COMPETITIVE AND COMPLEMENTARY EFFECTS OF BHINDI – COWPEA INTERCROPPING SYSTEM IN SUMMER RICE FALLOWS

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DECLARATION

I hereby declare that this thesis entitled **"Competitive and Complementary effects of bhindi — cowpea intercropping system in summer rice fallows"** 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 any degree, diploma, associate ship, fellowship or other similar title, of any other university or society.

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CERTIFICATE

Certified that this thesis entitled **"Competitive and complementary effects of bhindi - cowpea intercropping system in summer rice fallows"** is a record of research work done independently by Kala Rani, S. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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INTRODUCTION

LIST OF ABBREVIATIONS

g	- gram
kg	- kilo gram
mg	- milli gram
ha	- hectare
ha^{-1}	- per hectare
q	- quintals
t	- tonnes
BCS	- bhindi + cowpea intercropping system
N	- Nitrogen
P	- phosphorus
K	- potassium
M	- Metre
sq.m.	- square metre
BCR	- Benefit/cost ratio
RPL	- Return per rupee invested on labour
RPF	- Return per rupee invested on fertiliser
%	- per cent
POP	- Package of practices
Rs.	- Rupees

INTRODUCTION

In India, though a large variety of vegetables are produced, the daily per capita consumption of vegetables is only 18.5 kg which is much less than the requirement for a balanced diet (Shanmugavelu, 1989).

In Kerala, vegetables cover an area of 1.425 lakh hectares producing 1.62 lakh tonnes per year. About 50 per cent of our requirement is at present met by procurement from other states and thus 90 crores of rupees flow every year to neighbouring states for the purchase of vegetables alone. It is estimated that to bridge the gap between the demand and supply of vegetables, an additional 2.5 lakh hectare of area is to be brought under vegetables in Kerala (Report of Directorate of Agriculture, 1989).

Increasing the acreage under vegetables is rather difficult in the present situation. An acute shortage of vegetables and an acute scarcity of land area compel a Kerala farmer to exploit the full potential of the available limited land resources to the maximum possible extent through intercropping. The only way to enhance vegetable production is by cropping intensification in both time and space dimension i.e., by intercropping.

Vegetables are potential crops for the summer rice fallows of Kerala. Growing vegetables in the summer rice fallows is a common practice in Kerala. Bhindi is found to be the most profitable vegetable crop in summer rice fallows. In addition to its role as vegetable, bhindi has nutritional, economic and medicinal importance. Bhindi is very much suited for intercropping due to the slow initial growth and wider row spacing. By altering the row arrangement and adopting a paired row technique, intercropping can be made more profitable. Several studies had indicated the possibility of raising the crop successfully by adopting paired row technique (Olasantan and Aina, 1987; Olasantan, 1991).

Bhindi, being a soil exhausting crop, the inclusion of one quick growing leguminous crop like cowpea may benefit the companion crop through current nitrogen transfer and the succeeding crop through residual effect. There are several reports to show that inclusion of legumes in the cropping system had indeed benefited the associated crop and improved the soil nitrogen status, thus reducing the nitrogen application to the succeeding crop (Hall, 1974; Mandal et al. 1987; Stern, 1993).

The suitability of cowpea as an intercrop was studied in several experiments (Sheela, 1981; Geetha Kumari, 1989; Sunitha, 1990). Inclusion of vegetable cowpea in the system may provide another important vegetable to the farmer, besides improving the fertility status of soil. The cowpea variety Arka garima is bushy in habit and is reported to be suitable for partial shade situation (Raveendran and Kabeerathuma, 1991).

However, a quantitative analysis on the nitrogen requirement of such a system of intercropping has not been done so far and thus arise the necessity for taking up a study on the nitrogen management in bhindi + cowpea intercropping system.

Considering the above aspects, the present investigation was undertaken with the following objectives.

1. To find out the suitability of raising vegetable cowpea as an intercrop in bhindi
2. To find out a suitable planting geometry for a bhindi based intercropping system.
3. To study the nitrogen requirement of the intercropping system.
4. To work out the economics of the intercropping system.
5. To study the residual effect on the succeeding rice crop.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Vegetables are generally grown as sole crops in most of the situations. But recently some efforts are being attempted by scientists for exploring the possibility of intercropping vegetables with other crops or with other vegetable crops.

2.1. Intercropping practices involving vegetables

Vegetables were raised as intercrop with different types of base crops. Intercropping of vegetables with cereals were tried in many experiments.

Meenakshy et al. (1974) conducted an intercropping study on maize with different vegetables like bhindi, radish, cowpea, cluster bean, lablab, beet root, carrot and knolkhol. From the study, it was revealed that none of the vegetables that were intercropped along with maize had any significant adverse effect on the maize yield. The bhindi + maize combination has given the maximum additional return followed by cowpea + maize.

Uzo (1983) reported that in a mixed cropping study on maize, yam, bhindi and telfaria, only maize performed better when intercropped with one or two other crops. Mixed cropping did not favour yam, telfaria and bhindi.

Yield of cassava and maize was not seen affected by intercropping with bhindi or melon as reported by Ikeorgu et al. (1989).

Singh and Singh (1993) reported that when maize was intercropped with french beans, yield of maize was affected. The reduction in maize yield due to intercropping was 4.1%. Sole crop of french beans gave higher seed yield ha^{-1} than when grown as intercrop.

Reduction in yield due to intercropping was reported for wheat and french beans by Dahatonde et al. (1992).

Intercropping of sugarcane with vegetables was reported by many scientists.

Jayabal and Chockalingam (1990) reported that when sugarcane was intercropped with coriander, knolkhol, french beans, onion, radish, carrot, bhindi and cowpea, cane yield was not affected. However, the highest sugar yield (16.1 t ha^{-1}) and net return were obtained from the radish intercrop while the lowest sugar yield (12.8 t ha^{-1}) was obtained with bhindi intercrop.

Dixit and Misra (1991) observed that growing of intercrops like cowpea, bhindi and clusterbean in spring planted sugarcane were generally remunerative. Sugarcane + clusterbean intercropping was most profitable as it gave 18% higher cane yield and provided the highest net return.

Patil et al. (1991) found that it was possible to intercrop vegetables like bhindi, chilli, brinjal, onion and radish with sugarcane. The highest cane yield was recorded when sugarcane was intercropped with radish which was followed by sole crop of sugarcane and sugarcane + onion and the lowest yield of sugarcane was recorded under sugarcane + palak intercropping.

Intercropping sugarcane with tomatoes, cowpea, tinda, guar and bhindi decreased its yield by 15.8,19.3, 4.4, 12.8 and 22.3% respectively. Sugarcane + tinda produced highest return (Kumar et al. 1993).

Yadav and Prasad (1990) reported that when french bean was intercropped with sugarcane, bean yield was significantly affected by cultivar and population density. The long duration variety of french bean (PDR 14) and the higher population density adversely affected sugarcane shoot density due to increased plant competition and shading.

Intercropping of chilli with cotton and onion indicated that yields of chilli, cotton and onion were significantly higher under sole cropping than under intercropping. But gross return was higher in intercropped treatments than in sole crop treatments which indicated that intercropping was more profitable than sole cropping of cotton or chilli or onion (Dodamani et al., 1993).

Ramamurthy et al. (1993) reported that in chilli + finger millet intercropping system, the number of productive tillers per hill of finger millet was significantly higher in intercropping than in sole cropping, whereas, fruit yield of chilli was significantly lower under intercropping than under sole cropping.

Walter Dedio (1991) reported that intercropping of sunflower with garden pea gave an yield advantage upto 30%. The yield of sunflower was 12% more when it was inter cropped with peas than the sole crop yield of sunflower. The yield of peas, on the other hand, was depressed by about 32-50% when it had sunflower as a companion crop.

Aiyellagbe and Jolaoso (1992) found that intercropping of papaya with bhindi, water melon, sweet potato, amaranthus and potato indicated that all combination was more advantageous than the monocrop of papaya. A relay of bhindi followed by Jews' mallow (or sweet potato grown for fodder) was found suitable for alley cropping of papaya.

Budisantoso et al. (1991) conducted a study to determine the effect of intercropping vegetable crops on mulberry leaf production. He found that intercropping of potato, cabbage and tomato did not affect the mulberry leaf production.

A study on the effect of alley cropping with Leucaena leucocephala and fertiliser application on yield of vegetable crops revealed that bhindi plants in alley cropped plots were taller than those in control plots. Fruit number of bhindi did not differ between alley cropped and fertiliser control treatments (Palada et al., 1992).

Sheshadri et al. (1992) reported that it is possible to intercrop tobacco with vegetables like chilli and cowpea.

But maximum yield of tobacco was reported under sole crop of tobacco.

Vegetables were intercropped with other vegetables also. The information about the vegetable based intercropping system is inadequate. But a few workers have made some effort to evaluate the effect of intercropping on growth and yield of some of the vegetables.

Prabhakar and Srinivas (1982) reported that it was possible to intercrop bhindi with radish, cowpea and clusterbean. But returns from bhindi was reduced to about 11-18% due to intercropping. On the other hand, both cowpea and radish performed better when intercropped with bhindi.

Ramachander et al. (1989) found that it was possible to intercrop bhindi or chilli with peas, onion and knol knol. Highest yield of bhindi was recorded under bhindi + knolkhol intercropping system. In the case of chilli, highest yield was obtained in chilli + onion combination.

In rainfed areas of chottanagpur, intercropping of bhindi with cowpea or tomato was found to be suitable (Singh, 1990).

An experiment to study the feasibility of growing amaranthus on the growth and yield of bhindi proved that intercropping of bhindi with amaranthus recorded more fruit yield (10.36 t ha^{-1}) than pure crop of bhindi (9.66 t ha^{-1}). The economics of cultivation indicated that intercropping of vegetables resulted in higher economic return of Rs. 290/-

as against Rs. 5096/- recorded by growing bhindi alone (Prasanna Kumari Amma and Seemanthini Ram Das, 1991).

Ikeorgu (1990) conducted a glass house study on celosia, amaranthus and corchorus intercropping. The study revealed that intercropping is more advantageous than sole cropping of these crops.

On the contrary, negative influence of intercropping was also reported by some workers.

Olasantan (1985) conducted a study on bhindi + tomato intercropping and reported that when tomato was intercropped with bhindi, reduction in yield due to intercropping was more marked with the improved variety of tomato than with the local variety. The decrease in yield of improved tomato varieties and bhindi in the mixtures could be due to the severe interplant competition of both crops for nutrients, moisture and incident light.

Kadalli et al. (1988) reported that there was reduction in dry matter production of chilli when it was companioned with onion. The yield of chill was maximum in sole crops.

Singh (1991) reported that intercropping of tomato with peas, french beans, radish and onion reduced the number of fruits and fruit weight compared with pure crop of tomato. However, among the intercropping system, tomato + onion gave a significantly higher net return compared with other treatments and also tomato as a pure crop.

Natarajan (1992) reported that intercropping of chilli with different vegetables like country onion, bhindi, coriander and cowpea in two systems of planting of chilli adversely affected the growth of chilli. The economics revealed that bhindi was the best intercrop for chilli.

Intercropping studies have been reported in cole crops also. Intercropping of cabbage with radish, palak, methi, chakwat and knolkhol have shown that there is no significant reduction in yield. However, mean weight of head of cabbage was reduced by intercrops. Significant reduction in yield of cabbage was observed in cabbage + knolkhol intercropping system (Chavan et al., 1985).

Cauliflower was another main crop in the same study. Intercrops were beetroot, radish, lettuce, knolkhol, palak, green onion, coriander, chakwat, palak and methi. Mean weight of curd of cauliflower was reduced by intercrops. Significant reduction in yield of cauliflower was observed in cauliflower + beet root intercropping. From the economic consideration, use of radish or palak as an intercrop in these cole crops was found to be profitable.

It is possible to intercrop vegetables successfully with cassava.

Thomas et al. (1982) reported that intercropping of cassava with french bean was remunerative and it was possible to get an additional income of Rs.2400 ha^{-1} over a pure crop of cassava. Biju (1989) also found that intercropping of cassava with french bean is profitable.

Muthukrishnan and Thamburaj (1979) observed a reduction in growth and tuber yield of cassava plants when intercropped with cowpea.

Madhava Rao et al. (1986) reported that intercropping cassava with cowpea significantly lowered the stem thickness and vegetative yield of cassava.

Schultz et al. (1982) reported that intercropping of cucumber + tomato was efficient as the LER value was more than unity.

Olasantan (1985) conducted a study on bhindi + tomato intercropping systems. In mixed stands, bhindi and tomato were sown at spacing of 90 X 30 cm and 90 X 40 cm to give population densities of about 37,000 and 28,000 plants ha^{-1}. In monocultures, bhindi and tomato were sown at 60 X 30 cm and 60 X 40 cm to give population densities of about 65,000 and 42,000 plants ha^{-1} respectively. The relative yield due to intercropping between tomato variety and bhindi was less than one, while the sum of relative yield was greater than one.

Narwal and Ved Prakash (1989) reported that in an intercropping study on potato with gobhi sarson and mustard, intercropping of gobhi sarson produced higher LER (1.34) than Indian mustard intercropping (1.21).

The above mentioned references clearly indicated the possibility of growing vegetables as intercrop either with other annual or perennial crops or with other vegetable crops.

2.2 Planting geometry as influenced by intercropping

Yield advantages in intercropping occurs because component crops differ in their use of growth resources in such a way that when they are grown in combination, they are able to complement each other and so make better overall use of resources than when grown separately (Chatterjee et al., 1989).

For achieving this type of complementarity, the planting geometry of component crops should be optimum. Recent studies have shown that crop interactions modify the populations and planting pattern requirement and what is optimum under sole crop situation need not necessarily be optimum in intercropping.

2.2.1. Effect of planting pattern on growth character

Fowsi (1985) reported that in maize + bhindi intercropping system, bhindi plant grown in alternate rows with maize had the least number of branches, tallest stem and least dry matter production.

Olasantan and Aina (1987) reported that the best planting ratio for bhindi/tomato + cowpea intercropping system was one row of bhindi or tomato to one row of cowpea. They found that when bhindi + cowpea were planted in alternate rows, the plant height and leaf area per plant of bhindi were increased, but slightly reduced the branch number compared to alternate pairs of row. However, maximum plant height, leaf number per plant and leaf area were recorded under sole crop of bhindi.

Biju (1989) conducted a study on planting geometry and double intercropping in cassava with groundnut and french beans. From the study it was found that groundnut intercropped with cassava planted in ordinary method produced maximum plant height but reduced the number of branches and functional leaves compared to paired row method of planting. The sole crop of groundnut recorded the highest value for leaf area index at all stages of growth compared to groundnut intercropped with cassava.

Narwal and Ved Prakash (1989) conducted an experiment on intercropping of gobhi sarson and Indian mustard with potato in row ratios of 1:2, 1:3, 1:4, 2:2, 2:3 and 2:4 respectively. From the study it was found that paired row intercropping of gobhi sarson or Indian mustard with potato decreased the leaves of potato (13.0%).

Natarajan (1992) conducted a study on intercropping in chilli. The treatments included six intercrops viz. country onion, bhindi, coriander, green gram, blackgram and cowpea in two systems of planting of chilli. Under paired row system, a spacing of 60 cm between two paired rows and 30 cm between two rows within the pair and between the plants in the row were followed. The plant height was comparatively higher in paired row system than that in normal row system. It was the lowest in the treatment with cowpea as intercrop in normal row system. Among the treatments, chilli +coriander under paired row system recorded taller plants with more number of branches.

Dhingra et al. (1991) reported that in maize + mung bean intercropping systems, paired planting (2:2) recorded maximum total LAI. In the case of maize alone, LAI was maximum in alternate row (1:1) arrangement, whereas, in mung bean maximum LAI was recorded in 2:2 planting pattern.

On perusal of the review, it is clear that growth parameters like plant height, number of leaves, leaf area, branches etc. are influenced by different planting pattern.

2.2.2. Effect of planting pattern on yield, yield attributes and Economics

Ojeifo and Lucas (1987) considered that the best planting ratio for corchorus + tomato intercrop was two rows of corchorus and one row of tomato for maximum yield of corchorus. They found that to get maximum economic return from corchorus + tomato intercropping, the best row ratio should be one row of corchorus to two rows of tomato.

Experiment on intercropping tomato or bhindi with cowpea indicated that this system is more productive than sole cropping owing to the complementary effect of intercropping partners which were generally sown in alternate rows. The number of fruits per bhindi plant was more in alternate rows than in alternate pairs of rows and per plant yield was also maximum in alternate rows (Olasantan and Aina, 1987).

Narwal and Vedprakash (1989) found that paired row intercropping of gobhi sarson or Indian mustard with potato decreased the tuber yield of potato as compared to single row intercropping.

Biju (1989) conducted a study on planting geometry and double intercropping in cassava with french beans and groundnut and showed that cassava planted in paired rows with groundnut and french bean as first and second intercrop respectively recorded the maximum number of tubers per hill. The minimum number of tubers per plant was produced by cassava planted in ordinary method with groundnut as intercrop.

Yadav and Prasad (1990) reported that in sugarcane + french bean intercropping with systematic row arrangements of 1:1 and 1:2, yield of french bean was significantly reduced in 1:1 row arrangement. Sugarcane production was significantly lesser in 1:2 as compared to 1:1 row arrangement. It may be due to the competition for growth factors and shading effect.

Prasad and Singh (1991) conducted an experiment to evaluate the crop association of Kent oats and chinese cabbage. Nine intercrop combination viz. oats (Sole), Chinese cabbage (sole), oats + Chinese cabbage in 1:1, 2:2, 2:1, 1:2, 3:1 and 1:3 ratios were tested. The best row ratio was 1:2. It was also found that intercropping of oats and chinese cabbage in 1:1 row ratio was better than 2:2 row ratio.

Kushwah and Masood Ali (1991) reported that in french bean + potato intercropping system, reduction in yield of both the crops were observed due to intercropping irrespective of planting geometry.

Sheshadri et al. (1992) reported that in intercropping of tobacco with chilli, cowpea, redgram, groundnut, sesamum and soybean under paired and normal planting pattern, there was reduction in yield of tobacco due to intercropping. It was found that 2:2 planting pattern significantly reduced the total cured leaf yield as compared to normal planting of tobacco.

Natarajan (1992) found that intercropping of chilli with vegetables like onion, bhindi, coriander, green gram and cowpea, the intercrops except onion and coriander significantly reduced the yield of chilli. The sole crop of chilli recorded the highest yield of 1.944 t ha^{-1} followed by the treatment with coriander under paired row system recording 1.685 t ha^{-1} respectively. The yield of intercrops were the lowest in paired row system than in normal row system in all the treatments.

Misra et al. (1993) conducted an experiment on intercropping of arum with onion and radish at 1:1, 1:2 and

1:3 row ratios. They found that higher yield was obtained by intercrop under higher plant population (1:3). Variation in plant population from single row to triple row increased the yield by 44.02% in onion and 45.26% in radish. This was due to better utilisation of space and radiant energy by photosynthetic surface.

Intercropping of potato with sugarcane revealed that double row intercropping of potato recorded higher yield (17 t ha^{-1}) as compared to single row intercropping of potato (13.4 t ha^{-1}) (Yin and Yang, 1994).

