, i.e., 45 kg/ha beyond which a significant decline in growth was manifested.

Phosphorus being an essential constituent of cellular proteins and nucleic acids encourages the meristermatic activity in plants (Black, 1969). Increase in growth might be due to hastened meristematic activity, better root growth and better absorption of nutrients by increased application of P(Philip, 1993). The translocation of photosynthates by the action of P also effected an improvement in various growth parameters (Verma and Saxena, 1995). The infection of Rhizobium bacteria depends on their interception with the root hair. Under adequate phosphate application, nodulation increases due to high bacterial infection on account of properly developed rooting system and increased density of nodule bacteria (Srivastava and Varma, 1985). Increased nodulation implies greater symbiotic fixation of atmospheric N which also helps in cell division and root extension which might have resulted in vigorous plant growth and plant height (Deshpande and Bathkal, 1965, Singh, 1985). Similar results have been reported by Meena et al.(1991) in cluster bean and Joseph and Varma (1994) in chickpea. The highest level of P (60kg/ha) caused a significant reduction in growth parameters which might be attributed to the nutrient imbalance in the soil-plant system (Kumar and Agarwal, 1993). A declining trend in some growth parameters studied in frenchbean at highest levels of P compared to lower levels was also noted by Verma and Saxena(1995).

5.2 Days for 50 per cent flowering

The differential irrigation and phosphorus application showed significant influence on earliness of attaining 50 per cent flowering whereas density had no influence on the character. The number of days was minimum for I_3 and P_2 levels of irrigation and phosphorus and was on par with I_1 and P_3. Absence of phosphorus and lesser irrigation also delayed the flowering. An optimum density level D_2 also showed favourable effect on early flowering but did not reach a level of significance.

Fig. 3 Effect of Irrigation on total DMP (kg/ha)



Influence of P in hastening maturity is well documented. The stimulatory effect of P on growth might have resulted in early flowering. The trend of early flowering under higher levels of P was also noted by Balakumaran (1981) and Philip (1993) in cowpea. Better exploitation of phosphorus under higher moisture regimes was reported by Sharma et al. (1984) and Sarkar (1992) in green gram.

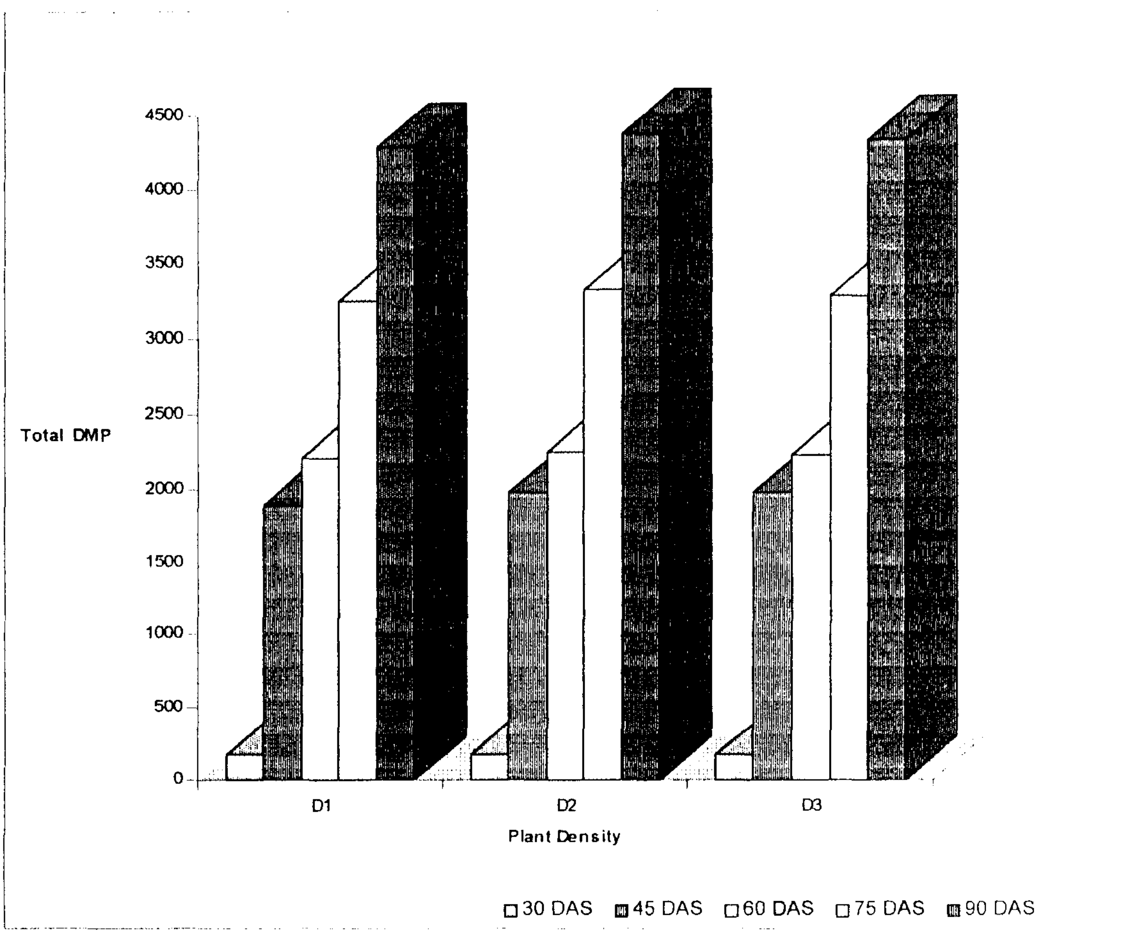
5.3 Total dry matter production (DMP)

In general the total DMP increased progressively upto 90 DAS with the highest rate of increase from 45 to 60 DAS. Varying levels of irrigation, plant density and phosphorus and their interaction had significant influence on DMP through out the crop growth period.

Frequent light irrigation (I_3) produced maximum dry matter and was superior to the other treatments except I_1 at 45 DAS. The least DMP was noticed with I_2 during all the growth stages (Fig.3).

Maintaining a higher level of ASM in the root zone could have resulted in adequate solubilization, mobilisation and translocation of native as well as applied nutrients (Gupta and Rai, 1989). 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). Higher uptake of nutrients in the frequently irrigated treatment

Fig. 4 Effect of Plant density on total DMP (kg/ha)

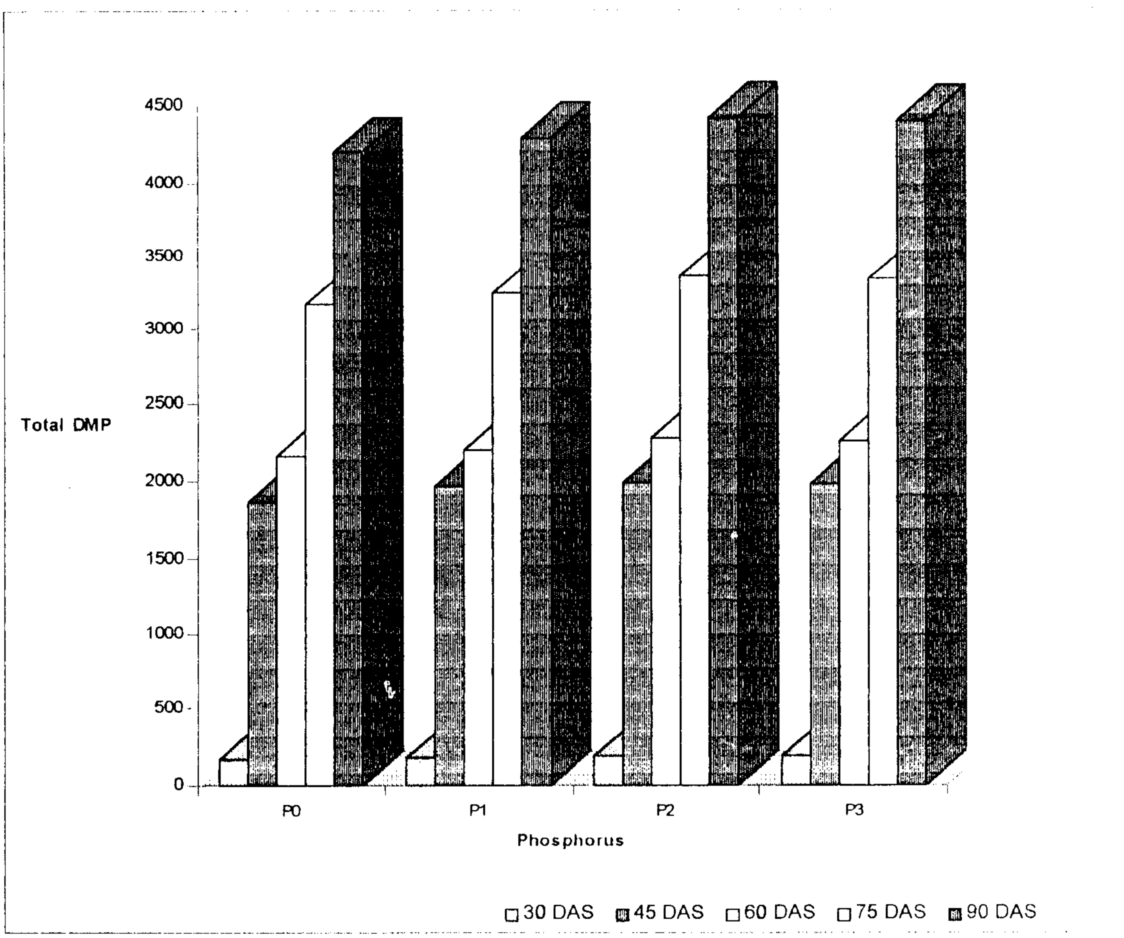


is evident from tables 4.8, 4.9 and 4.10 and has obviously resulted in better growth (Tables 4.1,4.2 and 4.3) and thereby enhanced DMP. Similar positive correlation between nutrient uptake and DMP was reported by Savithri (1980) in green gram. Higher DMP by the favourable influence on the production of photosynthates in frequently irrigated crops has also been reported by Subramanian et al.(1993) and Jyothi (1995) in vegetable cowpea. Similar results were also reported by Arya and Sharma (1990) in green gram and Rao et al. (1991) in black gram.

During the different stages of crop growth a plant density level D_2 (1 X 0.6m) gave significantly superior DMP over other levels. However at higher plant density a drastic reduction in DMP was noticed (Fig.4).

The result might be attributed to maximum exploitation of natural resources including space, light, nutrients and moisture under optimum density. An increased plant density limits the availability of space per plant and hence root configuration and plant productivity (Ahuja, 1984). Better growth of plants under medium density treatment as evident from tables 4.1,4.2 and 4.3 might have resulted in the highest DMP. A slight decrease in the values of growth parameters at low density level which might be due to higher level of moisture loss and greater extend of weed interference as discussed before might also be the reason for lower DMP. Beneficial effect of optimum density on dry matter accumulation have also been reported by Singh and Yadav (1994) in summer black gram and Dwivedi et al. (1994) in

Fig. 5 Effect of Phosphorus on total DMP (kg/ha)



french bean.

Application of graded levels of phosphorus produced significant increase in the total dry matter upto P_2 and thereafter a marked decrease was noted (Fig.5).

Favourable effect of P on a wide range of metabolic functions of the plant might have lead to increased dry weight as shown by increases in plant height, number of leaves and branches under higher levels of P (Balakumaran,1981). Better root growth in crops grown in phosphated soils resulting in higher nutrient uptake and the favourable effect of P on nodulation increasing N availablility might have also contributed to the high DMP.

5.4 Yield and yield attributes

5.4.1 Number of pods per plant

With an increase in soil moisture a gradual increase in the number of pods per plant was recorded and it reached maximum with the daily light irrigation treatment (I_3). A remarkable reduction in the character could also be noticed with the driest regime of I_2.

