AGROTECHNIQUES FOR SEED PRODUCTION IN VEGETABLE COWPEA *[Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt*]* var. Sharika

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DECLARATION

I hereby declare that this thesis entitled **"Agrotechniques for seed production in vegetable cowpea *(Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt*)* var. Sharika**" 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 **"Agrotechniques for seed production in vegetable cowpea *(Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt) var. Sharika"** is a record of research work done independently by Ms. Suja Abraham under my guidance and supervision and that it has not formed the basis for the award of any degree, fellowship or associateship to her.

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LIST OF ABBREVATIONS

@	-	at the rate of
ºC	-	degree Celsius
cv	-	cultivar
cm	-	centimetre
mm	-	millimetre
m	-	metre
g	-	gram
kg	-	kilogram
t	-	tonnes
LAD	-	leaf area duration
LAI	-	leaf area index
DAS	-	days after sowing
ANOVA	-	Analysis of variance
N	-	Nitrogen
NS	-	Non significant
P	-	Phosphorus
K	-	Potassium
S	-	Spacing
ha	-	hectare
BCR	-	Benefit Cost Ratio
DMC	-	Dry matter content
pts/ha	-	plants per hectare
q	-	quintal
DMP	-	dry matter production
viz.	-	namely
i.e.	-	that is

INTRODUCTION

1. INTRODUCTION

Vegetables play an important role in human nutrition by providing carbohydrates, proteins, minerals and vitamins. Keeping in view the largest demand of vegetables for domestic consumption and enormous scope of exports, the yield can be increased manifold and there is possibility of increasing the productivity by 200 to 300 per cent by using advanced technologies.

Good quality seed is the most important pre requisite for higher productivity and production of crops especially vegetable crops. Poor seeds will adversely affect the crop production and the economic status of the farmer. It is very well said "the agriculture of a country is as strong as its seed program". If the seed program is weak, agriculture will be weak and when agriculture is weak, the nation is weak. So, we can even say that the quality seeds hold the future of the nation. It has an important role in stabilizing the health and wealth of a nation.

The non availability of quality seeds due to inadequate production is the major constraint in the vegetable cultivation of India. The present requirement of vegetable seeds in the country is 48,000 tones per annum of which only 20,200t is supplied by authorized agencies (Prabhakar 1999). In Kerala, the seed requirement is 72 tonnes of which, only 20-25 per cent is supplied by authorized agencies (KAU 1991). Hence, the vegetable seed yield has to be stepped up from the present level to ensure the timely supply of seeds in adequate quality to the grower. The total area under vegetables in Kerala is 159,700 ha (State Planning Board, 2000).

Vegetable cowpea is one of the most important vegetables cultivated in Kerala owing to its high nutrient content, greater market price and consumer preference. Being a crop of legume, it has got a role in nitrogen enrichment of soil and can be grown as cover crop and catch crop. It can be grown throughout the year in Kerala. It is cultivated for its long green pods as vegetable and foliages as fodder. The cultivars grown for their immature pods are variously known as asparagus bean, snake bean or yard long bean. The sesquipedalis type grown in South India has very long pods and is commonly called the yard long bean.

Quality seed production is a highly specialized activity and vegetable produce retained for seed can not be substituted for quality seed and as it generally lack genetic vigour and has poor germination. The vegetable seed production comprises of complex interlocking operations that are necessary to ensure the regular supply of high quality seeds to farmers.

The factors like suitable season, seed quality and cultural operations like optimum density of crop, fertilizer nutrients, soil moisture, and plant protection measures play a great role in ensuring the quality of the seed apart from enhancing its productivity. ‘Sharika’ is the test variety used in this experiment. It is a high yielding variety developed by Kerala Agricultural University. The present study on seed production of vegetable cowpea was undertaken with the following objectives.

(i) Optimisation of resources such as nutrients viz. nitrogen and potassium

(ii) Optimisation of spacing

(iii) To ascertain the seed production potential of vegetable cowpea.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Seed is an important input in agricultural production. The production of good quality seeds in sufficient quantity is dependent on many aspects. Among them agro techniques play a major role. The optimum quantity of fertilizers and spacing required for the crop aimed for producing seeds cannot be overlooked. The best use of the available resources for seed production will result in the production of good quality seeds in an appreciable quantity. Vegetable seed production is even more important because today the food habits of people all around the world are being oriented towards consumption of more protective foods like vegetables and fruits. The results of experiments conducted in India and abroad on the seed production potential of vegetable cowpea and related crops as influenced by varying levels of nitrogen, potassium and spacing and their interaction effects are reviewed here.

2.1. EFFECT OF NITROGEN

Nitrogen plays a key role for proper growth and development of all cultivated crops. In legumes, it is necessary to provide a starter dose of nitrogen for the crop establishment. Through rhizobial nitrogen fixation many legumes fix nitrogen to the tune of 25 to 35 kg per ha. Patel (1979) and Raj and Patel (1991) found that cowpea responds well to moderate application of nitrogen. Regarding seed yield Akter *et al.*, (1998) reported that in cowpea grain yield increased with increasing levels of nitrogen but the most threshold effect was found with 20 kg. Nha^{-1}.

2.1.1 Effect of Nitrogen on Growth Characters

2.1.1.1 Length of Vine

Experiment conducted on green gram revealed that increasing the level of nitrogen from 0 to 60 kg. ha^{-1} significantly increased the plant height from 27.6 cm to 30.4 cm (Panda, 1972). According to Lenka and Satpathy (1976) application of 20 to 40 kg Nha^{-1} increased plant height in red gram.

George (1981) reported that in grain cowpea when 20 kg N ha^{-1} was applied as basal dose followed by 10 kg N ha^{-1} in soil at vegetative phase gave maximum plant height at all stages of growth.

There was a significant improvement in plant height with increasing levels of N upto 50 kg N ha^{-1} at 60 DAS in pigeon pea (Chittapur *et al.*, 1994). Dwivedi *et al.*, (1994) reported in french bean that with increase in nitrogen levels there is an increase in plant height. Jyothi (1995) noticed that in summer vegetable cowpea the plant height was appreciably increased by 20 kg N ha^{-1} up to 75 DAS.Baboo *et al.*, (1998) noted a significant increase in plant height with increasing levels of nitrogen upto 120 kg Nha^{-1} in french bean.

2.1.1.2 Branches per Plant

Joseph (1982) noticed that branching in chilli was significantly increased by nitrogen application. Srinivas (1983) observed significant increase in number of branches per chilli plant with increase in nitrogen. Plant height and branches per plant was not affected by application of diammonium phosphate in soybean according to Jayaraj *et al.*, (1992). Sherly (1996) noticed in chilli that branches per plant was maximum at higher levels of nutrients. Mohapatra (1998) reported that the number of branches in rice bean increased with increase in nitrogen. Branches per plant increased with increase in nitrogen up to 120 kg ha^{-1} in french bean in a study conducted by Prajapathi *et al.*, (2003). Hussaini (2004) reported that the number of branches were not significantly affected by application of 20 kg N ha^{-1} for cowpea.

2.1.1.3 Dry Matter Production

Savithri (1980) noted in cowpea that an increase in the levels of nitrogen resulted in an increase in the dry matter yield. Minchin (1981) found that providing inorganic nitrogen during the vegetative and reproductive phase stimulated dry matter production in nodulated cowpea plants. Application of 20 kg N ha^{-1} increased DMC per plant in bengal gram (Prasad and Singh, 1987). Singh and Khangarot (1987) reported that application of nitrogen profoundly enhanced the total dry matter production in chickpea. Reddy *et al.*, (1992) reported that in green gram the dry matter production was higher at all the stages of crop growth.

Jyothi (1995) noted that the application of nitrogen appreciably influenced the DMP at all stages of growth and also found that nitrogen at the rate of 30 kg ha^{-1} registered the maximum DMP. Akter *et al.*, (1998) reported that dry weight of plants increased significantly with increased levels of nitrogen upto 40 kg ha^{-1} in cowpea.

2.1.1.4 Shoot – Root Ratio

The shoot root ratio increased with increase in N fixation by cowpea group of *rhizobia* and application of 120 kg N ha^{-1} compared to 69 kg N ha^{-1} per season for pigeon pea (Narayanan and Sheldrake, 1976)

2.1.1.5 Leaf Area Index (LAI)

According to George (1981) at midpoint filling stage the LAI varied significantly when N was applied @ 20 kg N ha^{-1} basal and 10 kg N ha^{-1} in soil at vegetative phase in vegetable cowpea. In french bean an increase in N levels up to 80 kg ha^{-1} increased LAI (Hegde and Srinivas, 1989). In another experiment in cowpea, Ramamurthy *et al.*, (1990) found that the application of 20 kg N ha^{-1} recorded maximum leaf area index. Jadhav *et al.*, (1994) reported that leaf area increased with 60 kg N ha^{-1} in soybean. Jyothi (1995) noted in summer vegetable cowpea that maximum LAI was recorded when 20 kg N ha^{-1} was applied. LAI showed significant variation with N at 30 and 60 days when more N in the form of 6 t FYM and NPK @ 110:37:74 kg ha^{-1} were applied to bhindi (Isaac, 1995). Lakshmi (1997) reported in cucumber that LAI was significantly increased by nitrogen levels. With an increase in nitrogen levels LAI of groundnut increased significantly at different stages of growth upto 60 DAS (Barik *et al.*, 1998).

2.1.1.6 Days to Fifty Per cent Flowering

Rao and Gulshanlal (1986) noted in chilli a significant increase in the number of days to fifty per cent flowering with the increased levels of nitrogen upto 150 kg ha^{-1}. John (1989) observed that time taken for fifty per cent flowering in chilli significantly delayed with graded levels of nitrogen. Jyothi (1995) noticed that in vegetable cowpea nitrogen levels did not influence the time taken for fifty per cent flowering. However, a trend of earliness in flowering was observed at 30 kg N ha^{-1}.

2.1.2 Effect of Nitrogen on Yield and Yield Attributing Characters

2.1.2.1 Number of Pods per Plant

Kumar and Pillai (1979) reported that the maximum number of pods per plant was obtained by the application of 20 kg N ha^{-1} in cowpea var. P 118. According to Patel (1979) the application of 20 kg N ha^{-1} to cowpea remarkably influenced the yield attributes like number of green pods per plant. Ramamurthy *et al.,* (1990) found that application of 25 kg N $ha^{-1}$to cowpea produced maximum number of pods per plant. In french bean number of pods increased significantly with N fertilization over control as reported by Dahatonde *et al,.* (1992). Singh *et al.,* (1992) reported that when garden pea was fertilized with 18 kg N ha^{-1} it recorded maximum filled pods per plant. Jyothi (1995) reported that in summer vegetable cowpea application of 30 kg N ha^{-1} resulted in a significant increase in the number of pods per plant. Akter *et al.,* (1998) found that number of pods per plant was increased by nitrogen application and a profound increase was obtained with 20 kg N ha^{-1} over the lower level in grain cowpea. Nandan and Prasad (1998) found a significant improvement in pods per plant upto 120 kg N ha^{-1} in french bean. Baboo *et al.,* (1998) reported that there was significant increase in number of pods per plant in french bean with increasing N levels upto 120 kg N ha^{-1}. Application of nitrogen to mungbean positively affected the number of pods per plant, seed yield per plant compared to control (Patil *et al.,* 2005).

2.1.2.2 Weight of Dried Pods per Plant

According to Patel (1979) the application of 20 kg N ha^{-1} to cowpea remarkably influenced the weight of green pods per plant. Khade *et al.,* (1986) observed that application of 25 kg N ha^{-1} resulted in the maximum weight of dry pods per plant in black gram compared to application of 12.5 and 37.5 kg N ha^{-1}. Ramamurthy *et al.,* (1990) found that application of 25 kg N ha^{-1} to cowpea produced the maximum pod weight per plant.

2.1.2.3 Total Number of Pods Harvested per Plot

When 100kg DAP per hectare was applied to pigeon pea the yield per plot was increased (Mahajan *et al.,* 1998).

2.1.3 Seed Characters

2.1.3.1 Number of Seeds per Pod

Kumar and Pillai (1979) reported that the maximum number of seeds per pod was obtained by the application of 20 kg N ha^{-1} in a cowpea var. P 118. In a study on summer cowpea Raj and Patel (1991) reported that application of 20 kg N ha^{-1} significantly improved the number of grains per pod. When 80 kg N ha^{-1} was applied there was an increase in grains per pod in french bean (Dwivedi *et al.,* 1994). Jyothi (1995) reported that in summer vegetable cowpea application of 30 kg N ha^{-1} resulted in a significant increase in the number of seeds per pod. Singh *et al.,* (1996) found out that number of seeds per pod increased with increasing levels of N upto 120 kg N ha^{-1} in french bean.

2.1.3.2 Weight of Seeds per Pod

Isaac (1995) observed in bhindi that the weight of seeds per fruit was influenced by nitrogen application in the form of 6t FYM + NPK @ 50:8:25 $kgha^{-1}$.

2.1.3.3 Pod to Seed Ratio

Isaac (1995) observed that the fruit to seed ratio was not significantly influenced by nitrogen in an experiment with bhindi.

2.1.3.4 100 Seed Weight

Kumar and Pillai (1979) reported that maximum 100 seed weight was obtained by the application of 20 kg N ha^{-1} in cowpea var. P.118. Singh *et al.,* (1992) reported that when garden pea was fertilized with 18 kg N ha^{-1} it recorded the maximum 100 seed weight. Dwivedi *et al.,* (1994) found that the 100 seed weight in french bean was highest when N was applied at the rate of 80 kg ha^{-1}. 100 seed weight of seeds increased with increasing levels of N upto 120 kg N ha^{-1} in french bean in an experiment conducted by Singh *et al.,* (1996).

2.1.3.5 Seed Yield per Hectare

Kumar and Pillai (1979) and Kumar *et al.,* (1979) observed that application of 20 kg N ha^{-1} significantly influenced the grain yield in cowpea. Tank *et al.,* (1992) noticed that the crop fertilized with 20 kg N ha^{-1} out yielded the rest of the higher and lower levels of N recording significantly highest grain yield in summer green gram. The yield increased with an increase in nitrogen level upto 20 kg ha^{-1}

and further increase declined the yield. Bachchhav *et al.,* (1993) noticed that the application of 30 kg N ha^{-1} recorded significantly more seed yield in green gram. Jyothi (1995) reported that in summer vegetable cowpea the application of 30 kg N ha^{-1} resulted in maximum seed and haulm yield. Akter *et al.,*(1998) reported that in cowpea, seed yield increased with increasing levels of nitrogen, but the most threshold effect was found with 20 kg N ha^{-1}. Singh and Mishra (2004) reported that in carrot application of nitrogen @ 100 kg ha^{-1} gave high seed yield. Application of nitrogen increased seed yield per hectare in mungbean (Patil *et al.,* 2005).

2.1.3.6 Other Attributes of Seed

Isaac (1995) reported that the treatment of nitrogen in bhindi did not exert any significant influence on seed viability. Ashok *et al.,* (2004) reported that germination per centage was maximum for okra when it was treated at the rate of 125 kg N ha^{-1}. Chopra and Chopra (2004) observed in Pusa 44 rice, that the germination per centage was 95.1 when treated with 180 kg N ha^{-1}. Nitrogen positively influenced germination per centage in mungbean (Patil *et al.,* 2005).

Vijayakumar *et al.,* (1992) tried in snake gourd three levels of nitrogen, phosphorus and potassium and found that 12:24:12 g NPK pit^{-1} gave highest root length of seedling. Regarding root length of seedling Isaac (1995) reported that there was no significant effect by the application of nitrogen in the form of FYM and 50 kg N ha^{-1} as chemical fertilizer. In lettuce Sajjan *et al.,* (1998) reported that root length was increased by application of 150 kg N ha^{-1}. Ashok *et al.,* (2004) reported that root length increased with increase in nitrogen application in okra.

Naidu (1987) reported that cowpea cvCo-4 when treated with nitrogen @ 25 kg ha^{-1} recorded the highest dry weight of seedling. In the same experiment the vigour index was 3642.3. No significant effect was noticed by Isaac (1995) in the vigour index of seedling obtained from seeds of bhindi treated with 6t FYM and 50 kg N ha^{-1}. Ashok *et al.,* (2004) reported that vigour index was maximum when okra was treated with 150 kg N ha^{-1}. When Chopra and Chopra (2004) treated Pusa 44 rice with 120 kg N ha^{-1} the vigour index was maximum.

2.1.4 Effect of Nitrogen on Nutrient Composition and Uptake

Savithri (1980) reported in cowpea that application of nitrogen upto 30 kg N ha^{-1} resulted in maximum uptake of nitrogen. Jyothi (1995) reported that maximum uptake was noticed when 30kg N + 45 kg P_2O_5 ha^{-1} was applied in summer vegetable cowpea. Reddy *et al.,* (1992) reported in green gram that application of manures or fertilizers increased the N and K content in plant tissues. Bachchhav *et al.,* (1993) noticed in green gram that application of 30 and 45 kg N ha^{-1} significantly increased the N uptake by the seed compared with the control and 15 kg ha^{-1}.

In a pot culture study, Kadwe and Badhe (1973) observed that in black gram, application of 50 kg N ha^{-1} along with 1-12 kg Mo ha^{-1} appreciably increased the plant uptake of nitrogen. George (1981) reported in cowpea that plants supplied with 30 kg N ha^{-1} resulted in higher uptake of nitrogen. Here soil and foliar application resulted in higher uptake.

2.1.5 Effect of Nitrogen on the Economics of Cultivation

Azad *et al.,* (1992) observed a net profit of Rs.134/- per kg N ha^{-1} in field pea when N, P, K and Zn were applied at the rate of 18, 46, 40 and 25 kg ha^{-1}. Patel and Patel (1994) reported in pigeon pea that the net realization increased with successive increase in N level and the highest net realization of Rs.5,680/- per hectare was recorded with 20 kg N ha^{-1}. In vegetable cowpea maximum net returns (Rs.2,538.2 ha^{-1}) and BCR (1.17 : 1) were recorded when a combination of 30 kg N + 45 kg P_2O_5 ha^{-1} was applied to summer vegetable cowpea (Jyothi 1995). Geetha (1999) reported the maximum net returns of Rs.45977.8 ha^{-1} and BC ratio of 1.29 : 1 when N was applied at the rate of 20 kg ha^{-1} for vegetable cowpea.

2.2 EFFECT OF POTASSIUM

The requirement of plants for available K is quite high. It plays an important role in enzyme activation, water relations, energy relation, translocation of assimilates, N uptake and protein synthesis. In the case of legumes potassium enhances carbohydrate transport to nodules and utilization for synthesis of amino acids (Tisdale *et al.,* 1993).

2.2.1 Effect of Potassium on Growth Characters

2.2.1.1 Length of Vine

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

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

2.2.1.2 Branches per Plant

Branching of chilli was significantly increased by increased doses of potassium (Lakatos, 1982). Joseph (1982) and John (1989) observed no significant difference in number of branches due to graded levels of potassium. Jayaraj *et al.,* (1992) reported that the number of branches in soybean were not significantly affected by spraying nutrient mixture of K_2O and succinic acid. Hussaini (2004) reported that when K_2O was applied @ 20 kg ha^{-1} in cowpea the number of branches were on par with that of 0 kg K_2O ha^{-1}.

2.2.1.3 Dry Matter Content

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

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

2.2.1.4 Leaf Area Index (LAI)

Khanna *et al.,* (1980) reported that addition of K enhanced the rate of leaf expansion in both irrigated and unirrigated maize seedlings. Mathew (1981) found that higher potash levels tended to increase leaf area index at all stages, but it reached the level of significance only at 60^{th} day and at 60^{th} day 75 kg K_2O ha^{-1} had significantly increased leaf area index over the lower doses in groundnut. Growth parameters like leaf area index and leaf area duration increased significantly in french bean with upto 100 kg K_2O ha^{-1} (Sangakkara, 1996). Yahiya *et al.,* (1996) reported that the leaf area index significantly increased upto 75 kg K_2O ha^{-1} in pigeon pea. Lakshmi (1997) reported in cucumber that higher values of LAI was obtained at 60 DAS for 50 kg K_2O ha^{-1}. Sakeena (1998) reported that there was progressive improvement in LAI due to successive levels of potassium upto highest level tried ie. 70 kg K_2O ha^{-1} in rice.

2.2.1.5 Days to Fifty Per cent Flowering

John (1989) in vegetable chilli stated that effect of potassium in reducing the mean number of days required for fifty per cent flowering. Potassium at 65 kg ha^{-1} induced earliness in flowering significantly. Kanaujia *et al.,* (1997) observed in pea that there was no significant response in the case of days taken for the first flowering.

2.2.2 Yield characters

2.2.2.1 Number of pods per plant

Rao (1979) observed that number of filled pods increased with higher levels of potassium in groundnut. Singh *et al.,* (1992) observed that when 40 kg K_2O ha^{-1} was applied maximum filled pods per plant was produced in pea. Singh *et al.,*

(1994) reported that potassium application increased the entire yield contributing characters and observed significant effect on number of pods per plant only. Yahiya *et al.,* (1996) noted that application of 50 kg K_2O ha^{-1} significantly increased the number of pods per plant. Patra *et al.,* (1996) noted that application of potassium had no significant effect on yield attributes in kharif groundnut.

2.2.2.2 Weight of Dried Pods per Plant

Shekawat *et al.,* (1969) observed an increase in green pod yield of pea with 33.6 kg K_2O ha^{-1} and further increase in level upto 67.1 kg K_2O ha^{-1} did not correspondingly affect the green pod yield. Devarajan and Kothandaraman (1982) reported an increase in pod weight in groundnut with application of potassium.

2.2.2.3 Total Number of Pods Harvested per Plot

Manjhi and Chowdhary (1971) reported that the response of potash to various agricultural crops was not significant as majority of Indian soils are not deficient in potash. Yahiya *et al.,* (1996) reported in pigeon pea that application of 50 kg K_2O ha^{-1} significantly increased pod yield.