Tathode and Dhoble (1987) reported that in sorghum + pigeonpea intercropping system with different planting patterns viz. paired, normal and skip row planting, paired row planting pattern with intercrop gave significantly higher yield over normal planting pattern.

Dhingra et al. (1991) found that in maize + mung bean intercropping systems with 1:1, 2:1, 2:2 planting pattern, one row of mung bean planted between two normal spaced maize rows was the best planting pattern. Maximum maize yield was recorded in 1:1 planting pattern, whereas, 2:2 planting pattern recorded maximum mung bean yield.

Bezerra Neto et al. (1991) reported that in cotton + cowpea intercropping system with different planting pattern, the productivity of cotton with 2 rows of cotton for every one row of cowpea (2:1) was superior to the 1:1 row arrangement. The number of cowpea plants did not affect the yield of cotton greatly.

Singh et al. (1992) reported that in an experiment on intercropping of chickpea with wheat, barley, mustard and lentil at different planting patterns viz. 2:2, 4:2 row ratios, it was revealed that the paired row planting system (30/60 cm)of chickpea yielded 52% more than normal planting (30 cm) and reduction in chickpea yield due to wheat as intercrop in this pattern was only 31 per cent. It may be due to sufficient light interception through the space provided between pairs as compared to 30 cm row planting where dense canopy at flowering stage restrict the transmission of light to lower parts.

Sarkar and Pramanik (1992) conducted a study on sesamum + mung bean intercropping system with different planting patterns as mung bean in paired rows of 30/60 cm with one row of sesamum, sesamum + mung bean in alternate rows at 37.5 cm apart and sesamum + mung bean in alternate pairs of rows. From the study it was revealed that yield of sesamum + mung bean at their average row spacing of 37.5 cm in 2:2 row ratio planting pattern gave higher total yield of 11.3 q ha^{-1} followed by 10.7 q ha^{-1} in 1:1 row ratio and 10.1 q ha^{-1} in paired row planting of mung bean with one row of sesamum.

Narwal and Ved prakash (1989) found that intercropping of gobhi sarson or Indian mustard with potato increased the net return (48.6%) compared with their sole crops. Single row intercropping of gobhi sarson or Indian mustard with potato was highly economic (Rs. 13848 ha^{-1}) than paired row intercropping (Rs.11467 ha^{-1}). Intercropping of one row of gobhi sarson and three rows of potato (1:3)gave maximum net returns (Rs.14930 ha^{-1}) because both the component crops gave the maximum yield.

Prasad and Srivastava (1991) conducted an experiment on pigeonpea and soybean intercropping system with row arrangements 1:1 (60 cm apart) and 2:2 (30/90 cm) and found that 1:1 row arrangement of pigeonpea + soybean (Var. Bragg) gave the maximum net return.

Sarkar and pramanik (1992) reported that in sesamum + mung bean intercropping with 1:1, 2:1 and 2:2 row arrangement, the highest net return and benefit/cost ratio were recorded when sesamum and mung bean were intercropped in 2:2 planting pattern.

Natarajan (1992) conducted an experiment on intercropping in chilli with different vegetables. From the study, It was found that chilli + bhindi combination was the best recording the highest gross income of Rs.29,660 ha^{-1} under normal row system followed by Rs.25,960 under paired row systems as against Rs. 19,440 by the pure crop of chilli.

From various references, it is clear that planting pattern has a significant influence on the yield and economics of the intercropping system. When some plants gave higher yield under normal row planting pattern, some plants gave higher yield under paired row system.

2.2.3. Effect of Planting pattern on biological efficiency

Calculation of the basic biological efficiency of a given intercropping system is always worthwhile in any evaluation process. By studying the biological efficiency, the farmer can adjust the amount or proportions of crops by growing an appropriate ratio of the intercrop and one of the sole crops (Willey, 1979).

Venkateswarlu (1987) reported that in castor + clusterbean intercropping systems with 1:1, 2:1 and 2:2 row arrangements, there was a marginal increase in the productivity under 1:1 (LER = 1.2) and 2:2 (LER = 1.23) planting pattern of castor + clusterbean intercropping system as compared to 2:1 planting pattern.

Olasantan (1988) reported that in maize +melon intercropping, maize intercropped with melon in alternate pairs of rows (2:2) gave the best LER with very little reduction in melon seed yield.

Narwal and Ved Prakash (1989) reported that in an intercropping study on potato with gobhi sarson and mustard, the LER of gobhi sarson or Indian mustard was maximum in 2:2 and 2:3 row ratios and that of potato in 1:3 and 1:4 row ratios, owing to greater population of gobhi sarson or Indian mustard in the former and of potato in the latter ratios. Planting of potato in single row intercropping gave higher LER than in paired row intercropping.

Singh and Singh (1993) observed that paired maize + lentil in 1:3 ratio gave the higher LER followed by paired maize + french bean in 1:2 ratio.

Sarkar and pramanik (1991) reported that in a study on the effect of planting pattern in sesamum + mung bean with 2:1 and 1:1 row arrangements, aggressivity value indicated that it was positive for mung bean with most of the intercropping systems except mung bean in paired row planting. Sesamum was more competitive when intercropped with paired row planted mung bean.

Prasad and Singh (1991) reported that in oats + chinese cabbage intercropping systems in seven crop combination, the ATER did not give any advantage over pure stands.

Ravishankar and Sheela Vantar (1992) found that intercropping of sunflower and pigeonpea under 2:1 row proportion with 45 cm row spacing was found efficient and produced 18 per cent higher seed yield per unit area and time (ATER 1.18) than either of the sole crops.

Giri et al. (1983) reported that in an intercropping study on pigeon pea with mung bean, soybean and groundnut with 2:1, 2:2, and 1:1 row arrangement, it was found that grain yield equivalent was increased significantly by intercropping groundnut in two rows in the interspace of paired rows of pigeonpea (2:2) over all the other treatments.

2.2.4. Effect of planting pattern on dry matter production and nutrient uptake

Reddy et al. (1986) reported that when groundnut and pigeonpea were intercropped at three different row arrangements (4:1 5:1 and 6:1 with sole crop optimum population of groundnut (3,33,000 plants ha^{-1}) and three plant populations (301,000, 45,000 and 60,000 plants ha^{-1}) and 8:1 arrangement (which was farmers practice), the dry matter (kg ha^{-1}) of groundnut at harvest was significantly higher in sole groundnut than in intercropping treatments. Row arrangement of 5:1 on an average gave more dry matter than the remaining ones. At narrow row arrangement of 4:1, higher plant density of pigeonpea (100%) significantly reduced the dry matter of groundnut compared to wider row arrangements of 5:1, 6:1 and 8:1. The dry matter production of sole pigeonpea was significantly higher than any of the intercropping treatments. The 5:1 row arrangements produced maximum total dry matter (7409 kg ha^{-1}).

Birajdar et al. (1987) reported that in a nutrient uptake study in cotton intercropping system the uptake of nitrogen and phosphorus was not influenced significantly by different planting patterns. However, the normal planting pattern and narrow row spacing of cotton crop improved the Potassium uptake.

Studies on the nutrient uptake by rabi ratoon sorghum intercropped with cowpea under normal, paired and skip row planting pattern have shown that uptake of nitrogen by ratoon sorghum was not influenced significantly by the planting pattern and intercropping. However, the uptake of phosphorus and potassium was more in paired and normal planting and sole crop treatments. It was the lowest in the treatments of skip row planting and intercrop of cowpea for grain (Thawal and Pawar, 1988).

Biju (1989) reported that different planting geometry and double intercropping of cassava with groundnut and french bean did not affect the nitrogen, phosphorus and Potassium uptake of cassava and NPK contents of bhusa of groundnut and french beans.

It is seen from various references that nutrient uptake is increased by intercropping in some situations irrespective of different planting pattern, whereas, in some cases, nutrient uptake is maximum under sole cropping.

2.3. Nitrogen Management in Intercropping system

The legumes and non-legume species tapping different nitrogen sources (Hall 1974) may probably be the reason for their yield advantage when grown together over their monocultural alternatives (Trenbath, 1976). Legumes do not compete for nitrogen with the component crop and provide some nitrogen benefit (Weighmare and Nangju, 1976; Eaglesham et al., 1981; Singh, 1981) to a non-legume growing in association or a residual benefit to a subsequent crop (Seark et al., 1981; Mandal et al., 1987). Besides nitrogen available in the soil or applied in fertilizers, the most important source of nitrogen in a non-legume + legume intercropping system is the nitrogen fixed by the legume. Generally nitrogen transfer during the current season is small and most transfer occurs at the end of the legume crop cycle (Stern, 1993).

While in some circumstances intercropping with a legume may not contribute significantly to the total nitrogen economy, the loss of nitrogen from a comparable non-legume stand will be much greater (Ofori and stern, 1987). Their another finding is that shading of the legume by the non-legume component will reduce the growth of the legume and so reduce the amount of nitrogen fixed. Produce harvested from the component crop is likely to be the largest source of nitrogen loss from the intercrop system and can range from 50 to 150 kg N ha^{-1}.

Stern (1993) found that the amount of atmospheric nitrogen fixed by the legume declined with increasing soil nitrogen.

Soil factor also have an influence on the effectiveness of nitrogen transfer. Estimates of nitrogen transfer to a companion non-legume range between 25 and 155 kg N ha^{-1}. The amount of nitrogen fixed by the legume can range between 50 and 300 kg N ha^{-1} (Myers and Wood, 1987; Peoples and Herridge, 1990).

2.3.1. Growth, yield and economics as influenced by nitrogen level in intercropping system.

Olasantan (1991) conducted a study to investigate effect of intercropping on tomato or bhindi with cowpea at different nitrogen rates. In sole and intercropped tomato and bhindi, production of branches and leaves responded significantly to nitrogen level upto 60 kg ha^{-1}.

However, no effect of nitrogen was observed on days to first harvest in tomato and bhindi in both the systems.

He again found that the growth response of cowpea to nitrogen treatment did not differ appreciably when grown with tomato or bhindi. However, at higher nitrogen rates particularly 60 kg ha^{-1} cowpea grown with tomato or bhindi grow taller and had more branches and leaves than the plants with no nitrogen applied or those grown alone.

Ramshe and Surve (1984) reported that in sorghum + legume intercropping system with different nitrogen levels (40,80,120 kg ha^{-1}) maximum yield was obtained with 80 kg N ha^{-1}.

Tathode and Dhoble (1987) found that in sorghum + pigeonpea intercropping systems, the grain and stalk yield of pigeonpea was increased significantly with the 100% recommended dose of fertilizer to pigeonpea.

Yadav and Prasad (1990) reported that in sugarcane + french bean intercropping system with 0,40, 80 and 120 kg N

ha^{-1}, french bean yield increased markedly with increasing levels of nitrogen upto 80 kg ha^{-1}. In the case of sugarcane, maximum yield was recorded under 120 kg ha^{-1}. However, it was not significantly different from 80 kg N ha^{-1}.

Olasantan (1991) reported that growth response of tomato and bhindi to nitrogen fertiliser in sole cropping and intercropping with cowpea, the mean fruit weight did not differ significantly between the various fertilizer treatments. In intercropping, application of 30 kg N ha^{-1} significantly improved marketable fruit production of the tomato plant by about 35% compared with no nitrogen applied. Increasing the nitrogen rate to 60 kg ha^{-1}, however, did not further increase the yield significantly.

In the same experiment, yield response of bhindi to nitrogen was similar to those of tomato. In sole cropping when applied nitrogen rates were increased to 30 to 60 kg ha^{-1}, there was a significant increase of 15 to 30% in the marketable yield, whereas, yield increase was observed only upto 30 kg N ha^{-1} in intercropping. He again found that in the case of cowpea, plants with 30 kg N ha^{-1} or with no nitrogen applied often yielded more than those with 60 kg ha^{-1}. Compared with sole cropped cowpea, the grain yield was reduced by 45,40 and 65% when grown with tomato and by 48,38 and 58% when grown with bhindi at 0,30 and 60 kg nitrogen ha^{-1} respectively.

Prabhakar and Vishnu Shukla (1991) conducted a study on response of vegetable intercropping system to fertility regimes where sole and intercrops were grown under three fertility regimes viz. 100 + 44, 150 + 44 and 150 + 66 kg nitrogen and phosphorous ha^{-1}. They found that bhindi + french beans or bhindi + radish intercropping systems were superior to sole crops at all the levels of fertility, indicating better utilisation of fertilizer by the intercrops. French bean and bhindi + french bean combination responded upto 100 kg N + 44 Kg P ha^{-1}, whereas, radish and bhindi + radish intercropping systems responded upto the highest level viz. 150 kg N + 66 kg P ha^{-1}.

Balyan and Seth (1991) reported that in pearl millet + clusterbean intercropping system, 40 kg nitrogen ha^{-1} was sufficient for better growth and yield expressions. Beyond this level, there was no response .

In an intercropping study on maize with leafy vegetables (coriander, fenugreek and safflower) at graded levels of nitrogen viz. 0,60 and 120 kg N ha^{-1}, it was found that the grain and stover yield of maize and the yield of vegetables increased with increasing levels of nitrogen. Maize + safflower intercropping with 120 Kg N ha^{-1} produced significantly higher yield of safflower leaves (Jadhav et al., 1992).

Pujari et al. (1992) found that in a sorghum + pigeonpea intercropping system with 0,50 and 100% recommended dose of fertilizer, the highest yield of sorghum and pigeonpea were at 100% recommended dose of nutrients. Reducing the dose to 50% resulted in significant yield reduction of both the crops.

Studies on nitrogen management in potato based intercropping system revealed significant superiority of 150 kg N ha^{-1} over 100 kg ha^{-1} (Singh et al. 1993).

Rafey and Prasad (1992) reported that in maize + pigeonpea intercropping systems, intercrop association at 100% of the recommended level of nutrients for both the crops gave the maximum grain yield (4.11 t ha^{-1}) which was significantly superior to 75% and 50% of the recommendation.

Tathode and Dhoble (1987) in a sorghum + pigeonpea intercropping system with graded levels of nitrogen, concluded that 25 per cent recommended dose of fertiliser to pigeonpea as an intercrop was sufficient for meeting their requirement.

Intercropping of maize with safflower, coriander and fenugreek at graded levels of nitrogen viz. 0, 60 and 120 kg nitrogen ha^{-1}, the maximum gross monetary return was obtained by 120 kg N ha^{-1} for maize + safflower system (Jadhav et al 1992).

Rafey and Prasad (1992), based on an economic feasibility study on maize and pigeonpea intercropping at 100, 75 and 50% levels of recommended dose of nutrients, reported that maximum gross and net return (Rs.2728 ha^{-1}) were obtained from intercropping when both the crops were fertilised with 100% of the recommended dose. However, maximum net return per rupee investment was recorded under maize at 50% and pigeonpea at 100% nutrient level.

The economics of pigeonpea and soy bean intercropping at fertility levels of 0,50 and 100% recommended dose revealed that the application of 100% dose to pigeonpea and 75% dose to soybean gave the highest net return followed by sole pigeonpea at 100% nutrient level. The benefit cost ratio was maximum for 100 + 75% dose and was the lowest in 50 + 50% nutrient levels (Billore et al., 1993).

Based on the review, it can be concluded that for different cropping systems involving varied crops, the requirement of nitrogen differs markedly and hence to give a proper recommendation for any cropping system, specific study has to be undertaken.

2.3.2. Effect of Nitrogen on biological efficiency

Kushwah and Masood Ali (1991) reported that in french bean + potato intercropping system, the land equivalent ratio was higher for french bean + potato intercropping system ranging from 1.04 to 1.24 depending upon the fertiliser dose. French bean + potato with half recommended dose of fertiliser to french bean proved quite productive with yield advantage of 24% (LER 1.24) indicating thereby that french bean in intercropping needed only half of its recommended dose to achieve higher yield advantages.

Olasantan (1991) reported that when bhindi or tomato was intercropped with cowpea at 0, 30 and 60 kg N ha^{-1}, the value of LER differed with different nitrogen levels. He found that intercropping had a more depressive effect than nitrogen treatments particularly at the highest nitrogen rate. The highest LER value was reported with 30 kg N ha^{-1} and the lowest LER value was recorded under 60 kg N ha^{-1}.

Rafey and Prasad (1992) in a maize + pigeonpea intercropping systems with 50, 75 and 100% recommended fertiliser dose in nine combination, reported that the maximum LER value was recorded under maize at 50% and pigeonpea at 100% recommended levels of nutrients followed by both the crops at 100% nutrient level.

Billore et al. (1993) conducted a study on pigeonpea and soybean intercropping at 0,50,75 and 100% fertiliser levels and found that LER value ranged from 1.45 (100+ 75%) to 0.89 (50 +50%) indicating that LER was greatly affected due to the nutrient levels. In general, combination of 100 + 75% nutrient to pigeon pea + soybean gave better performance which was closely followed by 75+100% combination.

Singh et al. (1993) found that when potato was intercropped with garlic, onion, fennel, broad bean and french bean at 100 Kg N ha^{-1}, the LER value was more than one. But at 150 kg N ha^{-1}, intercropping with garlic recorded a value below unity.

2.4.3. Effect of nitrogen on soil nutrient status and uptake

In a legume + non-legume intercropping system where fertilizer nitrogen is limited, biological nitrogen fixation is the major source of nitrogen. The distance between the legume + non-legume root system is important because nitrogen is transferred through the intermingling root system.

Bandaropadhyay and De (1986) reported that when sorghum was grown in a mixture with legumes like groundnut, mung bean and cowpea, took up more nitrogen than sorghum grown as sole crop. In a mixture with mung bean, the total nitrogen uptake by sorghum was 8.65 g M^{-2} while with sorghum alone it was 6.79 g M^{-2}.

An experiment on nutrient uptake and efficiency of maize + cowpea intercropping system revealed that the per cent nitrogen content of pure maize with full nitrogen dose and mixed cropped maize with 50% nitrogen dose was not significantly different though the maize plant population was same in both the system. In the case of cowpea, nitrogen content was reduced in mixed cropping as compared to pure cropping (Patra _et_ _al_. 1986).

Musande and Chavan (1987) reported that studies on intercropping of cotton with green gram, black gram and groundnut at three fertilizer levels viz. 100% dose to cotton, 75% + 25% nitrogen, 100% + 25% nitrogen, the nitrogen use efficiency and total nitrogen uptake by cotton and intercrops were not influenced significantly by fertiliser levels.

Sharma and Choubey (1991) reported that in intercropping of maize with soybean or green gram, maize + soybean intercropping system at 30 and 60 Kg N ha^{-1} was quite comparable to pure maize grown with 60 and 120 kg N ha^{-1} respectively. There was a saving of 30-60 Kg N ha^{-1} with this system.

From these various studies it is clear that in most of the situations, nitrogen requirement of the crops can be reduced in intercropping system where a legume is included as an intercrop.

2.5. Effect of summer cropping on succeeding crop

The preceding crops have a profound influence on the growth and production of the succeeding crops (Repley, 1941). The growth character of plants may vary with species to species which would result in some after-effect on the soil where they grow and will have a marked influence on the growth and yield of succeeding crops.