Water deficits generally induced changes like retardation of floral primordia development, reduction in the number of flowers produced and fruits set and flower and early fruit abscission all of which lead to a decrease in the number of pods per plant produced (Kaufmann, 1972). A higher level of available moisture in the soil might have maintained better soil-plant-water balance and the scorching effect of advective summer heat could not have interfered with the normal plant metabolism (Singh and Singh, 1974). Higher number of pods per plant under frequently irrigated treatment might be attributed to the above reasons. Better growth of the plants observed in the I_2 treatment as noted from tables 4.1,4.2 and 4.3 might have directly reflected on this major yield attribute also. These results are in agreement with Ramamurthy et al.(1990) in grain cowpea and Jyothi (1995) in vegetable cowpea.

The medium density level D_2 had a favourable influence on the number of pods per plant in comparison with lower and higher densities. A significant decline in pod number was noted with the high density treatment.

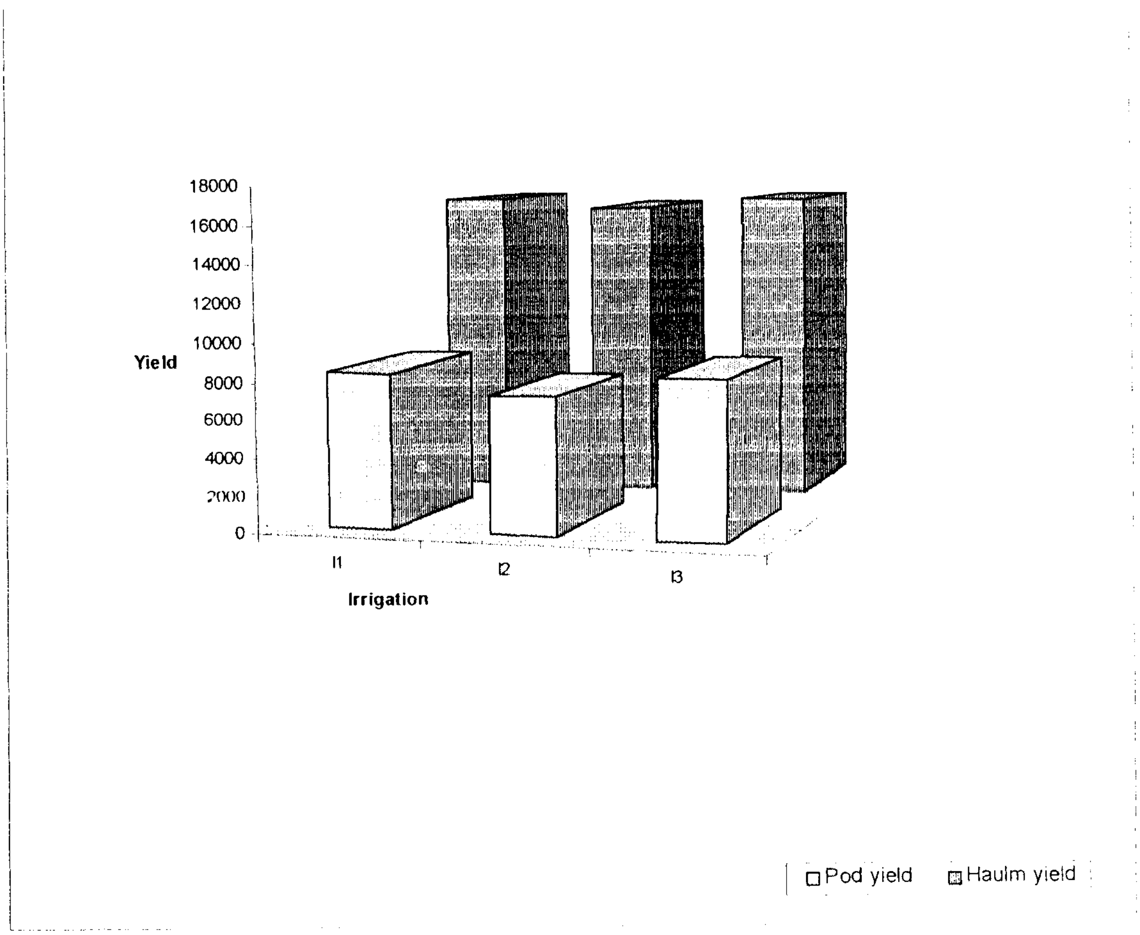
Higher DMP per plant and efficient grain filling by better translocation of photosynthates from the vegetative parts to the sink might have improved the yield components (Singh and Yadav, 1994). Reduced crop competition and optimum exploitation of natural resources might be the reason for better growth and DMP under medium density treatment. These results corroborate with the observations of Singh et al. (1991) in green gram, Ahuja (1984), Tripathi and Chauhan (1990) and Singh et al. (1994) in pigeon pea and Dwivedi et al.(1994) in french bean.

It was also evident from the results of the experiment that there was an appreciable increase in the number of pods per plant with increasing levels of applied P upto a level of 45 kg/ha(P_2) beyond which a decline was noticed.

This increase in yield attributes might be a direct consequence of growth characters like plant height and number of leaves and branches (Tables 4.1, 4.2 and 4.3) and also better uptake of nutrients (Tables 4.8, 4.9 and 4.10). An adequate supply of P is important in laying down the primordia for the reproductive parts of plants. It is also considered important in the formation of fruits and seeds. The presence of easily available P seems to have stimulated plants to produce more pods in grain cowpea (Philip, 1993). Phosphorus, being a major constituent of plant cell nucleus and growing root tips also helps in cell division and root proliferation enabling the plant to absorb more 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 (Jyothi, 1995). The medium P status of the experimental field might be one of the reasons for the lack of response at higher doses which could have resulted in nutrient imbalances in the soil. These findings corroborate the reports of Phookan and Shadeque (1994) in pea, Prihar (1990) and Sarkar et al.(1995) in chickpea and Abbas et al. (1994) in soy bean.

Effect of interactions between the treatments were also significant on the production of pods per plant. Among the various combinations of irrigation and density, irrigation and phosphorus and density and phosphorus the two factor combinations I_3D_2, I_3P_2 and D_2P_2 maintained their superiority from the

Fig. 6 Effect of Irrigation on pod and haulm yield (kg/ha)



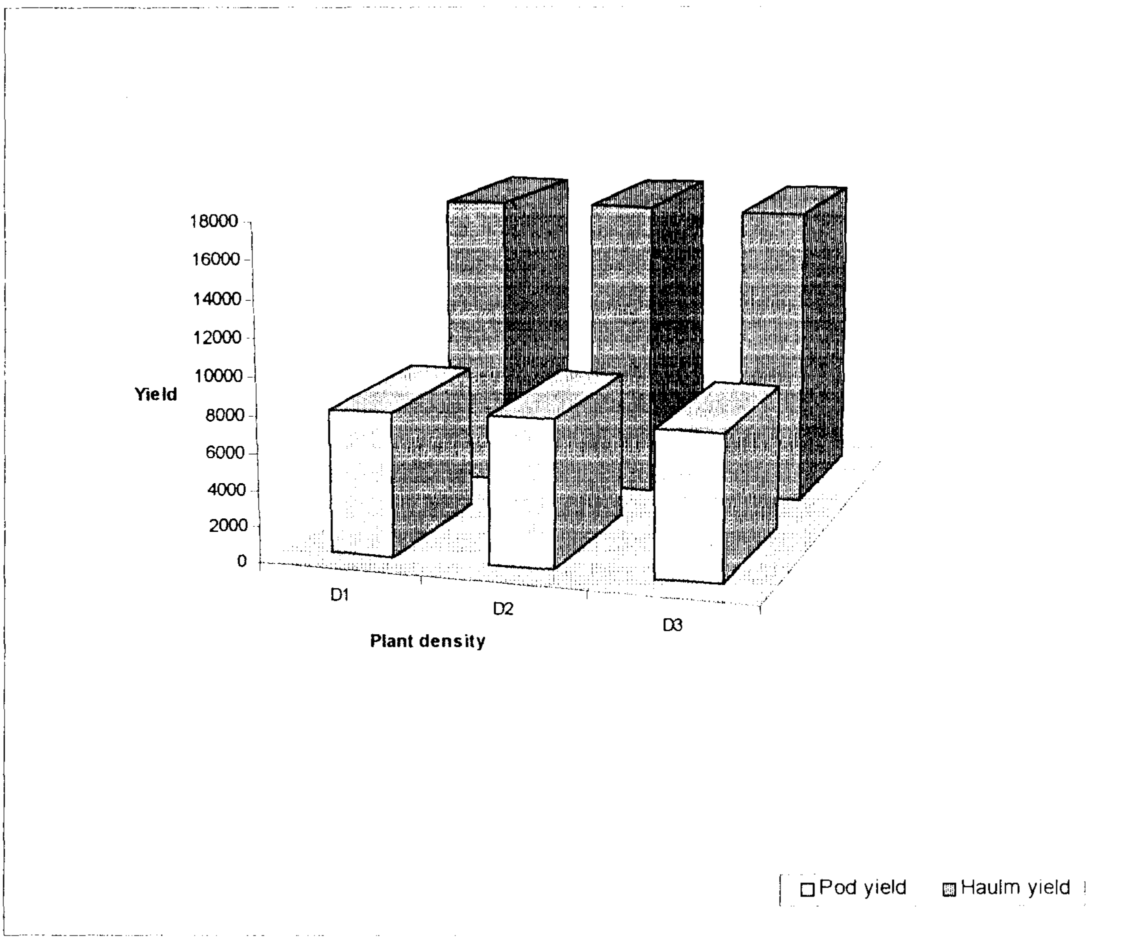
beginning to the end of the crop.

5.4.2 Yield

As it is clear from the data on green pod and haulm yield, the frequently irrigated treatment (I_3) had significant superiority with respect to the yield where as the driest soil (I_0) gave minimum yield (Fig.6).

This increase in pod and haulm yields in frequently irrigated plots might be a direct reflection of the improved growth (Tables 4.1, 4.2 and 4.3) number of pods (Table 4.6) and also nutrient uptake (Tables 4.8, 4.9 and 4.10) in this treatment. Similar relationship of growth parameters, yield contributing characters and nutrient uptake with yield has been reported by Kher et al.(1994) in summer cowpea, Varughese and Iruthavaraj (1993) in greengram and Jeyaraman (1994) in blackgram. Under unsaturated soil moisture environment a vapour gap would be formed around the roots by their turgor pressure under water stress. Such a gap if ever present would reduce the availability of nutrients to the roots probably due to lesser contact between roots and water particles causing drastic reduction in dry matter production and uptake of nutrients (Phillips, 1966). This might be the major reason for lower pod and haulm yields of crop experiencing moisture stress. Higher yield under low moisture stress treatments might be due to the adequate moisture availability through out the growth period resulting in better growth and development of yield attributes. Optimum moisture supply might have also solubilized, mobilized

Fig. 7 Effect of Plant density on pod and haulm yield (kg/ha)