Mathew (1981) observed that higher levels of potash significantly influenced pod yield with 75 kg K_2O ha^{-1} in groundnut. Yakadri *et al.,* (1992) reported in groundnut that pod yield was significantly influenced by the increasing levels of potassium upto 60 $kgha^{-1}$. Deshmukh *et al.,* (1993) noted that the pod yield increased significantly with application of 40 kg K_2O ha^{-1} over lower doses. Patra *et al.,* (1996) observed that application of potassium at the rate of 50 kg ha^{-1} significantly increased pod yield in groundnut. Kanaujia *et al.,* (1997) reported that green pod yield was increased by potassium application and highest values were recorded with 60 kg K_2O ha^{-1} in pea.

2.2.3 Seed Characters

2.2.3.1 Seeds per Pod

Effect of potassium was significant at 30 $kgha^{-1}$ which recorded the maximum number of seeds per pod in black gram (George, 1980). Chandran (1986) reported that when vegetable cowpea was treated with 30:60:30 kg NPK ha^{-1} the number of seeds per pod was highest. Yield parameter namely seeds per pod increased significantly with 100 kg K_2O ha^{-1} in french bean (Sangakkara, 1996).

2.2.3.2 Weight of Seeds per Pod

Mathew (1981) noted that increasing potash application in groundnut up to 75 kg K_2O ha^{-1} increased the number of pods per plant, weight of 100 pods and weight of 100 kernels.

2.2.3.3 Hundred Seed Weight

Nair (1978) reported a significant increase in 100 kernel weight due to potassium application in groundnut. Mathew (1981) noted that increasing potash application up to 75 kg K_2O ha^{-1} in groundnut increased the weight of 100 kernels. Gnanamurthy and Balasubramanian (1992) observed in groundnut that for plants receiving 150 per cent of the recommended dose of K the 100 kernel weight was higher than others. Singh *et al.,* (1992) observed that when 40 kg K_2O ha^{-1} was applied the maximum 1000 seed weight (g) was produced in pea. Yahiya *et al.,* (1996) noted that application of 50 kg K_2O ha^{-1} significantly increased 1000 seed weight over the control treatment.

2.2.3.4 Seed Yield per Hectare

Savithri (1980) noted that highest level of 30 kg K_2O ha^{-1} increased the grain yield significantly over 10 kg K_2O ha^{-1} in green gram. Singh *et al.,* (1992) observed in pea that application of 40 kg K_2O ha^{-1} significantly increased grain yield compared with the control. Singh *et al.,* (1992) reported that seed yield was found to improve with increase in levels of potassium in pigeon pea. In a pot culture experiment Singh *et al.,* (1992) reported that there was a significant increase in grain yield with increase in levels of potassium in pea.

2.2.3.5 Other Attributes of Seed

Vijayakumar *et al.,* (1995) reported that when brinjal was treated with 200:100:60 kg NPK ha^{-1} the seedlings gave the highest germination per centage. Tomar and Singh (2004) reported in okra that when NPK was applied @ 1:2:1 ratio the germination per centage and corresponding seed viability values were highest.

Kamaraj and Krishnaswamy (2003) reported that when urea and KH_2PO_4 were applied as foliar spray to hybrid rice the root length of seedling was the highest.

Jayaraj *et al.,* (1992) reported that when soybean was treated with DAP and K_2O nutrient mixture the vigour index was significant. Seed germination and vigour index was highest by application of potassium in cowpea (Srimathi and Jerlin, 1995). Sajjan *et al.,* (1998) reported that when NPK was applied @ 150:75:75 kg ha^{-1} to lettuce the vigour index was maximum. In the same experiment seedling dry weight was also maximum for the same level of fertilizers.

2.2.4 Effect of Potassium on Nutrient Composition and Uptake

Deshpande (1974) reported that in groundnut the per centage of N, P and K in various plant parts at harvest were not influenced by potassium application. Nair (1978) reported in groundnut that a significant difference in nitrogen content of haulm, shell and kernel due to difference in levels of potash application. N content of shell and kernel was significantly decreased by higher levels of potassium. He also observed a significant increase in potassium content of shell and kernel due to the increasing levels of potassium. Geetha (1999) reported that the uptake of Kwas significantly influenced by N and K@ 20 kg ha^{-1} at 30 DAS and N and K @ 0 and 20 kg ha^{-1} at 90 DAS.

2.2.5 Effect of Potassium on Economics of Cultivation

In an experiment with field pea Singh *et al.,* (1992) observed a net profit of Rs.13,281/- per hectare when N, P, K and Zn were applied at the rate of 18, 46,40 and 25 kg ha^{-1}. Singh *et al.,* (1994) noted in soybean that the mean net return increased by Rs.111 ha^{-1} only at 20 kg K_2O ha^{-1}, however, some reduction was observed when 30 or 40 kg K_2O ha^{-1} was applied. Patra *et al.,* (1996) reported that the application of K had no significant effect on net return in groundnut. Geetha (1999) reported that when different levels of potassium were compared a level of 20 kg K_2O ha^{-1} resulted in maximum net returns of Rs.47,452 ha^{-1} and BCR of 1.31.

2.3 EFFECT OF SPACING

Among the cultural practices proper spacing in a given area is an essential requirement to attain uniform plant stand which ultimately reflected on the seed yield and quality of a crop. The spacing of individual plants should be optimum. If the spacing is closer there will be competition for the resources. Much wider spacing will result in lesser number of plants and reduces the net yield from the plot. Vegetable cowpea being a climber needs suitable spacing for spreading the canopy.

2.3.1 Effect of Spacing on Growth Characters

2.3.1.1 Length of Vine

In black gram Saharia (1988) noted an increase in plant height at a spacing of 30 cm compared to 40 cm row spacing. Takuria and Saharia (1990) noted that the effect of plant density in plant height in summer green gram was non significant. A significant improvement in the plant height of red gram was noted by Padhi (1995) at a closer spacing of 30 cm compared to 45 cm. Mini (1997) reported that a spacing of 1x 0.6 m gave higher value for length of vine when vegetable cowpea was cultivated. Mozumder *et al.,* (2004) noted that in French bean a spacing of 30 x 15 cm gave maximum plant height. Balraj *et al.,* (2005) reported that a spacing of 60 x 30 cm for onion significantly influenced plant growth.

2.3.1.2 Number of Branches per Plant

The number of primary branches per plant in summer black gram was minimum at a row spacing of 30 cm compared to 15 and 22.5 cm (Singh and Yadav 1994). Improvement in the number of branches per plant was noted in red gram by Padhi (1995) at a closer spacing of 30 cm compared to 45 cm. Mozumder *et al.,* (2004) reported that the number of branches per plant was maximum for a spacing of 30x 15 cm.

2.3.1.3 Dry Matter Production

Kumar and Sharma (1989) noted that dry weight of roots and shoots of black gram was higher at a row spacing of 30 cm compared to closer spacing. Salam and Wahid (1993) reported in Pigeon pea when spacing was increased from 30 cm to 60 cm the DMC was maximum at 245 g per plant. Mini (1997) reported that a spacing of 1 x 0.6 m for vegetable cowpea gave maximum dry matter content upto 90 DAS.

2.3.1.4 Shoot Root Ratio

Kumar and Sharma (1989) noted that in black gram maximum value for shoot root ratio was obtained at a row spacing of 15 cm followed by 20 cm in an experiment with row spacings 15, 20 25 and 30 cm as treatments. Salam and Wahid

(1993) noted that in pigeon pea the shoot root ratio was maximum for a spacing of 60 cm when compared to 30 cm.

2.3.1.5 Leaf Area Index

Plant density can influence leaf area development thereby modifying LAI (Cutini, 1996), Kumar *et al.,* (1999) and Pospisil *et al.,* (2000).

2.3.1.6 Days to Fifty Per cent Flowering

Kanwar *et al.,* (2000) reported that a higher spacing of 60 X 30 cm reduces the days to flowering in onion when compared to a lower spacing of 45 X 30 cm. Mozumder *et al.,* (2004) reported that a lower spacing of 20 X 10 gave a lower number of days to flowering in french bean.

2.3.2 Effect of Spacing on Yield and Yield Attributing Characters

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).

Significant influence of plant density on yield has been reported in other crops also like red gram (Nivedita and Reddy, 1990) and Tripathi and Chauhan (1990), french bean, Haldavanekar *et al.,(* 1992) and Dwivedi *et al.,* (1994). Lentil (Watt and Singh, 1992) pea (Yadav *et al.,* 1990).

2.3.2.1 Number of Pods per Plant

Saharia (1988) reported that in black gram a wider row spacing of 40 cm produced more number of pods per plant compared to a narrower row spacing of 30 cm. In green gram and black gram the pod number per plant exhibited trend with decrease in the inter-row spacing from 30 to 15 cm (Prasad and Yadav , 1990) In summer, black gram maximum number of pods per plant was attained with 30 cm row spacing compared to 22.5 and 15 cm (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 45 cm but the effect on other yield attributes was not remarkable. Mini (1997) reported that a spacing of 1 X 0.6 m for vegetable cowpea gave the maximum number of pods and yield.

2.3.2.2 Weight of Dried Pods per Plant

Mozumder *et al.,* (2004) reported that when bush bean was raised at higher spacing of 30 X 15 cm single pod weight and maximum weight of pods per plant was obtained.

2.3.2.3 Pods Harvested per Plot

Yield per plot was highest at 30 X 10 cm spacing for pigeon pea (Mahajan *et al.,* 1998). Sairaj (2001) reported that the fruits per plot were significantly affected by the population density of gherkins. Mozumder *et al.,* (2004) has found out that in bush bean a spacing of 30 X 10 cm gave the maximum number of pods per plot but the maximum number of pods per plant was for a spacing of 25 X 15 cm. Closer spacing of 1.5 x 0.5 m significantly influenced fruit yield and seed yield since number of cucumber plants were more (Ravikumar *et al.,* 2005).

2.3.3 Seed Characters

2. 3.3.1 Number of Seeds per Pod.

Saharia (1988) reported that in black gram the effect of wider or closer spacings upon number of seeds per pod was non-significant. Prasad and Yadav (1990) observed in green gram and black gram grain number per pod was not affected by inter-row spacing. Sharma and Singh (2002) reported that the number of seeds per pod was maximum with highest plant density in pea. A study conducted by Singh and Mishra (2004) in carrot revealed that a spacing of 45 x 45 cm gave higher number of seeds per umbel.

2.3.3.2 Weight of Seeds per Pod

Pandey and Singh (1986) reported that weight of seed per fruit was highest (2.54 g) for a spacing of 45 X 30 cm compared to a lower spacing for okra. Similar findings with regard to effect of spacing on yield of seed were also reported by Donald (1954) Randhawa and Pannu (1969) and Pandey *et al.,* (1976).

2.3.3.3 Hundred Seed Weight

Saharia (1988) reported that in black gram a wider row spacing had no significant effect on hundred seed weight. Prasad and Yadav (1990) observed that in green gram and black gram the yield contributing character namely 1000 gram weight exhibited increasing trend with decrease in the inter-row spacing. In summer black gram maximum 1000 seed weight was attained with 30 cm row spacing compared to 22.5 and 15 cm, (Singh and Yadav, 1994). Sharma and Singh (2002) reported that in pea 100 seed weight to the different levels of plant density was non significant. Balraj *et al.,* (2005) reported that in onion a spacing of 60 x 30 cm influenced thousand seed weight.

2.3.3.4 Seed Yield per Hectare

In cowpea Subramanian *et al.,* (1977) observed that the effect of differential spacing on seed yield was significant. A closer spacing of 60 x 15 cm (1,11,000 plants ha^{-1}) recorded the highest seed yield and was superior compared to other spacings, 60 X 20 cm (86,000 plants ha^{-1}) and 60 X 25 cm (67000 plants ha^{-1}). Pandey and Singh (1986) reported that seed yield per hectare was maximum for the lowest spacing 45X15 cm and that is 11.85 q ha^{-1} in okra. Jain and Chauhan (1988) noted a significantly high seed yield at a spacing of 30 cm compared to higher and lower spacings in mung bean. Kumar and Sharma (1989) noted in black gram a significantly high grain yield at 30 cm row spacing compared to closer spacing. Thakuria and Saharia (1990) opined that grain yield was significantly higher at a plant density of 330 X 10^3 compared to a lower density of 200 x 10^3. In summer green gram Dwangan *et al.,* (1992) learned that a closer spacing (20 cm) significantly increased the seed yield compared with wider row (30 cm) spacing. With an increase in plant population in oil seed rape up to 170 plants m^{-2} yield increased (Sidlauskar and Bernotas, 2003). Mozumder *et al.,* (2004) observed in french bean that a spacing of 20 X 15 cm gave the highest seed yield per hectare. Balraj *et al.,* (2005) reported that a spacing of 60 x 30 cm for onion influenced seed yield per hectare.

2.3.3.5 Germination Percentage

Baswane and Pandita (1989) reported that when fenugreek was sown at a spacing of 10 X 40 cm the germination percentage of seeds obtained were maximum, i.e.98.66%. Vijayakumar *et al.,* (1995) reported that when brinjal was planted at a spacing of 75 X 60 cm, its seeds gave maximum germination per centage. Kanwar *et al.,* 2000 reported that the germination percentage of 69.3 was obtained when plants were spaced at 60x 30 cm for onion. In okra, (Yadav *et al.,*

2001) maximum germination percentage of 81.85% was obtained from seeds of plants spaced at 45 X 30 cm compared to a higher spacing of 67.5 X 20 cm. Jain *et al.,* (2002) stated that germination percentage is a more sensitive and better physiological index of seed quantity.

2.3.3.6 Vigour Index of Seedling

Baswana and Pandita (1989) noted that when fenugreek was sown at a spacing of 20 X 10 cm maximum vigour index was given by its seeds even though the value was not significantly superior to that of a spacing of 10 X 40 cm. Vijayakumar *et al.,* (1995) reported that when brinjal was planted at a spacing of 75 X 60 cm, significantly higher vigour index of 698 was given by the seed obtained. Yadav *et al.,* (2001) reported that maximum vigour index of 1970 were obtained from seeds of plants spaced at 45 X 30 cm.

2.3.3.7 Root Length of Seedling

Vijayakumar *et al.,* (1995) reported that when brinjal was planted at a spacing of 75 X 60 cm maximum root length of seedlings was resulted. Jain *et al.,* (2002) stated that seedling root length can also be considered as a sensitive physiological index of seed quality. Ashok *et al.,* (2004) noted in okra seedlings the root length was maximum for seeds from plants spaced at 60 X 30 cm. The lower and higher spacing gave lower values for seedling root length.

2.3.3.8 Seedling Dry Weight

Ashok *et al.,* (2004) reported that the seedling dry weight was maximum (64.22 mg) for seeds obtained from plants grown at a spacing of 60 X 30 cm. Ravikumar *et al.,* (2005) reported that in cucumber the seedling dry weight was not significantly influenced by spacing.

2.3.4 Effect of Spacing on Nutrient Composition and Uptake

Chavan and Kalra (1983) in groundnut variety TG-1 reported that wider rows of 45 cm, recorded higher content of N, P and K while uptake of these nutrients was higher at a closer spacing of 30 cm as the DMP was higher in this spacing. Jain and Chauhan (1988) observed higher protein content in green gram cultivars spaced at 22.5 cm over 15 cm but was on par with 30 cm which was attributed to more uptake of nitrogen at a wider spacing. . The protein content was maximum at the medium (111.1X10^3 plants ha^{-1}) than at the lowest (83.3 X 10^3 plants ha^{-1}) and the highest (1216.7 X 10^3 plants ha^{-1}) plant densities in pigeon pea 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. 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 availability and uptake of nutrients at the lowest level of population of 1,67,000 pts/ha compared to 2,00,000, 2,50,000 and 3,33,000 pts ha^{-1}. Mini (1997) reported that the uptake of N, P and K by vegetable cowpea was highest when the plant density was 16,667 pts ha^{-1}. In the same experiment the soil nutrient status after the experiment was maximum for a higher plant density, ie. 22,222 pts ha^{-1}.

2.3.5 Effect of Spacing on the Economics of Cultivation

Singh *et al.,* (1978) reported that in pigeon pea, the net return was higher at 50 cm (Rs.3965.65 ha^{-1}) at 75 cm row spacing. In french bean, net return was significantly higher with 400000 pts ha^{-1} (30 cm row spacing) compared to 286000 pts ha^{-1} (45 cm row spacing) and 200000 pts ha^{-1} (60 cm row spacing) as reported by Dwivedi *et al.,* (1994) In Indian butter bean, Patel *et al.,* (1994) noted maximum net return of Rs.3092 ha^{-1} under 45cm spacing. Both the net return and return per rupee invested decreased markedly due to reduction in plant density from 333000 to 167000 ha^{-1} in summer sesamum (Ghosh and Patra, 1994). Mini (1997) reported that in vegetable cowpea plant density level of 16667 pts ha^{-1} was most economic with highest BCR and net return and it was significantly superior to other treatment levels.

From the literature reviewed it is clear that not much work has been done regarding optimisation of nutrients and spacing. It has to be studied by conducting experiments repeatedly in different seasons to find out the most suitable rate of nutrients and conditions for raising a crop for seed purpose. This study has much need since seed is a very important input in raising a crop.

MATERIALS AND METHODS

3. MATERIALS & METHODS

The investigation was carried out with the objective of optimising nutrients namely nitrogen and potassium, spacing and for ascertaining the seed production potential of vegetable cowpea. 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 of the College of Agriculture, Vellayani located at 8.5^{o} north latitude and 76.9 ^{o} east longitude at an altitude of 29 m above mean sea level. The previous crop was snake gourd treated with recommended fertilizers.

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 1.

Table 1. Physico-chemical Properties of Soil

1. Mechanical composition

Sl. No.	Constituent	Content in Soil %	Method Used
1	Coarse Sand	46.0	Bouyoucos Hydrometer Method (Bouyoucos, 1962)
2	Fine Sand	20.0	
3	Silt	19.0	
4	Clay	15.0	

2. Chemical properties

Sl. No.	Parameters	Value (kg ha $^{-1}$)	Rating	Method
1	Available Nitrogen (kg / ha $^{-1}$)	153.66	Low	Alkaline potassium permanganate method (Subbiah and Asija, 1956)
2	Available P_2O_5 (kg ha $^{-1}$)	30.24	Medium	Bray colorimetric method (Jackson, 1973)
3	Available K_2O (kg / ha $^{-1}$)	44.80	Low	Ammonium acetate method (Jackson, 1973)
4	pH	5.10	Acidic	PH meter with glass electrode (Jackson, 1973)

3.1.3 Season

Field experiment was conducted during summer season (period extending from second week of January to third week of April 2001)

3.1.4 Weather Data (11.01.2001 to 19.04.2001)

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 of the Department of Agronomy, College of Agriculture, Vellayani and are presented in Fig. 1 and appendix 1.

3.1.5 Crop and Variety

Vegetable cowpea variety 'Sharika' was selected for the study.

3.1.6 Source of seed material

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

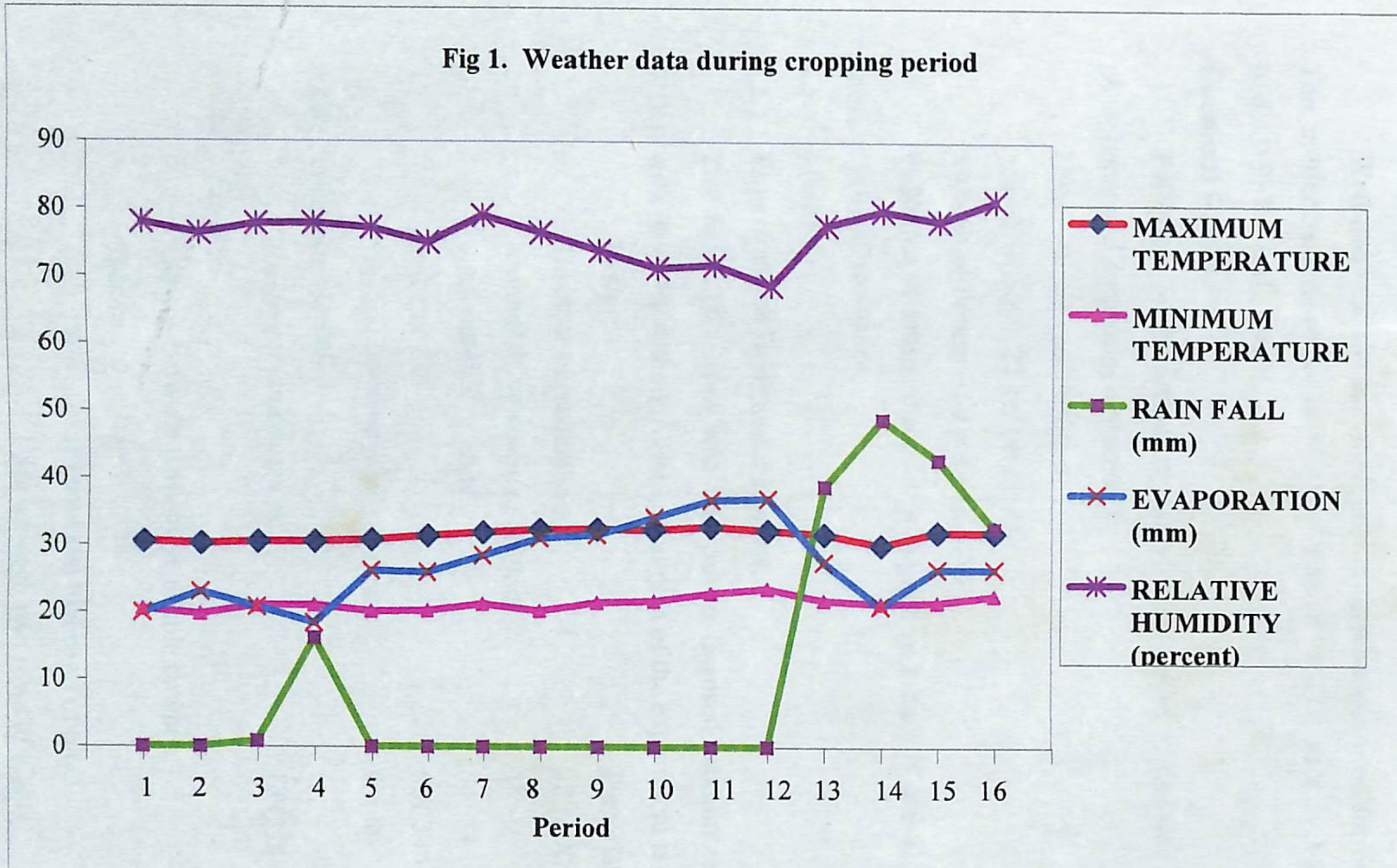


Fig 1. Weather data during cropping period
90
80
70
60
50
40
30
20
10
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
Period
MAXIMUM TEMPERATURE
MINIMUM TEMPERATURE
RAIN FALL (mm)
EVAPORATION (mm)
RELATIVE HUMIDITY (percent)

3.1.7 Manure and fertilizers

Organic manure

Well-decomposed and dried poultry manure was used for basal application. The nutrient composition is N (1 – 1.5) %, P_2O_5 (1.4 – 1.8) % and K_2O (0.8 – 0.9) % (KAU, 2002).