There are several reports to show that inclusion of legumes in the cropping system had indeed benefitted the associated crop (Saxena and Yadav, 1975; Tiwari and Bisen, 1975) and helped to save upto 25% of recommended level of nitrogen application to the associated crop (Morachan et al. 1977). Such practice improved soil nitrogen status thus reducing nitrogen application to the succeeding crop (Palaniappan, 1985).

Singh and Singh (1975) studied the effect of different short duration legumes (soybean, greengram and cowpea) on the succeeding wheat crop and found that wheat grown after all the legumes gave higher yield. The nitrogen equivalent estimated in these experiment was 46 kg ha^{-1} for cowpea, 31 kg ha^{-1} for green gram and 30 kg ha^{-1} for soybean.

Out of the different cropping systems tried in CSRC, Karamana, it was found that rice-rice-cassava (H-165) and rice-rice-bhindi gave the highest yield (Annual Report, AICARP, 1978).

Giri and De (1978) observed that previous crops of cowpea and groundnut proved most efficient in increasing the grain yield of succeeding bajra crop. The higher yields were apparently due to enrichment by the legumes with nitrogen. Purushothaman (1979) reported that rice-rice-green gram was best suited for Coimbatore region.

Sasidhar and Sadanandan (1980) recorded that from the five rice based cropping sequences studied, the rice-rice-cowpea gave the highest yield of rice than other cropping patterns.

Singh et al. (1981) found that when legumes like mung bean, urd bean and cowpea were followed by wheat, the nitrogen economy could be effected to the extent of 30-40 kg ha^{-1} and greengram, blackgram, red gram and cowpea could fix 202,61,224 and 198 kg nitrogen ha^{-1} respectively.

Rao et al. (1983) evaluated the nitrogen value for various legume based intercrop system and found that there was nitrogen contribution to the succeeding crop from the intercropped situation also, though the quantity is high for sole than intercropped situation.

From the studies on the fertilizer management in sorghum + legume intercropping system (groundnut, cowpea both for fodder and grain, soybean and green gram) and their residual effect on wheat, Wagmare and Singh (1984) reported that the grain yield of wheat after intercropping of sorghum with cowpea and groundnut was significantly greater than that after sole sorghum. During the harvesting of groundnut, larger number of active nodules was found in the soil. The fodder cowpea was harvested at the time when root and nodule development was at the maximum, thus the roots and nodules left in the soil resulted in more nitrogen for the succeeding cereal crop. On the other hand, in grain legumes like cowpea and greengram most of the fixed nitrogen was translocated to the grains and only a small amount left in the soil for the succeeding crop of wheat. Soybean depleted the soil nitrogen and resulted in no yield benefit to wheat.

Verma (1987) found that rotational cropping of rice-wheat and cowpea was good for maintaining fertility status of soil.

Studies on the effect of short duration legumes (Greengram, blackgram, cowpea) on the productivity of succeeding crops like mustard and barley under rainfed conditions revealed that pulse grown for grain did not show any beneficial effect on the yield of succeeding non-legumes compared with fallow treatment. The yield of succeeding crops increased with increasing levels of nitrogen upto 60 Kg ha^{-1} (Ahlawat <u>et</u> <u>al</u>. 1981).

Balyan and Seth (1991) conducted a study on the effect of planting geometry and nitrogen on pearl millet + clusterbean intercropping systems and their after effect on succeeding wheat and found that there was substantial increase in yield of wheat due to pearl millet + clusterbean intercropping.

Studies on the effect of summer legumes (urd bean, mung bean, cowpea, soybean, daincha) on the growth and productivity of succeeding kharif maize revealed that cowpea was significantly superior to other pulses in increasing the yield and yield attributing characters of the succeeding maize. On an average, there was 28.6% increase in maize grain yield in cowpea-maize system than fallow maize system (Srinivasan <u>et</u> <u>al</u>. 1991).

A study at Port Blair had shown that maximum rice yield was recorded under the treatment were cowpea was raised for vegetable purpose which was closely followed by the rotation where bhindi and maize were the previous crops (Annual Report, CARI, Port Blair, 1990-91).

From various references, it is clear that the yield of succeeding crop influences the performance of preceding crops.

On the basis of review of literature available on intercropping, it was understood that, vegetables can be intercropped with different base crops including vegetables and the yield of the intercropping system is seen modified greatly by the planting pattern and nutrient levels. For each system to be advantageous, the optimum planting geometry and nutrient level is to be worked out.

MATERIALS AND METHODS

MATERIALS AND METHODS

A field investigation was carried out during the summer season of 1993 to assess the feasibility of raising vegetable cowpea as an intercrop with bhindi in summer rice fallows and to find out a suitable planting geometry and optimum nitrogen level for the intercropping system. The materials used and methods adopted are detailed below.

3.1. Experimental site

The experiment was conducted in the rice fallow of the Instructional farm attached to the college of Agriculture, Vellayani. The farm is located at 8°18′ N latitude and 76°57′E longitude at an altitude of 29 m above mean sea level.

3.1.1 Soil

The soil of the experimental area comes under the textural class of sandy clay loam. The data on the mechanical and chemical properties of the soil are presented in Table 1.

3.1.2 Cropping history of the field

The experimental area was cultivated with a bulk crop of paddy during the previous season, giving the normal package of practice recommendation.

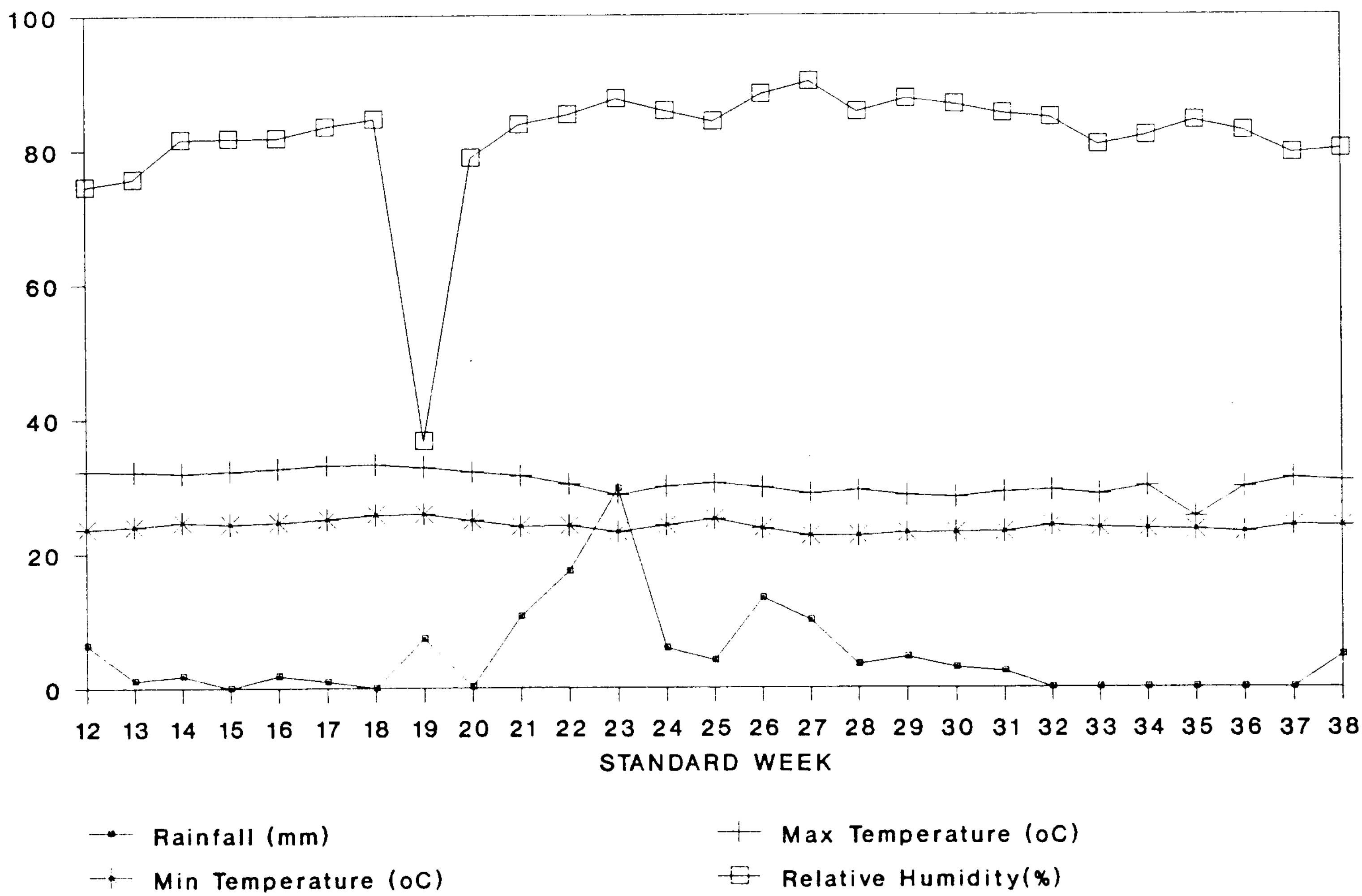
3.1.3 Season

The experiment was conducted during the summer season of 1993. The bhindi was sown on 21-3-93 and harvesting was completed by 23-6-93. The cowpea crop was sown on 29-3-93 and harvesting was completed by 23-6-93.

3.1.4 Weather conditions

The weekly averages of temperature, evaporation, relative humidity and rainfall during the cropping periods collected from the meteorological observatory at the College of Agriculture, Vellayani are presented in appendix I (Fig. 1).

Fig.1. Weather conditions during the cropping period



3.2. Materials

3.2.1 List of test crops and their major characteristics

Crop	Variety	Source	Evolved Name	Characteristics
1. Bhindi	Kiran	Agri.College Vellayani, Kerala	Single plant selection of kili-chundan	High yielding bhindi variety tolerant to fruit and shoot borer and yellow vein mosaic. The variety flowers in 35 days period and the first harvest can be done in 45 days. Mean fruit weight is 25-30 g.
2. Cowpea	Arka garima	IIHR, Bangalore	Selection	High yielding vegetable cowpea. Bushy habit with shallow root system and is suitable for intercropping. The yield ranges from 5-18 t ha^{-1}.

3.2.2 Manures and Fertilisers

Farm yard manure obtained from the local source was used in the study. Urea (46%N), super phosphate (18% P_2O_5) and muriate of potash (60% K_2O) were used as sources of nitrogen, phosphorus and potassium respectively.

3.3. Methods

3.3.1 Design and layout

The field experiment was laid out as factorial experiment in randomised block design (Figure 3).

3.3.2 Treatments

Treatments consisted of 2 types of planting pattern and 3 levels of nitrogen as detailed below. Two control plots with bhindi and cowpea as sole crops were also included as treatments.

I. Planting pattern of Bhindi + Cowpea intercropping systems (Figure 2)

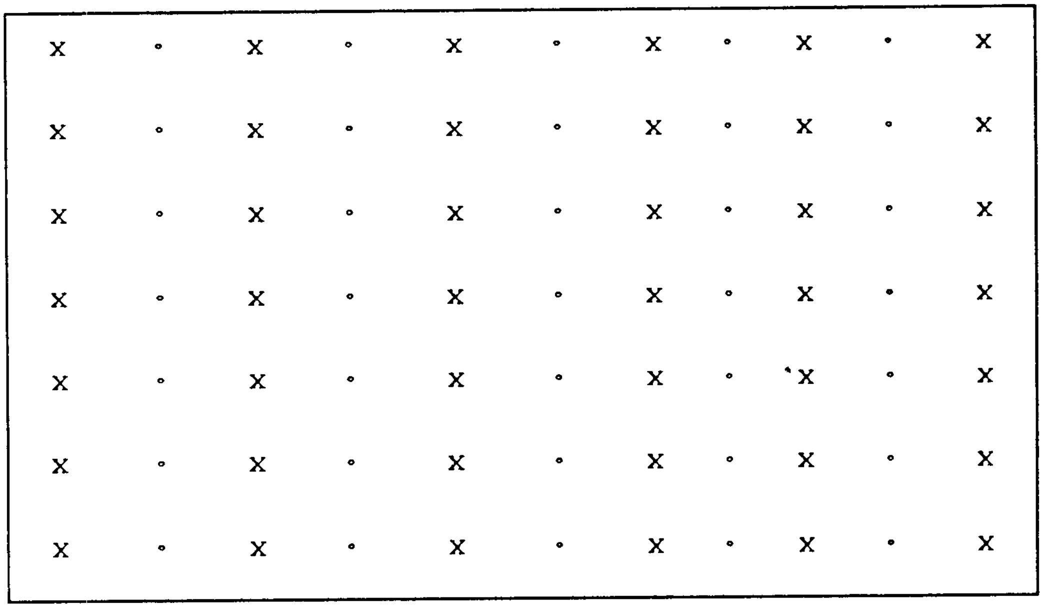
1. Normal row (G_1) - 60 x 45 cm
2. Paired row (G_2) - 45/75 x 45 cm

II. Nitrogen levels : 3

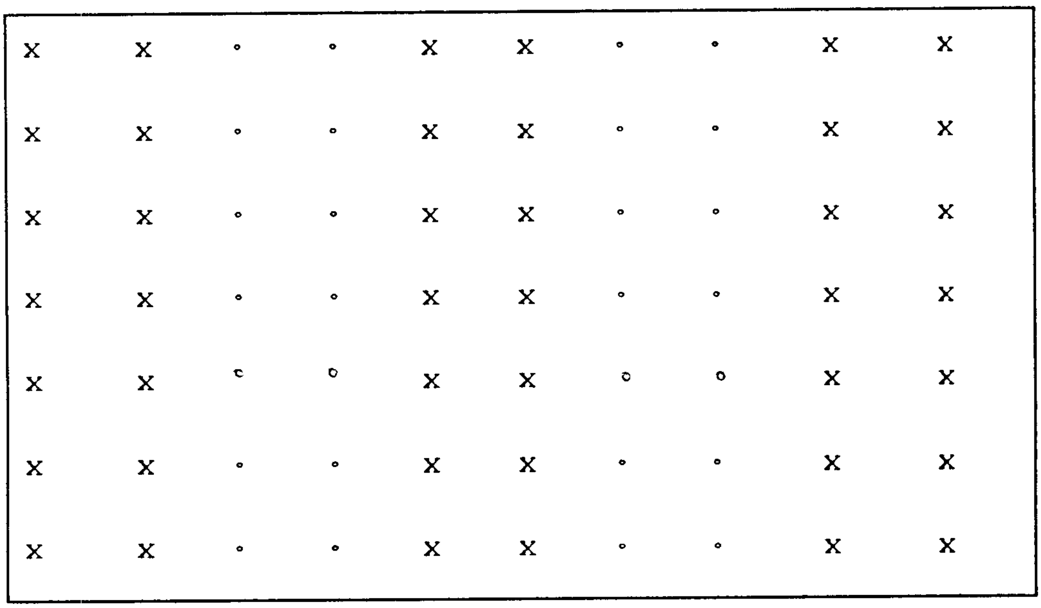
1. 100% of nitrogen recommendation (N_1) as package of practice's recommendation
2. 75% of nitrogen recommendation (N_2)
3. 50% of the recommendation (N_3)

Full dose P_2O_5 and K_2O was applied uniformly to all treatments.

FIG.2. PLAN OF CROP ARRANGEMENTS



a. Normal row arrangement



b. Paired row arrangement

xx Bhindi   ° ° Cowpea

3.3.3 Total treatment combinations

T1. G_1 N_1 - Normal planting pattern with 100% Nitrogen

T2. G_1 N_2 - Normal planting pattern with 75% Nitrogen

T3. G_1 N_3 - Normal planting pattern with 50% Nitrogen

T4. G_2 N_1 - Paired planting pattern with 100% Nitrogen

T5. G_2 N_2 - Paired planting pattern with 75% Nitrogen

T6. G_2 N_3 - Paired planting pattern with 50% Nitrogen

T7. C_1 - Sole crop of bhindi with recommended N, P and K.

T8. C_2 - Sole crop of cowpea with recommended N, P and K.

Number of replication - 3

Total number of plots - 24

Plot size (gross) - 3.6 x 3.15 M^2

A succeeding crop of rice was raised in all these plots with 75% of the fertiliser recommendation and the yield of grain and straw of individual plot was recorded to study the residual effects.

3.3.4 Test Crop spacing and plant population per plot

Crop	Spacing	Net plot size	No.of plants in gross plot	No.of plants in net plot
Bhindi				
Sole crop	60x45cm	2.4x2.25M^2	42	20
Normal row	60x45cm	2.4x2.25M^2	42	20
Paired row	45x45cm	2.4x2.25M^2	42	20

FIG.3. LAYOUT

Replication III	T3	T2	T5	T7	T6	T1	T4	T8
Replication II	T4	T1	T8	T3	T5	T6	T2	T7
Replication I	T5	T7	T4	T6	T1	T3	T8	T2

Treatments

T1 - G1N1 - Normal planting pattern with 100% nitrogen

T2 - G1N2 - Normal planting pattern with 75% nitrogen

T3 - G1N3 - Normal planting pattern with 50% nitrogen

T4 - G2N1 - Paired planting pattern with 100% nitrogen

T5 - G2N2 - Paired planting pattern with 75% nitrogen

T6 - G2N3 - Paired planting pattern with 50% nitrogen

T7 - C1 - Sole crop of bhindi with full POP recommendation

T8 - C2 - Sole crop of cowpea with full POP recommendation

Crop	Spacing	Net plot size	No.of plants in gross plot	No.of plants in net plot
Cowpea				
Sole crop	45x30cm	$3.0x2.25M^2$	84	50
Normal row	30x45cm	$2.4x2.25M^2$	35	20
Paired row	30x45cm	$2.4x2.25M^2$	28	20

3.3.5 Cultivation aspects

3.3.5.1 Land preparation

The experimental plot was dug twice, stubbles were removed, clods were broken and levelled. The field was then laid out into blocks and plots as per the experimental design. The plots were separated by channels of 30 cm width. The individual plots were thoroughly dug and levelled.

3.3.5.2 Application of manure and fertilisers

Uniform dose of FYM @12 t ha^{-1}. was applied to each plot. Fertiliser was applied to all 24 plots as per the treatments as detailed below.

Treatment	Crop	Urea	super phosphate	MOP	Time of application
		(kg ha^{-1})			
T1	Bhindi	54.33 54.33	50.00 --	50 --	Basal application one month after first application
	Cowpea	9.57 9.57	74.99 --	7.34 --	Basal application 20 days after sowing
T2	Bhindi	40.76 40.76	50.00 --	50 --	Basal application one month after first application
	Cowpea	7.18 7.18	74.99 --	7.34 --	Basal application 20 days after sowing
T3	Bhindi	27.18 27.18	50.00 --	50 --	Basal application one month after first application
	Cowpea	4.74 4.74	74.99 --	7.34 --	Basal application 20 days after sowing
T4	Bhindi	54.33 54.33	50.00 --	50 --	Basal application one month after first application
	Cowpea	7.61 7.61	58.33 --	5.85 --	Basal application 20 days after sowing
T5	Bhindi	40.76 40.76	50.00 --	50 --	Basal application one month after first application
	Cowpea	5.71 5.71	58.33 --	5.85 --	Basal application 20 days after sowing
T6	Bhindi	27.18 27.18	50.00 --	50 --	Basal application one month after first application
	Cowpea	3.77 3.77	58.33 --	5.85 --	Basal application 20 days after sowing
T7	Bhindi	54.33 54.33	50.00 --	50 --	Basal application one month after first application
T8	Cowpea	21.74 21.74	166.66 --	16.67 --	Basal application 20 days after sowing

3.3.5.3 Sowing

Bhindi seeds were dibbled at the rate of 2 seeds per hole at a depth of 3-5 cm. Crop arrangement was followed according to the treatment schedule. The seeds of cowpea were sown in the interspaces of the rows of bhindi and paired rows of bhindi in normal method and paired row method respectively. The cowpea seeds were sown at the rate of 2 seeds per hole. Gap filling and thinning were done on 10th day after sowing of bhindi to secure a uniform stand of the crop. Cowpea was also thinned after 10th day of sowing.