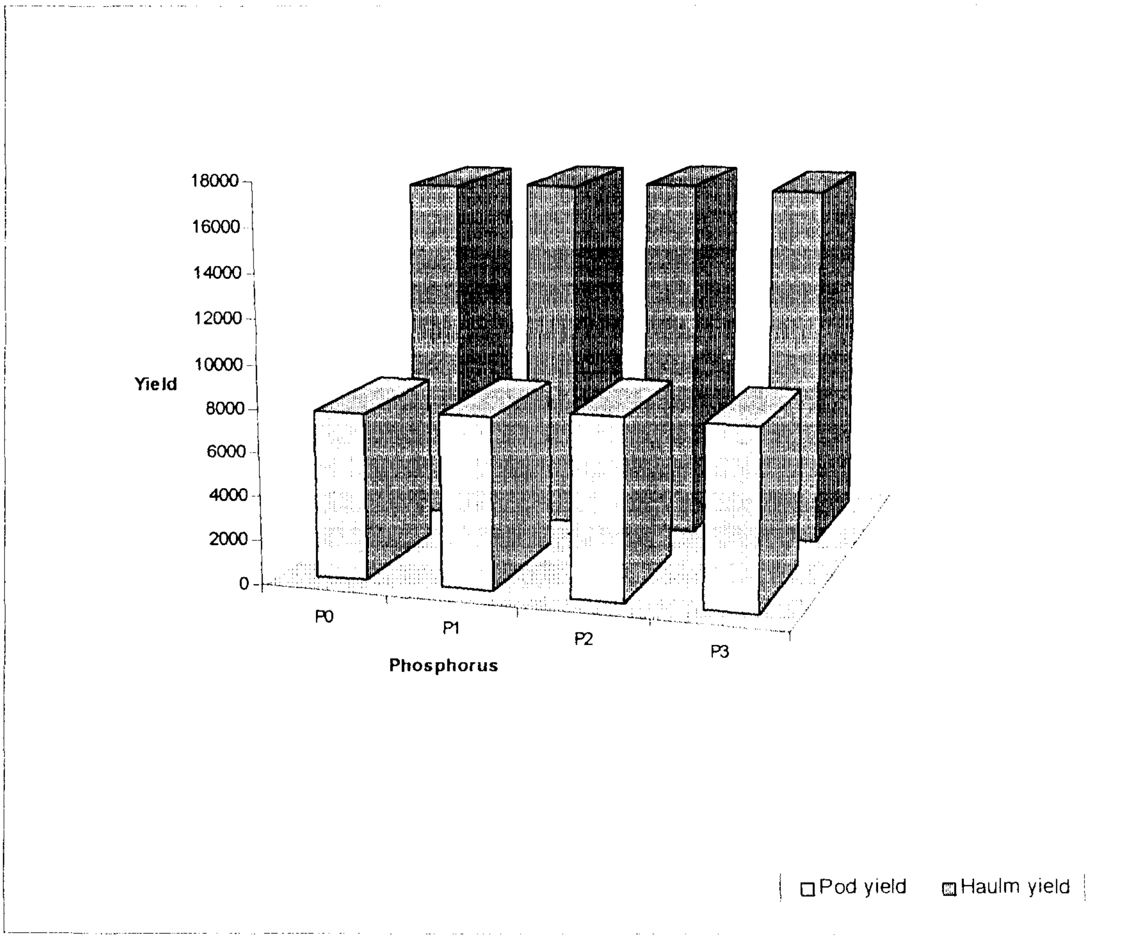


and translocated the native as well as applied N and other nutrients resulting in greater green pod and haulm yeilds. In general, these results are in confirmity with the findings of Mohanty and Sharma (1985), Misra and Gangwar (1987), Bachchhav et al. (1993), Varughese and Iruthayaraj (1993) and Trivedi et al. (1994) in greengram, Rao et al. (1991) and Jeyaraman (1994) in blackgram and Jyothi (1995) in vegetable cowpea.

Significant influence of plant density treatments on the green pod and haulm yields was also noticed from table 4.7. The density level D_2 resulted in appreciably high marketable pod and haulm yields as compared to D_1 and D_3. A marked decline in the yields was also effected by the D_1 (high density) treatment (Fig.7).

Better growth as expressed by the plant height, number of leaves and branches (Tables 4.1, 4.2 and 4.3), increased uptake of nutrients (Tables 4.8,4.9 and 4.10) and more DMP and number of pods per plant (Tables 4.5 and 4.6) might have resulted in higher green pod and haulm yields under the D_2 level of plant density. Maximum exploitaiton of resources viz. space, light, nutrients and soil moisture and reduced competition resulting in vigorous growth, DMP and better translocation of photosynthates from vegetative parts to the sink improving the yield components as a cumulative effect of proper development of roots and shoots in suitable plant geometry leading to better uptake and translocation of nutrients under medium density treatment might be the reason for better yields under D_2. Higher yields at

Fig. 8 Effect of Phosphorus on pod and haulm yield (kg/ha)



medium density followed by low (D_3) and high density (D_1) treatments proved the parabolic realtionship between plant density and yield. Higher yield of both pod and haulm under medium density treatments compared to higher and lower densities have also been reported by Prasad (1988) and Singh et al. (1990) in green gram, Gondalia et al. (1988), Nivedita and Reddy (1990) and Tripathi and Chauhan (1990) in pigeon pea. These results are also in confirmity with the reports of AICPIP (1988, 1990). The beneficial effect of medium density treatment over high density might also be due to better light penetration and higher photosynthetic efficiency resulting in better development of plant canopy (Rao et al., 1986). Similar results have been reported by Seshadri (1956) and Narayanan and Srivastava (1982).

Differential application of P was observed to have significant influence on the marketable pod and haulm yields. P_2O_5 @ 45kg/ha (P_2) gave highest yield while higher and lower doses resulted in significant decline. Absence of P application caused a reduction in both pod and haulm yields (Fig.8).

Although the phosphorus requirement of grain cowpea recommended for Kerala conditions is 30 kg/ha (KAU, 1993), the staggered pattern of harvesting during the period of one and a half to two months might have increased the nutrient requirement of the vegetable crop. The higher vegetable and haulm yields at a dose of 45 kg P_2O_5/ha might be the direct effect of improved growth, nutrient uptake, DMP and yield attributes (Tables 4.1, 4.2, 4.3, 4.5, 4.6, 4.8, 4.9 and 4.10). Such a positive relationship between yield and yield components have been observed by Singh(1985) and Jyothi(1995) in vegetable cowpea, Arya and Kalra (1988) in green gram and Singh and Tripathi (1992), Mishra (1993) and Shah *et al.*(1994) in black gram. At the highest level of P a decrease in both pod and haulm yield was noticed. This lack of response above 45 kg/ha might be due to the medium status of P in the experimental field. Application of P increases the concentration of P ions of the soil solution and ulitimately effects the formation of more nodules, vigorous root development, better N fixation and over all development of the plant (Abbas *et al.*, 1994). Increased availability of N and P to the plants leads to better plant growth resulting in better flowering and fruiting (Singh and Chaudhary, 1992) and increased photosynthesis (Phookan and Shadeque, 1994). Beneficial effect of P on flower primordia initiation and seed formation have been discussed before. An increase in the potential for exploitation of soil resources by the elongated root system might have also helped the plants to express better growth which ultimately reflected in increased haulm yield.

The treatment combinations I_3D_2, I_3P_2 and D_2P_2 among the various combinations of irrigation and density, irrigation and phosphorus and density and phosphorus and the three factor combination $I_3D_2P_2$ retained significant superiority throughout the crop compared to other combinations with respect to the marketable vegetable and haulm yields.

High moisture regimes rendered P more soluble and accordingly an increase in P availablity occured at the wettest regime (Sharma *et al.*, 1984). This might be the reason for the

Fig. 9 Effect of Irrigation on the uptake of nitrogen by the crop (kg/ha)

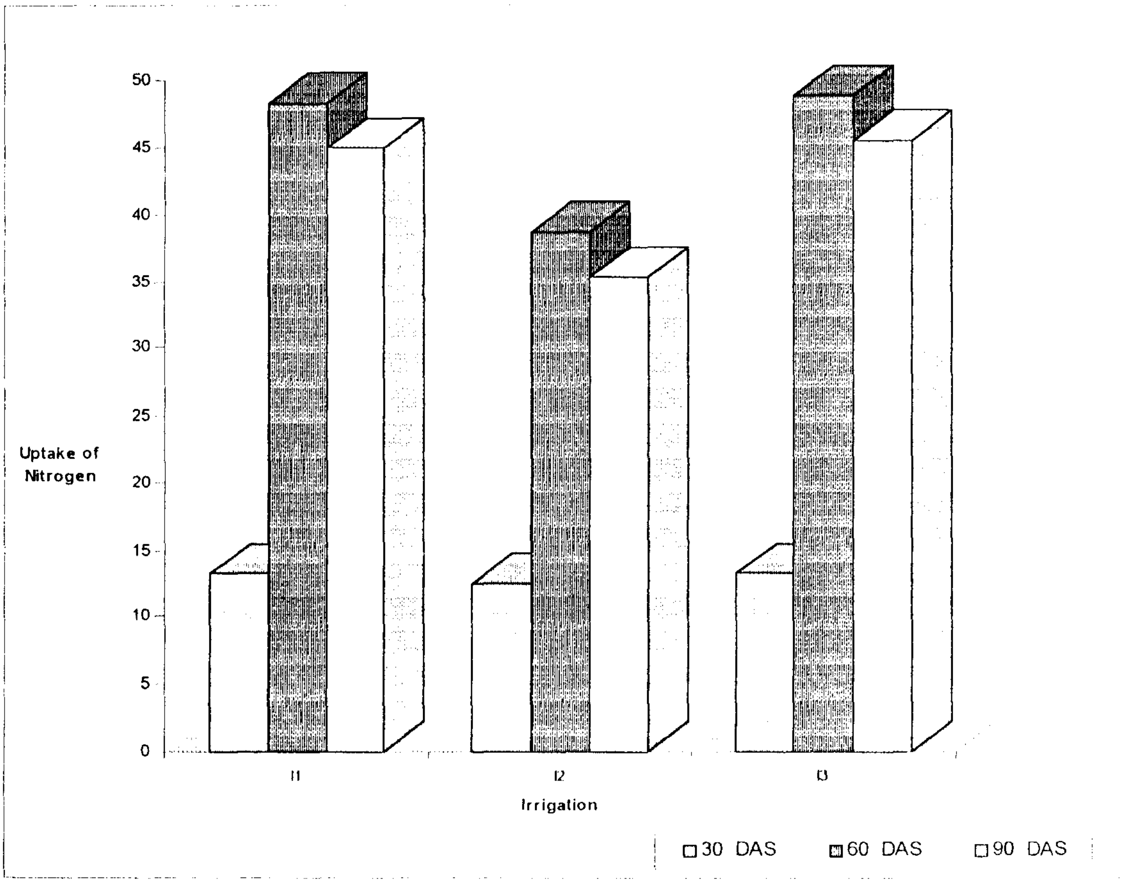


Fig. 12 Effect of Irrigation on the uptake of phosphorus by the crop (kg/ha)