Chemical fertilizers

Fertilizers of the following analysis were used as the sources of nitrogen, phosphorus and potassium respectively.

Urea – 46 per cent nitrogen

Mussoriephos – 22 per cent P_2O_5

Muriate of Potash – 60 per cent K_2O

Full dose of mussoriephos was applied as basal. N and K were applied in splits as per the treatments.

3.2 Methods

3.2.1 Experimental Design and Layout

The field experiment was laid out in factorial randomized block design (RBD) with three replications. The layout plan of the experiment is given in Fig. 2.

Design	:	Factorial RBD
Treatment combinations	:	18 (3 X 3 X 2)
Number of treatments per block	:	18
Total number of plots	:	54
Plot size	:	6 X 3 m
Spacing between plants in a row	:	0.6 m

3.2.2 Treatment Details:

Treatment combinations : 18 (3 X 3 X 2)

3.2.2.1 Factors

1 Spacing between rows of vegetable cowpea.

Spacing : Two levels

S_1 : 1m between two rows of plants

S_2 : 1.5m between two rows of plants

2 Nitrogen : Three levels

N_1 : 30kg N ha^{-1}

Fig. 2: Layout Plan of the Experimental Field

N

Replication III	T_7	T_3	T_{12}	T_8	T_{18}	T_2	T_{11}	T_5	T_1	T_{13}	T_{10}	T_{15}	T_{17}	T_9	T_4	T_{16}	T_{14}	T_6
Replication II	T_5	T_1	T_{10}	T_{13}	T_{18}	T_6	T_{16}	T_3	T_{14}	T_8	T_{11}	T_{17}	T_7	T_4	T_{12}	T_{15}	T_9	T_2
Replication I	T_4	T_9	T_3	T_6	T_{16}	T_{10}	T_{13}	T_7	T_{12}	T_2	T_{17}	T_{14}	T_{18}	T_{15}	T_8	T_{11}	T_1	T_5

T_1 ($N_1K_1S_1$)
T_2 ($N_1K_1S_2$)
T_3 ($N_1K_2S_1$)
T_4 ($N_1K_2S_2$)
T_5 ($N_1K_3S_1$)
T_6 ($N_1K_3S_2$)

T_7 ($N_2K_1S_1$)
T_8 ($N_2K_1S_2$)
T_9 ($N_2K_2S_1$)
T_{10} ($N_2K_2S_2$)
T_{11} ($N_2K_3S_1$)
T_{12} ($N_2K_3S_2$)

T_{13} ($N_3K_1S_1$)
T_{14} ($N_3K_1S_2$)
T_{15} ($N_3K_2S_1$)
T_{16} ($N_3K_2S_2$)
T_{17} ($N_3K_3S_1$)
T_{18} ($N_3K_3S_2$)

Design : Factorial RBD
Plot size : 6 X 3 m
Treatment combinations : 18 (3 X 3 X 2)

N_2 : 45kg N ha^{-1}

N_3 : 60kg N ha^{-1}

3 Potassium : Three levels

K_1 : 10kg K_2O ha^{-1}

K_2 : 15kg K_2O ha^{-1}

K_3 : 20kg K_2O ha^{-1}

Treatment combinations

$T_1 – N_1 K_1 S_1$	$T_5 – N_1 K_3 S_1$	$T_9 – N_2 K_2 S_1$	$T_{13} – N_3 K_1 S_1$	$T_{17} – N_3 K_3 S_1$
$T_2 – N_1 K_1 S_2$	$T_6 – N_1 K_3 S_2$	$T_{10} – N_2 K_2 S_2$	$T_{14} – N_3 K_1 S_2$	$T_{18} – N_3 K_3 S_2$
$T_3 – N_1 K_2 S_1$	$T_7 – N_2 K_1 S_1$	$T_{11} – N_2 K_3 S_1$	$T_{15} – N_3 K_2 S_1$	
$T_4 – N_1 K_2 S_2$	$T_8 – N_2 K_1 S_2$	$T_{12} – N_2 K_3 S_2$	$T_{16} – N_3 K_2 S_2$	

3.3 FIELD CULTURE

3.3.1 Land Preparation

The experimental field was dug twice, stubbles removed, clods broken and laid out into blocks and plots.

3.3.2 Manure and Fertilizer Application

Poultry manure was applied at the rate of one kilogram per pit and mixed well with topsoil. A common dose of phosphorus was applied as basal at the rate of 30 kg P_2O_5 ha^{-1}. Nitrogen and potassium were applied as per treatments. Half the dose of nitrogen and half the dose of potassium were applied as basal. One fourth of nitrogen and remaining half dose of potassium were applied 20 days after sowing. Remaining one fourth of nitrogen was applied one month after first application.

3.3.3 Sowing

Plots were taken and seeds were dibbled at the rate of three per hole at a depth of 5 cm at a spacing of 60 cm between plants. The two levels of spacing followed were 1X0.6 m and 1.5X0.6 m.

3.3.4 After Cultivation

Gap filling was done four days after sowing. The crop was thinned by removing the excess seedling one week after emergence retaining 2 seedling and the plants were trailed on pandhals. The crop was given regular weeding throughout the cropping period. Earthing up was also done along with topdressing. Five plants were selected randomly from each plot and tagged as observational plants. Daily irrigation was also given.

3.3.5 Plant Protection

Furadan 3G was applied against grass hopper attack. To prevent pod borer attack, which was found serious in the field, Ekalux 0.2 per cent was sprayed 40 days after sowing.

3.3.6 Harvesting

The first harvesting was done 48 DAS as vegetable. The second harvest was made at 65 DAS. Pods collected as vegetable were not weighed treatment-wise, but in bulk. The subsequent harvests were done for seed purpose. Total 3 harvests were made for seed purpose. The last harvest was done for vegetable purpose. The pods collected for seed purpose from each plot were sun dried and seeds were extracted manually. The seed yield from individual plot were recorded.

3.4 BIOMETRIC OBSERVATIONS

3.4.1 Length of Vine

Length was measured from the base of the plant to the terminal leaf bud and expressed in centimetre. The mean value of the length of five randomly selected observational plants from each net plot was computed at vegetative and harvest stages.

3.4.2 Branches per Plant

The mean value of number of branches per plant was computed from five observational plants at 30 DAS and 60 DAS stages.

3.4.3 Leaf Area Index (LAI)

Leaf area index was taken at 30 DAS and 60 DAS. Leaf area was measured using LI – 300 leaf area meter and expressed in square centimetre. LAI was worked out using the following equation:

$$LAI = \frac{\text{Total leaf area}}{\text{Land area}} \quad \text{(Watson, 1952)}$$

3.4.4 Leaf Area Duration (LAD)

Leaf area duration was computed using two successive LAI values obtained at an interval of 30 days. LAD was worked out using the following equation:

$$LAD = \left(\frac{LAI_2 + LAI_1}{2} \right) T_2 - T_1 \text{ (Watson, 1947)}$$

Where $T_2 - T_1$ shows the time interval in days for calculating the successive LAI

3.4.5 Shoot – Root Ratio

The five observational plants in each plot were uprooted after final harvest and dried under shade and then oven dried at 65°C. The mean values of shoot-root ratio were recorded. The same plants were used to record the DMP.

3.4.6 Dry Matter Production

DMP was recorded at final harvest stage. The plants were uprooted without damaging the roots and separated into leaves, stem and roots. These were dried under shade and then oven dried at 65°C for 10 hours till two consecutive weights coincided. The final weights were added and expressed in gram per plant.

3.4.7 Days to Fifty Per cent Flowering

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

3.5 YIELD AND YIELD ATTRIBUTES

3.5.1 Pods per Plant

Pods collected from five observational plants in each plot during all harvests were counted and average number of pods per plant were found out.

3.5.2 Weight of Dried Pods per Plant

Three harvests were made for dry pod collection. The weight of pods in each plot was measured and average weight of pods per plant were calculated.

3.5.3 Pods per Plot

Both green and dried pods harvested for vegetable and seed purpose were counted and the total number of pods were recorded for each plot.

3.6 SEED CHARACTER

3.6.1 Seeds per Pod

Seeds present in pods collected from five observational plants were separately counted and mean value was calculated.

3.6.2 Weight of Seeds per Pod

Weight of seeds obtained from pods collected from five observational plants were separately measured and mean value was calculated.

3.6.3 Pod to Seed Ratio

Total weight of pods collected from observational plants and total weight of seeds collected from these pods were measured and their ratio were calculated.

3.6.4 Hundred Seed Weight

Hundred seed each were collected at random from the observational plants and mean value of hundred seed weight was calculated.

3.6.5 Seed Yield per Hectare

Total weight of seeds obtained in three harvests from each plot were measured and mean value of seed yield per hectare was calculated.

3.6.6 Seed Viability

The salt used in this test is 2, 3, 5 – Triphenyl tetrazolium dichloride. Twenty-five seeds each were taken at random from all the treatments and bisected longitudinally after soaking in water for four hours. The bisected seeds were immersed in 0.1 % of Tetrazolium solution at pH value 8 for 8 hours. The seeds were then evaluated for seed viability (Lakon, 1942). Completely stained seeds are viable and were expressed in per centage.

3.6.7 Germination Per centage

Twenty-five seeds picked at random which were collected from the five observational plants, were sown in soil in plastic cups. Mean value of germination per centage was estimated.

3.6.8 Vigour Index of Seedling

Germination per centage and seedling length were multiplied to find the vigour index of seedling (Abdul – Baki and Anderson, 1973).

3.6.9 Root Length

Seedlings obtained from the seeds of the observational plants were randomly uprooted and mean value of root length was recorded and expressed in centimetre.

3.6.10 Seedling Dry Weight

Seedlings were randomly uprooted carefully 20 days after germination. The roots were washed and the soil particles were removed. They were placed in paper covers and oven dried at 65°C for 9 hours till two consecutive weights coincided. The weight was expressed in gram.

3.7 CHEMICAL ANALYSIS

3.7.1 Soil Analysis

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

3.7.2 Plant Analysis

Plant samples were analysed for nitrogen, phosphorus and potassium content at harvest. The samples were chopped and dried in an oven at 80°C till constant weights were obtained. Samples were ground sieved through 60-mesh sieve. The required quantities of samples were weighed out accurately in an electronic balance and used for chemical analysis. The nitrogen content in plants were estimated by modified microkjeldahl method (Jackson, 1973). The phosphorus content in plants were estimated colorimetrically (Jackson, 1973) and potassium by flame photometer method (Jackson, 1973)

3.8 ECONOMIC ANALYSIS

The economics of seed production was worked out and the net income and benefit cost ratio (BCR) were calculated as follows:

$$BCR = \frac{\text{Gross Income}}{\text{Total cost of seed production}}$$

3.9 STATISTICAL ANALYSIS

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

RESULTS

4. RESULTS

A field experiment on vegetable cowpea, variety 'Sharika' was conducted at the Instructional Farm of the College of Agriculture, Vellayani, during second week of January to last week of April 2001. The present investigation was done to evaluate the role of different agrotechniques like application of major nutrients viz. nitrogen and potassium along with optimum spacing of plants for ascertaining the seed production potential of vegetable cowpea. Effect of different levels of nitrogen, potassium and spacing were evaluated in the experiment. The experimental data collected were statistically analysed and results obtained are presented below.

4.1 GROWTH CHARACTERS

Plant growth was measured in terms of length of vine, number of branches per plant, dry matter content, shoot root ratio, leaf area index, leaf area duration and date of 50 per cent flowering.

4.1.1 Length of Vine

The average values of length of vine taken at two stages of growth i.e. at 30 days after sowing and 60 days after sowing were measured. The result presented in Table 2 revealed that the different levels of nitrogen, potassium and spacing did not make any statistically significant effect on the length of vine. The interaction effects of nitrogen and potassium presented in Table 25 reveals that the length of vine is also not influenced significantly by this interaction. Similarly the interaction effect of nitrogen and spacing (Table 26) and potassium and spacing (Table 27) also revealed that there was no significant variation in the length of vine as a result of these interactions.

In Table 28 the interaction effect of different levels of all the three treatments are given. The result revealed that the interaction effects of the N, K and spacing were not statistically significant.

4.1.2 Number of Branches per Plant

The mean number of branches per plant was recorded at 30 DAS and 60 DAS. In Table 3 the results of the main effect of different levels of N, K and

Table 2 Effect of different levels of nitrogen, potassium and spacing on length of vine

Treatments	Length of vine (cm)	
	30 DAS	60 DAS
N_1	257.57	396.66
N_2	264.44	399.73
N_3	257.93	396.98
SE	–	–
CD (0.05)	NS	NS
K_1	263.63	398.07
K_2	259.84	396.02
K_3	256.47	399.28
SE	–	–
CD (0.05)	NS	NS
S_1	260.14	396.80
S_2	259.82	398.78
SE	–	–
CD (0.05)	NS	NS

Table 3 Effect of different levels of nitrogen, potassium and spacing on number of branches per plant

Treatments	Number of branches per plant	
	30 DAS	60 DAS
N_1	1.89	4.80
N_2	1.79	4.70
N_3	1.82	4.89
SE	–	–
CD (0.05)	NS	NS
K_1	1.66	4.79
K_2	1.93	4.81
K_3	1.91	4.79
SE	–	–
CD (0.05)	NS	NS
S_1	1.89	4.78
S_2	1.78	4.81
SE	–	–
CD (0.05)	NS	NS

spacing on number of branches per plant are given. It revealed that the treatments had no significant effect on this growth character. The results of interaction effect of nitrogen and potassium (Table 25) nitrogen and spacing (Table 26) and potassium and spacing (Table 27) revealed that the interaction effect was not significant.

In Table 28 the mean values of the interaction effects of different levels of N, K and spacing upon number of branches per plant is given. The effect was non-significant.

4.1.3 Dry Matter Production

Data regarding the dry matter production with respect to the main effect of nitrogen, potassium and spacing are given in Table 4. Results revealed that application of nitrogen and potassium did not exert any significant influence on the dry matter content.

Among the treatments, spacing significantly influenced the dry matter yield per hectare. The mean value of dry matter content with S_1 (1 m row spacing) as spacing was 1693.73 kg ha-1 which was significantly higher than the effect of S_2 (1128.93 kgha^{-1}).

The interaction effects of N and K given in table 25 revealed that N and K interaction made significant influence upon the dry matter content. Among the treatment combinations N_1K_2 and N_3K_1 made significantly higher result than the other combinations of N and K. N_1K_2 (1657.90 kg ha^{-1}) and N_3K_1 (1668.03 kg ha^{-1}) were on par.

The interaction effects of nitrogen and spacing (Table 26) and potassium and spacing (Table 27) and combination of nitrogen, potassium and spacing (Table 28) were not significantly different with respect to this character.

4.1.4 Shoot – Root Ratio

The data regarding shoot : root ratio with respect to the main effect of nitrogen, potassium and spacing are given in Table 5. The result revealed that the treatments did not significantly influence this character.

The interaction effects of nitrogen and potassium (Table 25) and nitrogen and spacing (Table 26) potassium and spacing (Table 27) were not significantly

Table 4 Effect of different levels of nitrogen, potassium and spacing on dry matter production

Treatments	Dry matter production
	(kg ha^{-1})
N_1	1481.04
N_2	1371.82
N_3	1381.12
SE	–
CD (0.05)	NS
K_1	1433.02
K_2	1392.26
K_3	1408.70
SE	–
CD (0.05)	NS
S_1	1693.73
S_2	1128.93
SE	–
CD (0.05)	180.40 * *

Table 5 Effect of different levels of nitrogen, potassium and spacing on shoot root ratio

Treatments	Shoot root ratio
N_1	5.39
N_2	5.33
N_3	5.32
SE	–
CD (0.05)	NS
K_1	5.41
K_2	5.34
K_3	5.28
SE	–
CD (0.05)	NS
S_1	5.33
S_2	5.37
SE	–
CD (0.05)	NS

different with respect to this character. The interaction effect of nitrogen, potassium and spacing is given in Table 28. The effect was not significant.

4.1.5 Leaf Area Index

The data regarding the main effect of nitrogen, potassium and spacing on leaf area index is given in Table 6. At 30 and 60 DAS all the three levels of nitrogen had no significant effect with respect to this character.

Potassium had no statistically significant effect on LAI. Among the different levels of spacing S_1 had significantly higher effect than S_2 at 30 DAS and 60 DAS. LAI with S_1 and S_2 at 30 DAS was 0.48 and 0.32 respectively. LAI with S_1 and S_2 at 60 DAS was 1.25 and 0.88 respectively.

The interaction effect of nitrogen and potassium is given in Table 25. The result shows that the effect was non-significant. So also the interaction effect of nitrogen and spacing (Table 26) and interaction effect of nitrogen, potassium and spacing (Table 28) were also not statistically significant.

Among the interaction effects, in potassium and spacing (Table 27) gave statistically significant influence. K_3S_1 (0.54) had the significantly higher effect on LAI at 30 DAS. But at 60 DAS this interaction effect was not significant.

4.1.6 Leaf Area Duration

The data regarding the leaf area duration with respect to the different levels of treatments of nitrogen, potassium and spacing are given in Table 7 and the mean values of the interaction effect of nitrogen and potassium, nitrogen and spacing, potassium and spacing, nitrogen, potassium and spacing are given in Table 25, 26, 27 and 28 respectively.

The result revealed that from among the treatments, only the spacing gave statistically significant effect on LAD. S_1 was significantly superior than S_2 with respect to this character. The value of LAD for S_1 was 25.98 and for S_2 was 17.99

4.1.7 Days to Fifty Per cent Flowering

The mean value of date of 50 per cent flowering is given in Table 8. The result revealed that the main effect of treatment did not make any statistically significant influence on date of 50 per cent flowering. The data regarding the interaction effect of nitrogen and potassium (Table 25), nitrogen and spacing

Table 6 Effect of different levels of nitrogen, potassium and spacing on Leaf Area Index

Treatments	Leaf Area Index	
	30 DAS	60 DAS
N_1	0.36	1.03
N_2	0.36	1.07
N_3	0.38	1.10
SE	–	–
CD (0.05)	0.06 * *	NS
K_1	0.38	1.07
K_2	0.41	1.08
K_3	0.40	1.04
SE	–	–
CD (0.05)	NS	NS
S_1	0.48	1.25
S_2	0.32	0.88
SE	0.02	0.04
CD (0.05)	0.05 * *	0.11 * *

Table 7 Effect of different levels of nitrogen, potassium and spacing on Leaf Area Duration

Treatments	Leaf Area Duration (days)
N_1	22.39
N_2	21.44
N_3	22.13
SE	–
CD (0.05)	NS
K_1	21.78
K_2	22.44
K_3	21.74
SE	–
CD (0.05)	NS
S_1	25.98
S_2	17.99
SE	0.55
CD (0.05)	1.57 **

Table 8 Effect of different levels of nitrogen, potassium and spacing on days to 50 percent flowering

Treatments	Days to 50 perc ent flowering
N_1	44.61
N_2	44.72
N_3	44.67
SE	–
CD (0.05)	NS
K_1	44.61
K_2	44.67
K_3	44.72
SE	–
CD (0.05)	NS
S_1	44.52
S_2	44.81
SE	–
CD (0.05)	NS

(Table 26) potassium and spacing (Table 27) and nitrogen, potassium and spacing (Table 28) reveals that their influence were also not statistically significant.

4.2 YIELD OBSERVATIONS

The different aspects of yield were observed and recorded in terms of number of pods per plant, weight of dried pods per plant and total number of pods harvested per plot.

4.2.1 Number of Pods per Plant

The average values of number of pods per plant with respect to the main effects of nitrogen, potassium and spacing are given in Table 9.

Among the treatments spacing significantly influenced this character. S_2 gave higher effect of 22.66 than S_1 (18.23) on the number of pods per plant.

None of the interaction effects viz. nitrogen and potassium (Table 25), nitrogen and spacing (Table 26) potassium and spacing (Table 27) and nitrogen, potassium and spacing (Table 28) made any statistically significant effect upon this character.

4.2.2 Weight of Dried Pods per Plant

The data regarding this character with respect to the different levels of nitrogen, potassium and spacing are presented in Table 10. None of these treatments made any significant influence upon weight of dried pods per plant.

The interaction effects given in Table 25, 26, 27 and 28 revealed that there was no statistically significant effect upon this character.

4.2.3 Total Number of Pods Harvested per Plot

The mean values of the total number of pods harvested per plot with respect to the main effect of nitrogen, potassium and spacing are presented in Table 11. The result revealed that there was no statistically significant effect on this character.

Among the interaction effect of treatments nitrogen, potassium and spacing interaction effect given in Table 28 revealed that the effect was statistically significant. Among the combinations $N_1 K_2 S_1$ gave significantly higher value (790.33). $N_1 K_2 S_1$ was on par with $N_2 K_1 S_1$ (704.67) and $N_2 K_3 S_1$ (635.33). The effect of all the other combinations of N, K & S were on par.