3.3.5.4 After Cultivation

Crop was irrigated on alternate days and weeding was done as and when required. Top dressing was done one month after sowing along with intercultivation.

3.3.5.6 Plant Protection

Prophylactic sprays of plant protection chemicals were given to protect the crops from pests and diseases.

3.3.5.7 Harvesting

The bhindi fruits were harvested on alternate days from the 45th day onwards after sowing (3-5-93). Altogether 25 harvests were taken over the entire cropping period. The harvesting of intercrop cowpea was started 50th day onwards after sowing (21-5-93). Altogether 17 harvest of cowpea were taken over the entire cropping period. Harvesting of both the crops were completed by 23-6-93. The maturity of fruits of bhindi and cowpea pods were judged by visual observation.

The bhusa of cowpea and leaves with petiole of the bhindi crop were incorporated into the soil in situ after the final harvest.

3.3.5.8. Cultivation details of succeeding paddy crop

A bulK crop of paddy was raised retaining the same experimental lay out of the previous crop. Bunds of 30 cm width were taken between the plots. The plot size was 3 x 2.55 M^2. The bhusa of crops were allowed to decompose for about a week. Twenty three days old seedlings of variety Red Triveni were planted at a spacing of 15 x10 cm on 1-6-94. The crop was given 75% of the fertiliser dose recommended by the POP of Kerala Agricultural University. Plant protection measures were taken as and when required. Crop was harvested on 22-9-'94. One row was left from each side of the plot as border rows and were harvested and removed first. Later, net plots were harvested separately. Grain and straw yield of each plot were recorded separately.

3.4. Observations recorded

3.4.1 Growth characters

Five plants each of bhindi and cowpea were selected at random as observational plants in each plot after eliminating the border rows and all the biometric observations were recorded from these plants at various growth stages. Random samples were selected for destructive sampling for dry weight observations.

3.4.2.a. Observations on bhindi

3.4.2.a(1). Height of plants

From the observational plants, the height was measured from the base to the terminal buds and the average was worked out.

3.4.2.a(2). Height of the first bearing node

The height from the base to the first bearing node was measured from the five observational plants. The average was worked out and expressed in cm.

3.4.2.a(3). Canopy spread

Canopy spread of observational plants was measured using a thread and scale from the standing plants and was expressed in cm.

3.4.2.a(4). Leaf area index (LAI)

All leaves collected from the sample plant were used for measuring the leaf area index. The leaf area was measured by using leaf area meter. The leaf area per plant was divided by the land area occupied by the plant and expressed as LAI.

3.4.2.a(5). Root length

Plants were uprooted and the root system was separated. After cleaning, the entire length of the tap root was measured by using a thread and scale and the mean was worked out and expressed in cm.

3.4.2.a(6). Root spread

The root system of the uprooted plant was spread over a plain paper. The length of the longest lateral root on both sides of the tap root was measured using a thread and scale and their average was found out.

3.4.2.a(7). Total dry matter production

Dry matter production of bhindi was recorded at three growth stages viz. 30,60 and 90 days after sowing. The same sample plants used for measuring LAI was used for this observation also. After taking LAI the whole plant with leaves, stem and roots was oven dried at 70±5°C to constant weight. The final dry weight was averaged and expressed in kg ha^{-1}.

3.4.2.a(8). Crop growth rate (CGR)

It is the rate of increase in dry weight per unit area per unit time. CGR between 30-60 DAS and 60-90 DAS were worked out by using the following formula as explained by Hunt (1978) and expressed in mg^{-2} day^{-1}.

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

Where W_2 and W_1 are dry matter production at time t2 and t1 respectively and p is the ground area.

3.4.2.a(9). Relative growth rate (RGR)

The rate of increase in dry weight per unit dry weight per unit time expressed as mg day^{-1} was calculated by the following formula suggested by Blackman (1919).

$$RGR = \frac{\log_e W_2 - \log_e W_1}{t_2-t_1}$$

Where, W_1 and W_2 are dry matter of the plant produced at time t_1 and t_2 respectively.

3.4.2.a(10). Net assimilation rate (NAR)

The rate of increase in dry weight per unit leaf area per unit time was worked out by the following formula of Enyi (1946). This was expressed in mg $cm^{-2}day^{-1}$.

$$NAR = \frac{(W_2-W_1)(\log_e L_2-\log_e L_1)}{(t_2-t_1)\ (L_2-L_1)}$$

Where, W_1 and W_2 are dry weights of the plant produced at time t_1 and t_2 respectively. L_1 and L_2 are the leaf area of the plant at time t1 and t2 respectively.

3.4.2(b) Yield observations

3.4.2.b(1) Days to 50% flowering

Total number of plants flowered was counted daily in each plot and the date on which 50% of the plants flowered was taken as the days to 50% flowering.

3.4.2.b(2) Number of fruits per plant

Total number of fruits obtained from the five observational plants was counted and average was worked out.

3.4.2.b(3) Length of fruits

The fruit length was measured from the fruits of observational plants at every alternate harvest and the average was worked out and expressed in cm.

3.4.2.b(4) Girth of fruits

Measurement of this attribute was made by winding thread around the middle most length of the individual fruit. The fruits used for measuring the length were used for this observation also. The mean value was worked out and expressed in cm.

3.4.2.b(5) Fruit Weight per plant

The weight of fruits of the observational plants from the 25 harvests was taken separately and the average was worked out.

3.4.2.b(6) Total fruit yield

The weight of fruits from the 25 harvests were totalled up at the end of the cropping season and the yield in quintals per hectare was worked from the net plot yield.

3.4.2.b(7) Total bhusa yield

After the final harvest, whole plants from each plot were uprooted. Leaves and stem were separated and weights of the leaves, stem with petiole and roots were taken separately. The weights are added together and converted to per ha to obtain the total bhusa yield ha^{-1}.

3.4.3. Intercrop

3.4.3.1 Plant height

From the observational plants, the height was measured from the base to the growing point and the average was worked out.

3.4.3.2 Plant spread

The plant spread from one end to the other end of the observational plants was measured using a thread and scale and the average was worked out and expressed in cm.

3.4.3.3 Root spread

The lateral roots of the root system was spread over a plain paper. The length of the longest lateral root on both sides of the tap root was measured using a thread and scale and was expressed in cm.

3.4.3.4 Yield of pod

The weight of pods from the 17 harvests and were totalled up at the end of the cropping season and the yield per plot was calculated and converted to ha^{-1} yield.

3.4.3.5 Yield of bhusa

After the final harvest, whole plants from each plot were uprooted and the weight of bhusa was taken and expressed in q ha^{-1}.

3.4.4. Uptake of nutrients

The plant samples of bhindi were analysed for nitrogen content at monthly intervals, and phosphorus and potassium content at the final harvest.

The plant samples of cowpea were analysed for nitrogen, phosphorus and potassium at the final harvest.

The plant was chopped and dried in air oven at 70 ± 5°c separately till constant weights were obtained. Samples were ground to pass through a sieve of 0.5 mm mesh. The required quantity of samples were then weighed out accurately in physical balance and analysed.

3.4.4.1 Uptake of nitrogen

The nitrogen content in plant was estimated by the modified microkjeldahl method (Jackson, 1973) and the uptake of nitrogen was calculated by multiplying the nitrogen content of plant with the total dry weight of plant. The uptake value was expressed in kg ha^{-1}.

3.4.4.2 Uptake of phosphorus

The phosphorus content of the plant samples were colorimetrically determined by wet digestion of the sample and developing colour by Vanado-Molybdo phosphoric yellow colour method and read in Klett Summerson photoelectric colorimeter (Jackson, 1973). The uptake of phosphorus was calculated by multiplying the phosphorus content and dry weight of plants. The uptake values were expressed in kg ha^{-1}.

3.4.4.3 Uptake of potassium

The potassium content in plant sample was estimated by the flame photometric method in the flame photometer after wet digestion of the sample. Based on the potassium content in the plant and the dry matter produced at harvest, the uptake in kg ha^{-1} was worked out.

3.4.5 Biological efficiency

The biological efficiency of intercropping is determined by comparing the productivity of a given area of intercropping with that of sole crops.

There are many competition functions proposed to describe the competitive relationships in intercropping.

3.4.5.1 Land equivalent ratio (LER)

It was worked out from the data on the yield of bhindi and cowpea both in mixture and pure culture. It was worked out by using the formula suggested by Mead and Willey (1980).

$$LER = \frac{Y_{ab}}{Y_{aa} \times Z_{ab}} + \frac{Y_{ba}}{Y_{bb} \times Z_{ba}}$$

Y_{ab} and Y_{ba} are the individual crop yield in intercropping and Y_{aa} and Y_{bb} are their yields as sole crop. Z_{ab} and Z_{ba} are proportion of land area occupied in intercropping when compared to sole crop for species 'a' and 'b' respectively.

3.4.5.2 Land equivalent coefficient (LEC)

LEC was worked out for the mixture plots using the formula suggested by Adetiloye *et al*. (1983).

LEC = LB x LC

LB - LER of bhindi

LC - LER of cowpea.

3.4.5.3 Area-time equivalent ratio (ATER)

ATER was worked out by using the formula suggested by Hiebsch and Mc Collum (1987) as detailed below.

$$ATER = \frac{(R_{ya} \times t_a) + (R_{yb} \times t_b)}{T}$$

R_y = Relative yield of species 'a' or 'b' ie., yield of intercrop/yield of main crop

t = duration (days) for species 'a' or 'b'

T = duration (days) of the intercropping system.

3.4.5.4 Aggressivity

This was proposed by Mc Gilchrist (1965) and calculated by using the formula

$$A_{ab} = \frac{Y_{ba}}{Y_{bb} \times Z_{ba}} - \frac{Y_{ab}}{Y_{aa} \times Z_{ab}}$$

Y_{ab} and Y_{ba} are the individual crop yield in intercropping and Y_{aa} and Y_{bb} are their yields as sole crop. Z_{ab} and Z_{ba} are proportion of land area occupied in intercropping when compared to sole crop for species 'a' and 'b' respectively.

3.4.6 Economic efficiency

Ultimate aim of intercropping is to increase the monetary returns per unit area. So economic evaluation becomes a necessity to assess how best an intercropping system is economically viable. The following economic indices were used to evaluate the system. They were calculated on the basis of prices of produce, labour charge and fertiliser cost at the time of experimentation (Palaniappan, 1985).

3.4.6.1 Cost of cultivation

It was calculated by adding the expenditure incurred on different items such as labour, seeds, fertiliser and other chemicals and expressed in Rs ha^{-1} based on which the following parameters were worked out.

3.4.6.2 Gross return

This was calculated on the basis of market price of the produce and expressed as Rs ha^{-1}.

3.4.6.3 Net return

This was calculated by subtracting the total (variable) cost of cultivation from the gross return of different treatments.

3.4.6.4 Per day return (income per day)

It is calculated by using the formula

$$\text{Per day return} = \frac{\text{Net return}}{\text{Cropping period (days)}}$$

3.4.6.5 Benefit/cost ratio (BCR)

BCR was worked out as per the formula given below

$$\text{BCR} = \frac{\text{Gross return}}{\text{Cost of cultivation}}$$

3.4.6.6 Return per rupee invested on inputs

a. Return per rupee invested on labour

This was worked out by using the formula

$$\frac{\text{Gross return} - \text{cost of cultivation except that incurred on labour}}{\text{Cost of labour}}$$

b. Return per rupee invested on fertilisers

It gives an estimate of the production per unit cost spent on fertiliser for different treatments. It was calculated by using the formula

$$\frac{\text{Gross return} - \text{cost of cultivation except that incurred on fertilisers}}{\text{Cost of fertilisers}}$$

3.4.6.7 Bhindi equivalent yield

This was calculated by converting the yield of intercrop cowpea into yield of base crop bhindi considering the market rates. It was calculated by using the formula suggested by Prasad and Srivastava (1991)

Bhindi equivalent yield (kg ha^{-1})

$$= \frac{\text{Yield of cowpea (kg ha}^{-1}\text{)}}{\text{Market price of Bhindi (Rs kg}^{-1}\text{)}} \times \text{Market price of cowpea (Rs kg}^{-1}\text{)}$$

3.4.6.8 Monetary advantage based on LER

It was calculated by using the formula suggested by Willey (1979).

Monetary advantage based on LER

$$= \text{Value of combined intercrop yield} \times \frac{\text{LER}-1}{\text{LER}}$$

Where LER = land equivalent ratio

3.4.7. Soil analysis

Soil samples were taken from the experimental area before and after the experiment. The air dried samples were analysed for available nitrogen by the alkaline potassium permanganate method (Subbiah and Asija, 1956) available P_2O_5 by Bray colorimetric method (Jackson, 1973) and available K_2O by the ammonium acetate method (Jackson, 1973).

3.4.8. Statistical analysis

The analysis of variance technique was applied to draw inferences from the data (Cochran and Cox, 1965). Wherever the effects were found to be significant, critical differences were given for effecting comparison among the mean. Correlation studies were also carried out between yield and yield attributes.

Table 1 Physico-chemical properties of soil

A. Physical composition

Sl. No. 1.	Parameter 2.	content in soil (%) 3	Method used 4
1.	Coarse sand	13.80	Bouyoucos
2.	Fine sand	33.50	Hydrometer method
3.	Silt	28.00	
4.	Clay	24.00	(Bouyoucos, 1962)

B. Chemical composition

Sl. No.	Parameter	Content kg ha^{-1}	Rating	Method used
1.	Available N (kg ha^{-1})	302	Medium	Alkaline Potassium Permanganate method (Subbiah and Asija, 1956)
2.	Available P_2O_5 (kg ha^{-1})	35	Medium	Bray colorimetric method (Jackson, 1973)
3.	Available K_2O (kg ha^{-1})	182	Medium	Ammonium acetate method (Jackson, 1973)
4.	pH	4.5	Acidic	PH meter with glass electrode (Jackson, 1973)

RESULTS

RESULTS

An investigation was carried out at the Instructional Farm, college of Agriculture, Vellayani during the summer season of 1993 to find out the possibility of raising cowpea as intercrop in bhindi and evaluating the crop association effect in different planting pattern and at varying levels of nitrogen. The study also aims at evaluating the biological efficiency and economic feasibility of the bhindi + cowpea intercropping system. The results of this study are statistically analysed and are presented here in 6 sections viz.

1. Effect of intercropping on main crop (bhindi)
2. Effect of intercropping on intercrop (cowpea)
3. Biological efficiency of the intercropping system
4. Economic suitability of the intercropping system.
5. Soil fertility as influenced by intercropping.
6. Effect of summer cropping on succeeding rice crop.

4.1. Effect of intercropping on bhindi

4.1a. Growth characters

4.1a(1). Height of Plant

The mean height of plants recorded at 30th, 60th and 90th DAS are presented in Table 2.

Table 2. Height of plant (cm) as affected by planting pattern and nitrogen levels

Treatments	Height (cm)		
	30 DAS	60 DAS	90 DAS
Planting pattern			
G_1	26.98	117.33	187.51
G_2	21.94	105.84	165.78
F (1,12)	2.80	1.61	6.06*
CD (0.05)	-	-	19.24
Nitrogen levels			
N_1	21.32	106.47	171.83
N_2	26.00	122.07	184.07
N_3	26.07	106.23	174.03
F(2,12)	1.09	1.34	0.73
CD	-	-	-
Control (C1)	29.53	130.20	190.53
F(Treated vs. C1)	1.63	2.41	1.41
SE	3.68	11.10	33.32

* - Significant at 5% level.

It is evident from the data that there was no significant difference in plant height upto 60 DAS due to different planting patterns. But at 90 DAS, plant height differed significantly due to planting pattern. The normal planting pattern (G_1) recorded an average height of 187.51 cm which was significantly superior to paired row planting with average height of 165.7 cm.

Nitrogen levels had no significant effect on plant height at any of the growth stages.

Interaction effect was not significant at all the growth stages.

Height of intercropped plants were on par with the plant height of sole crop.

4.1a.(2). Height of first bearing node

The height of first bearing node was recorded and are presented in Table 3.

Either the main effect of nitrogen and planting pattern or their interaction did not produce any significant differences in the height of first bearing node. Sole crop of bhindi produced the first fruit at a height of 25.93 cm which was not significantly higher than the intercropped plants.

4.1a (3). Canopy spread

Canopy spread was recorded at 30,60 and 90 DAS and are presented in Table 4 and 4a.

Table 3. **Height of the first bearing node (cm) as affected by planting pattern and nitrogen levels**

Treatments	Height (cm)
Planting pattern	
G_1	25.11
G_2	24.68
F (1,12)	0.04
CD	-
Nitrogen levels	
N_1	22.57
N_2	27.73
N_3	24.40
F (2,12)	2.19
CD	-
Control	25.93
F (Treated vs. C1)	0.15
SE	2.50

Table 4. Canopy Spread (cm) as affected by planting pattern and nitrogen levels

Treatments	Canopy spread (cm)		
	30 DAS	60 DAS	90 DAS
Planting pattern			
G_1	25.36	82.47	79.58
G_2	23.09	77.96	71.73
F (1,12)	0.46	4.23	15.71*
CD (0.05)	-	-	4.38
Nitrogen levels			
N_1	21.30	79.13	75.37
N_2	26.87	84.50	76.83
N_3	24.50	77.00	74.77
F (2,12)	0.94	4.14*	0.39
CD (0.05)	-	5.85	-
Control (c1)	31.47	91.27	82.27
F (Treated vs. C1)	2.69	14.53**	6.38*
SE	4.08	2.69	2.42

* - Significant at 5% level

Table 4a. Combined effect of planting pattern and nitrogen levels on canopy spread of bhindi at 60 DAS

Treatments	Nitrogen levels		
	N_1	N_2	N_3
Planting pattern			
G_1	82.40	81.93	83.07
G_2	75.87	87.07	70.93

G X N

CD (0.05)	8.28
SE	2.69

Canopy spread did not differ significantly due to planting pattern upto 60 DAS. However, at 90 DAS normal planting pattern recorded more canopy spread (79.58 cm) than paired row system (71.73 cm).

The effect of nitrogen levels on canopy spread was significant only at 60 DAS. At this stage N_2 (75% of nitrogen) recorded an average spread of 84.5 cm which was on par with N_1 (100% of nitrogen) but superior to N_3.