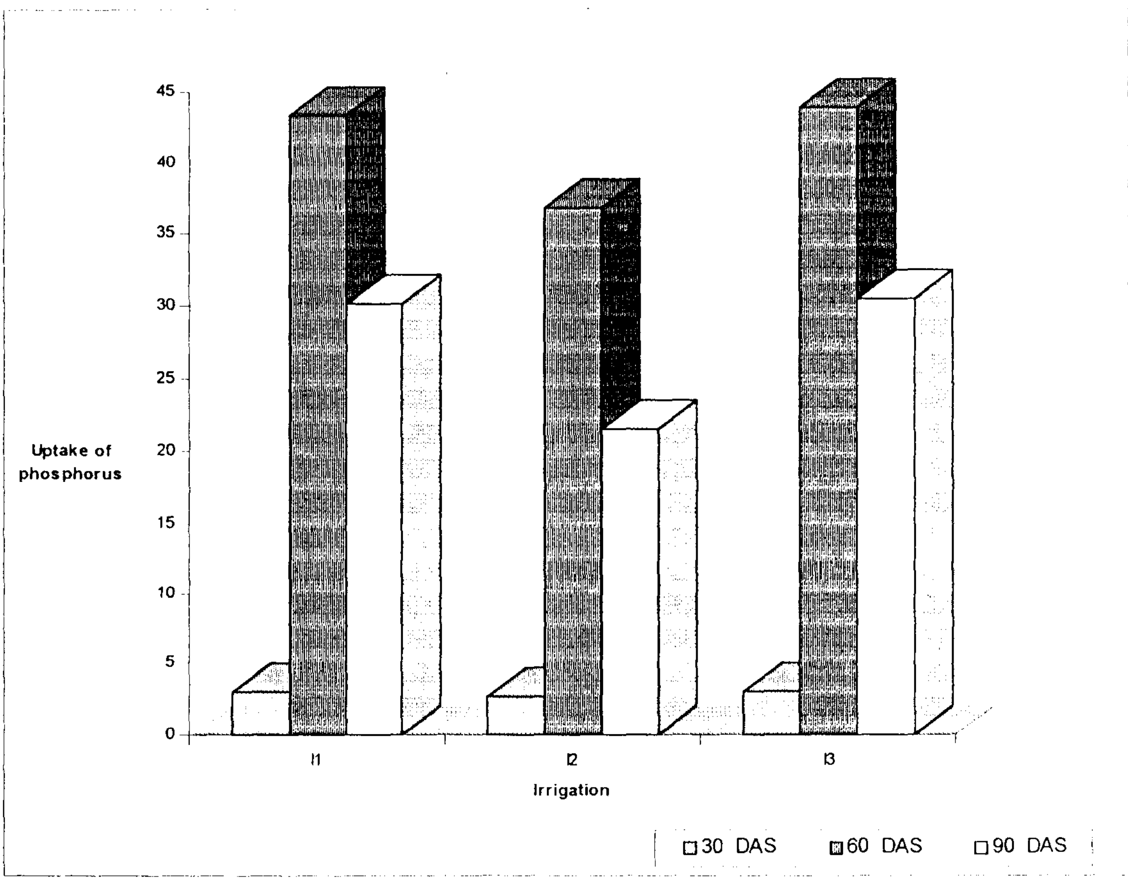
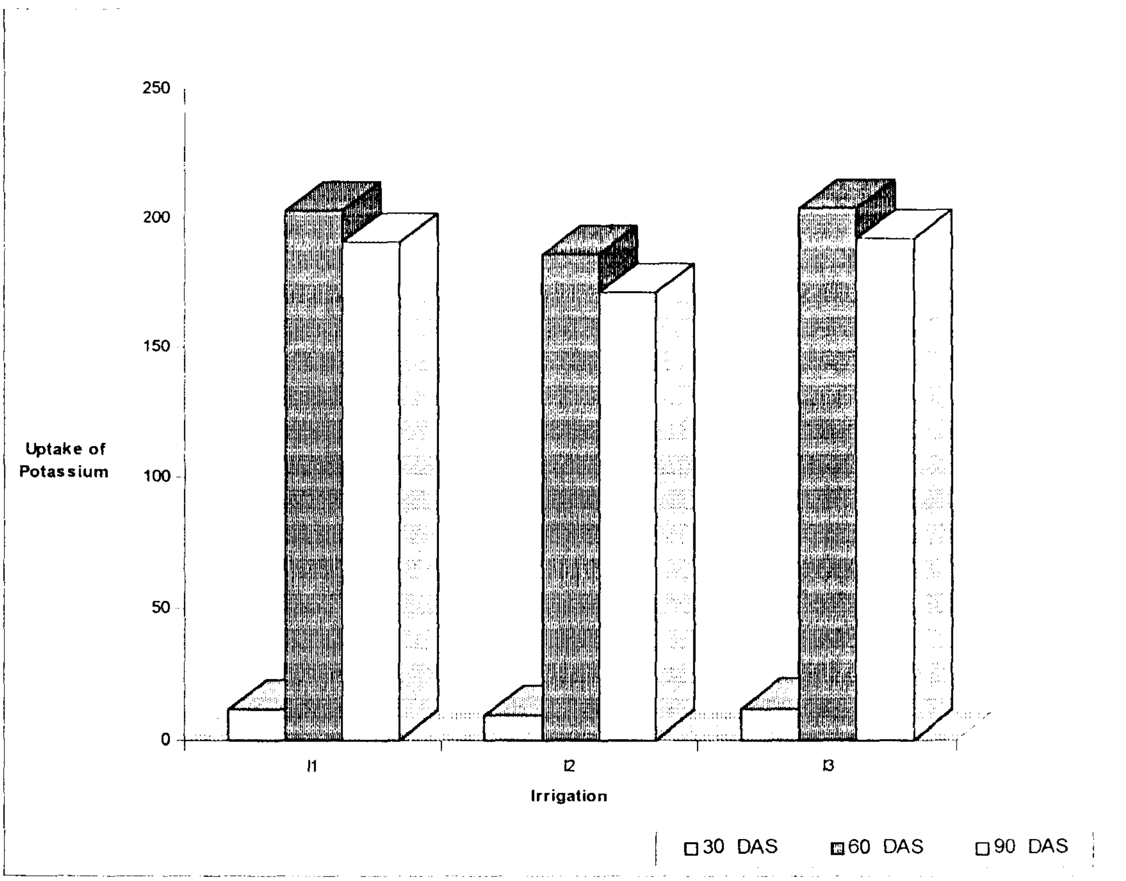


Fig. 15 Effect of Irrigation on the uptake of potassium by the crop (kg/ha)



interaction effect of irrigation and phosphorus on grain yield. More number of irrigations applied frequently at critical stages of water need coupled with ample supply of P might be ascribed to greater uptake and subsequent assimilation of P leading to maximum expression of yield attributes, which in turn resulted in higher yield in green gram (Sarkar, 1992). These results are in close confirmity with Agarwal et al .(1976) in green gram, Sarkar et al.(1995) in chickpea and Singh and Tripathi (1992) in black gram.

The response to applied P tended to increase the pod yield with increase in plant population as reported by Chavan and Kalra (1983) in ground nut. Significant interaction effect of phosphorus and density has also been observed in the yield of french bean (Haldavanekar et al. (1992).

5.5 Nutrient uptake

Irrigation treatments profoundly influenced the uptake of N,P and K during all the growth stages. The maximum uptake was noted with I_3, the daily light irrigation treatment followed by I_1 and I_2 i.e., irrigation at 10 and 15 mm CPE (Fig. 9, Fig. 12 and Fig. 15).

This might be due to the increased total DMP recorded in frequently irrigated plots (Table 4.5). Higher uptake of nutrients due to higher DMP under frequently irrigated treatments was also observed by Singh and Tripathi (1992) in summer blackgram and Rajput et al.(1991) in soybean. Better availability of the nutrients due to solubilization, mobilization

Fig. 10 Effect of Plant density on the uptake of nitrogen by the crop (kg/ha)

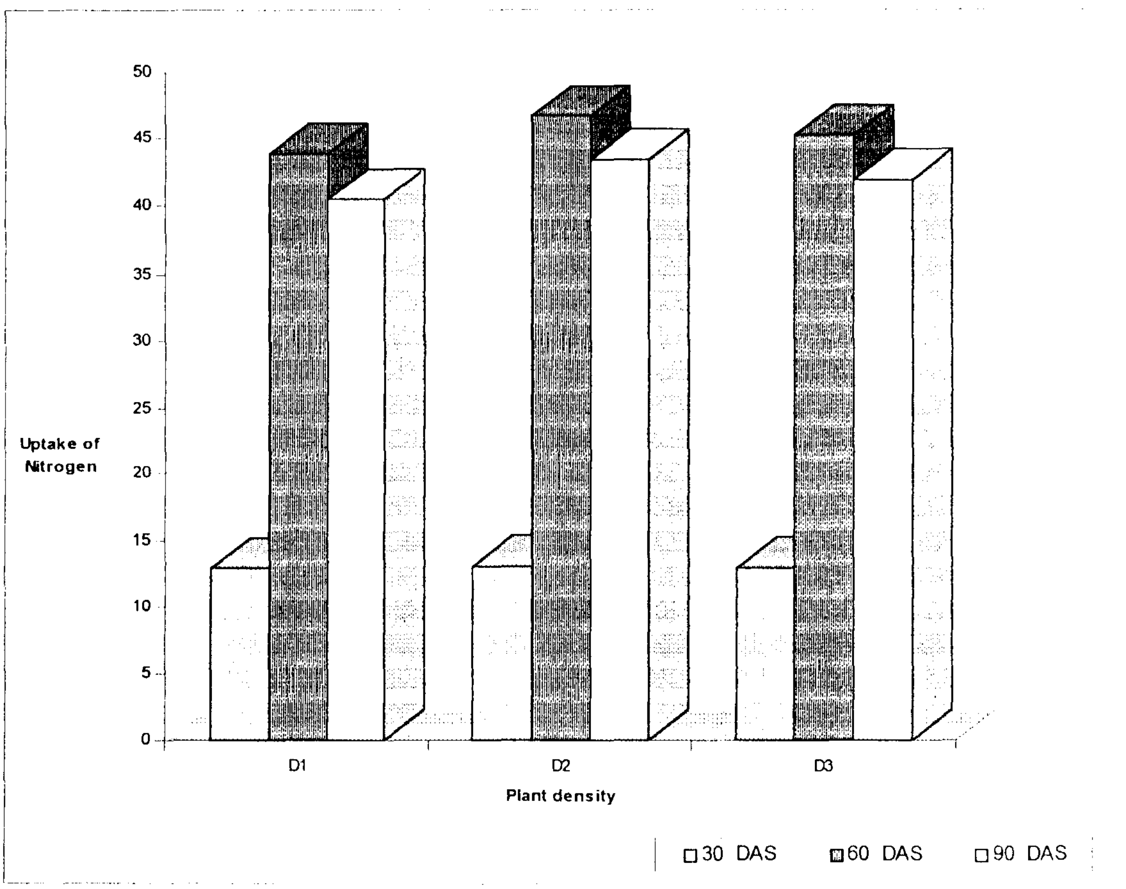


Fig. 13 Effect of Plant density on the uptake of phosphorus by the crop (kg/ha)