Table 9 Effect of different levels of nitrogen, potassium and spacing on pods per plant

Treatments	Pods per plant
N_1	21.73
N_2	20.57
N_3	19.04
SE	–
CD (0.05)	NS
K_1	21.40
K_2	21.13
K_3	18.79
SE	–
CD (0.05)	NS
S_1	18.23
S_2	22.66
SE	1.45
CD (0.05)	4.17 *

Table 10 Effect of different levels of nitrogen, potassium and spacing on weight of dried pods per plant

Treatments	Weight of dried pods per plant (g)
N_1	53.08
N_2	48.24
N_3	47.29
SE	–
CD (0.05)	NS
K_1	52.89
K_2	54.25
K_3	41.97
SE	–
CD (0.05)	NS
S_1	45.84
S_2	53.56
SE	–
CD (0.05)	NS

Table 11 Effect of different levels of nitrogen, potassium and spacing on number of pods harvested per plot

Treatments	Number of pods harvested per plot
N_1	526.39
N_2	513.28
N_3	465.72
SE	–
CD (0.05)	NS
K_1	520.00
K_2	526.17
K_3	459.22
SE	–
CD (0.05)	NS
S_1	550.37
S_2	453.22
SE	–
CD (0.05)	NS

The interaction effect of nitrogen and potassium (Table 25), nitrogen and spacing (Table 26) and potassium and spacing (Table 27) shows that there was no statistically significant influence upon the total number of pods harvested per plot.

4.3 Seed Characters

4.3.1 Number of Seeds per Pod

The data pertaining to this character with respect to main effect of nitrogen, potassium and spacing is given in Table 12. The result showed that there were no significant effects upon this character.

The interaction effects given in Table 25 (nitrogen and potassium), Table 26 (nitrogen and spacing) Table 27 (potassium and spacing) and Table 28 (nitrogen, potassium and spacing) revealed that they had no statistically significant influence on the number of seeds per pod.

4.3.2 Weight of Seeds per Pod

The data pertaining to the weight of seeds per pod with respect to the different levels of nitrogen, potassium and spacing are presented in Table 13.

Among the treatments potassium had significant effect on weight of seed per pod. K_2 gave significantly higher weight (1.80g). K_1 (1.65g) and K_3 (1.52g) were on par.

The interaction effect of potassium and nitrogen (Table 25), nitrogen and spacing (Table 26), potassium and spacing (Table 27) and interaction effect of nitrogen, potassium and spacing given in Table 28 revealed that they were not able to make any statistically significant influence upon this character.

4.3.3 Pod to Seed Ratio

The mean values of pod to seed ratio with respect to different levels of nitrogen, potassium and spacing are presented in Table 14. The data revealed that the treatments did not make any significant effect on the pod to seed ratio.

Among the interaction effects of the treatments, the combination of nitrogen and potassium (Table 25) had significant influence upon this character. Significantly higher influence was made by N_1K_1 (1.96), while N_1K_3 (2.03), N_3K_2 (1.99) and N_3K_3 (2.01), which were on par. N_1K_3 gave the highest ratio. Rest of the interaction effect of nitrogen and potassium were on par.

Table 12 Effect of different levels of nitrogen, potassium and spacing on number of seeds per pod

Treatments	Seeds per pod
N_1	14.68
N_2	14.64
N_3	14.41
SE	–
CD (0.05)	NS
K_1	14.33
K_2	14.31
K_3	15.09
SE	–
CD (0.05)	NS
S_1	14.75
S_2	14.40
SE	–
CD (0.05)	NS

Table 13 Effect of different levels of nitrogen, potassium and spacing on weight of seeds per pod

Treatments	Weight of seeds per pod (g)
N_1	1.65
N_2	1.71
N_3	1.61
SE	–
CD (0.05)	NS
K_1	1.65
K_2	1.80
K_3	1.52
SE	–
CD (0.05)	0.18
S_1	1.63
S_2	1.67
SE	–
CD (0.05)	NS

Table 14 Effect of different levels of nitrogen, potassium and spacing on pod to seed ratio

Treatments	Pod to seed ratio
N_1	1.92
N_2	1.79
N_3	1.89
SE	–
CD (0.05)	NS
K_1	1.84
K_2	1.80
K_3	1.96
SE	–
CD (0.05)	NS
S_1	1.86
S_2	1.87
SE	–
CD (0.05)	NS

The interaction effect of nitrogen and spacing is given in Table 26. There was no significant effect on pod to seed ratio. N_1S_1 gave the highest value of 1.97. The interaction effect of potassium and spacing are given in Table 27. The interaction effect was not significant. The NKS interaction (Table 28) had no significant effect.

4.3.4 Hundred Seed Weight

The data pertaining to hundred seed weight with respect to nitrogen, potassium and spacing are given in Table 15. The result revealed that the treatments had no statistically significant effect on weight of hundred seeds.

The interaction effect of nitrogen and potassium (Table 25), nitrogen and spacing (Table 26), potassium and spacing (Table 27) and nitrogen, potassium and spacing (Table 28) also revealed that the interaction effect of the different treatment combinations upon hundred seed weight was non significant.

4.3.5 Seed Yield per Hectare

The data regarding the mean values of seed yield per hectare with respect to different levels of nitrogen, potassium and spacing are given in Table 16. The result revealed that there was no statistical significance due to treatments.

The interaction effects given in Tables 25, 26, 27 and 28 were not statistically significant on this character.

4.3.6 Seed Viability

The data regarding the average values for seed viability with respect to the main effects are given in Table 21. The data revealed that the seed viability was not statistically influenced by the different levels of treatments.

The interaction effect due to the different treatment combinations are given in Table 25 (interaction effect of nitrogen and potassium), Table 26 (interaction effect of nitrogen and spacing), Table 27 (interaction effect of potassium and spacing) and Table 28 (interaction effect of nitrogen, potassium and spacing) revealed that none had made statistically significant effect upon seed viability.

4.3.7 Germination Percentage

The data pertaining to germination percentage with respect to different levels of nitrogen, potassium and spacing are given in Table 17. The data reveals

Table 15 Effect of different levels of nitrogen, potassium and spacing on hundred seed weight

Treatments	Hundred seed weight (g)
N_1	19.23
N_2	18.80
N_3	18.60
SE	–
CD (0.05)	NS
K_1	18.94
K_2	18.69
K_3	18.99
SE	–
CD (0.05)	NS
S_1	18.90
S_2	18.85
SE	–
CD (0.05)	NS

Table 16 Effect of different levels of nitrogen, potassium and spacing on seed yield per hectare

Treatments	Seed yield per hectare (kg ha^{-1})
N_1	424.16
N_2	438.43
N_3	401.19
SE	–
CD (0.05)	NS
K_1	442.53
K_2	464.51
K_3	358.92
SE	–
CD (0.05)	NS
S_1	511.83
S_2	419.94
SE	–
CD (0.05)	NS

Table 17 Effect of different levels of nitrogen, potassium and spacing on tetrazolium test for seed viability

Treatments	Seed viability percentage
N_1	99.3 (85.1)
N_2	98.5 (82.9)
N_3	99.7 (87.0)
SE	–
CD (0.05)	NS
K_1	99.3 (85.2)
K_2	99.6 (86.2)
K_3	98.8 (83.7)
SE	–
CD (0.05)	NS
S_1	99.4 (85.7)
S_2	99.1 (84.4)
SE	–
CD (0.05)	NS

Data in parenthesis : angular transformation

Table 18 Effect of different levels of nitrogen, potassium and spacing on germination percentage of seeds

Treatments	Germination percentage of seeds
N_1	97.4 (80.8)
N_2	96.4 (78.9)
N_3	99.1 (84.4)
SE	–
CD (0.05)	NS
K_1	98.0 (81.9)
K_2	98.5 (82.9)
K_3	96.6 (79.3)
SE	–
CD (0.05)	NS
S_1	98.5 (82.9)
S_2	96.9 (79.9)
SE	–
CD (0.05)	NS

Data in parenthesis : angular transformation that the treatments had no statistically significant effect upon germination percentage.

The interaction effect of nitrogen and potassium given in Table 25, interaction effect of nitrogen and spacing which is presented in Table 26, interaction effect of potassium and spacing given in Table 27 and the interaction effect of nitrogen, potassium and spacing shown in Table 28 made it clear that the treatment combinations also did not make any statistically significant variation upon the germination percentage.

4.3.8 Vigour Index of Seedling

The mean value of the data regarding the vigour index of seedlings with respect to different levels of nitrogen, potassium and spacing are given in Table 18. The result showed that there was no statistically significant effect on the vigour index of seedlings by the treatments.

The interaction effect of nitrogen and potassium (Table 25), interaction effect due to nitrogen and spacing (Table 26), interaction effect of potassium and spacing (Table 27) and nitrogen, potassium and spacing (Table 28) revealed that they too did not have any significant influence upon this character of the seedlings.

4.3.9 Root Length

The average value of root length with respect to the different levels of nitrogen, potassium and spacing, the interaction effect due to different treatment combinations viz., nitrogen and potassium interaction, nitrogen and spacing interaction, potassium and spacing interaction and nitrogen, potassium and spacing interactions are given in Tables 19, 25, 26, 27 and 28 respectively. The data in these tables revealed that the different levels of these treatments and their combinations did not make any statistically significant effect on root length of seedlings.

4.3.10 Seedling Dry Weight

The data pertaining to seedling dry weight with respect to effect of nitrogen, potassium and spacing is given in Table 20. There was no statistically significant effect upon the character by the different levels of treatments.

Table 19 Effect of different levels of nitrogen, potassium and spacing on vigour index of seedling

Treatments	Vigour index of seedling
N_1	2399
N_2	2187
N_3	2240
SE	–
CD (0.05)	NS
K_1	2323
K_2	2279
K_3	2224
SE	–
CD (0.05)	NS
S_1	2297
S_2	2254
SE	–
CD (0.05)	NS

Table 20. Effect of different levels of nitrogen, potassium and spacing on root length of seedling

Treatments	Root length of seedling (cm)
N_1	13.40
N_2	14.17
N_3	13.39
SE	–
CD (0.05)	NS
K_1	13.06
K_2	13.94
K_3	13.97
SE	–
CD (0.05)	NS
S_1	13.49
S_2	13.83
SE	–
CD (0.05)	NS

Table 21 Effect of different levels of nitrogen, potassium and spacing on dry weight of seedling

Treatments	Dry weight of seedling (g)
N_1	0.12
N_2	0.12
N_3	0.11
SE	–
CD (0.05)	NS
K_1	0.11
K_2	0.12
K_3	0.12
SE	–
CD (0.05)	NS
S_1	0.12
S_2	0.12
SE	–
CD (0.05)	NS

The interaction effect of treatment combination of nitrogen and potassium given in Table 25, revealed that there was not any significant influence upon this character. So also, the interaction effect of nitrogen and spacing (Table 26) potassium and spacing (Table 27) and that of nitrogen, potassium and spacing (Table 28) did not make any statistically significant effect on seedling dry weight.

4.4 CHEMICAL ANALYSIS

Chemical analysis was done to find out the major nutrient status of the plants and soil after the final harvesting of pods. The initial values of soil N, P and K were 153.66 kg ha $^{-1}$, 30.24 kg ha $^{-1}$and 44.80 kg ha $^{-1}$ respectively.

4.4.1 NPK Content in Plant

4.4.1.1 Nitrogen Content in Plant

The data pertaining to nitrogen content of plant with respect to the main effects are given in Table 22. Among the main effects spacing has shown statistically significant effect on nitrogen content of plants. S_1 gave highest content of 26.97 kg ha^{-1} and was significantly superior to S_2, which gave a value of 19.38 kg ha^{-1}.

Among the interaction effects the treatment combination of nitrogen and potassium (Table 25) had statistically significant effect on plant nitrogen. The treatment combination of N_1K_2 and N_3K_1 were significantly superior to other combinations. N_1K_2 and N_3K_1 were on par and their values are 27.84 kg ha^{-1} and 27.59 kg ha^{-1}. The lowest was reported for N_3K_3 (20.38 kg ha^{-1}).

The interaction effect of other combinations viz., nitrogen and spacing (Table 26), potassium and spacing (Table 27) and nitrogen, potassium and spacing (Table 28) show that the effects were not significant.

4.4.1.2 Phosphorus Content in Plants

The mean values concerning the phosphorus content in plants after the final harvesting with respect to different levels of main effects are furnished in Table 22.

Among the main effects, spacing (S_1) gave statistically superior result for phosphorus content of 12.36 kg ha^{-1}. Among the interaction effects of the treatment combination of nitrogen and potassium (Table 25) gave statistically significant results. N_1K_2 (12.10 kg ha^{-1}) and N_3K_1 (12.21 kg ha^{-1}) were significantly superior

Table 22 Effect of different levels of nitrogen, potassium and spacing on the content of nitrogen, phosphorus and potassium in plants

Treatments	Plant		
	N	P	K
	(kg ha^{-1})		
N_1	24.11	10.83	45.02
N_2	22.58	10.01	43.66
N_3	22.84	10.12	43.69
SE	–	–	–
CD (0.05)	NS	NS	NS
K_1	23.80	10.52	43.53
K_2	23.55	10.20	44.48
K_3	22.18	10.23	44.37
SE	–	–	–
CD (0.05)	NS	NS	NS
S_1	26.97	12.36	52.84
S_2	19.38	8.28	35.41
SE	1.00	0.47	2.03
CD (0.05)	2.87 **	1.36 **	5.83 **

to other combinations of N & K and they were on par. The other interaction effects viz., nitrogen and spacing (Table 26), potassium and spacing (Table 27) and nitrogen, potassium and spacing furnished in Table 28 revealed that there were not any statistically significant influences upon plant P after final harvesting.

4.4.1.3 Potassium Content in Plants

The mean values with respect to main effects are presented in Table 22. The result showed that in the case of potassium content in plants, only the main effect of spacing had statistically significant effect. S_1 gave the significantly higher quantity of 52.84 kg ha^{-1}.

The interaction effect of nitrogen and potassium (Table 25), nitrogen and spacing (Table 26), potassium and spacing (Table 27) and interaction effect of nitrogen, potassium and spacing given in Table 28 revealed that they had no statistically significant effect on plant K.

4.4.2 Available NPK Content in Soil

4.4.2.1 Available Nitrogen in the Soil

Main effects of different levels of treatments are furnished in Table 23. Even though the soil treated with the highest level of nitrogen i.e., N_3 had the highest content of nitrogen (173.01 kg ha^{-1}) it was not statistically significant. Nitrogen content with respect to potassium levels and spacing were also non-significant.

The interaction effect due to N and K, N and spacing, K and spacing and N, K and spacing upon available soil nitrogen is presented in Tables 25, 26, 27 and 28 respectively. The result revealed that interaction effects were not significant.

4.4.2.2 Available Phosphorus in the Soil

Data regarding the available phosphorus content in soil with respect to the main effects are given in Table 23. The table revealed that there was no statistically significant effect upon the phosphorus content of soil.

The interaction effect due to nitrogen and potassium, nitrogen and spacing, potassium and spacing, nitrogen, potassium and spacing are given in Table 25, 26, 27 and 28 respectively. The result revealed that there was no statistically significant effect on the available phosphorus content in the soil.

Table 23 Effect of experiment on the content of nitrogen, phosphorus and potassium in soil

Treatments	Soil		
	N	P	K
	(kg ha^{-1})		
N_1	169.52	44.93	60.98
N_2	168.65	44.52	62.22
N_3	173.01	45.12	68.44
SE	–	–	–
CD (0.05)	NS	NS	NS
K_1	172.83	45.18	60.98
K_2	167.78	44.09	59.73
K_3	170.57	45.31	70.93
SE	–	–	–
CD (0.05)	NS	NS	NS
S_1	169.69	44.95	63.88
S_2	171.09	44.76	63.88
SE	–	–	–
CD (0.05)	NS	NS	NS

4.4.2.3 Available Potassium Content in the Soil

The data pertaining to the available potassium content in soil is presented in Table 23. The result revealed that the potassium content in soil was highest (68.44 kg ha^{-1} and 70.93 kg ha^{-1}) in the soil which were treated with the highest level of nitrogen (N_3) and potassium (K_3) respectively. The potassium content in soil has shown increasing trend with increase in nitrogen application. Even though there was an increasing trend for available potassium content with respect to the main effects of N and K the quantity were not statistically significant. Spacing S_1 and S_2 gave the same values of 63.88 kg ha^{-1} and were non-significant.

The interaction effects due to combination of nitrogen and potassium given in Table 25, nitrogen and spacing given in Table 26 and nitrogen, potassium and spacing given in Table 28 revealed that they were not significant.

The interaction effect of treatment combination of potassium and spacing are given in Table 27. It revealed that this treatment combination had a statistically significant effect on available potassium in soil after harvesting. K_3S_2 gave the significantly highest value of 87.1 kg ha^{-1}. All other combinations were on par.

4.5 ECONOMICS OF CULTIVATION

Economics of production of eighteen factorial treatment combinations are presented in Table 24.

The data indicated that net returns and benefit–cost ratio (BCR) were higher with the treatment combination $N_1K_2S_1$. It gave the maximum net returns of Rs.117501 per hectare and BCR of 1.76. The next highest value for net returns and BCR was given by the treatment combination $N_3K_1S_1$. The values are Rs.100870/- per hectare and 1.66 respectively.

Eight treatment combinations made loss since seed yield was low.

Table 24 Economics of cultivation (ha^{-1}) *

Treatments	Net returns (Rs.)	**Benefit : Cost (ratio)**
T_1 ($N_1K_1S_1$)	-31694	0.79
T_2 ($N_1K_1S_2$)	-8343	0.94
T_3 ($N_1K_2S_1$)	117501	1.76
T_4 ($N_1K_2S_2$)	33618	1.22
T_5 ($N_1K_3S_1$)	-33668	0.77
T_6 ($N_1K_3S_2$)	23951	1.15
T_7 ($N_2K_1S_1$)	69586	1.45
T_8 ($N_2K_1S_2$)	-8695	0.94
T_9 ($N_2K_2S_1$)	31383	1.21
T_{10} ($N_2K_2S_2$)	34993	1.23
T_{11} ($N_2K_3S_1$)	66510	1.43
T_{12} ($N_2K_3S_2$)	-59146	0.61
T_{13} ($N_3K_1S_1$)	100870	1.66
T_{14} ($N_3K_1S_2$)	23024	1.15
T_{15} ($N_3K_2S_1$)	33407	1.22
T_{16} ($N_3K_2S_2$)	-53679	0.65
T_{17} ($N_3K_3S_1$)	-48878	0.68
T_{18} ($N_3K_3S_2$)	-9279	0.94

***Data statistically not analysed**

Wage rate = Rs.170 per day

Cost of inputs.