The interaction effect between planting pattern and nitrogen levels was significant only at 60 DAS. With normal planting, no significant difference in canopy spread was seen but with paired row planting, the canopy spread was found to be more for plants fertilized with N_2 in comparison with N_1 and N_3.

The canopy spread of sole crop of bhindi was significantly higher than intercropped treatments at 60 and 90 DAS recording maximum canopy spread of 80.21 cm and 75.66 cm respectively.

4.1a(4). Leaf Area Index (LAI)

The LAI recorded at 30, 60, and 90 days after sowing are presented in Table 5.

Leaf area index of bhindi did not differ significantly either due to planting pattern or due to N levels at any of the growth stages.

The interaction effect had no significant influence

Table 5. LAI as affected by planting pattern and nitrogen levels

Treatments	LAI 30 DAS	60 DAS	90 DAS
Planting pattern			
G_1	0.614	2.009	1.579
G_2	0.510	1.759	1.462
F (1,12)	0.630	1.607	0.264
CD (0.05)	-	-	-
Nitrogen levels			
N_1	0.472	1.905	1.507
N_2	0.647	1.972	1.562
N_3	0.568	1.775	1.493
F (2,12)	0.592	0.343	0.034
CD (0.05)	-	-	-
Control (C1)	0.43	2.45	2.02
F (Treated vs. C1)	0.577	4.653*	2.730
SE	0.161	0.242	0.278

on LAI of bhindi.

Leaf area Index of sole crop of bhindi was found to be significantly higher than intercropped plants at 60 DAS and sole crop of bhindi recorded a leaf area index of 2.45.

4.1a(5). Root length

The root length at 30,60 and 90 days after sowing are presented in Table 6.

There was no significant difference in root length of bhindi either due to planting pattern or nitrogen levels upto 60 DAS, but at 90 DAS, root length was significantly higher with normal planting pattern, the length being 24.33 cm.

The effect of N was observed at 90 DAS alone. N_2 recorded an average length of 24.00 cm which was on a par with N_1 (100% nitrogen level) but significantly higher to N_3.

The interaction effect was not significant at any of the growth stages.

The root length of sole crop of bhindi was significantly different from that of intercropped plants at 60 and 90 DAS. Root length of sole crop of bhindi was 18.33 cm and 26.0 cm at 60 and 90 DAS.

4.1a (6). Root spread

Table 7 presents the root spread at 30, 60 and 90 DAS.

Table 6. Root length of plant (cm) as affected by planting pattern and nitrogen levels

Treatments	Root length (cm)		
	30 DAS	60 DAS	90 DAS
Planting pattern			
G_1	10.11	15.78	24.33
G_2	10.61	14.50	20.89
F (1,12)	0.11	1.36	20.14**
CD (0.05)	-	-	1.16
Nitrogen levels			
N_1	10.42	15.58	23.17
N_2	11.50	15.67	24.00
N_3	9.17	14.17	20.67
F (2,12)	0.83	0.790	6.811*
CD (0.05)	-	-	2.05
Control (C1)	13.17	18.33	26.0
F(Treated vs. C1)	2.05	4.86*	11.14**
SE	1.81	1.34	0.94

* - Significant at 5% level

** - Significant at 1% level

Table 7. Root spread of bhindi (Cm) as affected by planting pattern and nitrogen levels

Treatments	Root spread (cm)		
	30 DAS	60 DAS	90 DAS
Planting pattern			
G_1	48.11	65.22	72.22
G_2	40.22	48.22	56.89
F (1,12)	0.98	4.66	3.95
CD	-	-	-
Nitrogen levels			
N_1	46.17	61.83	66.67
N_2	48.33	59.17	71.16
N_3	38.00	49.17	55.83
F (2,12)	0.63	0.96	1.39
CD	-	-	-
Control (C1)	39.00	53.00	78.33
F(Treated vs. C1)	0.24	0.13	1.82
SE	9.75	9.65	9.45

The root spread was not influenced either by the planting pattern or due to N levels. Also no interaction was detected.

Sole crop of bhindi recorded 78.33 cm of root spread at 90 DAS which was on a par with intercropped plants.

4.1a (7). Total dry matter production

Dry matter production at 30,60 and 90 DAS were recorded and are presented in table 8 and 8a.

The dry matter production was significantly influenced by planting pattern alone. The normal planting (G_1) was significantly superior to paired planting pattern (G) at all the growth stages. AT 90 DAS, the total dry matter production by normal planting pattern (G_1) was 6244 kg ha^{-1} in comparison with G_2 with 4927 kg ha^{-1}.

Significant interaction was detected between N and planting pattern at 60 and 90 DAS. At the lower level of N, dry matter production was significantly more with normal planting pattern, while at medium level of nitrogen, no significant difference was seen.

At 60 and 90 DAS, the dry matter production by sole crop bhindi was 3951 and 6737 kg ha^{-1} respectively which were significantly different from intercropped plants.

4.1a (8). Crop growth rate (CGR) of bhindi

Crop growth rate of bhindi at initial and final

Table 8. Total dry matter production of bhindi (kg ha^{-1}) as affected by planting pattern and nitrogen levels

Treatments	Total dry matter production		
	30 DAS	60 DAS	90 DAS
Planting pattern			
G_1	491.36	3690.53	6244.36
G_2	405.06	2963.21	4927.12
F (1,12)	6.05*	18.07**	41.77**
CD (0.05)	76.46	372.84	444.14
Nitrogen levels			
N_1	435.31	3288.21	5452.71
N_2	459.88	3376.29	5848.33
N_3	449.45	3316.11	5456.17
F (2,12)	0.165	0.092	1.66
CD	-	-	-
Control (C1)	502.59	3950.98	6736.78
F(Treated vs. C1)	1.373	7.60*	18.22**
SE	42.98	209.56	249.63

* - Significant at 5% level
** - Significant at 1% level

Table 8a. Combined effect of planting pattern and nitrogen level on dry matter production of bhindi at 60 and 90 DAS

Treatments	Nitrogen levels		
	N_1	N_2	N_3
Planting pattern			
<u>60 DAS</u>			
G_1	3834.56	3204.69	4032.34
G_2	2741.85	3547.89	2599.87
<u>90 DAS</u>			
G_1	6551.10	5427.89	6754.09
G_2	4354.32	6268.76	4158.27

G X N

	60 DAS	90 DAS
CD (0.05)	645.78	769.27
SE	209.56	269.63

Table 9. Crop growth rate (CGR) of bhindi (mg^{-2} day^{-1})

Treatments	Initial state (30-60 DAS)	Final stage (60-90 DAS)
<u>Planting pattern</u>		
G_1	1.067	0.851
G_2	0.853	0.654
F (1,12)	12.62**	28.45**
CD (0.05)	0.132	0.080
<u>Nitrogen levels</u>		
N_1	0.951	0.722
N_2	0.972	0.824
N_3	0.966	0.713
F (2,12)	0.045	3.74
CD (0.05)	-	-
Control (C1)	1.15	0.928
F(Treated vs. C1)	5.695**	12.93**
SE	0.073	0.045

** - Significant at 1% level

Table 9a. Combined effect of planting pattern and nitrogen levels on the CGR of bhindi at the initial final stage

Treatments	Nitrogen levels		
	N_1	N_2	N_3
Planting pattern			
Initial stage			
G_1	1.117	0.916	1.167
G_2	0.785	1.029	0.744
Final stage			
G_1	0.906	0.741	0.907
G_2	0.538	0.907	0.518

G x N

	Initial stage	Final stage
CD (0.05)	0.227	0.339
SE	0.073	0.045

stage are presented in Table 9 and 9a.

The planting pattern significantly influenced the crop growth rate of bhindi at both the stages. The CGR was high with normal planting pattern. But the CGR was not influenced by N levels.

The interaction between planting pattern and nitrogen levels was also significant at all growth stages. At N_1 and N_3 levels CGR was significantly higher with normal planting pattern, but on par at N_2 level.

The sole crop of bhindi recorded CGR of 1.149 $mg^{-2} day^{-1}$ and 0.928 $mg^{-2}day^{-1}$ at initial and final stages respectively and was significantly superior to the intercropped plants.

4.1a (9). Relative growth rate (RGR) of bhindi

Relative growth rate of bhindi at initial and final stages are presented in Table 10.

The relative growth rate of bhindi was not significantly influenced either by planting pattern or nitrogen levels and interaction between planting pattern and nitrogen.

The sole crop of bhindi also recorded almost similar RGR as with intercropped plants. A general decline in the RGR was observed for all the treatments during the final stage.

Table 10. Relative growth rate (RGR) of bhindi (mg day^{-1})

Treatments	Initial stage (30-60 DAS)	Final stage (60-90 DAS)
Planting pattern		
G_1	67.35	17.58
G_2	66.15	16.77
F (1,12)	0.134	0.735
CD (0.05)	-	-
Nitrogen levels		
N_1	67.23	16.69
N_2	66.63	18.26
N_3	66.39	16.58
F (2,12)	0.023	1.318
CD (0.05)	-	-
Control (C1)	68.91	17.77
F(Treated vs. C1)	0.249	0.22
SE	4.006	1.160

Table 11. Net assimilation rate (NAR) of bhindi (Mg cm^{-2} day^{-1})

Treatments	Initial stage (30-60 DAS)	Final stage (60-90 DAS)
Planting pattern		
G_1	0.981	0.485
G_2	0.923	0.433
F (1,12)	0.209	0.754
CD	-	-
Nitrogen levels		
N_1	0.969	0.426
N_2	0.913	0.517
N_3	0.975	0.434
F (2,12)	0.096	0.926
CD	-	-
Control (C1)	1.005	0.426
F(Treated vs. C1)	0.100	0.173
SE	0.155	0.074

4.1a (10). Net assimilation rate (NAR) of bhindi

NAR of bhindi at initial and final stage are presented in Table 11.

The NAR of bhindi was not significantly influenced either by planting pattern or nitrogen levels and interaction between planting pattern and nitrogen.

The sole crop of bhindi recorded almost similar NAR as with intercropped plants.

A general decline in the NAR was observed for all the treatments during the final stage.

4.1b. Yield attributes and yield

4.1b (1). Days to 50 per cent flowering

Mean number of days taken for 50 per cent flowering are given in Table 12.

The number of days taken to 50 per cent flowering was found to be more with paired row planting. When normal row planting pattern took about 38.89 days to reach 50 per cent flowering, paired row planting took about 40.22 days.

The nitrogen level had no significant effect on the number of days to 50 per cent flowering.

Interaction effect was not significant with regard to 50 per cent flowering.

The sole crop of bhindi took 38.67 days to reach 50 percent flowering.

Table 12. yield attributes of bhindi

Treatments	Days to 50% flowering	Number of fruits plant	length of fruit (Cm)	girth of fruit (Cm)
<u>Planting pattern</u>				
G_1	38.89	18.89	17.38	5.25
G_2	40.22	15.73	16.99	4.98
F (1,12)	13.09**	6.10*	1.31	2.68
CD (0.05)	0.80	2.78	-	-
<u>Nitrogen levels</u>				
N_1	40.17	17.00	16.96	5.01
N_2	39.17	18.23	17.66	5.31
N_3	39.33	16.70	16.95	5.03
F (2,12)	2.82	0.539	1.91	1.40
CD (0.05)	-	-	-	-
Control (C1)	38.67	22.86	18.23	5.48
F(Treated vs. C1)	3.32	10.79**	5.37*	2.73
SE	0.45	1.57	0.42	0.20

* - significant at 5% level

** - significant at 1% level

4.1b (2). Number of fruits per plant

The mean number of fruits recorded per plant are shown in Table 12.

Planting pattern exerted a significant effect on the total number of fruits per plant. Maximum number of fruits per plant (18.89) was recorded under normal row planting pattern which was significantly higher than that of paired row planting pattern (15.73).

Nitrogen levels had no significant influence on the number of fruits per plant.

Interaction effect was not significant.

However, sole crop bhindi produced 22.86 fruits per plant which was significantly higher than those given by intercropped plants.

4.1b (3). Length and girth of fruits

The data on mean length and girth of fruits are presented in Table 12.

The length and girth of fruits were not significantly influenced either by the planting pattern or nitrogen levels and their interaction.

Sole crop of bhindi recorded significantly higher fruit length of 18.23 cm than intercropped bhindi. However, the girth of fruits was not significant between sole and intercropped plants.

4.1b (4). Fruit weight per plant

Table 13 shows the mean value of fruit weight per plant.

The fruit weight per plant was significantly influenced by the planting pattern. The normal row planting recorded an average fruit weight per plant of 536.96 g which was significantly higher than 418.71 g with paired row planting pattern.

Nitrogen levels did not influence the weight of fruits per plant.

Interaction effect of nitrogen level and planting pattern was also not significant.

The highest fruit weight of 582.33 g per plant was recorded by the sole crop bhindi which was not significantly different from intercropped plants.

4.1b (5). Total fruit yield (q ha^{-1})

The data on the yield of fruits are presented in Table 13.

Normal row planting pattern recorded a fruit yield of 128.27 q ha^{-1} which was significantly higher to paired row planting pattern with 91.12 q ha^{-1} yield.

The effect of nitrogen levels on the fruit yield was not significant.

The interaction between nitrogen levels and planting pattern was not significant.

Table 13. Yield of bhindi

Treatments	Fruit weight per plant(g)	Total fruit yield (q ha^{-1})
Planting pattern		
G_1	536.96	128.27
G_2	418.71	91.12
F (1,12)	7.99**	10.33**
CD (0.05)	91.12	25.18
Nitrogen levels		
N_1	448.07	104.19
N_2	515.30	124.52
N_3	470.13	100.38
F (2,12)	0.896	1.68
CD	-	-
Control (C1)	582.33	150.87
F (Treated vs. C1)	3.57	7.25*
SE	51.21	14.15

* - Significant at 5% level

** - Significant at 1% level

The sole crop recorded fruit yield of 150.87 q ha^{-1} which was significantly higher than that recorded by intercropped plants.

4.1b (6). Total bhusa yield of bhindi (q ha^{-1})

The data on mean value of bhusa yield of bhindi is presented in Table 14 and 14a.

There was significant variation in bhusa yield due to planting pattern. The normal planting pattern recorded a significantly higher bhusa yield (244.24 q ha^{-1} to paired row planting (171.03 q ha^{-1}).

Nitrogen levels had significant influence on the bhusa yield of bhindi. N_2 recorded the highest bhusa yield of 230.36 q ha^{-1} which was significantly higher than N_1 and N_3 which were on par.

The interaction between planting pattern and nitrogen levels was found to be significant. At normal planting pattern, bhusa yield was on par with the three levels of N, but at paired row planting, bhusa yield was high with N_2 level.

Maximum bhusa yield was recorded by sole cop bhindi which was significantly superior to intercropped treatments.

4.1c. Nutrient uptake by bhindi

4.1c (1). Nutrient uptake by bhindi plant

The data on total uptake of nitrogen at 30,60 and 90

Table 14. Total bhusa yield of bhindi

Treatments	Bhusa Yield q ha^{-1}
<u>Planting pattern</u>	
G_1	244.24
G_2	171.03
F (1,12)	63.92**
CD	19.95
<u>Nitrogen levels</u>	
N_1	196.80
N_2	230.36
N_3	195.73
F (2,12)	6.17*
CD	24.44
Control (C1),	207.64
F (Treated vs. C1)	14.36**
SE	11.21

* - Significant at 5% level

** - Significant at 1% level

Table 14a. Combined effect of planting pattern and nitrogen level on bhusa yield of bhindi

Treatments	Nitrogen levels		
	N_1	N_2	N_3
Planting pattern			
G_1	248.10	236.59	248.02
G_2	145.50	224.14	143.45

G X N CD (0.05) - 34.56 SE - 11.21

DAS are presented in Table 15, 16 and 16a.

Uptake of N by plants was influenced by planting pattern at all growth stages and the normal planting pattern recorded the higher uptake value than paired planting pattern. Similarly the P and K uptake was also significantly high in normal row planting.

The nitrogen levels had no significant influence on the N, P, and K uptake by plants at any of the growth stages.

The interaction between planting pattern and nitrogen levels also had no influence on the nitrogen and K uptake by bhindi plants. However, interaction had significant influence on P uptake. At N_2 level, though no significant difference in uptake of P was seen, at N_1 and N_3 levels uptake was high with normal planting pattern.

The N, P and K uptake by sole crop of bhindi significantly differed from the uptake of intercropped plants at 90 DAS.

4.1c (2). Nutrient uptake by bhindi fruits

Table 17 shows the mean value of nitrogen uptake by bhindi plants. Here also normal planting resulted in higher uptake of N, P and K by fruits and were not influenced by the nitrogen levels and interactions.

The sole crop recorded higher N, P and K uptake by fruits.

Table 15. Uptake of Nitrogen by bhindi at 30, 60 and 90 DAS

Treatments	Nitrogen uptake (kg ha^{-1}) 30 DAS	60 DAS	90 DAS
Planting pattern			
G_1	4.57	35.18	28.12
G_2	3.44	26.78	22.79
F (1,12)	6.03*	13.32**	6.49*
CD	1.01	5.01	4.57
Nitrogen levels			
N_1	3.88	31.29	25.28
N_2	4.07	31.35	25.48
N_3	4.08	30.32	25.61
F (2,12)	0.082	0.084	0.009
CD	-	-	-
Control (C1)	4.97	36.84	32.67
F (Treated vs. C1)	2.47	3.69	6.78*
SE	0.57	2.82	2.57

* - Significant at 5% level

Table 16. Phosphorus and potassium uptake of Bhindi(kg ha^{-1}) (90 DAS)

Treatments	Phosphorus	Potassium
Planting pattern		
G_1	14.13	49.37
G_2	12.26	40.02
F (1,12)	7.17*	10.99*
CD (0.05)	1.52	6.16
Nitrogen levels		
N_1	13.05	43.51
N_2	13.37	46.12
N_3	13.17	44.43
F (2,12)	0.07	0.29
CD (0.05)	-	-
Control (C1)	16.08	52.88
F (Treated vs. C1)	9.82**	4.86*
SE	0.854	3.46

Table 16a. Combined effect of planting pattern and nitrogen levels on the phosphorus uptake of bhindi

Treatments	Nitrogen levels		
	N_1	N_2	N_3
Planting pattern			
G_1	14.84	12.48	15.06
G_2	11.25	14.25	11.29

G X N CD (0.05) - 2.63 SE - 0.85

* - Significant at 5% level
** - Significant at 1% level

Table 17. N, P and K uptake of bhindi fruits

Treatments	Nitrogen	Phosphorus	Potassium
Planting pattern			
G_1	36.79	17.12	40.72
G_2	25.69	13.87	28.77
F (1,12)	11.41**	4.91*	10.80*
CD (0.05)	7.17	3.19	7.92
Nitrogen levels			
N_1	30.03	15.59	33.47
N_2	34.99	16.29	38.69
N_3	28.69	14.59	32.06
F (2,12)	1.36	0.45	1.23
CD (0.05)	-	-	-
Control (C1)	43.29	20.34	44.97
F(Treated vs. C1)	8.51*	6.24*	4.52
SE	4.02	1.79	4.45

* - Significant at 5% level

** - Significant at 1% level

4.2. Effect of intercropping on cowpea

4.2.1. Plant height

The plant height of vegetable cowpea was recorded at 30, 60 and 75 DAS and the mean values are presented in Table 18.