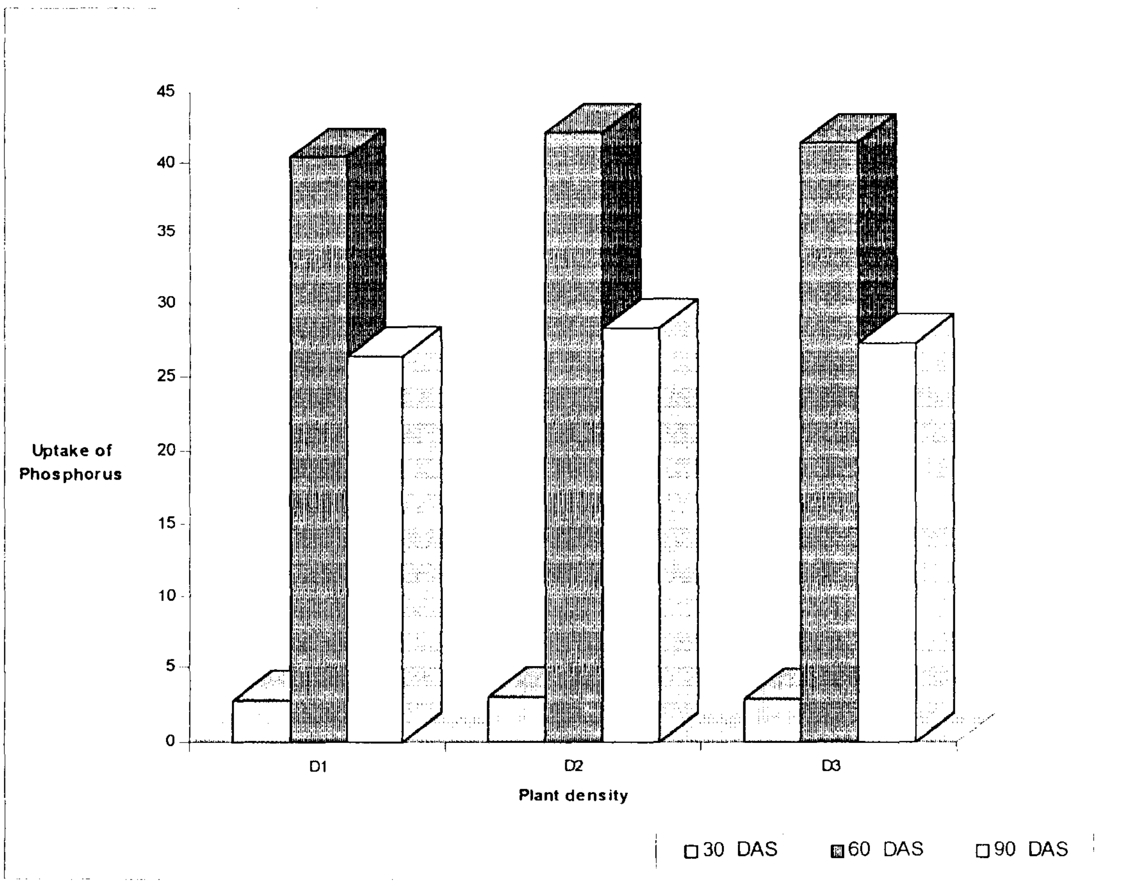
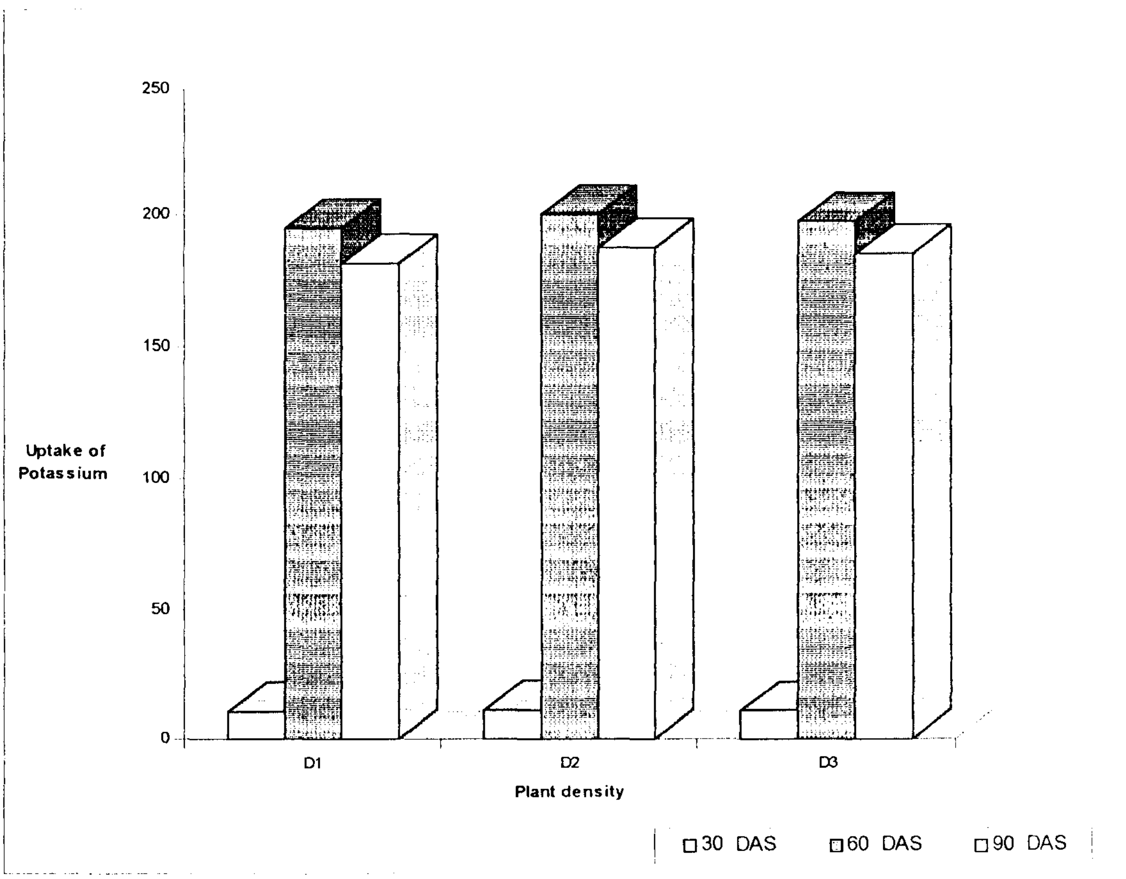


Fig. 16 Effect of Plant density on the uptake of potassium by the crop (kg/ha)



and translocation of native as well as applied nutrients under adequately moist soil conditions resulting in higher level of absorbtion and content in the plant parts may also be the reason for higher nutrient uptake under frequently irrigated conditions. These results are also in corroboration with Bachchhav et al. (1993). The reasons attributed in section 5.4.2 for the reduced uptake of nutrients and DMP under moisture stressed conditions resulting in lower yields (Phillips, 1966) holds good here also.

The uptake of nutrients showed significant variations due to differences in plant density. The medium density level D2 showed significantly higher uptake of nutrients than lower and higher densities. The high density treatment recorded minimum values for uptake of nutrients (Fig. 10, Fig.13 and Fig.16).

These results might be a direct consequence of the increased DMP recorded in this treatment (Table 4.5). Increased plant density limits the availability of space per plant and hence root configuration and uptake of nutrients where as a lower density level results in moisture loss from the exposed soil due to inadequate canopy coverage affecting the availability of nutrients and also a higher extend of weed interference which compete even more efficiently with the crop plants for the nutrients. Singh and Yadav (1994) also noted better uptake and translocation of nutrients in blackgram under medium and high density treatments as compared to low density treatment.

Fig. 11 Effect of Phosphorus on the uptake of nitrogen by the crop (kg/ha)

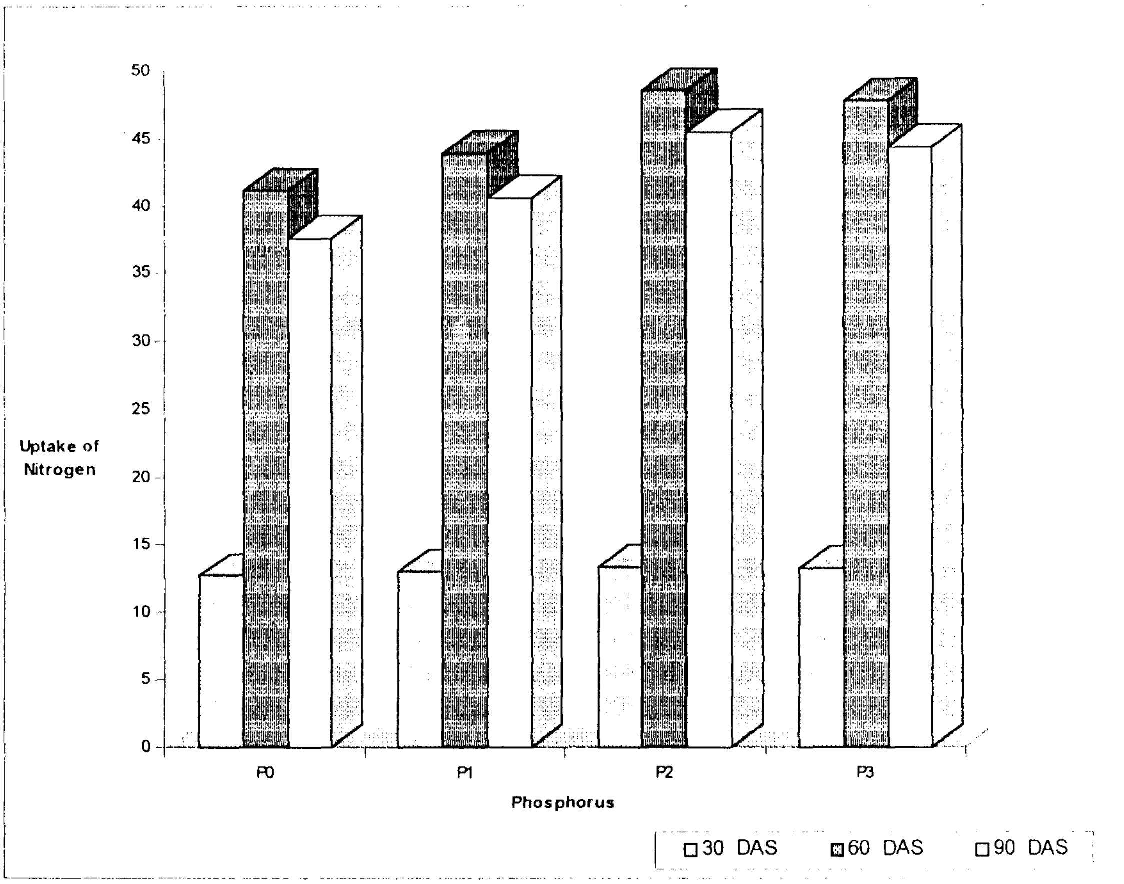


Fig. 14 Effect of Phosphorus on the uptake of phosphorus by the crop (kg/ha)

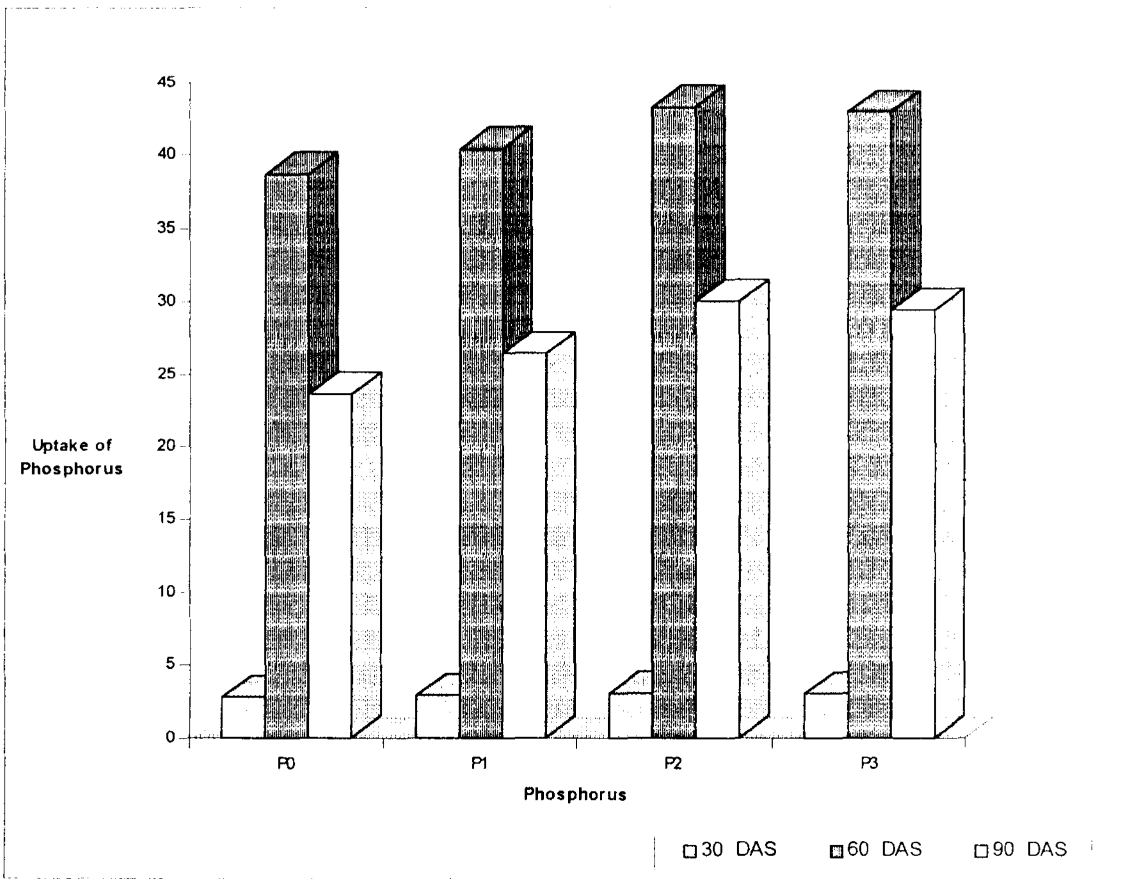
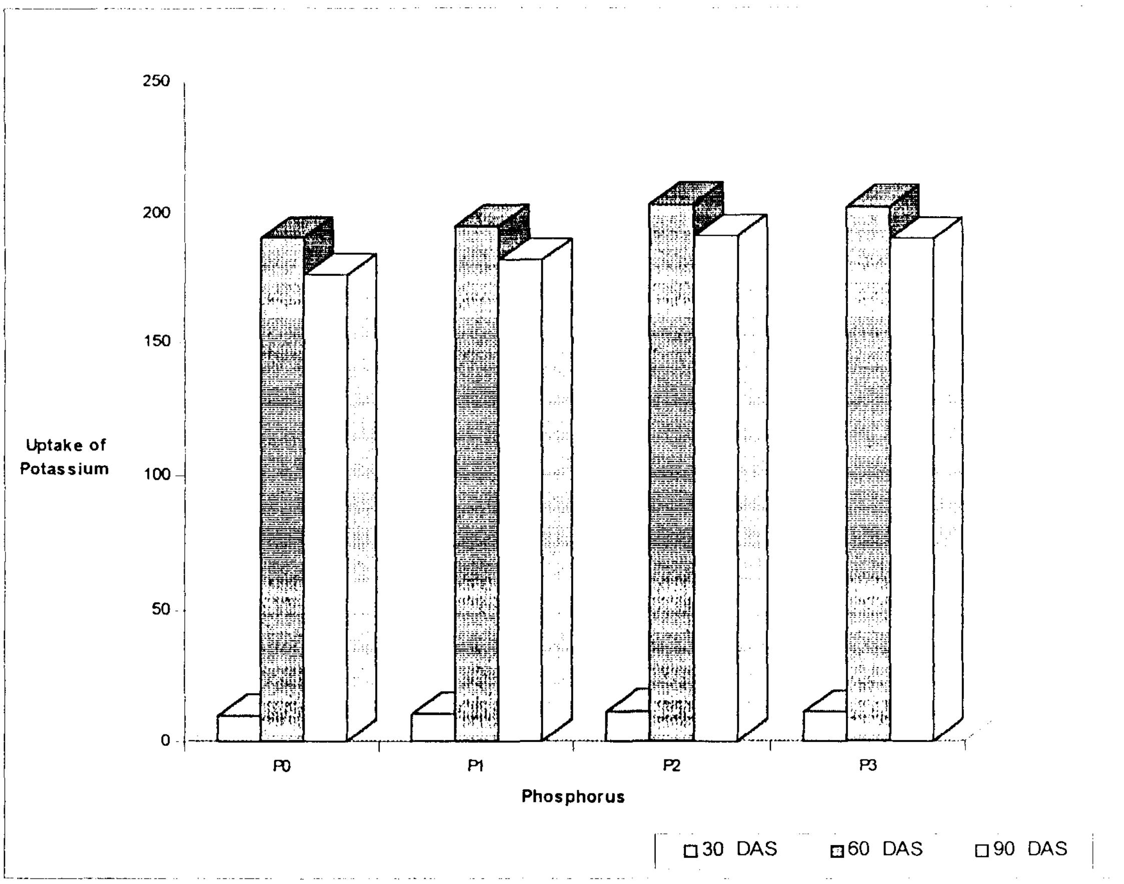