Seeds = Rs.400 kg^{-1}

Poultry manure = Rs.2 kg^{-1}

N(urea) = Rs.5 kg^{-1}

P_2O_5 (MRP) = Rs.4 kg^{-1}

K_2O (MOP) = Rs.6 kg^{-1}

Pandhal = Rs.900/-

PP Chenicals = Rs.197/-

Cost of produce

Seeds = Rs.400 kg^{-1}

Table 25 Interaction effect of different levels of nitrogen & potassium

Interaction effect on	Treatments										
	N_1K_1	N_1K_2	N_1K_3	N_2K_1	N_2K_2	N_2K_3	N_3K_1	N_3K_2	N_3K_3	SE	CD
Length of vine at 30 DAS (cm)	260.77	260.00	251.93	268.60	259.70	265.03	261.53	259.83	252.43	–	NS
Length of vine at 60 DAS (cm)	400.97	382.93	406.07	392.10	409.77	397.33	401.13	395.37	394.43	–	NS
Number of branches per plant at 30 DAS	1.57	2.10	2.00	1.63	1.77	1.97	1.77	1.93	1.77	–	NS
Number of branches per plant at 60 DAS	4.67	4.47	5.27	5.00	4.60	4.50	4.70	5.37	4.60	–	NS
Dry matter content (kg ha^{-1})	1288.26	1657.90	1496.96	1342.77	1248.90	1523.78	1668.03	1269.98	1205.36	133.31	382.71*
Shoot root ratio (w/w)	5.51	5.32	5.33	5.28	5.31	5.40	5.44	5.40	5.12	–	NS
Leaf Area Index at 30 DAS	0.43	0.50	0.46	0.31	0.40	0.36	0.40	0.34	0.39	–	NS
Leaf Area Index at 60 DAS	1.04	1.09	0.96	1.05	1.13	1.03	1.12	1.03	1.15	–	NS
Leaf Area Duration	22.13	23.83	21.23	20.45	22.97	20.90	22.75	20.53	23.10	–	NS
Days to 50% flowering	44.67	44.67	44.50	44.50	44.33	45.33	44.67	45.00	44.33	–	NS
Number of pods per plant	20.14	25.54	19.50	22.49	20.36	18.85	21.58	17.50	18.03*	–	NS
Weight of dried pods per plant (g)	44.95	68.14	46.16	53.16	49.58	41.97	60.55	45.03	37.77	–	NS
Total pods per plot	473.67	642.33	463.17	567.17	489.83	482.83	519.17	446.33	431.67	–	NS
Number of seeds per pod	13.91	15.68	14.45	14.95	15.08	13.88	14.13	14.50	14.58	–	NS
Weight of seeds per pod (g)	1.49	1.93	1.54	1.67	1.86	1.60	1.79	1.60	1.42	–	NS

Table 25 Interaction effect of different levels of nitrogen & potassium (Continued)

Interaction effect on	Treatments										
	N_1K_1	N_1K_2	N_1K_3	N_2K_1	N_2K_2	N_2K_3	N_3K_1	N_3K_2	N_3K_3	SE	CD
Pod to seed ratio (w/w)	1.96	1.76	2.03	1.87	1.65	1.84	1.68	1.99	2.01	0.09	0.27*
100 seed weight (g)	19.50	18.95	19.23	19.03	18.42	18.95	18.28	18.72	18.80	–	NS
Seed yield per hectare(kg ha^{-1})	331.76	570.83	369.91	458.33	465.31	391.67	537.50	357.41	310.18	–	NS
Seed viability #	97.7 (83.0)	99.3 (87.4)	97.7 (84.9)	97.8 (85.1)	96.5 (82.5)	96.3 (81.2)	98.8 (87.4)	99.7 (88.6)	98.3 (85.0)	–	NS
Germination percentage #	93.3 (77.7)	96.7 (83.9)	95.0 (80.8)	95.0 (82.5)	91.7 (78.1)	91.7 (76.3)	96.7 (85.6)	98.3 (86.9)	95.0 (80.8)	–	NS
Vigour index	2480.00	2250.00	2468.00	2235.00	2238.00	2087.00	2255.00	2348.00	2117.00	–	NS
Root length (cm)	12.60	14.33	13.27	13.90	13.88	14.73	12.67	13.60	13.92	–	NS
Seedling dry weight (g)	0.12	0.12	0.12	0.12	0.12	0.11	0.11	0.12	0.11	–	NS
Plant N (kg ha^{-1})	21.25	27.84	23.25	22.57	22.26	22.91	27.59	20.54	20.38	2.12	6.08*
Plant P (kg ha^{-1})	9.54	12.10	10.85	9.81	9.22	10.99	12.21	9.28	8.86	1.00	2.88*
Plant K (kg ha^{-1})	39.78	49.53	45.77	40.16	41.16	49.66	50.65	42.74	37.68	–	NS
Soil N after crop (kg ha^{-1})	173.00	166.75	168.82	171.96	162.03	171.96	173.53	174.57	170.92	–	NS
Soil P after crop (kg ha^{-1})	45.33	45.24	44.21	43.62	43.81	46.14	46.58	43.21	45.57	–	NS
Soil K after crop (kg ha^{-1})	56.00	56.00	70.93	59.73	56.00	70.93	67.20	67.20	70.93	–	NS

Data in parenthesis : angular transformation

Table 26 Interaction effect of different levels of nitrogen & spacing

Interaction effect on	Treatments							
	N_1S_1	N_1S_2	N_2S_1	N_2S_2	N_3S_1	N_3S_2	SE	CD
Length of vine at 30 DAS (cm)	256.13	259.00	268.07	260.82	256.22	259.64	-	NS
Length of vine at 60 DAS (cm)	396.04	397.27	396.42	403.04	397.93	396.02	-	NS
Number of branches per plant at 30 DAS	1.89	1.89	1.84	1.73	1.93	1.71	-	NS
Number of branches per plant at 60 DAS	4.80	4.80	4.98	4.42	4.56	5.22	-	NS
Dry matter content (kg ha^{-1})	1742.57	1219.51	1638.22	1105.42	1700.40	1061.85	-	NS
Shoot root ratio (w/w)	5.36	5.41	5.32	5.34	5.30	5.34	-	NS
Leaf Area Index at 30 DAS	0.55	0.38	0.45	0.27	0.45	0.30	-	NS
Leaf Area Index at 60 DAS	1.20	0.86	1.25	0.89	1.30	0.90	-	NS
Leaf Area Duration	26.17	18.62	25.43	17.45	26.33	17.92	-	NS
Days to 50% flowering	44.22	45.00	44.89	44.56	44.44	44.89	-	NS
Number of pods per plant	18.37	25.09	19.30	21.84	17.02	21.06	-	NS
Weight of dried pods per plant (g)	44.51	61.65	47.22	49.26	45.79	49.78	-	NS
Total pods per plot	551.00	501.78	589.78	436.78	510.33	421.11	-	NS
Number of seeds per pod	14.65	14.71	14.78	14.50	14.81	14.00	-	NS
Weight of seeds per pod (g)	1.55	1.75	1.73	1.69	1.62	1.59	-	NS

Table 26 Interaction effect of different levels of nitrogen & spacing (Continued)

Interaction effect on	Treatments							
	N_1S_1	N_1S_2	N_2S_1	N_2S_2	N_3S_1	N_3S_2	SE	CD
Pod to seed ratio (w/w)	1.97	1.86	1.72	1.86	1.89	1.90	–	NS
100 seed weight (g)	19.50	18.96	18.90	18.70	18.31	18.89	–	NS
Seed yield per hectare (kg ha^{-1})	425.28	422.72	522.22	354.65	454.32	349.07	–	NS
Seed viability #	97.9 (83.9)	98.6 (86.2)	97.6 (84.1)	96.2 (81.7)	99.7 (88.9)	98.2 (85.2)	–	NS
Germination percentage #	94.4 (80.9)	95.6 (81.8)	94.4 (80.9)	91.1 (77.0)	98.9 (87.9)	94.4 (80.9)	–	NS
Vigour index	2375.00	2423.00	2238.00	2135.00	2277.00	2203.00	–	NS
Root length (cm)	13.60	13.20	13.50	14.84	13.36	13.43	–	NS
Seedling dry weight (g)	0.12	0.12	0.11	0.12	0.11	0.11	–	NS
Plant N (kg ha^{-1})	27.38	20.84	26.60	18.57	26.93	18.74	–	NS
Plant P (kg ha^{-1})	12.68	8.98	11.91	8.11	12.48	7.76	–	NS
Plant K (kg ha^{-1})	52.01	38.04	53.33	34.00	53.19	34.19	–	NS
Soil N after crop (kg ha^{-1})	168.30	170.75	165.16	172.13	175.61	170.40	–	NS
Soil P after crop (kg ha^{-1})	44.84	45.01	44.40	44.64	45.60	44.63	–	NS
Soil K after crop (kg ha^{-1})	64.71	57.24	64.71	59.73	62.22	74.67	–	NS

Data in parenthesis : angular transformation

Table 27 Interaction effect of different levels of potassium & spacing

Interaction effect on	Treatments							
	K_1S_1	K_1S_2	K_2S_1	K_2S_2	K_3S_1	K_3S_2	SE	CD
Length of vine at 30 DAS (cm)	258.36	268.91	261.80	257.89	260.27	252.67	–	NS
Length of vine at 60 DAS (cm)	398.89	397.24	391.69	400.36	399.82	398.73	–	NS
Number of branches per plant at 30 DAS	1.73	1.58	1.96	1.91	1.98	1.84	–	NS
Number of branches per plant at 60 DAS	4.47	5.11	4.87	4.76	5.00	4.58	–	NS
Dry matter content (kg ha^{-1})	1735.59	1130.45	1590.42	1194.10	1755.17	1062.23	–	NS
Shoot root ratio (w/w)	5.31	5.50	5.40	5.28	5.26	5.31	–	NS
Leaf Area Index at 30 DAS	0.42	0.34	0.49	0.34	0.54	0.27*	0.03	0.08
Leaf Area Index at 60 DAS	1.28	0.86	1.22	0.95	1.25	0.84	–	NS
Leaf Area Duration	25.52	18.03	25.62	19.27	26.80	16.68	–	NS
Days to 50% flowering	44.44	44.78	44.67	44.67	44.44	45.00	–	NS
Number of pods per plant	18.38	24.42	19.61	22.65	16.68	20.91	–	NS
Weight of dried pods per plant (g)	48.09	57.69	53.11	55.39	36.33	47.61	–	NS
Total pods per plot	551.44	488.56	599.33	453.00	500.33	418.11	–	NS
Number of seeds per pod	14.21	14.45	15.51	14.67	14.52	14.09	–	NS
Weight of seeds per pod (g)	1.63	1.67	1.81	1.78	1.46	1.58	–	NS

Table 27 Interaction effect of different levels of potassium & spacing (Continued)

Interaction effect on	Treatments							
	K_1S_1	K_1S_2	K_2S_1	K_2S_2	K_3S_1	K_3S_2	SE	CD
Pod to seed ratio (w/w)	1.85	1.82	1.73	1.87	2.00	1.92	–	NS
100 seed weight (g)	18.97	18.91	18.52	18.87	19.22	18.77	–	NS
Seed yield per hectare (kg ha^{-1})	498.15	586.91	534.56	394.47	369.45	345.06	–	NS
Seed viability #	98.4 (85.4)	97.8 (85.0)	99.3 (87.8)	97.7 (84.6)	97.3 (83.8)	97.6 (83.5)	–	NS
Germination percentage #	95.6 (81.8)	94.4 (82.0)	97.8 (85.9)	93.3 (79.9)	94.4 (80.9)	93.3 (77.7)	–	NS
Vigour index	2459.00	2187.00	2312.00	2245.00	2119.00	2329.00	–	NS
Root length (cm)	12.87	13.24	14.48	13.40	13.11	14.83	–	NS
Seedling dry weight (g)	0.12	0.11	0.12	0.12	0.11	0.12*	0.01	0.02
Plant N (kg ha^{-1})	27.88	19.73	25.43	21.67	27.60	16.75	–	NS
Plant P (kg ha^{-1})	12.81	8.24	11.59	8.81	12.67	7.79	–	NS
Plant K (kg ha^{-1})	52.19	34.87	50.59	38.36	55.73	33.01	–	NS
Soil N after crop (kg ha^{-1})	170.04	175.61	170.39	165.17	168.65	172.49	–	NS
Soil P after crop (kg ha^{-1})	44.43	45.92	45.11	43.07	45.31	45.30	–	NS
Soil K after crop (kg ha^{-1})	69.69	52.27	67.20	52.27	54.76	87.11	9.56	27.45*

Data in parenthesis : angular transformation

Table 28 Interaction effect of different levels of nitrogen, potassium & spacing

Treatment	Length of vine at 30 DAS (cm)	Length of vine at 60 DAS (cm)	Number of branches per plant at 30 DAS	Number of branches per plant at 60 DAS	Dry matter content (kg ha^{-1})	Shoot root ratio (w/w)	Leaf Area Index at 30 DAS	Leaf Area Index at 60 DAS	Leaf Area Duration	Days to 50% flowering	Number of pods per plant	Weight of dried pods per plant (g)	Total number of pods per plot	Number of seeds per pod	Weight of seed per pod (g)
$N_1K_1S_1$	253.60	393.53	1.47	4.47	1545.03	5.30	0.52	1.14	24.90	44.00	14.10	31.61	423.33	14.03	1.41
$N_1K_1S_2$	267.93	408.40	1.67	4.87	1031.48	5.72	0.34	0.95	19.35	45.33	26.19	58.29	524.00	13.79	1.57
$N_1K_2S_1$	261.20	378.73	2.20	4.33	2003.44	5.38	0.57	1.16	26.00	44.67	26.35	71.27	790.33	15.87	1.88
$N_1K_2S_2$	258.80	387.13	2.00	4.60	1312.36	5.26	0.42	1.02	21.05	44.67	24.72	65.00	494.33	15.50	1.98
$N_1K_3S_1$	253.60	415.87	2.00	5.60	1679.22	5.41	0.54	1.29	27.60	44.00	14.64	30.66	439.33	14.07	1.38
$N_1K_3S_2$	250.27	396.27	2.00	4.93	1314.69	5.25	0.37	0.62	14.85	45.00	24:35	61.67	487.00	14.83	1.69
$N_2K_1S_1$	265.00	398.47	1.87	4.87	1631.77	5.15	0.36	1.31	25.10	44.67	23.50	54.55	704.67	13.87	1.60
$N_2K_1S_2$	272.20	385.73	1.40	5.13	1053.78	5.41	0.26	0.79	15.80	44.33	21.48	51.78	429.67	16.03	1.73
$N_2K_2S_1$	259.67	391.87	1.47	5.00	1215.37	5.55	0.45	1.32	26.55	44.67	13.20	35.33	429.33	15.67	1.85
$N_2K_2S_2$	259.73	427.67	2.07	4.20	1282.44	5.08	0.36	0.94	19.40	44.00	27.52	63.83	550.33	14.50	1.86
$N_2K_3S_1$	279.53	398.93	2.20	5.07	2067.53	5.26	0.53	1.12	24.65	45.33	21.19	51.78	635.33	14.80	1.72
$N_2K_3S_2$	250.53	395.73	1.73	3.93	980.03	5.55	0.20	0.94	17.15	45.33	16.52	32.17	330.33	12.97	1.47
$N_3K_1S_1$	256.47	404.67	1.87	4.07	2029.98	5.50	0.38	1.39	26.55	44.67	17.55	58.11	526.33	14.73	1.89
$N_3K_1S_2$	266.60	397.60	1.67	5.33	1306.08	5.38	0.42	0.85	18.95	44.67	25.60	63.00	512.00	13.53	1.69
$N_3K_2S_1$	264.53	404.47	2.20	5.27	1552.45	5.28	0.44	1.18	24.30	44.67	19.29	52.72	578.33	15.00	1.71
$N_3K_2S_2$	255.13	386.27	1.67	5.47	987.50	5.51	0.24	0.88	16.75	45.33	15.72	37.33	314.33	14.00	1.50
$N_3K_3S_1$	247.67	384.67	1.73	4.33	1518.77	5.12	0.54	1.34	28.15	44.00	14.21	26.55	426.33	14.70	1.27
$N_3K_3S_2$	257.20	404.20	1.80	4.87	891.96	5.12	0.24	0.96	18.05	44.67	21.85	49.00	437.00	14.47	1.57
SE	–	–	–	–	–	–	–	–	–	–	–	–	*106.25	–	–
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	305.03	NS	NS

Table 28 Interaction effect of different levels of nitrogen, potassium & spacing

Treatment	Length of vine at 30 DAS (cm)	Length of vine at 60 DAS (cm)	Number of branches per plant at 30 DAS	Number of branches per plant at 60 DAS	Dry matter content (kg ha^{-1})	Shoot root ratio (w/w)	Leaf Area Index at 30 DAS	Leaf Area Index at 60 DAS	Leaf Area Duration	Days to 50% flowering	Number of pods per plant	Weight of dried pods per plant (g)	Total number of pods per plot	Number of seeds per pod	Weight of seed per pod (g)
$N_1K_1S_1$	253.60	393.53	1.47	4.47	1545.03	5.30	0.52	1.14	24.90	44.00	14.10	31.61	423.33	14.03	1.41
$N_1K_1S_2$	267.93	408.40	1.67	4.87	1031.48	5.72	0.34	0.95	19.35	45.33	26.19	58.29	524.00	13.79	1.57
$N_1K_2S_1$	261.20	378.73	2.20	4.33	2003.44	5.38	0.57	1.16	26.00	44.67	26.35	71.27	790.33	15.87	1.88
$N_1K_2S_2$	258.80	387.13	2.00	4.60	1312.36	5.26	0.42	1.02	21.05	44.67	24.72	65.00	494.33	15.50	1.98
$N_1K_3S_1$	253.60	415.87	2.00	5.60	1679.22	5.41	0.54	1.29	27.60	44.00	14.64	30.66	439.33	14.07	1.38
$N_1K_3S_2$	250.27	396.27	2.00	4.93	1314.69	5.25	0.37	0.62	14.85	45.00	24:35	61.67	487.00	14.83	1.69
$N_2K_1S_1$	265.00	398.47	1.87	4.87	1631.77	5.15	0.36	1.31	25.10	44.67	23.50	54.55	704.67	13.87	1.60
$N_2K_1S_2$	272.20	385.73	1.40	5.13	1053.78	5.41	0.26	0.79	15.80	44.33	21.48	51.78	429.67	16.03	1.73
$N_2K_2S_1$	259.67	391.87	1.47	5.00	1215.37	5.55	0.45	1.32	26.55	44.67	13.20	35.33	429.33	15.67	1.85
$N_2K_2S_2$	259.73	427.67	2.07	4.20	1282.44	5.08	0.36	0.94	19.40	44.00	27.52	63.83	550.33	14.50	1.86
$N_2K_3S_1$	279.53	398.93	2.20	5.07	2067.53	5.26	0.53	1.12	24.65	45.33	21.19	51.78	635.33	14.80	1.72
$N_2K_3S_2$	250.53	395.73	1.73	3.93	980.03	5.55	0.20	0.94	17.15	45.33	16.52	32.17	330.33	12.97	1.47
$N_3K_1S_1$	256.47	404.67	1.87	4.07	2029.98	5.50	0.38	1.39	26.55	44.67	17.55	58.11	526.33	14.73	1.89
$N_3K_1S_2$	266.60	397.60	1.67	5.33	1306.08	5.38	0.42	0.85	18.95	44.67	25.60	63.00	512.00	13.53	1.69
$N_3K_2S_1$	264.53	404.47	2.20	5.27	1552.45	5.28	0.44	1.18	24.30	44.67	19.29	52.72	578.33	15.00	1.71
$N_3K_2S_2$	255.13	386.27	1.67	5.47	987.50	5.51	0.24	0.88	16.75	45.33	15.72	37.33	314.33	14.00	1.50
$N_3K_3S_1$	247.67	384.67	1.73	4.33	1518.77	5.12	0.54	1.34	28.15	44.00	14.21	26.55	426.33	14.70	1.27
$N_3K_3S_2$	257.20	404.20	1.80	4.87	891.96	5.12	0.24	0.96	18.05	44.67	21.85	49.00	437.00	14.47	1.57
SE	–	–	–	–	–	–	–	–	–	–	–	–	*106.25	–	–
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	305.03	NS	NS

DISCUSSION

5. DISCUSSION

The role of balanced fertilization especially of nitrogen and potassium has got much relevance on the production of quality seeds. There is not much research evidence for the impact of cultural practices on the quality and quantity of seeds of vegetable cowpea. Plant population per unit area is one of the contributing factors and has got an influencing factor with the crop nutrition in maximizing the productivity of seed. Vegetable cowpea being one of the most preferred vegetable crops of Kerala State owing to its nutritive value and consumer preference requires detailed studies on nitrogen and potassium fertilization.

The production of quality seeds is also influenced by cultural practices especially plant population per unit area.

Investigation was done to evaluate the effect of nitrogen and potassium fertilization and spacing on the quality and quantity of seed production in vegetable cowpea. The results presented in chapter 4 of the experiment are discussed in this chapter.

5.1 GROWTH CHARACTERS

Though the nitrogen and potassium levels had no significant effect on length of vine in 30 and 60 DAS there was an increasing trend up to the second level of nitrogen (45 kg. N ha^{-1}). Nitrogen is a growth element as reported by Panda (1972) and Jyothi (1995) while there was also inconsistent effect reported by Nandan and Prasad (1998) as the poor impact on vine length resulted in this study.

Similarly, the different spacing and interaction effects between nutrient levels and spacing could not produce a significant effect on plant height.

The treatments either alone and interaction effect could not effect significantly the number of branches at 30 and 60 DAS. Contribution of nitrogen by fixation, residual soil fertility and other cultural operations might be the reasons for the poor effect of tested nitrogen levels. It may be inferred that since the soil status of potassium is low the applied potassium levels could not exert an effect on the growth characters and it may be attributed to fixation of potassium.

There was also no significant effect due to spacing and the interaction among the treatments. These results were in conformity with the results of Nandan and Prasad (1998).

Among the treatments spacing alone could exhibit a significant effect on dry matter production. With regard to nitrogen and potassium nutrition the trend as noticed in length of vine and number of branches were exhibited in the case of DMP also. The poor effect of potassium may be attributed to the release of fixed K to the plant.

Spacing made significant effect on DMP of plant. Among the different levels of spacing S_1 (1 x 0.6m) has recorded maximum DMP which was significantly superior than the other level S_2. A significant improvement in DMP due to spacing has been reported by Mini (1997).

The higher DMP in S_1 might be due to higher number of plants per unit area. This trend was not noticed in other plant characters viz. plant height and branches per plant and it may be due to the fact that data on DMP was recorded at the time of final harvest while other growth characters were recorded up to 60 DAS. Spacing of 1 X 0.6m being the better treatment might have provided the optimum use of available resources like space, light, moisture and nutrients resulting in better expression of DMP.

Interaction effect due to nitrogen and potassium also significantly influenced the dry matter production though the individual effects of nutrient were in the contrary. Even if interaction effect due to nitrogen and potassium was not significant in the case of growth characters like length of vine and number of branches it could exert significant effect on the DMP during harvest stage. About 30 to 45 days more of plant growth has also contributed for the higher dry matter and its significance.

From the scrutiny of the result of nutrient uptake data, it can also be inferred that the interaction effect of nitrogen and potassium on DMP was mainly due to influence of higher nitrogen uptake than potassium. Nitrogen in the presence of potassium has favourable role in enhancing DMP.