The plant height did not differ significantly due to planting patterns at 60 and 75 DAS. However, at 30 DAS, there was significant variation in plant height due to planting pattern. The paired row planting pattern recorded higher plant height than the normal row planting (10.67 cm).

The effect of nitrogen levels and interaction between the planting pattern and nitrogen levels were not significant.

The plant height of sole crop of cowpea was on par with intercropped cowpea plants at 60 and 90 DAS, whereas, plant height at 30 DAS (15.4 cm) was higher than all the intercropped plants.

4.2.2. Plant spread

The plant spread was recorded at 30, 60 and 75 DAS and the mean values are presented in Table 19 and 19a.

At 30 DAS, there was significant difference in plant spread due to planting patterns. The paired row planting

Table 18. Height of cowpea as influenced by planting pattern and nitrogen levels

Treatments	Height (cm)		
	30 DAS	60 DAS	75 DAS
<u>Planting pattern</u>			
G_1	10.67	37.072	42.64
G_2	12.20	38.64	43.96
F (1,12)	7.56*	0.71	0.88
CD (0.05)	1.22	-	-
<u>Nitrogen levels</u>			
N_1	12.37	37.57	44.93
N_2	10.50	37.07	41.77
N_3	11.43	38.93	43.20
F (2,12)	3.74	0.353	1.71
CD (0.05)	-	-	-
Control (C2)	15.4	40.33	46.87
F(Treated vs. C1)	28.913*	0.99	2.92
SE	0.683	2.30	1.72

* - Significant at 5% level

Table 19. Plant spread (cm) of cowpea as influenced planting pattern and nitrogen levels.

Treatments	Plant spread (cm)		
	30 DAS	60 DAS	75 DAS
<u>Planting pattern</u>			
G_1	14.27	43.82	46.56
G_2	16.42	46.93	48.13
F (1,12)	16.30**	3.91	0.67
CD	1.16	-	-
<u>Nitrogen levels</u>			
N_1	15.93	48.10	47.40
N_2	14.70	43.97	47.30
N_3	15.40	44.07	47.30
F (2,12)	1.79	2.993	0.001
CD	-	-	-
Control (C2)	19.6	51.33	50.26
F(Treated vs. C1)	36.29**	8.19*	1.31
SE	0.65	1.93	2.37

* - Significant at 5% level

** - Significant at 1% level

Table 19a. Combined effect of planting pattern and nitrogen levels on the plant spread of cowpea at 30 DAS

Treatments	Nitrogen levels		
	N_1	N_2	N_3
Planting pattern			
30 DAS			
G_1	14.80	14.73	13.27
G_2	17.07	14.67	17.53
60 DAS			
G_1	47.73	44.33	39.40
G_2	48.47	43.60	48.73

G x N

	30 DAS	60 DAS
CD (0.05)	2.02	5.94
SE	0.65	1.93

pattern recorded a higher plant spread of cowpea than normal planting pattern. However, at 60 and 75 DAS, there was no significant variation in plant spread due to planting pattern.

Nitrogen levels had no significant influence on the plant spread of cowpea at any of the growth stages.

However, the interaction effect between the planting pattern and nitrogen levels was significant upto 60 DAS. At 30 DAS, paired planting pattern fertilised with N_1 and N_3 level were found to be significantly higher than all other treatment. But at 60 DAS, normal planting pattern fertilised with N_3 was significantly inferior to all other treatments.

The sole crop of cowpea recorded the highest plant spread of 19.6 cm, 51.33 cm and 50.26 cm at 30, 60 and 90 DAS respectively which was significantly higher than treatments at 30 and 60 DAS.

4.2.3. Root spread

The root spread of cowpea was recorded at 30, 60 and 75 DAS and are presented in Table 20.

Root spread of cowpea was not influenced either by the planting pattern, nitrogen levels or their interaction at any of the growth stages.

The root spread of sole crop cowpea was on par with intercropped cowpea plants. However, a general decline in root spread was observed under intercropped situation when compared to sole crops.

Table 20. Root spread of cowpea as influenced by planting pattern and Nitrogen levels

Treatments	Root spread (cm)		
	30 DAS	60 DAS	75 DAS
Planting pattern			
G_1	20.06	29.39	36.78
G_2	24.44	34.50	41.44
F (1,12)	0.52	2.07	1.27
CD (0.05)	-	-	-
Nitrogen levels			
N_1	22.92	32.25	40.00
N_2	21.50	30.75	37.33
N_3	22.33	32.83	40.00
F (2,12)	0.02	0.123	0.18
CD (0.05)	-	-	-
Control (C2)	27.17	38.33	46.33
F(Treated vs. C1)	0.37	1.85	1.74
SE	7.47	4.35	5.07

4.2.4. Yield of cowpea

The data on the yield of cowpea is presented in Table 21.

The planting pattern significantly influenced the yield of cowpea. The paired planting pattern recorded an average yield of 47.46 q ha^{-1} which was significantly higher than normal row planting pattern (31.78 q ha^{-1}).

The nitrogen levels and the interaction between planting pattern and N levels had no significant influence on the yield of cowpea.

The yield of sole crop of cowpea (89.29 q ha^{-1}) was significantly higher than all the intercropped plants.

4.2.5. Bhusa yield of cowpea

The data on the bhusa yield of cowpea is presented in Table 21.

Planting patterns significantly influenced the bhusa yield of cowpea. The paired row planting pattern recorded a bhusa yield of 78.03 q ha^{-1} which was significantly superior to normal row planting.

The nitrogen levels and the interaction effect were not significant.

Sole crop of cowpea produced a bhusa yield of 176.66 q ha^{-1} which was significantly higher than all the intercropped plants.

Table 21. Yield of cowpea (q ha^{-1}) as influenced by planting pattern and nitrogen levels

Treatments	Pod yield	Bhusa yield
Planting pattern		
G_1	31.78	50.61
G_2	47.46	78.03
F (1,12)	10.73**	14.01**
CD (0.05)	10.44	15.96
Nitrogen levels		
N_1	43.44	69.64
N_2	35.65	57.32
N_3	39.78	65.99
F (2,12)	0.87	0.99
CD (0.05)	-	-
Control (C2)	89.29	176.66
F (Treated vs. C2)	61.48*	134.39**
SE	5.87	8.97

Table 22. **Nitrogen, Phosphorus and Potassium uptake of Cowpea (kg ha^{-1})**

Treatment	Nitrogen	Phosphorus	Potassium
<u>Planting pattern</u>			
G_1	33.271	16.92	23.23
G_2	38.574	17.16	29.31
F (1, 12)	1.84	0.038	9.94*
CD (0.05)	--	--	4.20
<u>Nitrogen levels</u>			
N_1	38.978	17.92	26.77
N_2	34.89	16.56	25.33
N_3	33.90	16.63	26.71
F (2, 12)	0.631	0.521	0.239
CD (0.05)	--	--	--
Control(C_2)	76.31	36.03	62.98
F (Treated vs. C2)	60.91**	137.91**	207.15**
SE	4.79	1.49	2.36

* - Significant at 5% level
** - Significant at 1% level

4.2.6. Nutrient uptake by cowpea

The mean value of uptake of nutrients viz. N, P and K by cowpea is presented in Table 22.

The main effect of planting pattern or nitrogen levels and their interaction did not significantly influence the N and P uptake by cowpea. However, K uptake was significantly influenced by planting pattern recording the maximum uptake under paired planting pattern.

The N, P and K uptake of sole crop of cowpea was significantly higher than all the intercropped treatments.

Sole crop recorded phosphorus uptake of 36.04 kg ha^{-1} which was significantly superior to all the intercropped plants.

4.3. Biological efficiency of intercropping system

4.3.1. Land equivalent ratio (LER)

The data on LER are presented in Table 23.

The total LER of bhindi and cowpea intercropping system was not influenced by planting pattern significantly. However, LER of individual crops varied due to different planting pattern. While bhindi crop recorded higher LER in normal planting pattern, for cowpea, paired planting was the best.

The nitrogen levels and the interaction between planting pattern and nitrogen levels did not influence LER significantly.

Table 23. Biological efficiency of the Intercropping system

Treatment	LER(B)	LER(C)	Total LER	LEC	ATER
Planting pattern					
G_1	0.85	0.91	1.75	0.76	1.65
G_2	0.60	1.35	1.95	0.76	1.76
F (1, 10)	8.26**	12.94**	2.35	0.005	0.57
CD (0.05)	0.188	0.272	--	--	--
Nitrogen level					
N_1	0.69	1.21	1.90	0.75	1.76
N_2	0.82	1.03	1.86	0.83	1.74
N_3	0.67	1.13	1.80	0.70	1.62
F (2, 10)	1.39	0.78	0.19	0.34	0.46
CD	-	-	-	-	-
SE	0.10	0.14	0.1567	0.15	0.161

** - Significant at 1% level

4.3.2. Area-time equivalent ratio (ATER)

The data on ATER is presented in Table 23.

From the data it is evident that the ATER did not differ significantly either due to planting pattern, nitrogen levels or their interactions.

4.3.3. Land equivalent coefficient

The data on LEC is presented in Table 23.

As in the case of ATER, LEC also did not differ significantly either due to planting pattern, nitrogen levels or their interaction.

4.3.4. Aggressivity

Data on aggressivity values are presented in Table 24, 24a, and 24b.

The results indicated that aggressivity values were significantly influenced by planting pattern. In both the planting pattern, cowpea was more aggressive than bhindi. The dominance of cowpea was more significant in paired planting pattern.

Nitrogen levels did not influence the aggressivity of crops significantly. However, at higher levels of nitrogen, cowpea was more aggressive.

The interaction effect of planting pattern and nitrogen levels were significant on aggressivity of crops. At

Table 24. Bio-economic suitability of the intercropping system

Treatments	Aggressivity of bhindi	Aggressivity of cowpea	Monetary advantage based on LER	bhindi Equivalent yield Kg ha^{-1}
Planting pattern				
G_1	- 0.061	0.061	14825.56	4765.25
G_2	- 0.741	0.741	15590.00	7118.63
F (1, 10)	16.43**	16.43**	0.1002	10.72*
CD (0.05)	0.373	0.373	-	1565.53
Nitrogen levels				
N_1	- 0.526	0.526	15663.00	6509.67
N_2	- 0.208	0.208	16028.50	5347.93
N_3	- 0.468	0.468	13931.83	5968.26
F (2, 10)	1.36	1.36*	0.29	0.873
CD (0.05)	-	-	-	-
SE	0.20	0.20		379.93

* - Significant at 5% level

** - Significant at 1% level

Table 24a. Combined effect of planting pattern and nitrogen levels on aggressivity of bhindi

Treatment	Nitrogen levels		
	N_1	N_2	N_3
Planting pattern			
G_1	0.054	-0.197	-0.038
G_2	-1.106	-0.219	-0.897

G x N
CD 0.647
SE

Table 24b. Combined effect of planting pattern and nitrogen levels on aggressivity of cowpea

Treatment	Nitrogen levels		
	N_1	N_2	N_3
Planting pattern			
G_1	-0.054	0.197	0.038
G_2	1.106	0.219	0.897

G X N

CD (0.05) 0.647
SE 0.20

normal planting pattern, the aggressivity value was more or less same for all the levels of nitrogen. But at paired planting pattern, N_1 recorded higher value followed by N_2.

4.4. Economic suitability of intercropping system

4.4.1. Gross return

The Table 25 shows the mean value of gross return.

There was no significant increase in the gross return from the intercropping system either due to different planting patterns, nitrogen, or interactions. However, normal row planting recorded a gross return of Rs. 35096.33 which was Rs.2634.66 more than paired planting pattern.

The gross return from sole crop bhindi was Rs. 30172.67 and that from cowpea was Rs. 26787.67. These were significantly lesser than intercropped plants.

4.4.2. Net return

The data on net return is presented in Table 25.

As in the case of gross return planting patterns, the nitrogen levels and their interactions fail to exert any significant influence on the net return. However, normal planting pattern performed better giving a higher net return of Rs. 17754 as compared to Rs. 15,575 for paired planting pattern.

Table 25. Economic suitability of the intercropping system

Treatment	gross return (Rs.)	Net return (Rs.)	Benefit cost ratio (Rs.)
Planting pattern			
G_1	35096.33	17754.24	2.02
G_2	32461.67	15575.20	1.93
F (1, 14)	1.321	0.888	0.395
CD	-	-	-
Nitrogen levels			
N_1	33725.00	16471.2	1.952
N_2	35598.83	18511.69	2.092
N_3	32013.17	15011.27	1.882
F (2, 14)	0.816	0.771	0.644
CD	-	-	-
Control -C1	30172.67	13158.2	1.77
C2	26787.67	16437.02	2.57
F (Treated vs. C1)	1.414	1.3145	0.98
F (Treated vs. C2)	5.318*	0.0057	8.544**
SE	2807.61	2831.479	0.188

The interaction effect was also not significant.

The sole crop bhindi recorded a net return of Rs. 13158.2 and that of cowpea was Rs. 16437.0.

4.4.3. Per day return

The data on per day return are presented in Table 26.

The per day return was not influenced either by planting pattern, nitrogen levels or the interaction of the above factors.

Sole crop of bhindi and cowpea produced per day return of Rs 146.2 and Rs. 205.69 respectively.

4.4.4. Benefit/cost ratio (BCR)

The data on benefit/cost ratio are presented in Table 25.

The BCR was not significantly influenced by planting pattern. However, normal row planting recorded higher BCR of 2.02 than paired planting pattern (1.93).

The nitrogen level and the interaction between planting pattern and nitrogen levels were not significant.

The sole crop of cowpea recorded highest BCR of 2.57.

Table 26. Economic suitability of the intercropping system

Treatment	Return/rupee on fertiliser (Rs.)	Return/rupee on labour (Rs.)	per day return (Rs.)
Planting pattern			
G_1	18.51	3.22	197.27
G_2	18.03	2.95	173.06
F (1, 14)	0.0375	0.0494	0.852
CD (0.05)	-	-	-
Nitrogen levels			
N_1	15.76	3.06	183.01
N_2	20.69	3.31	205.69
N_3	18.36	2.88	166.79
F (2, 14)	1.326	0.043	0.740
CD (0.05)	-	-	-
C1	17.15	2.31	146.20
C2	22.90	4.29	205.69
F (Treated vs. C1)	0.116	0.225	1.26
F (Treated vs. C2)	2.006	0.548	0.341
SE	3.028	0.403	32.12

4.4.5. Return per rupee invested on labour

The data on return per rupee invested on labour is presented in the Table 26.

There was no significant difference in the return per rupee invested on labour, either due to planting pattern, nitrogen levels or interaction between planting pattern and nitrogen levels.

There was no significant difference between sole crops and intercropped plants. However, sole crop of cowpea recorded maximum return per rupee on labour.

4.4.6. Return per rupee invested on fertilisers

The data on return per rupee invested on fertiliser is presented in the Table 26.

Return per rupee invested on fertiliser was not significantly influenced by planting pattern nitrogen levels and their interaction. However N_2 level recorded a maximum return of Rs. 20.68 closely followed by N_3 levels (Rs. 18.36).

The sole crop of cowpea produced higher return per rupee invested on fertiliser than sole crop of bhindi. However the value of sole crops were not significantly higher than intercropped treatments.

4.4.7. Monetary advantage based on LER

The data on monetary advantage based on LER is presented in Table 24.

The monetary advantage was not significantly influenced by planting pattern, nitrogen levels or their interaction. However, paired planting pattern recorded a higher monetary advantage of Rs. 15590 compared to normal planting pattern (Rs. 14825.56). The N_2 level recorded highest monetary advantage of Rs. 16028.5 which was Rs. 365.5 and Rs. 2096.67 more than N_1 and N_3 levels.

4.4.8. Bhindi equivalent yield

The data on bhindi equivalent yield was presented in Table 24.

The bhindi equivalent yield was significantly influenced by paired planting pattern recording the maximum value of 7118.63 kg which was 2351.63 kg. more than normal planting pattern.

The nitrogen levels and the interaction had no significant influence on bhindi equivalent yield.

4.5. Soil analysis

4.5.1. Soil nitrogen

Table 27 shows the mean value of soil nitrogen.

Soil nitrogen did not differ significantly either due to planting pattern, nitrogen levels or their interaction.

Table 27. Soil Analysis (kg ha^{-1})

Treatments	Soil Nitrogen	Soil Phosphorus	Soil Potassium
<u>Planting pattern</u>			
G_1	311.98	53.07	148.38
G_2	359.23	60.12	149.13
F (1,14)	2.66	7.89*	0.248
CD (0.05)	-	0.38	-
<u>Nitrogen levels</u>			
N_1	355.21	57.48	149.77
N_2	295.09	54.28	147.97
N_3	356.51	58.02	148.53
F(2,14)	1.959	0.862	0.131
CD (0.05)	-	-	-
Control (C1)	323.34	61.33	146.67
(C2)	393.84	62.46	144.73
F(Treated vs. C1)	0.12	2.023	0.578
F(Treated vs. C2)	2.31	3.126	2.145
SE	35.46	3.07	2.54

The nitrogen content of sole crop plot of bhindi and cowpea were not significantly higher than intercropped plots. However, the value was more in sole crop cowpea plot.

4.5.2. Soil phosphorus

The mean value of soil P is presented in Table 27.

From the data, it is seen that the soil phosphorus was significantly influenced by the planting pattern. The paired row planting pattern recorded higher soil phosphorus (60.12 kg ha^{-1}) than normal row planting (53.07 kg ha^{-1}).

The nitrogen levels and the interactions between N levels and planting pattern had no significant influence on the soil phosphorus.

The phosphorus content in plots of sole bhindi and cowpea crops did not differ significantly from that of intercropped plots.

4.5.3. Soil potassium

The mean value of soil potassium is presented in Table 27.

Soil potassium did not differ significantly either due to planting pattern, nitrogen levels or their interaction.

The potassium content of sole crop plots of bhindi and cowpea was also on par with intercropped plots.

Table 28. Yield (t ha^{-1}) of succeeding rice crop

Treatments	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
Planting pattern		
G_1	3.62	3.23
G_2	3.96	3.48
F (1,14)	0.79	0.31
CD (0.05)	0.81	0.3122
Nitrogen levels		
N_1	3.75	3.56
N_2	3.79	3.59
N_3	3.84	2.97
F(2,14)	0.0207	1.139
CD (0.05)	-	-
Control (C1)	3.94	3.22
F(Treated vs. C1)	0.0815	0.095
F(Treated vs. C2)	0.2133	0.004
SE	0.467	0.466

4.6. Effect of summer cropping on succeeding rice crop

4.6.1 Grain yield of rice (t ha^{-1})

The planting pattern, nitrogen levels or their interaction did not produce any significant effect on the grain yield of rice.

Grain yield from sole cropped plots was also on par with intercropped plots.

4.6.2. Straw yield of rice (t ha^{-1})

The mean value of straw yield of rice is presented in Table 28.

The straw yield of rice was not significantly influenced either by planting pattern, nitrogen levels or their interactions.

Straw yield of rice from the sole crop plots of cowpea and bhindi was also on par with the above treatments.