Fig. 17 Effect of Phosphorus on the uptake of potassium by the crop (kg/ha)



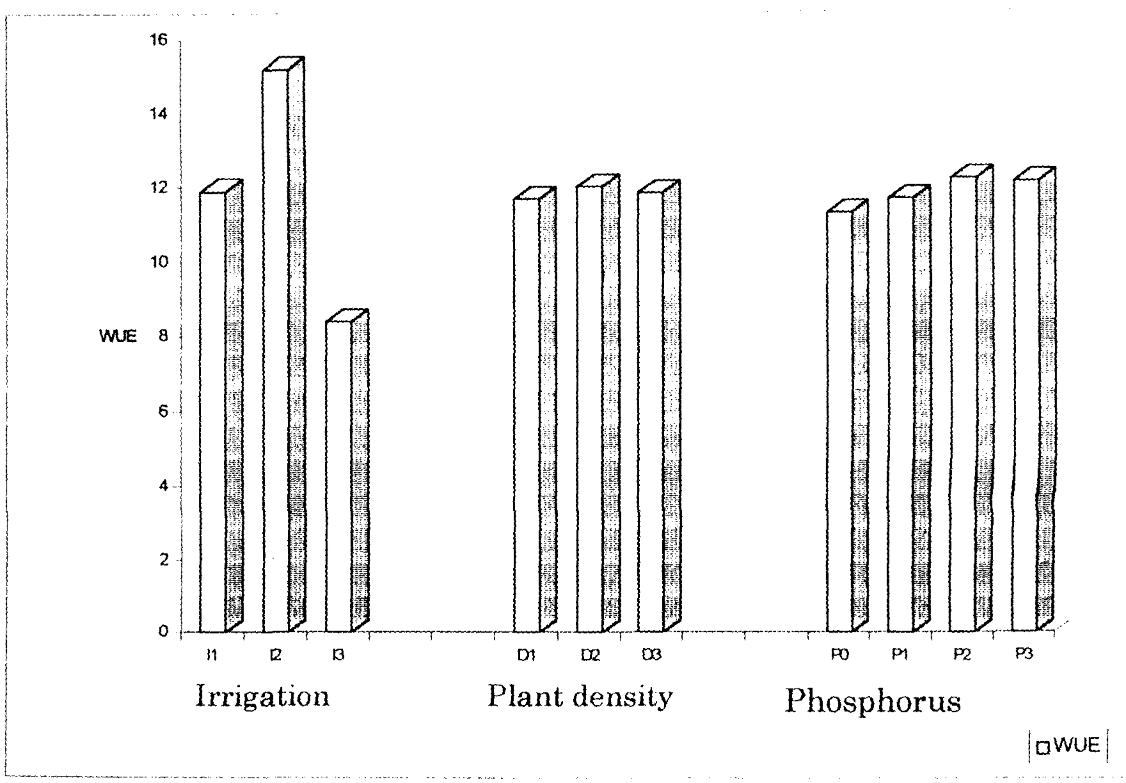
The uptake of all the three nutrient elements was found to increase regularly with the increase in the level of phosphorus upto 45kg/ha (P_2) and thereafter a significant reduction was noted. Absence of phosphorus recorded least uptake of nurtients (Fig.11,Fig.14 and Fig .17).

This trend might be attributed to the increased DMP at the particular level of P (Table 4.5). Similar relationship between DMP and nutrient uptake has also been observed by Kumar et al.(1979), Balakumaran (1981) and Philip (1993) in grain cowpea and Jyothi (1995) in vegetable cowpea. Role of P in proper root development, nodulation, nitrogen fixation, meristematic activity and translocation is well known and this explains its influence on the uptake of nutrients. Higher uptake of N,P and K following P application might be a cumulative effect of increased DMP and nutrient content on account of higher availability of nutrients (Dashora and Jain , 1994).

5.8 Soil nutrient status after the experiment

The significant influence of differential irrigation is evident from the data presented in table 4.11. The treatment that received less irrigation (I_2) registered maximum contents of available N,P and K followed by I_1 and the minimum contents were recorded in the daily light irrigation treatment (I_3) indicating that the soil nutrient status after the experiment decreased as the frequency of irrigation increased. The higher level of available soil moisture might have enhanced the uptake of N,P and

Fig. 18 Effect of Irrigation, Plant density and Phosphorus on water use efficiency(WUE) (kg/ha/mm)



K (Tables 4.8, 4.9 and 4.10) which might have resulted in lower contents of available N,P and K in the I_3 treatment. These results confirms the findings of Rajan (1991) and Jyothi (1995).

The density levels also manifested appreciable effect on the nutrient status of the soil. The high density treatment (D_1) recorded maximum contents of N,P and K in the soil followed by the low density treatment (D_3). The lowest nutrient content was observed with D_2, the medium density treatment (Table 4.11). The inverse relationship between nutrient uptake (Tables 4.8,4.9 and 4.10) and soil nutrient content is observed here also.

The nutrient content of the soil was found to decrease with the increasing levels of phosphorus upto P_2 after which there was an increase in the status. This might be attributed to the increased total DMP and uptake of N,P and K at higher dose of P(P_2). The increased nutrient content at a still higher dose might be due to lower DMP and uptake due to the nutrient imbalance caused by overdose of P (Tables 4.5, 4.8,4.9 and 4.10) These findings corroborate the report of Jyothi (1995).

5.9 Moisture studies

5.9.1 Water use efficiency

Varying levels of irrigation was observed to have significant influence on the efficiency of water use by the crop. Maximum WUE was noted with I_2, the least frequent irrigation treatment followed by I_1 and the least value with the daily irrigation treatment, I_3(farmer´s practice) clearly indicating that the WUE was higher in less frequent irrigation schedules

(Fig.18).

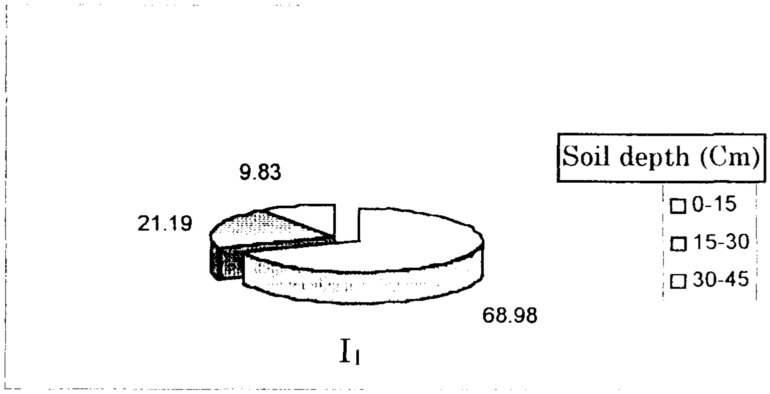
WUE is likely to increase with decrease in soil moisture supply until it reaches the minimum critical level because the plants may try to economise water loss in the range from minimum critical to the optimum soil moisture level, ie, under limited water condition (Raghu and Choubey, 1983). Considering the availability of soil moisture, proportionately higher yield was obtained from less frequently irrigated crop increasing the WUE. Major portion of the water above the optimum level might be lost in the form of excessive evaporation, transpiration or even as deep percolation. Lower leaf number and area might have been responsible for the lower rate of transpiration from the lesser irrigated treatment and this might also have reflected in the higher WUE in I_2 though the yield was less in this treatment. Increased WUE due to less frequent irrigation was also reported by Pal and Jana (1991), Bachchhav et al.(1993) and Pannu and Singh (1993) in green gram, Vijayalakshmi and Aruna (1994) in black gram, Dobariya et al. (1985) in chickpea and Jyothi (1995) in vegetable cowpea. Evapo-transpiration is always at a near potential rate when water supply is adequate, whereas yield which is a complex phenomenon depending on several factors may not be optimal (Slatyer,1967) .

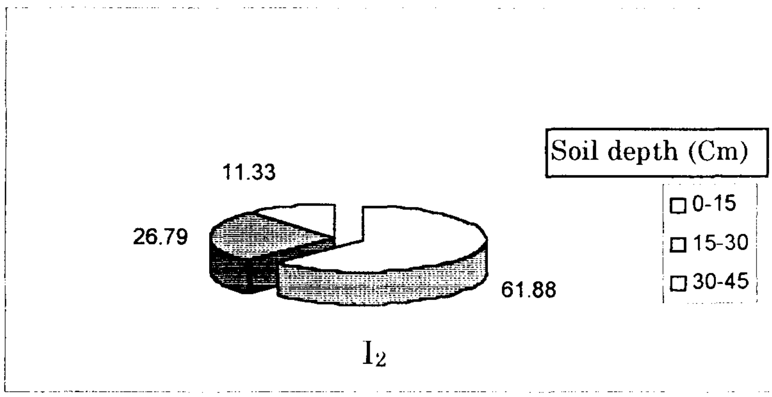
The density levels also recorded marked influence on the WUE. D_2.the medium density treatment recorded superiority in the efficiency of water use over the lower and higher density treatments, whereas the high density treatment D_1 resulted in the minimum value for this character (Fig.18). This might be a direct reflection of the trend in yield which followed the same pattern (Table 4.7). At the same level of available soil moisture higher yield will naturally result in higher water use efficiency or in turn, optimum exploitation of soil moisture and thereby nutrients by the proper development of roots and shoots in suitable plant geometry might have increased the yield in this treatment. In the low density treatment, a higher rate of evaporation from the exposed soil surface due to inadequate canopy coverage and profuse growth of weeds which transpire huge quantities of water compared to crop plants might have also contributed to the lower WUE. Higher efficiency of water use under optimum plant densities has also been observed by Dwangan et al.(1992) in summer green gram.