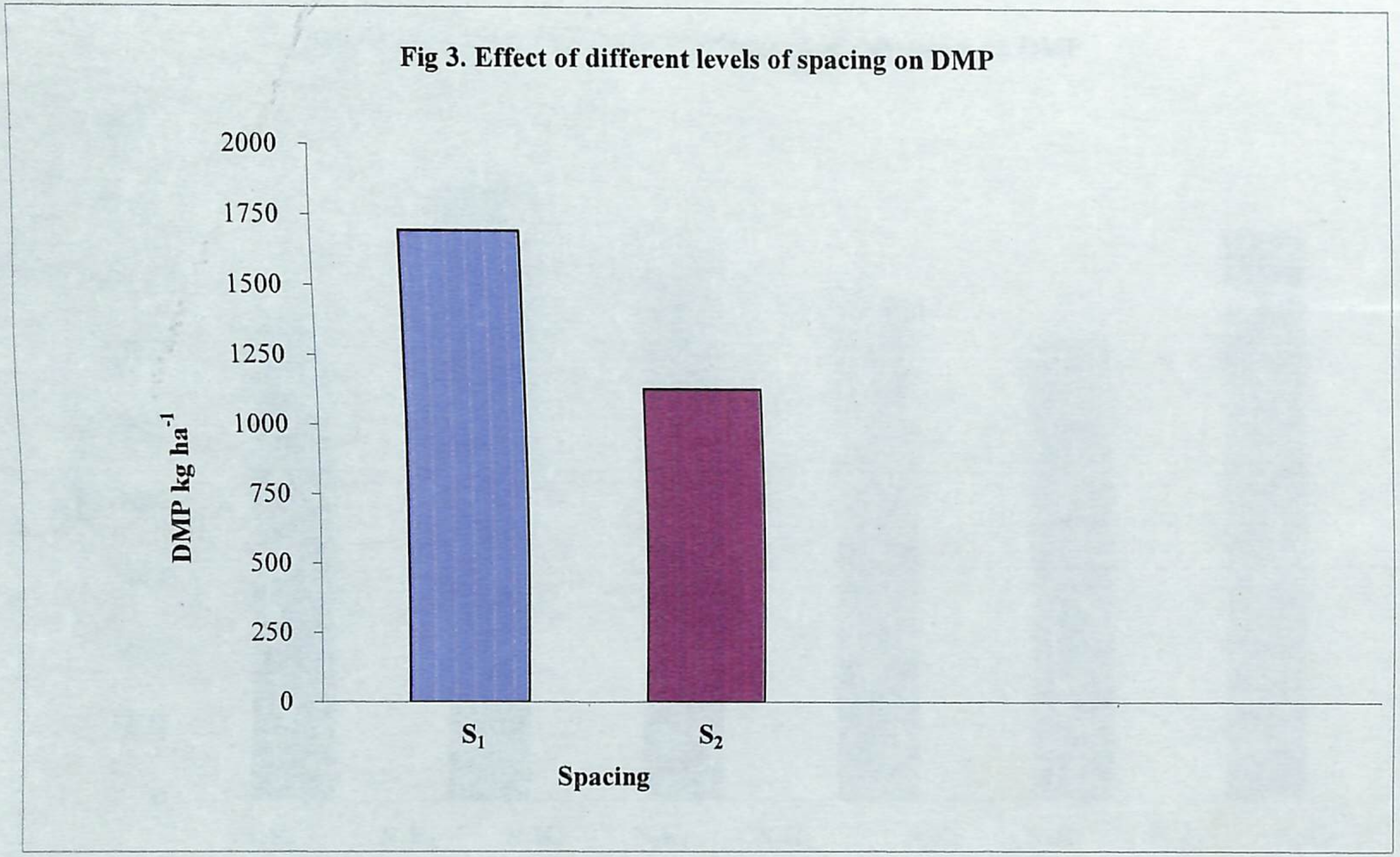
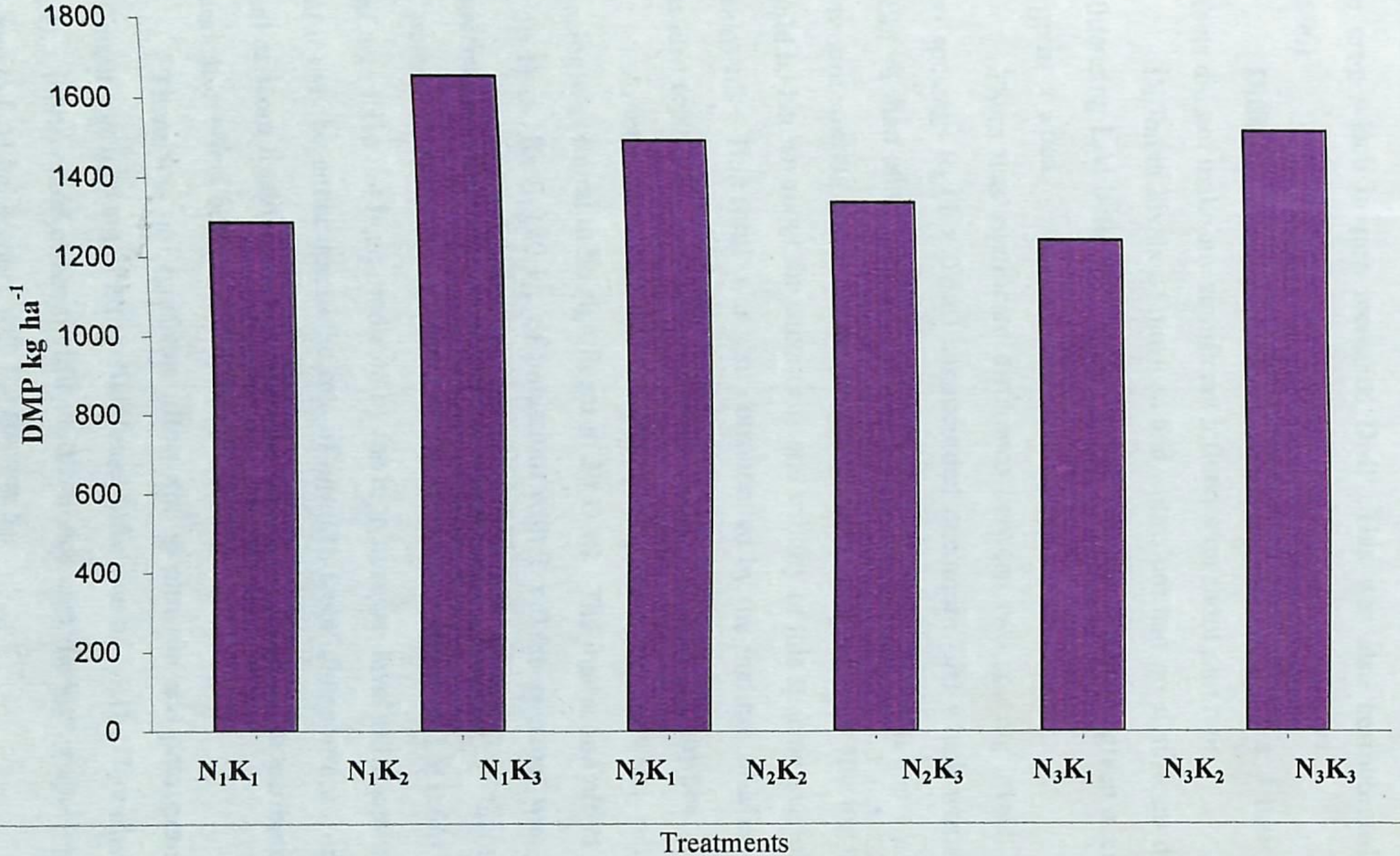


Fig 3. Effect of different levels of spacing on DMP
2000
1750
1500
1250
1000
750
500
250
0
DMP kg ha-1
S1
S2
Spacing

Fig 4 Effect of different levels of nitrogen and potassium on DMP



Increased nutrients increased photosynthetic surface area resulting in more production, assimilation, translocation of photosynthates during the later stages of the crop which in turn increased DMP. This was also corroborated by Sherly (1996).

Different levels of nitrogen, potassium and spacing and their interaction effects did not make any significant influence on shoot root ratio.

Different levels of nitrogen and potassium had no significant difference in influencing LAI both in 30 and 60 DAS. George (1981) has given a similar report in grain cowpea.

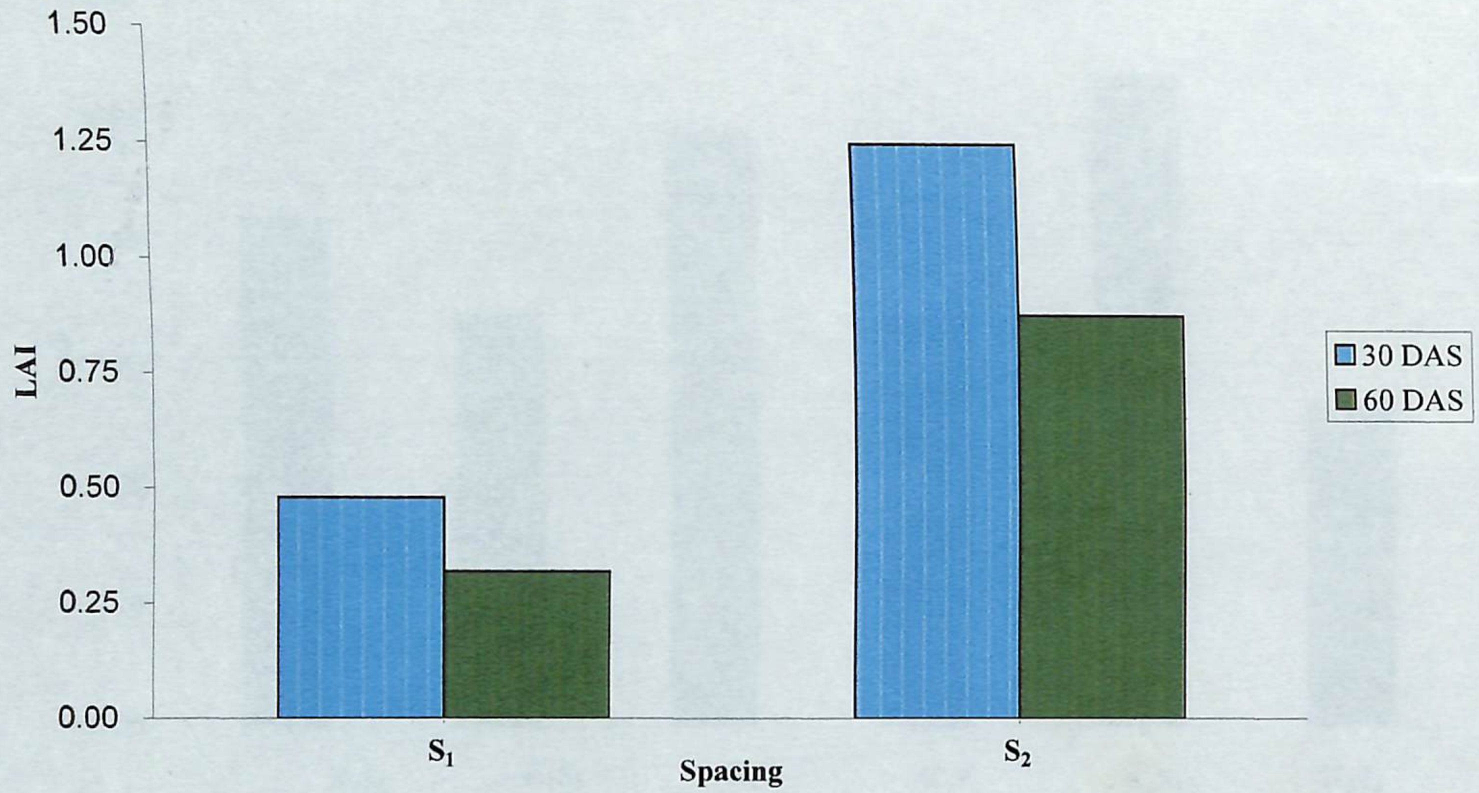
There was significant difference between two spacing levels. Among the two spacings S_1 (1 x 0.6m) has recorded maximum LAI which was significantly different than other spacing. From these it can be understood that 1 x 0.6m is the optimum spacing and if the study was made with some more spacing treatments it could be known about the superiority and validity of this spacing over other spacing treatments. This result was also corroborated by the findings of Mini (1997) who has also reported 1 x 0.6m as optimum spacing for vegetable cowpea.

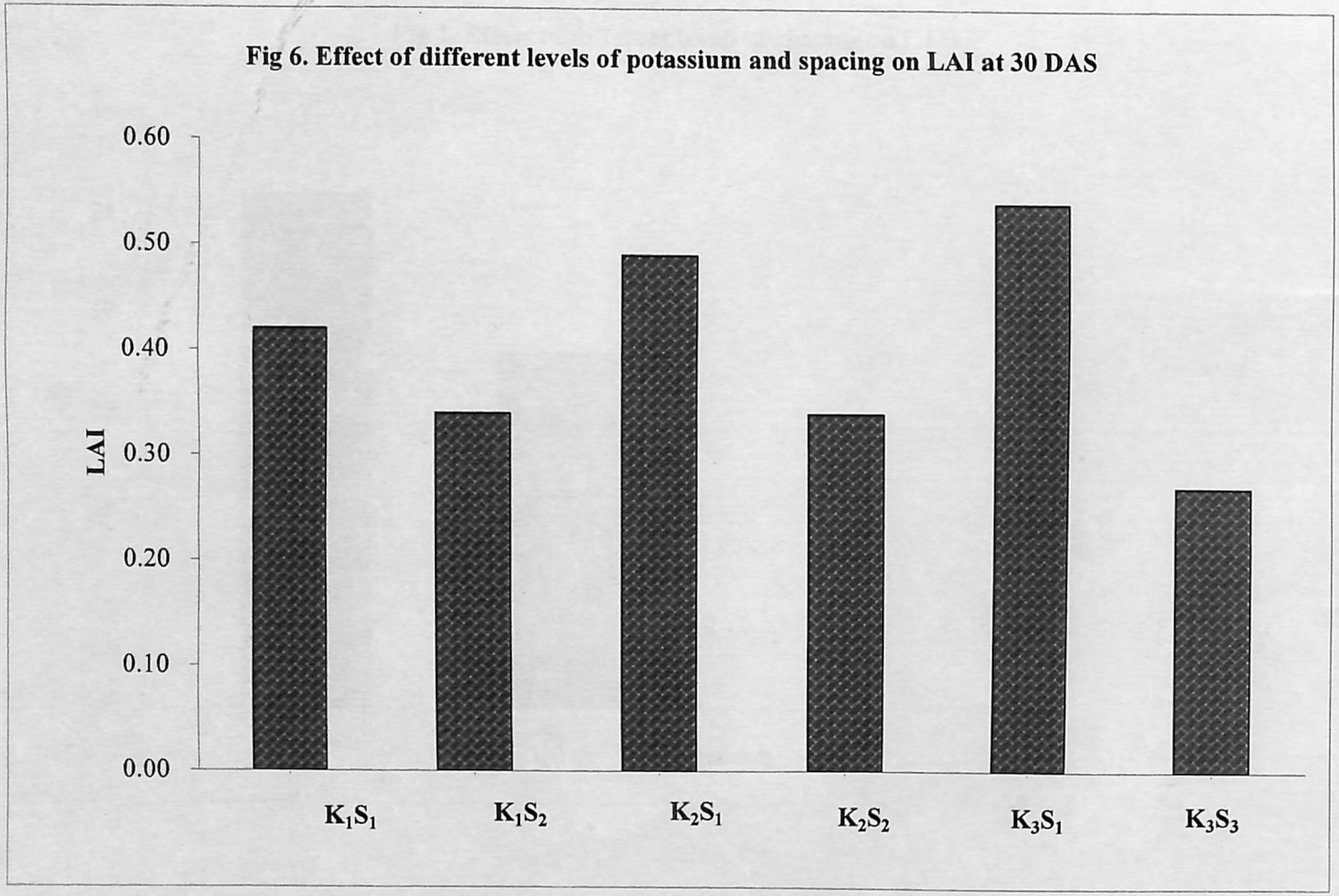
Among the interaction effect only interaction between potassium and spacing was found to be significant in 30 DAS. The interaction effect were absent at 60 DAS. K_3 S_1 (20 kg. of potassium with 1 x 0.6m spacing) was found to be significantly superior than all other combinations of 30 DAS. A favourable effect of potassium could be expressed at the optimum spacing of 1 x 0.6m while better leaf area have not been produced by the high nitrogen level at the optimum spacing and it may be either due to the role of nitrogen from other sources from the soil as well as from fixation or due to the insufficient levels tested in attributing this poor interaction effect between nitrogen and spacing.

There was no significant effect due to nitrogen and potassium levels. The different spacings could effect significant influence on LAD. Here also the spacing S_1 (1 x 0.6m) could effect significant difference over the higher spacing. This could be due to LAI being more with the spacing S_1.

There was no significant influence due to different interactions on LAD.

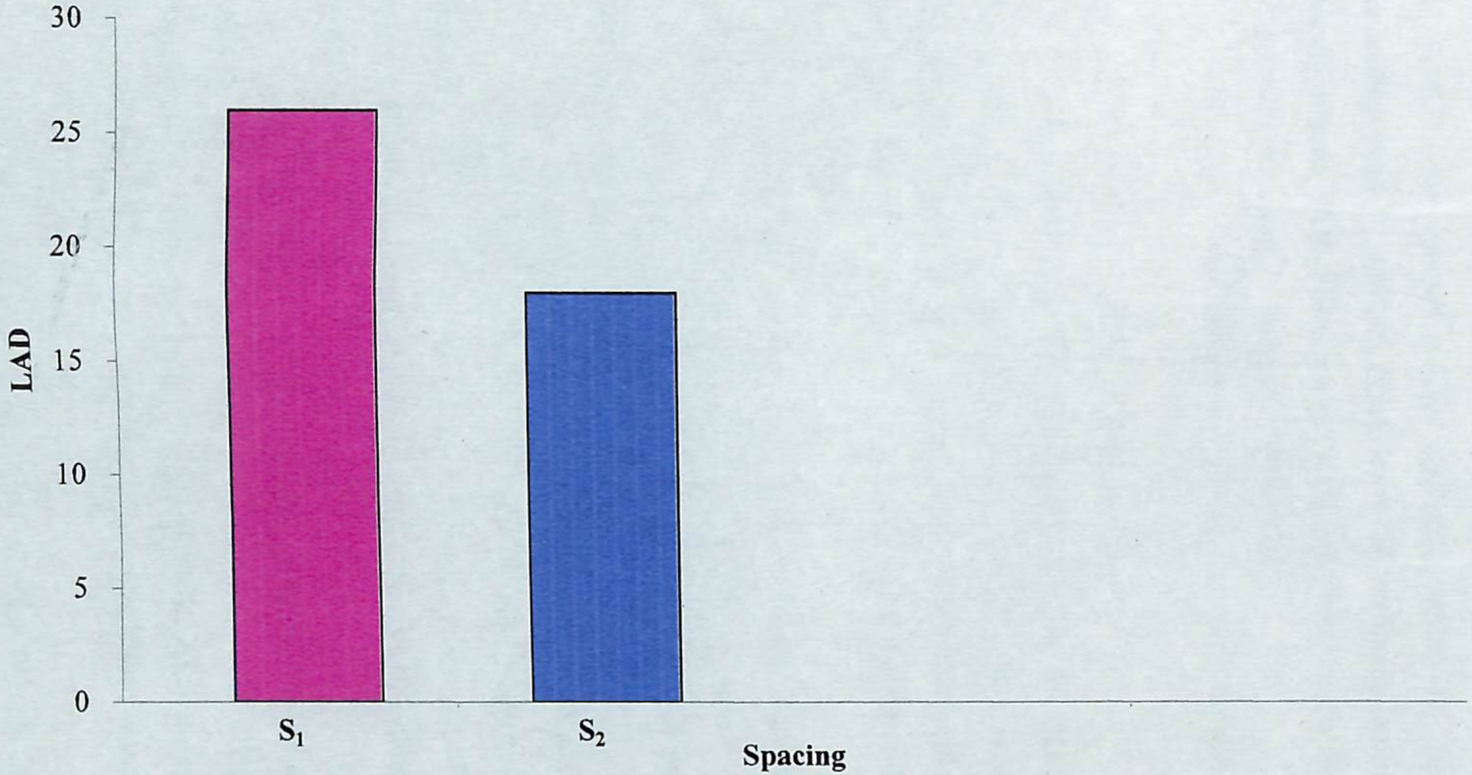
Fig 5. Effect of different levels of spacing on LAI





Treatments

Fig 7. Effect of different levels of spacing on LAD



Different levels of nitrogen and potassium gave a trend in delaying the flowering but it was not significant. Similar trend by John (1989) and Kanaujia *et al.,* (1997) were reported in chilli and pea respectively. Spacing also showed an increasing trend in delaying flowering with increasing spacing even though it was not significant. Mini (1997) has reported that plant density did not influence days to 50 per cent flowering in a significant manner.

No significant influence was effected by interaction between treatment levels.

5.2 YIELD AND YIELD ATTRIBUTES

Among the main effects a significant effect on pods per plant was noticed by spacing alone. More number of pods per plant was recorded by S_2 which was significantly superior to S_1. This may be due to less competition to the resources in the wider spacing treatment leading to increased productivity. Saharia (1988) also observed a similar result.

There was no significant influence on weight of dried pods per plant due to nitrogen, potassium and spacing and their interaction effect.

Though increased level of nitrogen decreased the pods per plot it was not statistically significant.

The effect of potassium on pods per plot was also not significantly different.

Because of more number of plants in S_1 treatment, more pods per plant was recorded but it was not significantly different. Even though more pods per plant were there in S_2, it could not result in more pods per plot because of less number of plants in S_2 (1.5 x 0.6m) spacing.

Among the interaction effect only interaction due to nitrogen, potassium and spacing had statistical influence on this character. $N_1K_2S_1$, $N_2K_1S_1$ and $N_3K_1S_1$ were superior and are on par. It may be noted that spacing S_1 has got a definite role in influencing the effect of nitrogen and potassium in interaction.