4.7. Correlation studies

Simple correlation studies were undertaken with a view to elucidate the relationship of each of the various yield and yield attributing characters, viz., plant height, leaf area index, canopy spread, root length, root spread and

Table 29. Soil balance sheet (kg ha^{-1})

	Total nutrient uptake			Applied nutrient			Soil balance			Soil test data after the experiment		
	N	P	K	N	P	K	N	P	K	N	P	K
$T_1(G_1N_1)$	109.77	50.62	113.65	143.00	84.5	71.5	33.03	33.88	-42.15	317.34	53.63	148.47
$T_2(G_1N_2)$	102.62	46.79	112.52	128.25	84.5	71.5	25.63	37.71	-41.02	264.77	52.80	148.60
$T_3(G_1N_3)$	103.15	46.91	112.47	113.50	84.5	71.5	10.35	37.59	-40.97	313.85	52.77	148.06
$T_4(G_2N_1)$	90.62	42.49	93.83	133.00	75.5	66.5	42.38	33.01	-27.33	393.08	61.33	151.07
$T_5(G_2N_2)$	99.84	45.47	107.75	118.75	75.5	66.5	18.91	30.03	-41.25	325.43	55.77	147.33
$T_6(G_2N_3)$	82.66	41.90	92.64	104.50	75.5	66.5	21.84	33.60	-26.14	359.17	63.27	149.00
$T_7(C_1)$	80.76	36.42	97.85	98.00	44.0	49.0	17.24	7.58	-48.85	323.34	61.33	146.67
$T_8(C_2)$	76.31	36.03	62.98	100.00	90.0	50.0	23.69	53.97	-12.98	393.84	62.46	144.73

Soil test data before the experiment
N - 302
P - 35
K - 182

Table 30. Light interception at 60 DAS ($\mu E\ S^{-1}M^{2}$)

	Over bhindi canopy	Over cowpea canopy	Ground level	Percentage light interception by cowpea canopy
T_1	12.11	4.56	2.15	37.60
T_2	11.35	3.33	0.97	29.33
T_3	11.61	3.22	1.35	27.73
T_4	11.34	9.21	1.54	81.21
T_5	11.53	6.06	1.24	52.55
T_6	10.96	8.94	1.37	81.56
T_7	11.90	-	1.57	100.00
T_8	-	10.48	2.22	

dry matter production each at 30, 60 and 90 DAS and yield attributing characters like days to 50% flowering, number of fruits, length and girth of fruits were calculated (Table 31). The result showed that all the correlation coefficient were statistically significant. A negative correlation was obtained between yield and days to 50% flowering.

Table 31

Bhindi

Correlation studies

1.	Yield x Height of Plants at 30 DAS	+ 0.7499**
2.	Yield x Height of plants at 60 DAS	+ 0.7341**
3.	Yield x Height of plants at 90 DAS	+ 0.7260**
4.	Yield x canopy spread at 30 DAS	+ 0.6556**
5.	Yield x canopy spread at 60 DAS	+ 0.7752**
6.	Yield x canopy spread at 90 DAS	+ 0.7994**
7.	Yield x leaf area index at 30 DAS	+ 0.4494*
8.	Yield x leaf area index at 60 DAS	+ 0.6757**
9.	Yield x leaf area index at 90 DAS	+ 0.4630**
10.	Yield x Root length at 60 DAS	+ 0.5411*
11.	Yield x Root length at 90 DAS	+ 0.6730**
12.	Yield x Root spread at 60 DAS	+ 0.4593*
13.	Yield x Root spread at 90 DAS	+ 0.5934**
14.	Yield x Days to 50% flowering	- 0.7052**
15.	YieldxNumber of fruits per plant	+ 0.8793**
16.	Yield x length of fruit	+ 0.7478**
17.	Yield x girth of fruit	+ 0.6891**
18.	Yield x fruit weight per plant	+ 0.8525**
19.	Yield x bhusa yield	+ 0.8401**
20.	Yield x N uptake at 30 DAS	+ 0.4792**
21.	Yield x N uptake at 60 DAS	+ 0.7658**
22.	Yield x N uptake at 90 DAS	+ 0.6375**
23.	Yield x P uptake at 90 DAS	+ 0.7495**
24.	Yield x K uptake at 90 DAS	+ 0.8389**
25.	Yield x dry matter production at 60 DAS	+ 187990**
26.	Yield x dry matter production at 90 DAS	+ 0.8090**

DISCUSSION

DISCUSSION

The present investigation is aimed at assessing the possibility of raising cowpea as intercrop in bhindi and evaluating the crop association effect in different planting pattern and at varying levels of nitrogen. The study also aims at evaluating the biological efficiency and economic feasibility of the bhindi + cowpea intercropping system. The data collected on various growth and yield characters, plant uptake and soil nutrient content are analysed statistically and the results are discussed in this chapter in different sections viz.

1. Effect of planting pattern, nitrogen levels and interactions on growth and yield of main crop bhindi in intercropping system.
2. Effect of intercropping of bhindi VS. sole cropping.
3. Effect of planting pattern, nitrogen levels and interaction on growth and yield of cowpea in intercropping system.
4. Effect of intercropping cowpea Vs. sole cropping.
5. Evaluation of bhindi + cowpea intercropping system for their biological efficiency and economic suitability.
6. Soil nutrient analysis
7. Effect of summer cropping on succeeding crop.

5.1.1. Effect of Planting pattern on growth and yield of bhindi

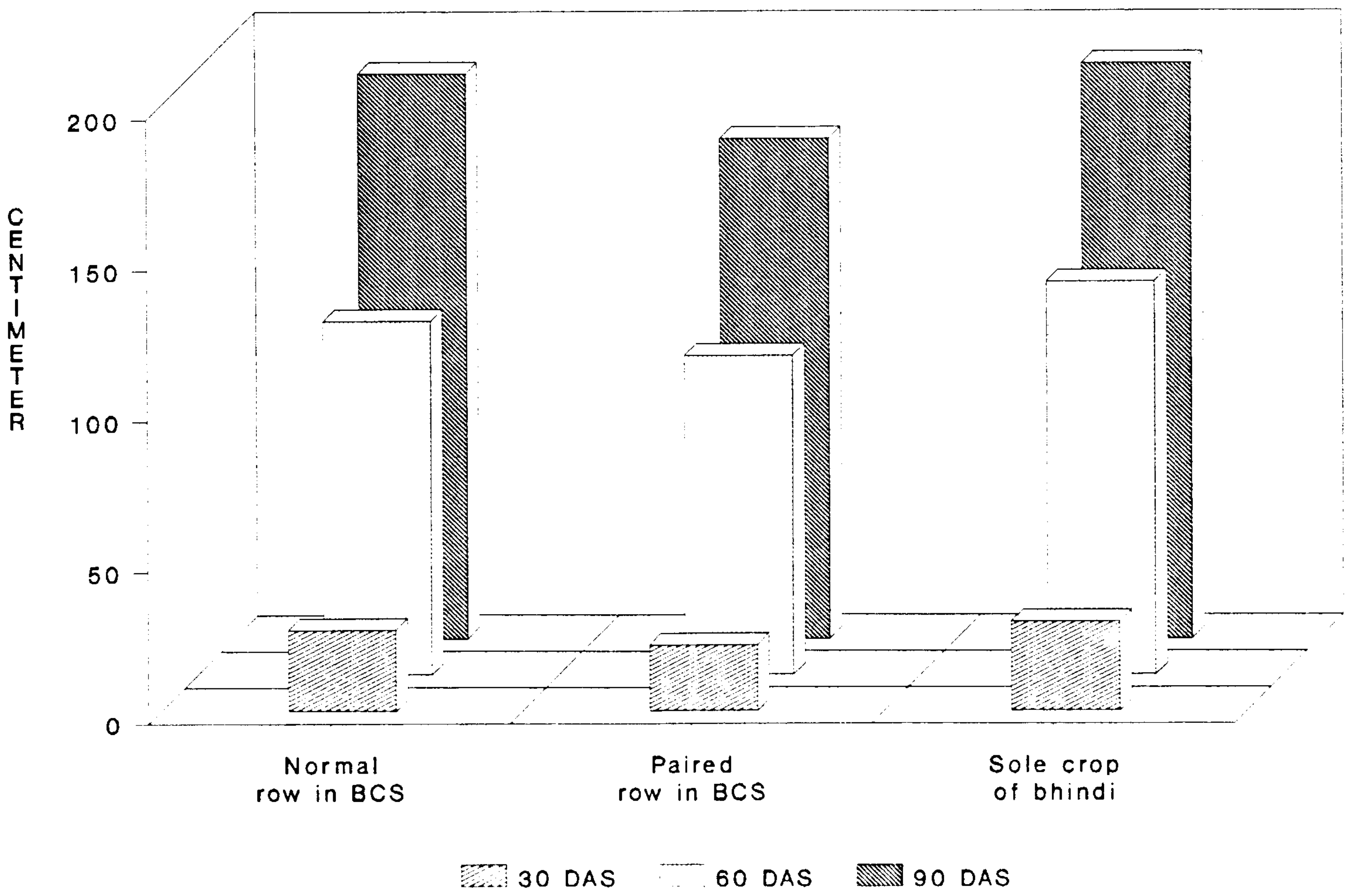
a. Growth parameters

In this chapter, effect of planting pattern on growth characters of bhindi are discussed.

From the results, it was revealed that plant height, canopy spread, root length, total dry matter production and crop growth rate were significantly influenced by planting pattern.

The results revealed that the height of bhindi plants differed significantly due to planting pattern at 90 DAS recording the highest value for bhindi crop planted in normal row alternating with cowpea (Table 2). Bhindi plants in paired row were the shortest at all the growth stages recording a plant height of only 165.78 cm at harvest as against 187.51 cm in normal planting pattern (Fig.4). The lower value for plant height of bhindi in paired row arrangement might be due to the higher interspecific competition persisting there. Olasantan and Aina (1987) reported that the plant height of bhindi was more where bhindi + cowpea were planted in alternate rows rather than in alternate pairs of rows. Geetha Kumari (1989) also found that the plant height of maize was more in normal row arrangement alternating with one row of cowpea than in paired planting pattern.

Fig.4. Plant height of bhindi as affected by planting pattern



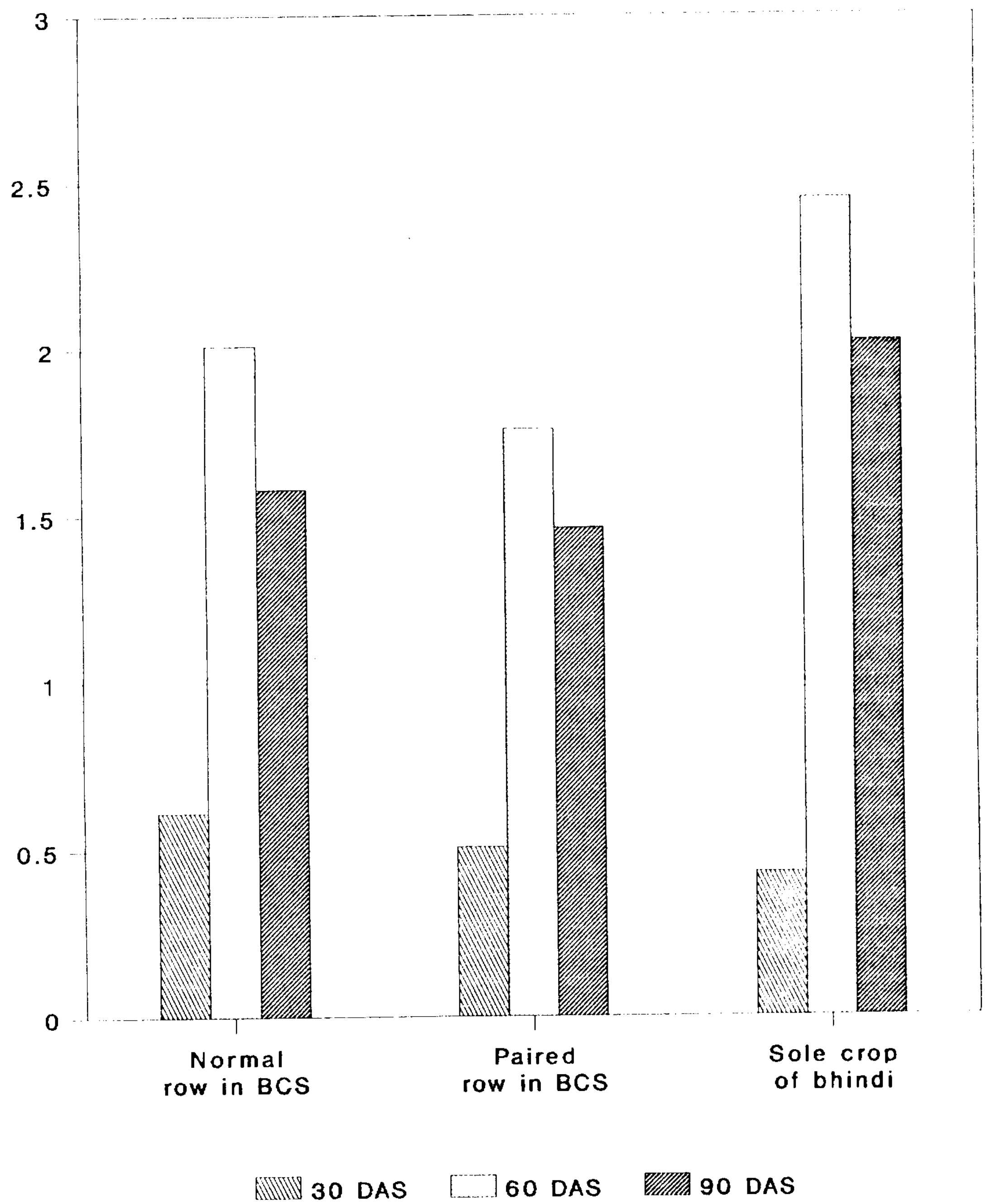
The effect of planting geometry on first bearing node was almost similar to that of plant height though not appreciable.

Canopy spread of bhindi also differed significantly due to planting pattern (Table 4 and 4a). As in the case of plant height, the canopy spread was higher for normal row method which may be due to the less competition effect in this treatment leading to the production of higher number of leaves and branches.

The result obtained on LAI substantiate the above statement recording a higher LAI for normal row pattern (Table 5). Enhanced leafiness due to normal row arrangement as compared with paired row, in maize + cowpea intercropping system was reported by Geetha Kumari (1989). Leaf area index for normal planting pattern was 0.61, 2.01 and 1.58 at 30, 60 and 90 DAS which were higher than that for paired planting pattern (Fig.5). Within the paired row,bhindi plants were very close and this intraspecific competition might have resulted in the reduced leaf expansion. Reports of Olasantan and Aina (1987) in a bhindi cowpea intercropping system is in agreement with the present result.

The growth and development of roots of bhindi were also seen influenced by planting pattern. The plants in the normal row method recorded a higher root length (Table 6) and root spread (Table 7) as compared to that of paired row. Bhindi plants in normal row arrangement had to face less

Fig.5. LAI of bhindi
as affected by planting pattern



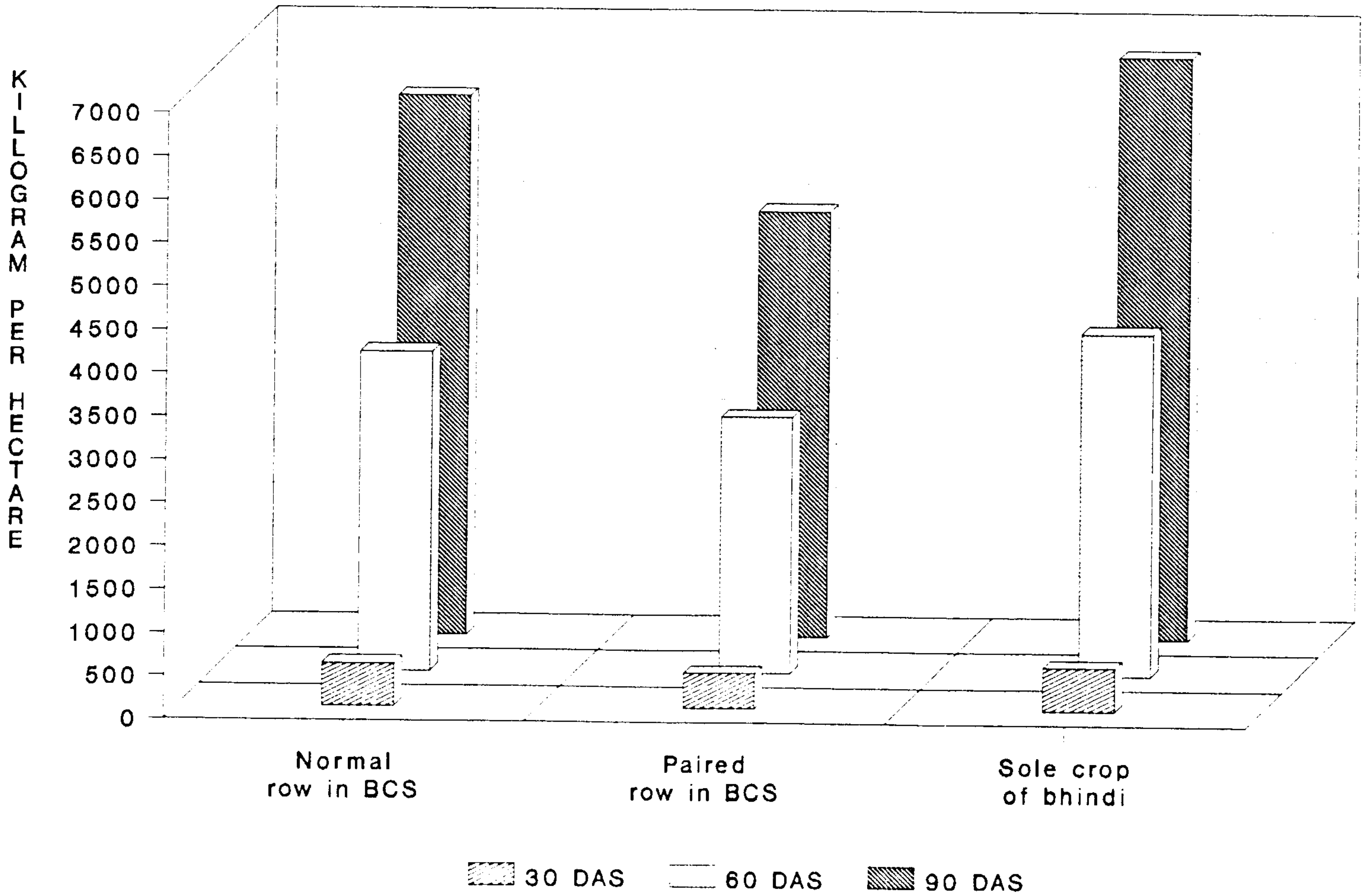
competition for space (below ground) as compared to bhindi plants in paired row arrangement. Roots of cowpea would have interfered with the root growth of bhindi in paired pattern and this interference might have unfavourably affected the development of roots of bhindi.