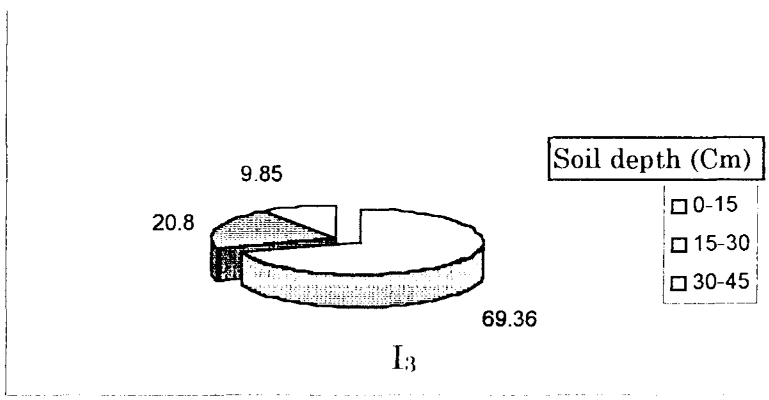
Significant differences were observed in WUE with varying levels of phoshorus. Increase in P level upto P_2 resulted in increase in WUE after which, a notable reduction occured with P_3 (Fig.18).

This increase in the efficiency of water use might be due to higher yield corresponding to the treatment compared to other treatments(Table 4.7). Phosphorus might have helped in the formation of an extensive root system which could have exploited moisture even from deep layers of the soil thus increasing the yield and thereby the efficiency of water use. An increase in WUE with higher levels of P was also reported by Subramaninan et al.(1993) in cowpea and Dwangan et al. (1993) in in green gram.

Fig. 19 Effect of Irrigation on moisture extraction pattern (MEP)(per cent)





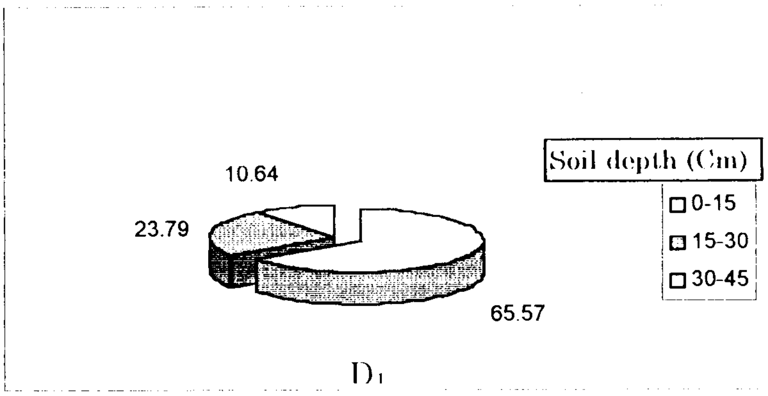


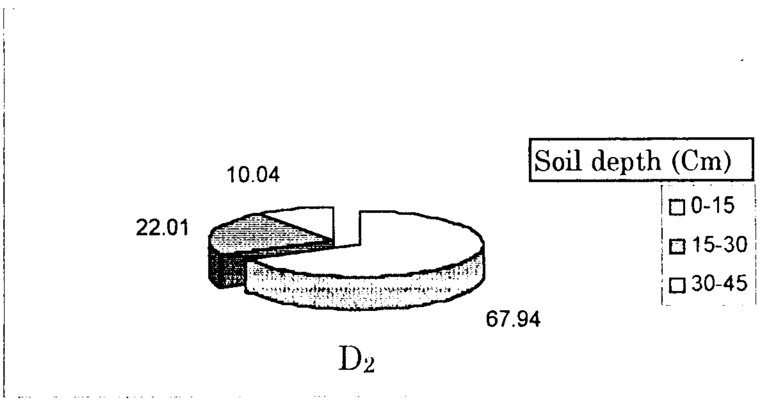
5.9.2 Moisture extraction pattern (MEP)

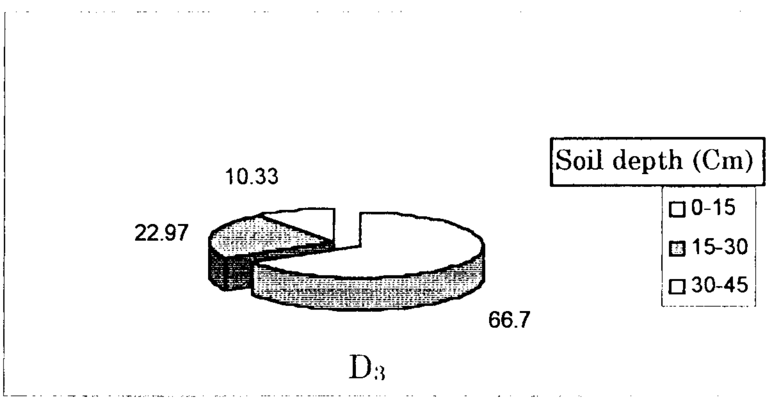
It is evident from the data presented in table 4.13 that the percentage extraction of moisture from the top layer (0-15cm) was higher with wetter regimes and was maximum with the daily irrigation treatment(I_3) and minimum with I_0, the least frequently irrigated treatment. But the extraction of moisture from the deeper layers increased with moisture stress (Fig.19).

Frequent wetting of the upper surface layer exposed to the hot atmosphere created a higher vapour pressure gradient between the crop canopy and the atmosphere which might have caused a relatively larger loss of water from the soil surface than in less frequent irrigation schedules resulting in a higher moisture depletion from surface layer in frequently irrigated schedule. A substantial shift in the rooting pattern of the crop to the deeper layers with moisture stress might be the reason for higher extraction from deeper layers under less frequently irrigated condition (Pannu and Singh 1993). Black (1973) has observed that root grows deeper into the soil in search of water when the moisture supply is not adequate in the surface layer of soil. These results are in corroboration with the findings of Arya and Sharma (1990) and Bachchhav et al.(1993) in green gram and Singh and Tripathi (1992) in black gram. It was also noted that the crop extracted most of the moisture required from the top soil layer (0-15 cm). This might be due to the additive effect of higher transpiration from the increased leaf area and

Fig. 20 Effect of Plant density on moisture extraction pattern (MEP) (per cent)





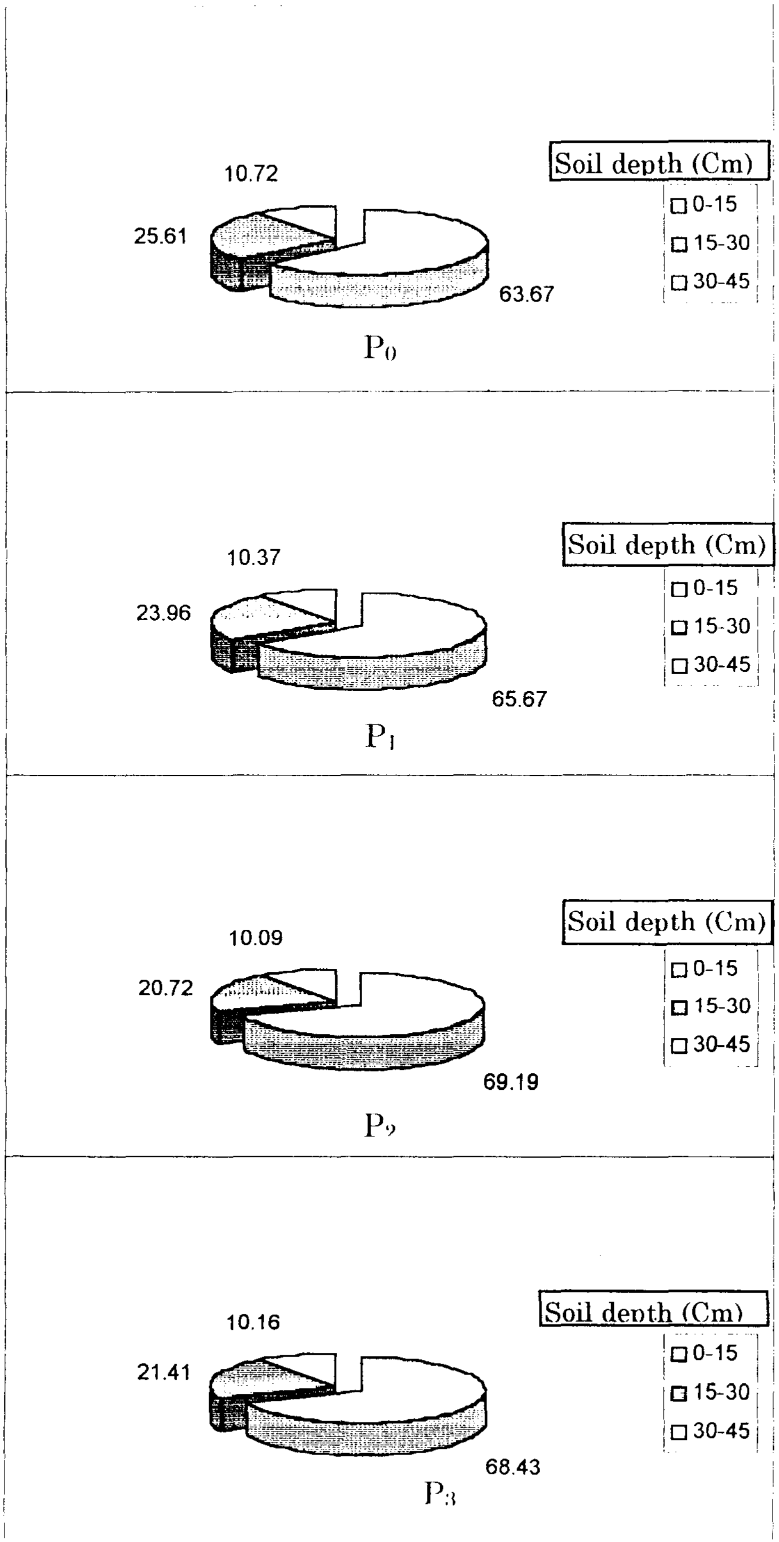


more water loss from the soil surface through evaporation. This is in agreement with the findings of Jyothi (1995). Similar results have also been reported by Nayar and Singh (1985) in chickpea, Khade et al. (1986) and Arya and Sharma (1990) in green gram and Sinha and Pal (1991) in blackgram.

The plant density treatments also caused appreciable variation in the moisture extraction pattern. The density level D_2 resulted in the highest percentage of mositure extraction from the top layer followed by D_3, while D_1 extracted more water from the deeper layers (Fig.20).

The higher degree of competition among the crop plants in high density treatment as observed by Singh et al. (1991) in green gram, Kumar and Sharma (1989) in black gram and Tripathi and Chauhan (1990) in pigeon pea might have resulted in a shift in the rooting density and proliferation towards deeper soil layers in search of available mositure. This explains the higher extend of mositure uptake from deeper soil layers in D_1. In case of low density treatment, loss of huge volumes of moisture by way of evaporation from exposed surface soil and transpiration by the profusely growing weeds might have resulted in lesser volume of available moisture for crop exploitation from surface layer and thereby increased uptake from deeper layers. The medium density treatment with proper development of roots and shoots in suitable plant geometry having adequate canopy coverage and a healthy level of competition among crop plants could absorb a higher percentage of moisture requirement from the surface soil. Dwangan et al. (1992) also noted that closely spaced crop

Fig. 21 Effect of Phosphorus on moisture extraction pattern (MEP) (per cent)



extracted more water from the top soil.