5.3 SEED CHARACTERS

Number of seeds per pod was not significantly influenced by nitrogen, potassium and spacing and their interaction effects. This may be due to the fact that nitrogen requirement of cowpea which is a leguminous crop is low when compared

Fig 8. Effect of different levels of spacing on pods per plant

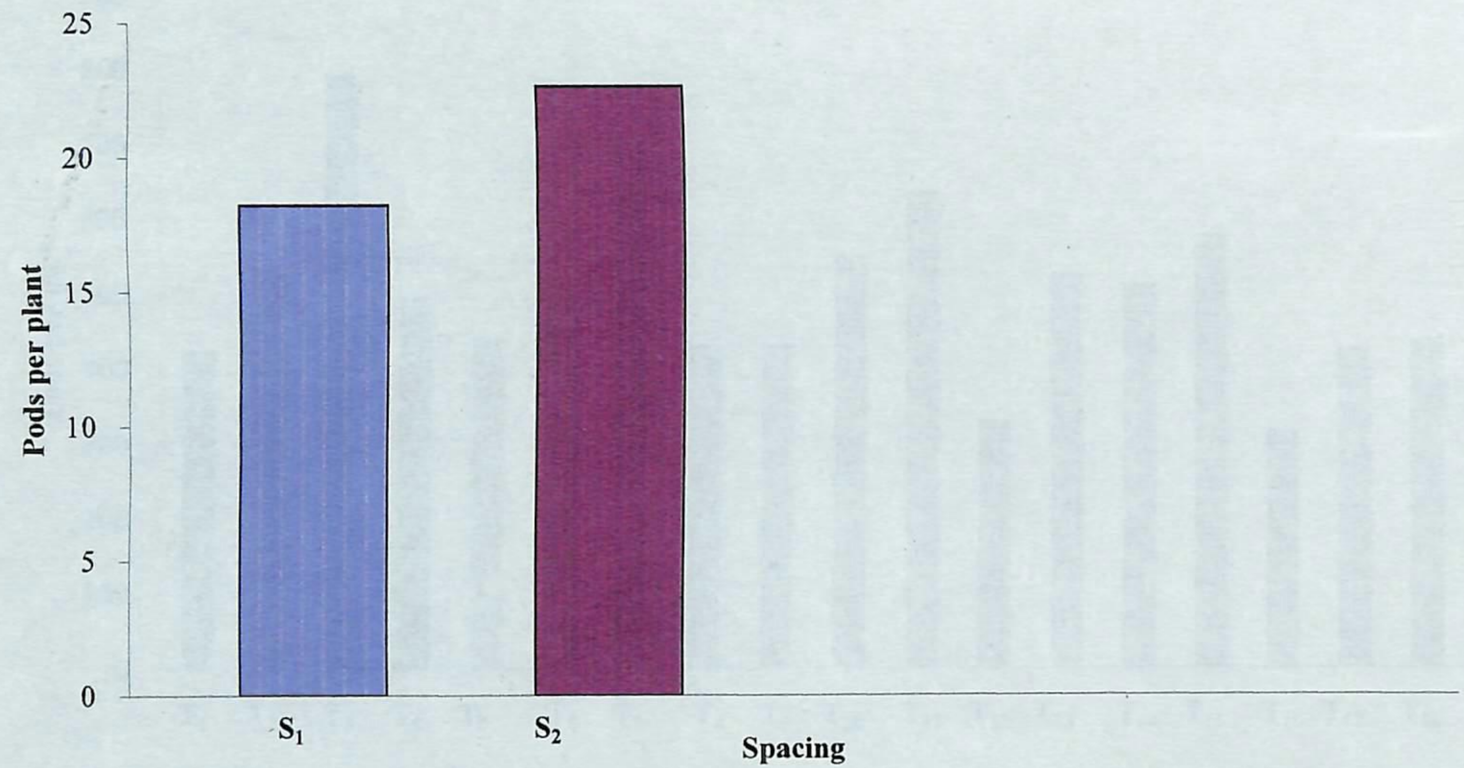
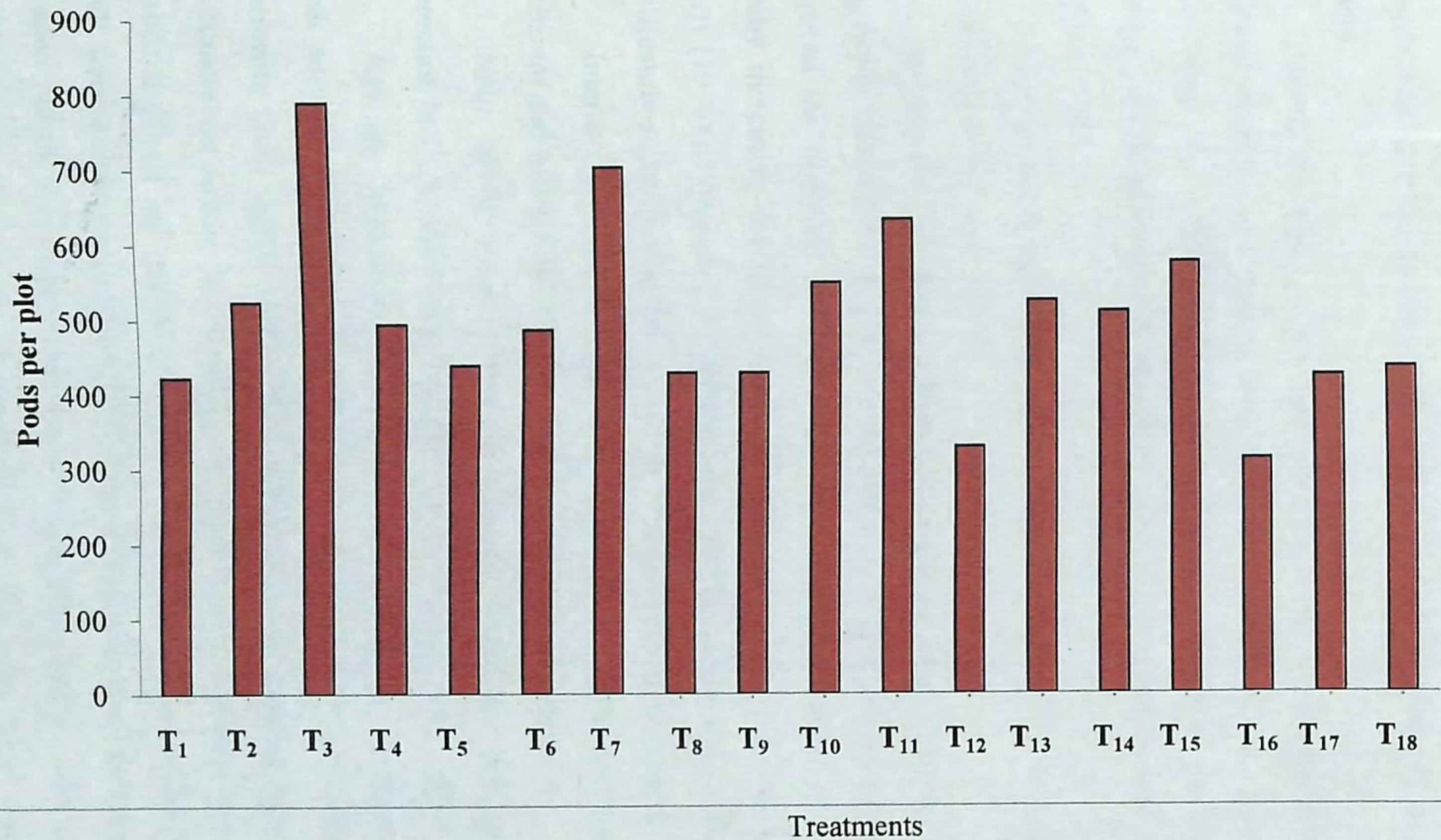


Fig 9. Effect of different levels of nitrogen, potassium and spacing on pods per plot



to other crops and the recommended level of grain cowpea is 20 kg N ha^{-1} (KAU 2002) and the levels of nitrogen tested were higher than the requirement and excess nitrogen may have a diminishing effect on the yield attribute viz. number of seeds per pod.

Among the main effects only potassium had significant influence on the weight of seeds per pod. The medium level K_2 (15 kg K_2 O ha^{-1}) gave significantly higher weight than other two levels K_1 and K_3 which were on par with each other. Mathew (1981) has reported that potassium has favourable role in influencing weight of seeds.

There was no significant effect due to main effect of nitrogen, potassium and spacing on pod to seed ratio.

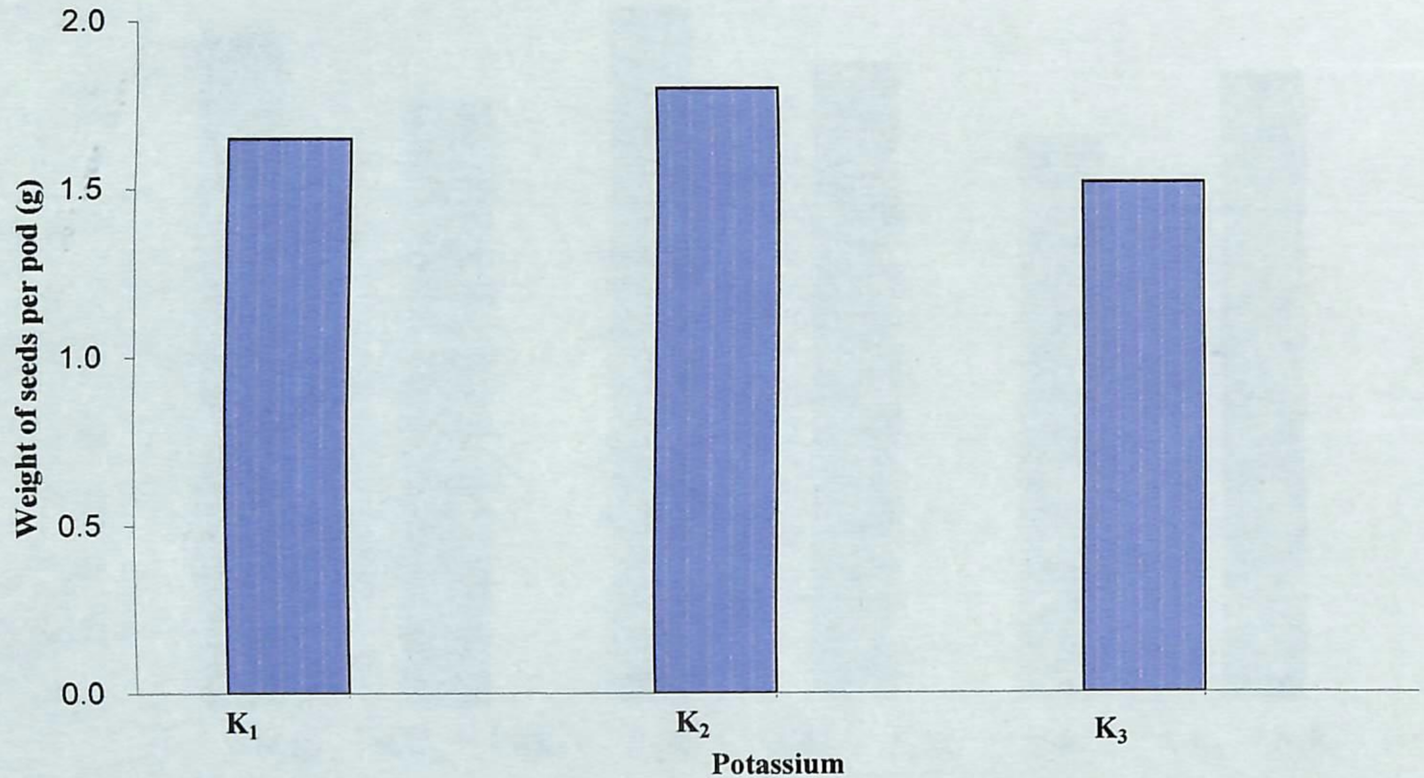
Among the interaction effect, interaction between nitrogen and potassium statistically influenced the pod to seed ratio. Nitrogen and potassium might have enhanced the production and translocation of photosynthates to growing points thereby increasing the number of pod producing nodes resulting in better pods. Sherly (1996) has reported similar findings in chilli. In the present study, N_1K_3 was significantly superior over the rest of the combinations of nitrogen and potassium.

Interaction between nitrogen and spacing, potassium and spacing, nitrogen potassium and spacing did not significantly affect this character.

None of the main effects of nitrogen potassium and spacing or their interaction had any statistically significant effect on 100 seed weight.

Nitrogen, potassium and spacing did not make any statistically significant effect on seed yield per hectare. From this result, one can infer that the levels of treatments with regard to nitrogen, potassium and spacing were found to be insufficient for testing in the field. As for nitrogen, the recommended level for cowpea is 20 kg ha^{-1} and it is normally less than the recommended phosphorus level, since phosphorus requirement is more than nitrogen, the treatment levels of nitrogen tested are more than this recommended level. More over, the soil contribution and symbiotic nitrogen fixation may also have contributed to the growth and yield characters since the level of nitrogen selected for testing in this experiment is found to be in excess. The lowest level of nitrogen is as good as the

Fig 10. Effect of different levels of potassium on weight of seeds per pod



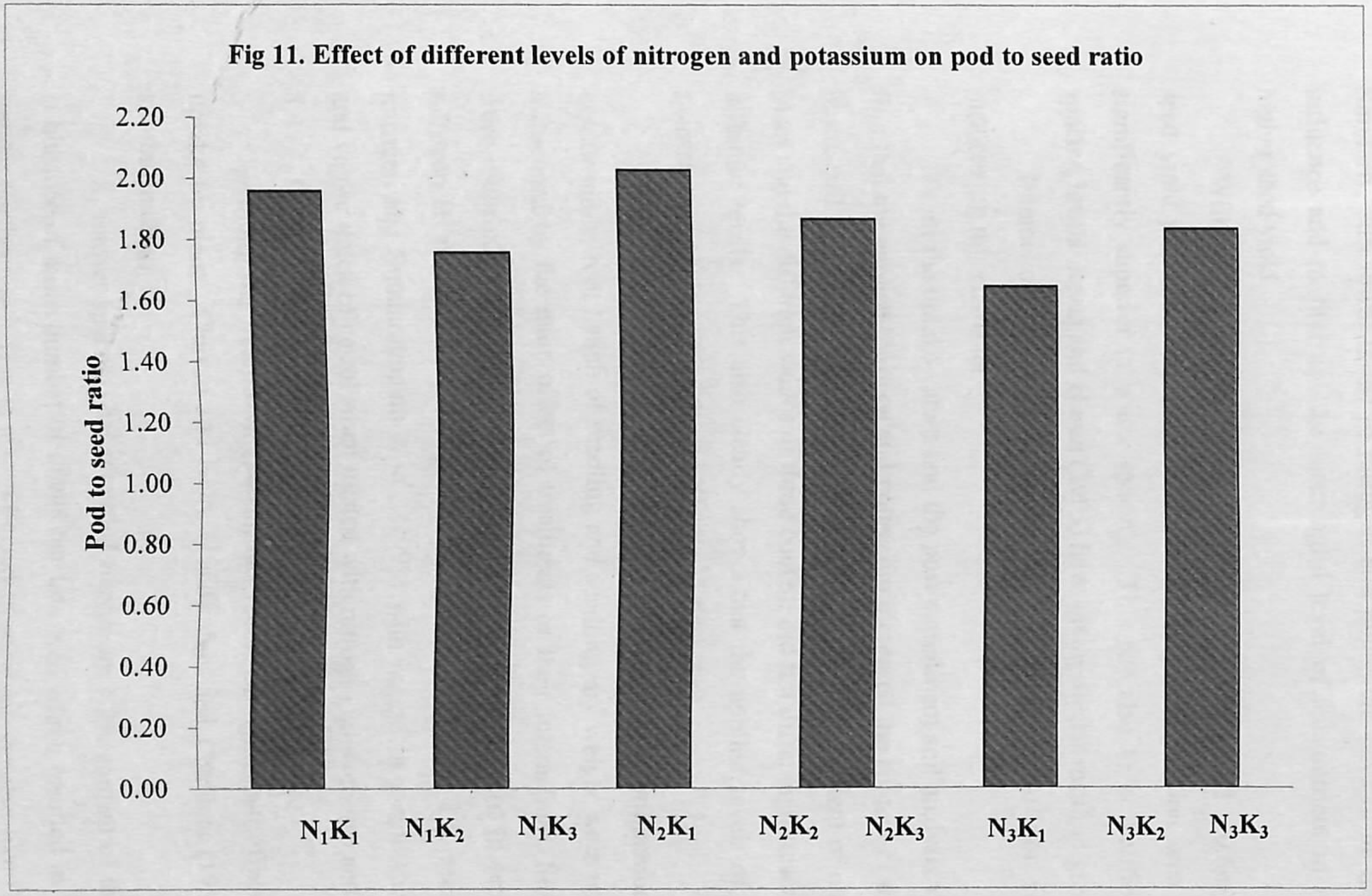


Fig 11. Effect of different levels of nitrogen and potassium on pod to seed ratio
Pod to seed ratio
2.20
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
N1K1
N1K2
N1K3
N2K1
N2K2
N2K3
N3K1
N3K2
N3K3

Treatments

highest level for recording the seed yield per hectare and other characters. Similarly, still lower levels of nitrogen and potassium have to be tested for their influence and to find out the meaningful level of this nutrient in recording the higher seed yield.

With regard to spacing though the closer spacing S_1 (1 x 0.6m) gave higher seed yield per hectare due to more number of plants per unit area but it is not significantly superior to wider spacing. This has also to be verified with more spacing levels. Rezai and Hasan (1995) have given similar result in green gram.

Interaction effect among the treatments was also not significant in influencing this character.

From the uptake values and the post experiment soil analysis values we can find that the applied nitrogen and potassium increased the content of these nutrients in the soil. There was no corresponding increase in the content of nutrients in the plant and the different values of these content did not differ significantly among the different levels. This also clearly shows that the applied levels of nitrogen and potassium are in excess of the requirement of the crop.

The other attributes of seed like seed viability, germination percentage, vigour index, root length of seedling and seedling dry weight were not statistically influenced by the main effect of treatments or their interactions. Similar findings were reported by Zanin and Mota (1995) in okra with regard to seed vigour and nitrogen levels, Vinay and Singh (1999) in okra with regard to seed quality and nitrogen and Sundaralingam *et al.*, (1998) with regard to germination percentage and vigour index of carrot when treated with nitrogen, phosphorus and potassium.

5.4 PLANT UPTAKE OF NUTRIENTS

Among the treatments spacing has recorded significant effect on the NPK uptake by plant. Chavan and Kalra (1983), Jain and Chauhan (1988) had given similar findings.

S_1 (closer spacing) has recorded maximum NPK content of the plant. This is because of more number of plants per unit area which resulted in the maximum uptake per hectare. This is also reflected in other parameters like DMP and seed yield per hectare.