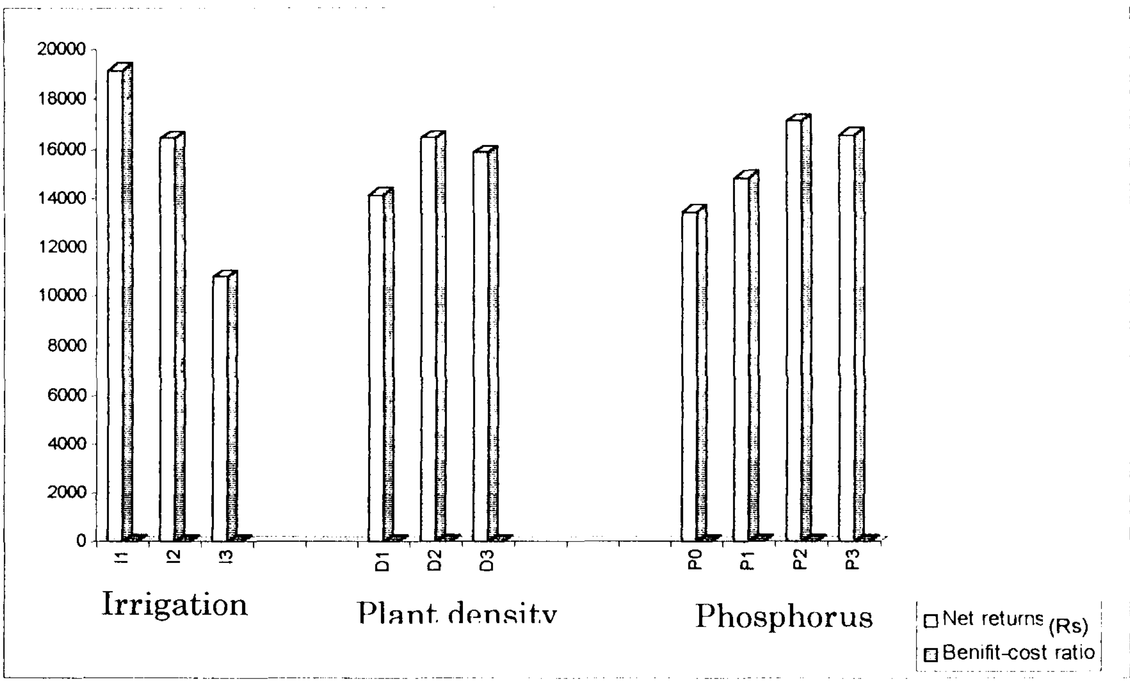
Percentage of moisture depletion from the top 15cm soil layer increased progressively with increasing levels of phosphorus upto 45 kg/ha (P_2) but a higher dose decreased the extraction from top soil layer (Fig.21). Improved growth of crop plants under the optimum level of phosphorus, already identified as 45 kg/ha may have resulted in significant increase in the yield of green matter which means greater quantity of organic matter added to the soil conserving mositure of the surface layer thereby increasing the mositure extraction from the top layer by the crop.

5.10 Economics of cultivation

It was evident from the economic analysis that the net returns and benefit-cost ratio (BCR) were higher with the I_1 treatment. Even though higher yields were obtained with the daily irrigation treatment, I_3 it was computed as least economic. This proves that the increase in labour cost for irrigating daily could not be compensated by the increase in green pod yield. The lower yield under I_2 treatment resulted in low net returns and BCR (Fig.22).

Among the different levels of plant density tried, the medium density level D_2 was identified as most economic with the highest net returns and BCR while D_1 was noted as least economic (Fig.22). This might be a direct reflection of the increased yield and lower cost of cultivation due to less seed requirement in this treatment compared to the high density treatment D_1.

Fig. 22 Effect of Irrigation, Plant density and Phosphorus on economics of cultivation



An appreciable increase in the net returns and BCR was also recorded with increase in the doses of P upto 45 kg/ha (P_2) due to high yield of marketable pods, but a higher dose was found to be less economic due to a decline in yield. Absence of phosphorus drastically reduced the net returns and BCR due to lower pod yield (Fig.22).

Among the various combinations of irrigation and plant density, irrigation and phosphorus and plant density and phosphorus the combinations I_1D_2, I_1P_2 and D_2P_2 was computed as most economic while I_3D_1, I_3P_0 and D_1P_0 was least economic. The three factor combination $I_1D_2P_2$ gave highest net returns and BCR while $I_3D_1P_0$ gave the lowest values for the parameters.

SUMMARY

SUMMARY

A field experiment was conducted in the summer ri fallows at the Instructional Farm attached to the College Agriculture, Vellayani during 1994-'95 to study the response vegetable cowpea to phosphorus under varying moisture levels a plant density. The soil of the experimental field was sandy cla loam in texture with a bulk density ranging from 1.30 to 1.33 kg m acidic in reaction and medium level in the status of availab nitrogen, phosphorus and pottasium. The quantity of rainfal received during the crop growth peroid was meagre. The experimen was laid out in strip- split plot design with three replication The treatments comprised of three levels of irrigatio (I_1- Irrigating the crop at 10mm CPE value to a depth of 20mm I_2- Irrigating the crop at 15mm CPE value to a depth of 20mm a I_3- Daily light irrigation to a depth of 10mm), three levels plant density (D_1 - 22,222 pts/ha (0.75x0.6m), D_2 -16,667 pts/h (1.0x0.6m) and D_3 - 13,333pts/ha (1.25x0.6m) and four levels phosphorus (P_0 -no phosphorus, P_1 - 30 kg/ha P_2O_5, P2 -45kg/ha P_2O_5 P_3 - 60kg/ha P_2O_5). Observations were made on growth, yield a quality characters of the crop, data were stastistically analys and the results of the study are summarised below:-

1. It was observed that the plant height increased progressivel upto 90 DAS. The irrigation levels I_3 and I_1 showed a marke increase in plant height over I_2. I_3 was also significantl superior to I_1. The trend remained the same upto the end of th cropping period. A plant density level D_2 showed significantl higher value for plant height while D_1 gave the lowest values. The

phosphorus level P_2 was significantly superior to all other level with respect to the height of plants while with P_0 a significant reduction in plant height was noted. The other growth parameters like the number of leaves and branches followed the same trend.

2. The days for 50 per cent flowering was also influenced by irrigaion treatments . Early flowering was observed with I_3 and I_1 and delayed flowering with I_2. However, plant density did not influence in attaining of 50 per cent flowering. Phosphorus application at all levels induced earliness in flowering and P_2 level gave earliest flowering.

3. The total DMP of the crop increased progressively upto 90DAT. The irrigation level I_3 recorded maximumDMP during all the growth stages. A plant density level D_2 gave maximum DMP uniformly upto 90 DAT. A significant increase in the total DMP was manifested throughout the crop growth with increase in the level of P upto P_2 but a higher dose resulted in significant reduction in DMP.

4. The number of pods per plant was substantially increased by frequent irrigation giving a maximum value with I_3 level of irrigation which was significantly superior over other levels. Also a plant density level D_2 and a phosphorus level P_2 resulted in significantly higher number of pods compared to other levels.

5. Differential irrigation had significant influence on the yield of green pod and haulm with I_3 giving superior values compared to I_1 and I_2. I_2 recorded lowest yields. A plant density level D_2 and a phosphorus level P_2 resulted in highest yields compared to other levels of plant density and phosphorus.

6. The uptake of N,P and K by the crop was significantly high with I_2 level of irrigation, D_2 level of plant density and P_2 level of phosphorus compared to other levels of irrigation, density and phosphorus. The soil nutrient status after the experiment was also significantly influenced by the treatments. I_2 recorded maximum content of residual nutrients N,P and K compared to other levels of irrigations. Also D_1 and P_0 levels of plant density and phosphorus recorded maximum values for the character.

7. The highest efficiency of water use was observed when the frequency of irrigation was lowest, i.e., I_2 level and I_3 gave the least water use efficiency. The plant density level D_2 and phosphorus level P_2 also showed maximum efficiency of water use compared to other levels.

8. Considering the pattern of moisture extraction it was noted that the percentage of extraction from the top soil layer (0-15 cm) increased with wetter regimes and was maximum with I_3 treatment. Percentage extraction from deeper layers increased with drier regimes. A plant density level D_2 and phosphorus level P_2 also showed significantly higher extend of extraction of moisture from top soil layer.

9. It was evident from the results that an irrigation level I_1, plant density level D_2 and phosphorus level P_2 was most economical with the highest net retuns and BCR and was significantly superior to other treatment levels. I_1 registered the highest net returns of Rs. 10161.48 per hectare with a BCR of 1.62. Among the plant densitylevels D_2 gave maximum net income of Rs. 10421.31 per hectare and a BCR of 1.53. Comparing the different levels of

phosphorus P2 resulted in maximum net returns of Rs. 17080.50 per hectare and a BCR 1.55.

Scrutinizing the overall trend in the study revealed that it is profitable to irrigate the crop at a CPE value of 10mm to a depth of 20mm during the entire period of crop growth. It is also observed that a plant density level of 16,667 pts/ha and a phosphorus level of 45kg/ha is most profitable for the cultivation of vegetable cowpea cv.Malika in summer rice fallows in Southern Kerala.

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ABSTRACT

RESPONSE OF VEGETABLE COWPEA

(*Vigna sesquipedalis* (L.) Fruw.) TO PHOSPHORUS

UNDER VARYING MOISTURE LEVELS AND PLANT DENSITY

By

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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

1997

ABSTRACT

An experiment was conducted at the Instructional Farm attached to the College of Agriculture, Vellayani in the summer rice fallows during 1994-'95 to study the response of vegetable cowpea cv. Malika to phosphorus under varying moisture levels and plant density. The experiment was laid out in strip-split plot design with 3 replications. The treatments included three levels each of irrigation and plant density and four levels of phosphorus.

The study revealed that the crop responded to irrigation, plant density as well as phosphorus levels. The biometric characters like plant height, number of leaves and branches per plant, earliness in flowering, total DMP and yield attributing characters like number of pods per plant were favourably influenced by giving daily light irrigation of 10mm (farmer's practice) throughout the crop period. The maximum values for the above said characters were also observed at a plant density level of 16,667 pts/ha (1.0x0.6m) and a phosphorus level of 45kg/ha compared to the other levels.

The maximum yield of green pods and haulm was obtained by daily light irrigation with 10mm water and a plant density of 16,667 pts/ha. The crop responded upto 45 kg/ha P_2O_5 application. The uptake of major nutrients N,P and K by the crop also followed the same trend.

But the water-use efficiency was highest for the least freqently irrigated treatment viz. irrigating at 15mm CPE and was

found to decrease with increase in the frequency of irrigation. plant density level of 16,667 pts/ha and a phosphorus level 45kg/ha also recorded maximum water-use efficiency. Soil moistu extraction pattern showed that less frequent the irrigatio more the percentage of absorbtion from deeper soil layers. A plan density level of 16,667pts/ha as well as a phosphorus level 45kg/ha also gave maximum absorbtion from top soil layers where as higher plant density gave maximum absorbtion from the deeper soi layers.

The available N,P and K contents of the soil after the experiment indicated a decrease in the soil nutrient status with an increase in the moisture level of the soil. The highest nutrient status was also noted with a density level of 16,667 pts/ha and a phosphorus level of 45kg/ha.

The results of economic analyisis revealed that the net income and benefit-cost ratio was maximum by irrigating the crop at 10mm CPE, at a plant density of 16,667 pts/ha and a phosphorus level of 45kg/ha.