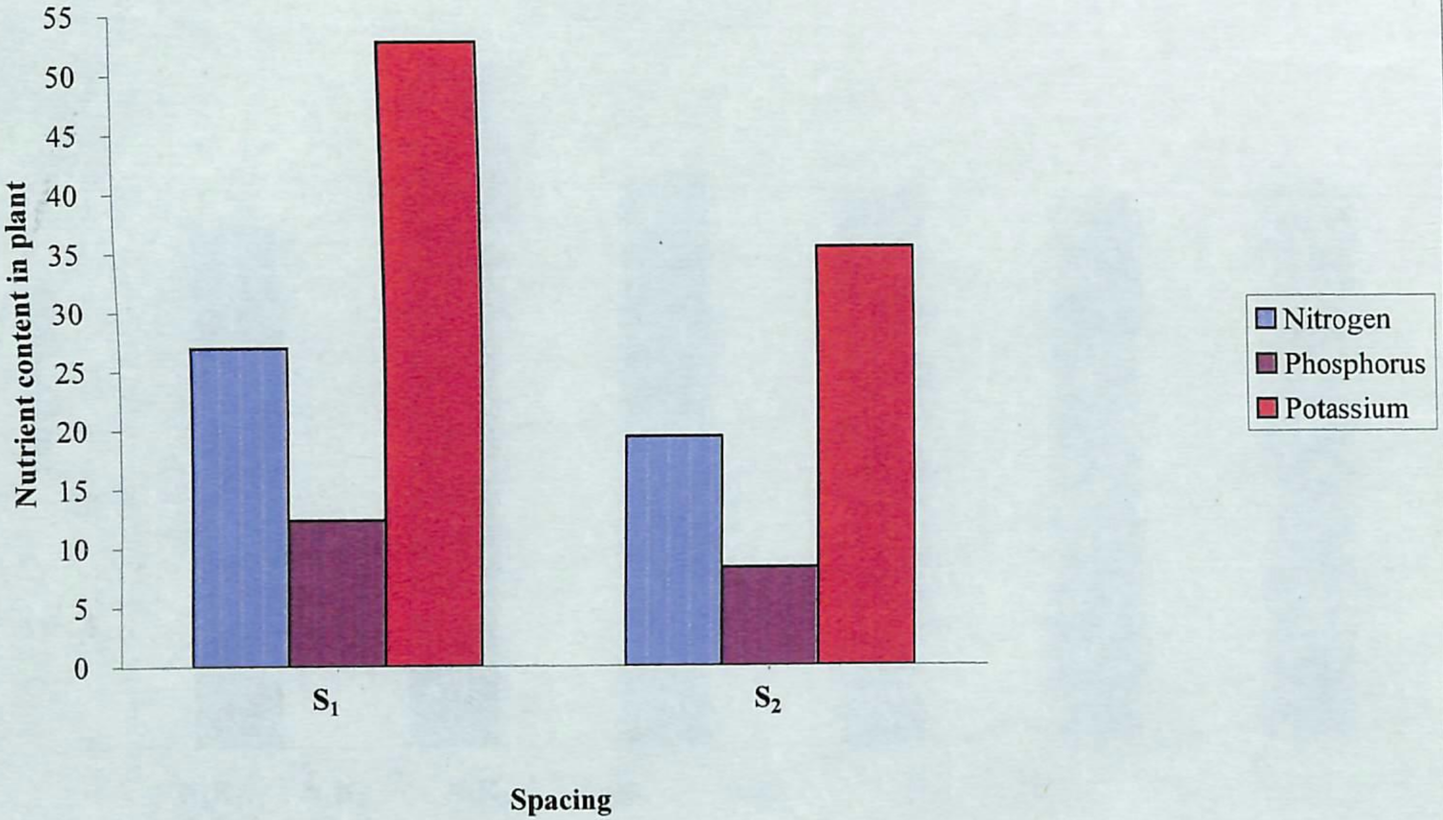


Fig 12. Effect of different levels of spacing on nutrient content in plant

Fig 13. Effect of different levels of nitrogen and potassium on plant nitrogen

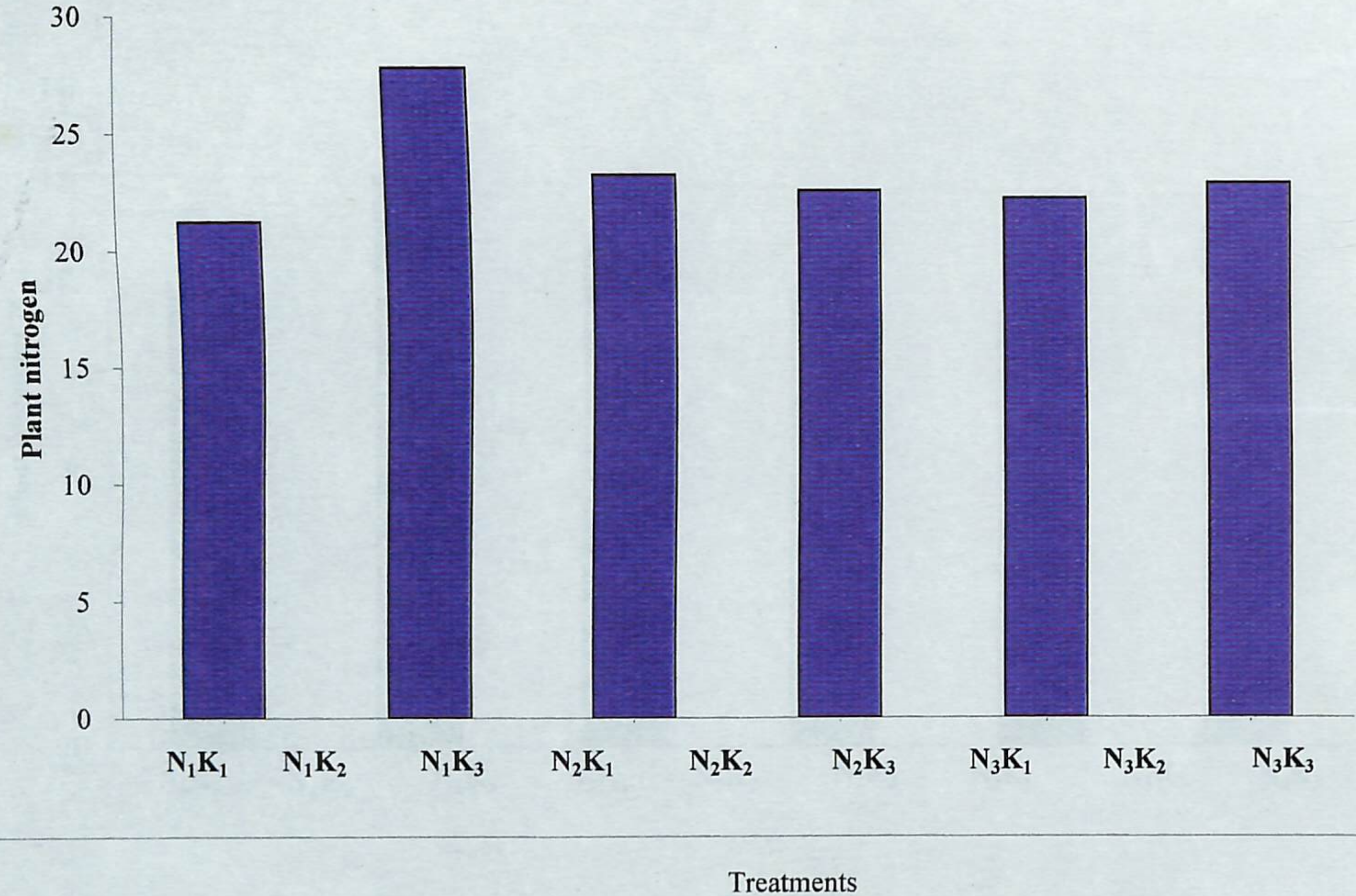
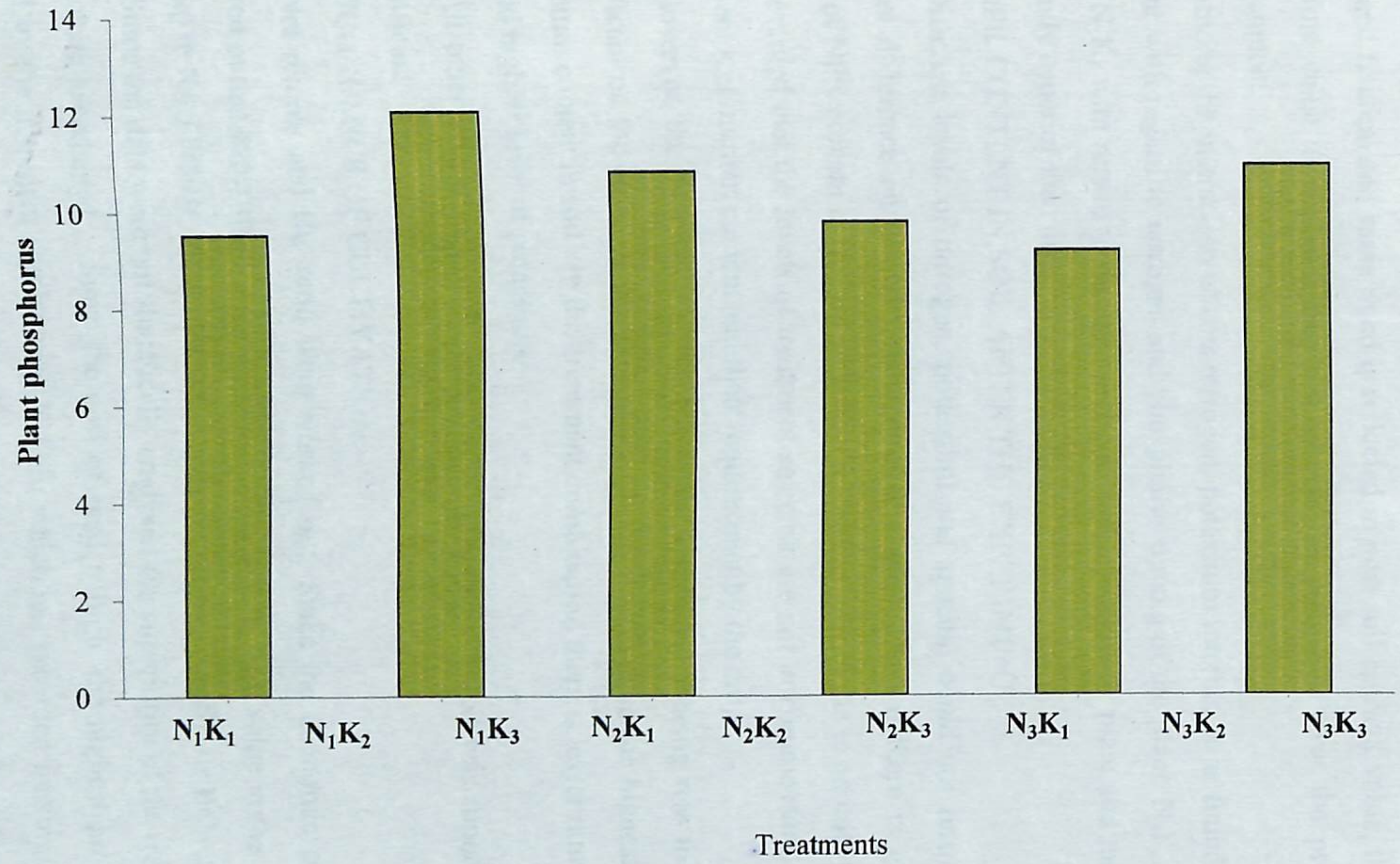


Fig 14. Effect of different levels of nitrogen and potassium on plant phosphorus



Poor effect on uptake of nutrient by other treatments namely nitrogen and potassium may be because the requirement of crop is easily met by other sources like soil and fixation and same trend is reflected in post soil nutrient value, though the absolute value in post soil nitrogen content has increased over the pre soil nitrogen content.

Among the interaction effects nitrogen, potassium interaction is found to be significant with regard to nitrogen and phosphorus uptake of the plant. N_1K_2 is on par with N_3K_1 with regard to nitrogen and phosphorus uptake by plant and they are significantly superior than other combinations.

5.5 NPK CONTENT IN SOIL AFTER THE EXPERIMENT

Different levels of nitrogen, potassium and spacing could not result in a significant difference on the NPK content in the soil. Even if there is general increase of NPK content in the soil than that before the start of the experiment. This clearly revealed that the levels of treatment selected are not in commensurate with the inherent soil nutrient content and their requirement by the crop.

However, the interaction effect due to potassium and spacing was found to be significant on the effect of soil potassium content. K_3S_2 gave the highest value of potassium content in soil. In this treatment combination there is lesser number of plants and highest level of potassium.

All other interactions with regard to NPK content of soil was found to be non significant.

5.6 ECONOMICS OF CULTIVATION

Net returns and BC ratio were worked out. Since the economic produce considered in this experiment is seed which fetches a very high value in the market returns up to Rs. 117501/- were obtained for the treatment $N_1K_2S_1$. Its BC ratio was 1.76. Since the data were not statistically analysed the superiority of the treatment could not be ascertained. Since the cost of seed is high, the highest profit was obtained by the treatment combination $N_1K_2S_1$ which has recorded maximum seed yield. This shows that the low level of nitrogen, closer spacing and medium level of potassium has played a role in fetching a higher profit.

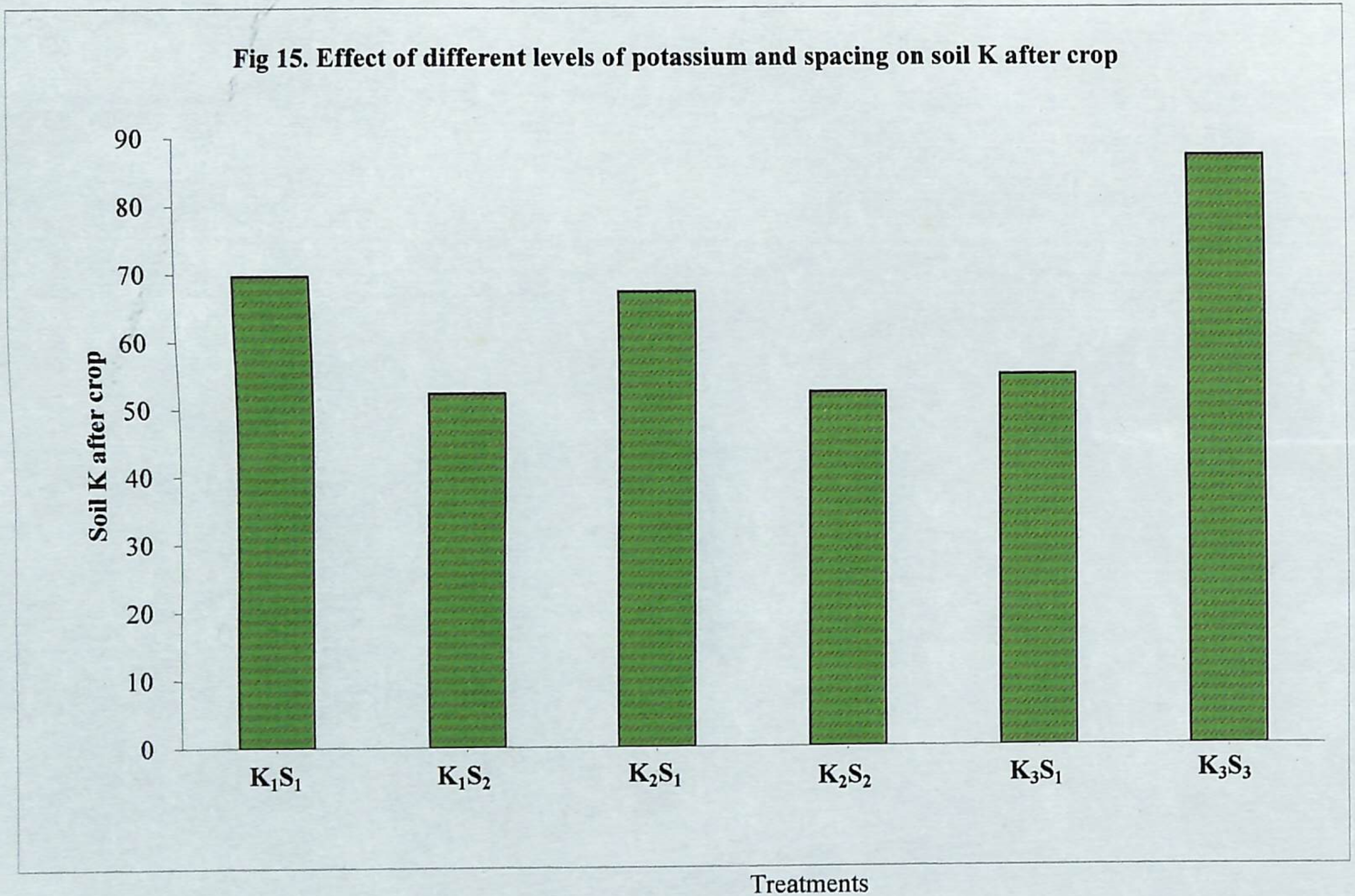


Fig 15. Effect of different levels of potassium and spacing on soil K after crop
Soil K after crop
90
80
70
60
50
40
30
20
10
0
K1S1
K1S2
K2S1
K2S2
K3S1
K3S3
Treatments

SUMMARY

6. SUMMARY

A field experiment was conducted in the Instructional Farm of the College of Agriculture, Vellayani during first week of January to third week of April 2001. It was done to evaluate the role of different agro techniques like application of major nutrients viz. nitrogen and potassium along with optimum spacing of plants for ascertaining the seed production potential of vegetable cowpea. The soil of the experimental site was sandy clay loam in texture, acidic in reaction and low in the status of available nitrogen, medium in available phosphorus and low in available potassium. The experiment was laid out in factorial randomized block design with three replications. The treatments comprised of three levels of nitrogen (N_1 – 30 kg N ha^{-1}, N2 – 45 kg N $ha^{-1}$and N_3 – 60 kg N ha^{-1}), three levels of potassium (K_1 – 10 kg K_2O ha^{-1}, K_2 – 15 kg K_2O $ha^{-1}$and K_3 – 20 kg K_2O ha^{-1}) and two levels of row spacing (S_1 – 1 X 0.6m and S_2 – 1.5 X 0.6m). Observations were made on growth, yield and seed characters of the crop, data were statistically analysed and the results of the study are summarised below.

1 Growth parameters like length of vine, branches per plant, shoot root ratio and days to 50 per cent flowering were not affected remarkably by the different levels of nitrogen, potassium and spacing.

2 In the case of dry matter content nitrogen and potassium did not affect it in a significant manner. But the spacing S_1 was significantly superior over S_2 in the case of DMC

3 Leaf area index differed significantly with nitrogen at 30 DAS. N_1 was superior to N_2 and N_3. But at 60 DAS all these levels did not affect the parameter significantly. Spacing S_1 was significantly superior than S_2 at 30 DAS and 60 DAS.

4 Leaf area duration was significantly affected by the lower level of spacing viz. S_1. But nitrogen and potassium levels did not differ markedly.

5 Pods per plant differed significantly with spacing. $S_2$was superior than S_1. Nitrogen and potassium levels did not make any significant influence over number of pods per plant.

6 Other yield characters viz. weight of dried pods per plant and total number of pods harvested per plot were not significantly influenced by the different levels of treatments.

7 Seed characters like seed per pod, pod to seed ratio, hundred seed weight, seed yield per hectare, seed viability, germination percentage, vigour index, root length of seedling and seedling dry weight also were not significantly influenced by the treatments.

8 In the case of the seed character weight of seed per pod, the second level of potassium (K_2) made a significant effect. K_2 was superior than $K_1$and K_3. Other treatments did not make any influence.

9 Soil nitrogen, soil phosphorus and soil potassium did not differ significantly in the plots with respect to the different levels of treatments.

10 Uptake of nitrogen, phosphorus and potassium was significantly higher for the lower level of spacing S_1. Different levels of nitrogen and potassium did not markedly influence the uptake of nutrients.

11 Interaction effect due to nitrogen and potassium significantly influenced DMC, pod to seed ratio and uptake of nitrogen and phosphorus by plants. All other characters were not influenced by this interaction.

12 Interaction effect due to potassium and spacing significantly influenced LAI at 30 DAS, seedling dry weight and potassium content of soil after experiment.

13 Interaction effect due to nitrogen, potassium and spacing affected the total pods per plot significantly. All other attributes remained uninfluenced.

14 The highest net returns per hectare and BC ratio were given by $N_1K_2S_1$ and the values are Rs. 117501 ha^{-1} and 1.76 respectively.

Future line of study:

More number of treatments towards higher and lower levels of nitrogen, potassium and spacing may be tested to get a significant effect for seed yield per hectare and other attributes. Since flowering in vegetable cowpea is of protracted nature the effect of the time of application of nitrogen and potassium towards pod formation with higher plant density may also be studied.

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*Originals not seen.

ABSTRACT

AGROTECHNIQUES FOR SEED PRODUCTION IN VEGETABLE COWPEA *[Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt*]* var. Sharika

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Abstract of the
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ABSTRACT

A field experiment was conducted in the Instructional Farm of the College of Agriculture, Vellayani during the period extending from first week of January to third week of April 2001 to study the effects of different levels of nitrogen, potassium and spacing on the growth characters, yield and yield attributes, seed characters and seed quantity, nutrient uptake and economics of cultivation for seed production of vegetable cowpea *(Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt) var. Sharika. The soil of the experimental site was sandy clay loam in texture, acidic in reaction, low in available nitrogen, medium in available phosphorus and low in available potassium. The treatment consisted of two levels of spacing (S_1 – 1 X 0.6m and S_2 – 1.5 X 0.6m), three levels of nitrogen (N_1 – 30 kg N ha^{-1}, N2 – 45 kg N $ha^{-1}$and N_3 – 60 kg N ha^{-1}) and three levels of potassium (K_1 – 10 kg K_2O ha^{-1}, K_2 – 15 kg K_2O $ha^{-1}$and K_3 – 20 kg K_2O ha^{-1}). The experiment was laid out in factorial randomized block design. An abstract of the result is given below.

Among the growth characters spacing had a significant effect on DMP,LAI at 30 and 60 DAS and LAD. For all these parameters the highest or the best values were given by the lowest spacing S_1 (1 X 0.6m).

Nitrogen and potassium were not able to influence any of the growth parameters in a significant way.

Among the yield characters spacing was able to make an impact on pods per plant. Here S_2 the wider spacing (1.5 X 0.6m) gave a significantly higher value.

With regard to the seed characters second level of potassium (K_2 – 15 kg K_2O ha^{-1}) has significantly influenced the weight of seeds per pod.

The first level of spacing S_1 (1 X 0.6m) has again influenced the NPK uptake of plants in a statistically significant way.

The interaction effect of potassium and spacing had significantly affected the growth character viz. LAI at 30 DAS. The treatment K_3S_1, i.e. 20 kg K_2O ha^{-1}

and 1 X 0.6m spacing was found to be the best among the combinations that influence the leaf area index.

The interaction of nitrogen and potassium has significantly influenced another growth character viz. DMP. Here N_3K_1 i.e. 60 kg N ha^{-1} and 10 kg K_2O ha^{-1} was found to be the best among the treatment combinations.

Interaction of nitrogen and potassium also influenced the seed character viz. pod to seed ratio. In this case N_1K_3 (30 kg N ha^{-1} and 60 kg K_2O ha^{-1}) gave the highest value. The interaction of nitrogen and potassium also significantly influenced the uptake of nitrogen and phosphorus. Both N_1K_2 (30 kg N ha^{-1} and 15 kg K_2O ha^{-1}) and N_3K_1 (60 kg N ha^{-1} and 10 kg K_2O ha^{-1}) had influenced the uptake of nitrogen and phosphorus in a significant way.

The interaction of nitrogen, potassium and spacing were able to significantly influence the yield character viz. pods per plot. $N_1K_2S_1$(30 kg N ha^{-1}, 15 kg K_2O ha^{-1} and 1 X 0.6m spacing), $N_2K_1S_1$ (45 kg N ha^{-1}, 10 kg K_2O ha^{-1} and 1 X 0.6m spacing) were superior with regard to this character.

Different levels of nitrogen, potassium, spacing and their interaction did not significantly influence other growth characters like length of vine, number of branches per plant, shoot root ratio, days to 50 per cent flowering, yield characters like weight of dried pods per plant and seed characters like hundred seed weight, seed yield per hectare, germination percentage, vigour index, root length of seedling, dry weight of seedling and seed viability.

Maximum profit was obtained (Rs. 117501/-) for the treatment combination $N_1K_2S_1$ i.e. 30 kg N ha^{-1}, 15 kg K_2O ha^{-1} and 1 X 0.6m spacing.

APPENDIX

APPENDIX

Weather data during the cropping period

PERIOD OF WEEKS			MAXIMUM TEMPERATURE (°C)	MINIMUM TEMPERATURE (°C)	RAIN FALL (mm) Weekly total	EVAPORATION (mm) Weekly total	RELATIVE HUMIDITY (percent)
2001							
January 8	– January 14	(1)	30.48	20.47	0.00	19.90	77.93
January 15	– January 21	(2)	30.24	19.70	0.00	23.00	76.29
January 22	– January 28	(3)	30.51	21.01	0.80	20.80	77.78
January 29	– February 4	(4)	30.53	21.04	16.20	18.40	77.86
February 5	– February 11	(5)	30.83	20.19	0.00	26.20	77.21
February 12	– February 18	(6)	31.44	20.29	0.00	26.00	75.07
February 19	– February 25	(7)	31.96	21.27	0.00	28.50	79.07
February 26	– March 4	(8)	32.34	20.27	0.00	31.10	76.57
March 5	– March 11	(9)	32.44	21.54	0.00	31.60	73.93
March 12	– March 18	(10)	32.37	21.76	0.00	34.20	71.36
March 19	– March 25	(11)	32.80	22.94	0.00	36.80	71.85
March 26	– April 1	(12)	32.26	23.60	0.00	37.00	68.78
April 2	– April 8	(13)	31.71	21.84	38.80	27.50	77.71
April 9	– April 15	(14)	30.08	21.37	48.80	21.00	79.86
April 16	– April 22	(15)	32.03	21.57	42.80	26.50	78.36
April 23	– April 29	(16)	32.00	22.58	32.60	26.50	81.36