The total dry matter production of bhindi was found to be significantly influenced by planting pattern (Table 8 and 8a). The normal planting pattern recorded maximum dry matter production throughout the growth stage which was 17.56, 19.7 and 21 per cent more than paired planting pattern at 30,60 and 90 DAS (Fig.6). The increased plant height, plant spread and root length are the reasons for the increased total dry matter production. Similar increase in dry matter production of sorghum in alternate row arrangement of sorghum + cowpea was reported by Baker (1979). Sunitha (1990) also found that maize recorded maximum dry matter production at normal planting pattern than under paired planting pattern in maize + cowpea intercropping system.

Similar to the effect of photosynthetic area, the photosynthetic efficiency of bhindi plants as computed from RGR, NAR and CGR was also maximum for normal row planting pattern as compared to paired row. But the effect was significant only for CGR (Tables 9 and 9a).

The CGR of normal planting pattern was 25 and 30 per cent higher than that at paired planting pattern at initial and final stage respectively. Since CGR is directly influenced

Fig.6. Dry matter production of bhindi as affected by planting pattern



by LAI (Watson, 1952), the increase in CGR due to normal planting pattern can be attributed to increased LAI. A similar observation on CGR due to increased LAI of bhindi was reported by Bindu (1994).

Closer spacing of bhindi plants within the paired row might have resulted in reduced photosynthetic efficiency and thus reduced growth rate. For maximum growth expression of any plant, the same must be in receipt of all the resources like water, nutrients and land area at optimum level. Based on the spacing experiments, the optimum land area required for a bhindi crop is specified as 0.27 sq.m. (package of practice recommendation, KAU, 1989). In paired row planting though the total land area available for a single plant is same as that in normal row, within the pairs spacing is only 45 cm, whereas, in normal row it is 60 cm. So some intraspecific mutual shading might have occurred on the paired row side of the crop.

From the data it is clear that the general growth rate of plant was declining at the reproductive phase. As the crop advanced to its senescence stage, a reduction in metabolic activities might have occurred resulting in reduced rate of increase in dry weight and reduced growth rate at the later stage. Similar results have been observed by Ramana Gowda (1981) in fodder cowpea and Bindu (1994) in bhindi plants.

Thus all the growth parameters of bhindi was maximum under normal planting pattern.

b. Yield attributes and yield

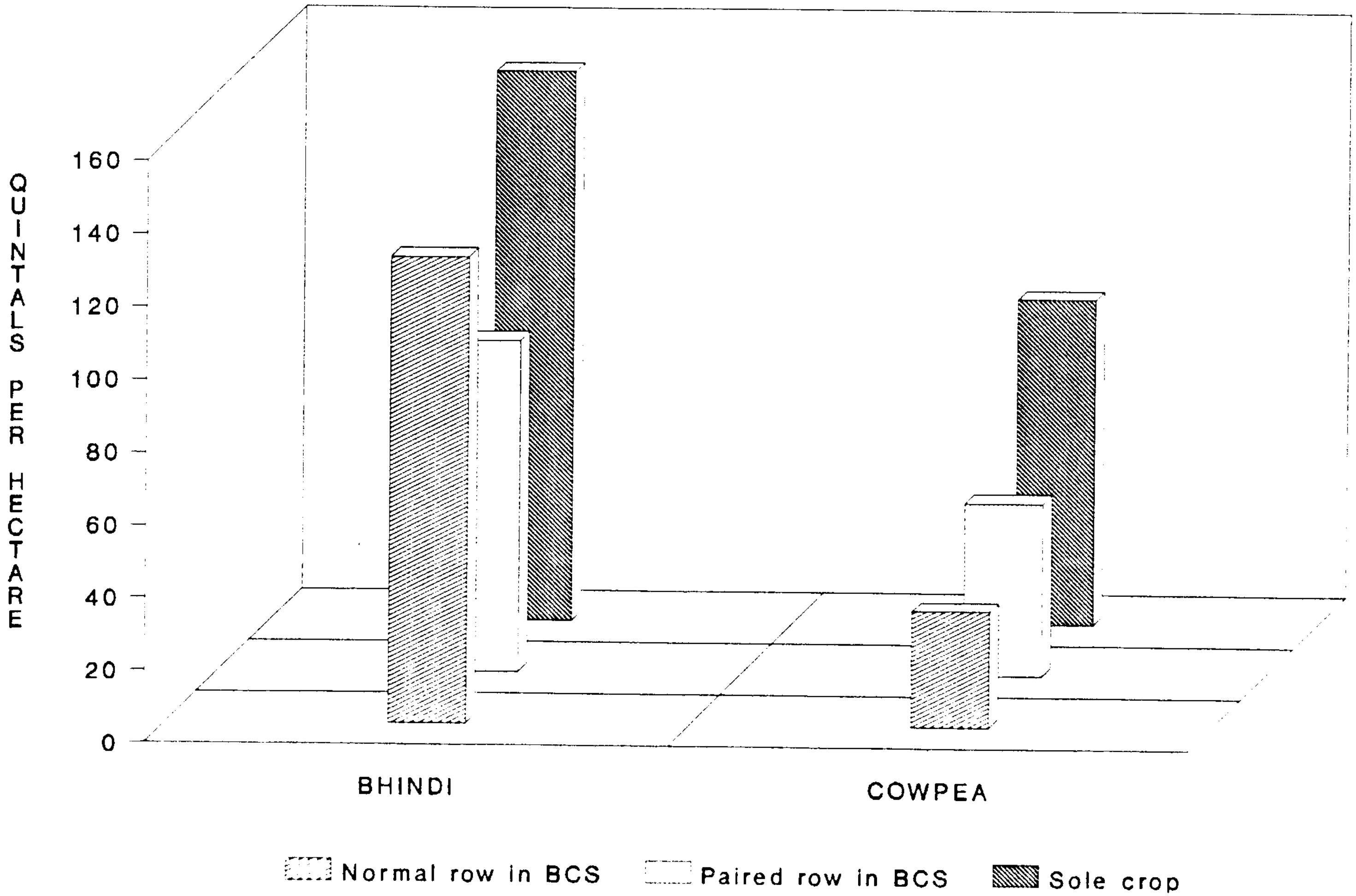
Similar to the effect on growth expressions, the yield and yield attributes of bhindi were also seen improved by normal row arrangement.

Significance in the difference was observed on days to 50 per cent flowering, number of fruits per plant, fruit weight per plant, total fruit yield and bhusa yield of bhindi.

The results revealed that normal planting pattern recorded lesser number of days to reach 50 per cent flowering as compared to paired row (Table 12). In normal planting pattern, plants showed a higher growth rate at the initial stage which probably might have resulted in the completion of vegetative phase at an early date resulting in early flower production (Ray Noggle and George, 1986).

As in the case of days to 50 per cent flowering, number of fruits per plant (Table 12) was also found to be significantly influenced by the planting pattern. The per plant fruit number in normal planting pattern was 18.89 and that for paired row was only 15.73. A higher plant spread recorded in the normal planting pattern might have resulted in the production of more number of flowers and fruits. Similar positive correlation between branches and number of fruits was recorded by Honey Mathew (1986). The better number of fruit per plant of bhindi in normal row arrangement in a bhindi +

Fig.7. Fruit yield of bhindi and cowpea as affected by planting pattern



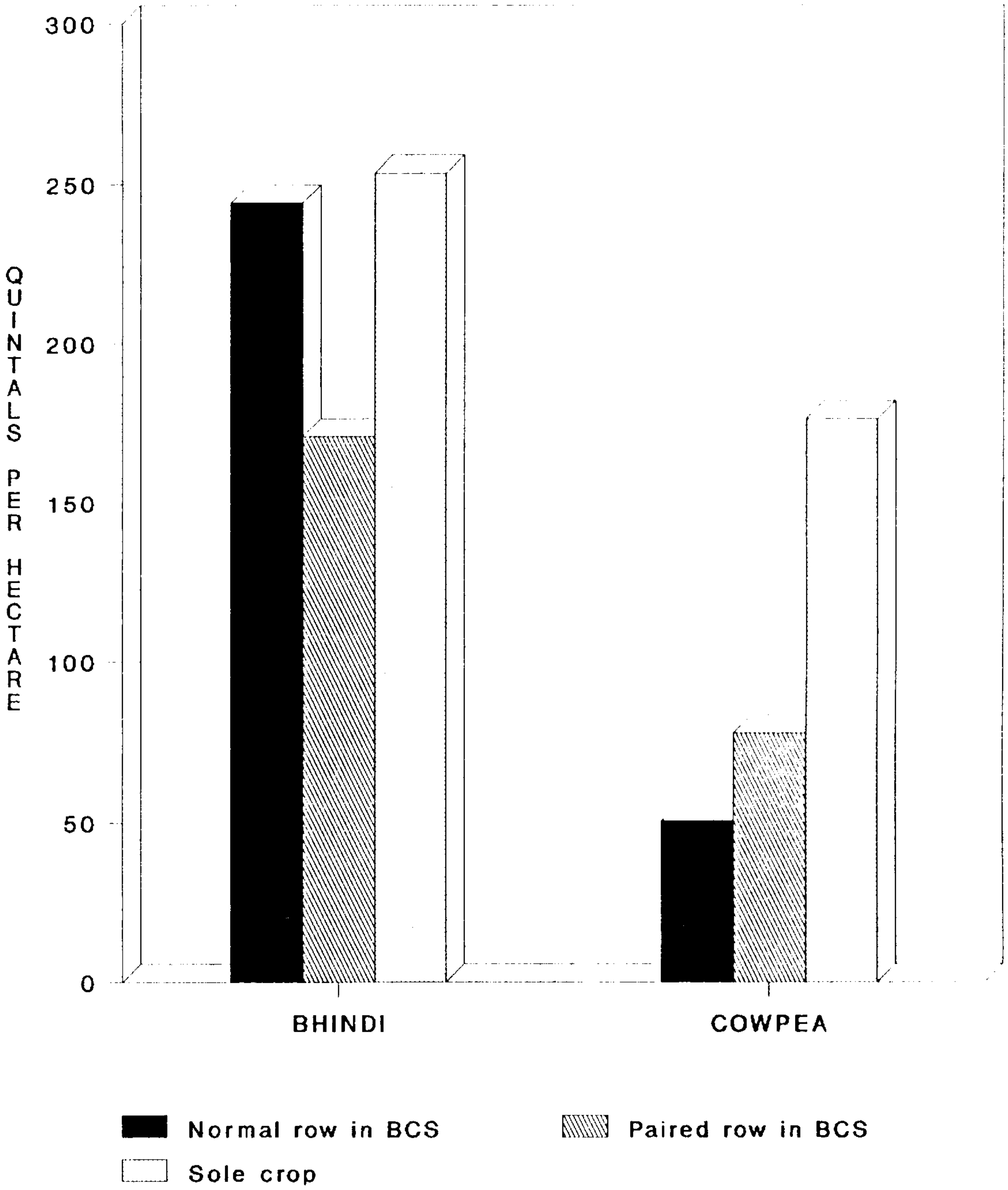
cowpea intercropping system was reported by Olasantan and Aina (1987).

Though the length and girth of fruits (Table 12) were not significantly influenced by the planting pattern, normal planting pattern recorded maximum fruit length and girth of 17.38 cm and 5.25 cm respectively.

On the other hand, planting pattern significantly influenced the fruit weight per plant (Table 13). The normal planting pattern recorded maximum fruit weight of 536.96 g per plant which was about 30 per cent more than paired planting pattern. The higher fruit weight in normal planting pattern was due to higher number of fruits and more length and girth of fruits. The results are in accordance with the findings of Olasantan and Aina (1987).

As in the case of fruit weight, total fruit yield ha^{-1} was also significantly influenced by planting pattern (Table 13). The plants grown in normal planting pattern recorded maximum fruit yield of 128.27 q ha^{-1} which was about 40 per cent more than paired planting pattern (Fig.7). The increased fruit weight per plant, more number of fruits per plant, increased length and girth of fruits were the reasons for higher yield in normal planting pattern than paired planting pattern. This is in accordance with the findings of Olasantan (1992) in bhindi + cowpea intercropping system, Narwal and Ved Prakash (1989) in potato + gobhisarson/Indian mustard intercropping system and Dhingra et al. (1991) in

Fig.8. Bhusa yield of bhindi and cowpea as affected by planting pattern



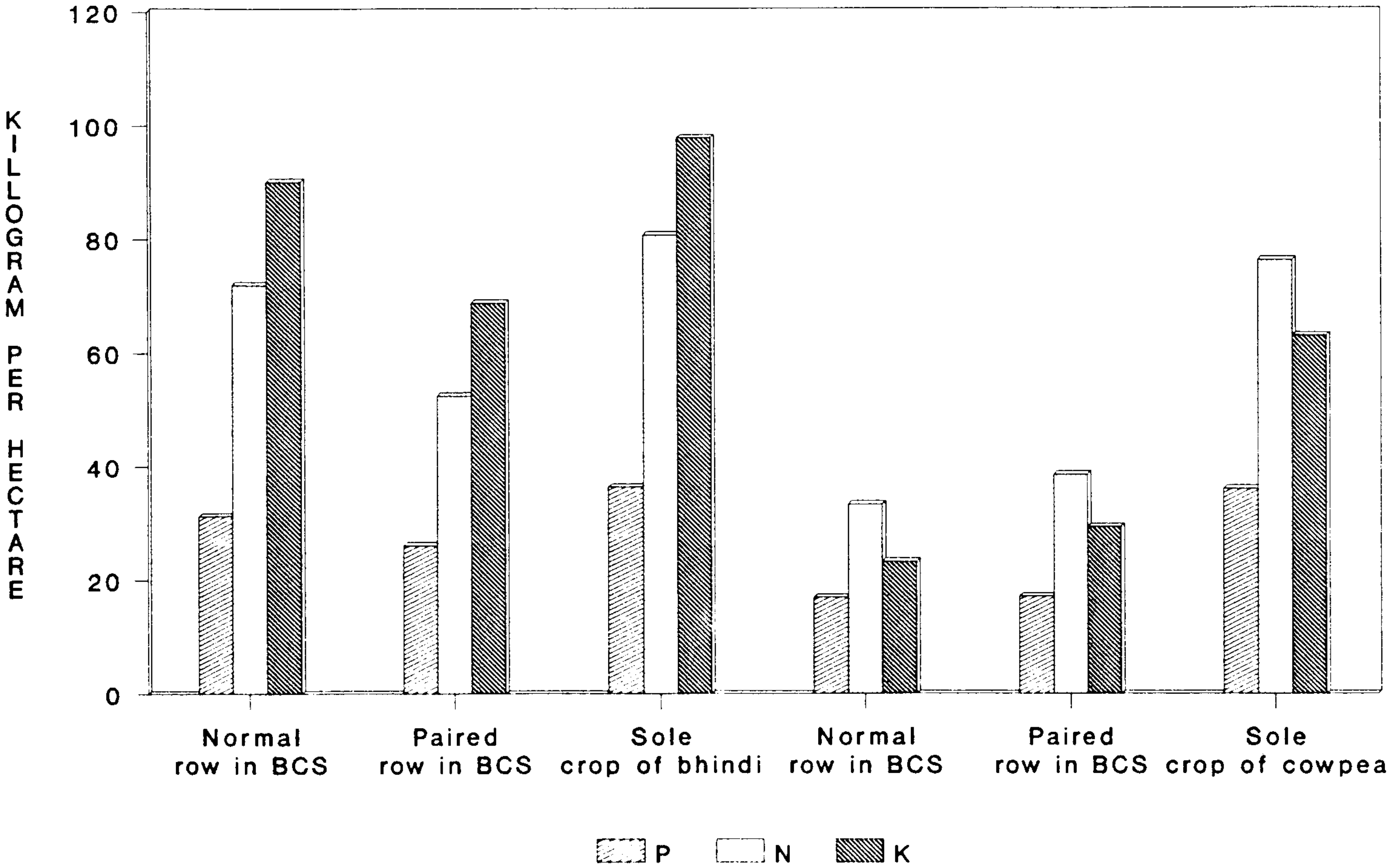
maize + mungbean intercropping system where they found that normal row arrangement recorded higher yield as compared to paired row arrangement.

Total bhusa yield of bhindi (Tables 14 and 14a) was found significantly influenced by the planting pattern. The normal planting pattern recorded maximum bhusa yield at about 244.2 q ha^{-1} which was about 73.21 q ha^{-1} more than paired planting pattern (Fig.8). The maximum bhusa yield in normal planting pattern was due to higher growth rate as observed from growth parameters. Similar results were reported by Sunitha (1990) in maize + cowpea intercropping system.

The nitrogen uptake by bhindi plant was found significantly influenced by planting pattern at all the growth stages (Table 15). The uptake of nitrogen by plant was more in normal row method as compared to paired row method at all the growth stages. The maximum uptake was observed after 60 days of sowing and at this stage, 31 per cent increased uptake was recorded by normal planting pattern over that of paired row (Fig.13). The increased bhusa production by the normal row method is the reason for the increased nitrogen uptake.

As in the case of nitrogen, phosphorus and potassium uptake was maximum under normal planting pattern (Table 16 and 16a). The phosphorus and potassium uptake under normal planting pattern was 14.13 and 49.37 kg ha^{-1}. and that of paired planting was 12.26 and 40.0 kg ha^{-1} respectively. The maximum phosphorus and potassium uptake in normal planting

Fig.13. Uptake of nutrients by bhindi and cowpea as influenced by planting pattern



pattern was due to higher dry matter production coupled with higher root length and root spread of plants under that treatment. Sunitha (1990) also found that in maize + cowpea intercropping system, maximum uptake of nutrients by maize crop was recorded under normal planting pattern as compared to paired planting pattern.

Uptake of nitrogen, phosphorus and potassium by bhindi fruit (Table 17) was found to be significantly influenced by planting pattern. The nitrogen, phosphorus and potassium uptake by bhindi fruit under normal planting pattern was 36.79, 17.12 and 40.72 kg ha^{-1} and that under paired pattern was 25.69, 13.87 and 28.77 kg ha^{-1}. The increased uptake of nutrients in normal planting pattern was the resultant effect of increased fruit weight in that treatment.

Thus the results on growth, yield and uptake observations revealed the superiority of normal row method of planting bhindi in a bhindi + cowpea intercropping systems.

5.1.2. Effect of nitrogen on growth and yield characters of bhindi in intercropping system

a. Growth parameters

In this chapter influence of nitrogen on growth characters of bhindi are discussed.

The results revealed that there was no significant difference in plant height of bhindi due to different nitrogen levels at all the growth stages (Table 2). However, maximum plant height of 184.06 cm was recorded under 75 per cent nitrogen recommendation at 90 DAS. The plant height of bhindi at the highest dose of nitrogen was only 171.83 cm. At the highest dose of nitrogen, growth of cowpea was prolific and its interference with bhindi growth was much higher as it was planted in the interspace and this might have resulted in reduced plant height of bhindi. Non significant influence of plant height of tomato in the intercropping system due to different level of nitrogen was reported by Olasantan (1991) in tomato + cowpea intercropping system.

The effect of nitrogen on the height of first bearing node (Table 3) was not significant.

The canopy spread was significantly influenced by nitrogen levels only at 60 DAS. The 75% nitrogen level recorded highest canopy spread of 84.5 cm which was followed by 100% nitrogen level (79.13 cm) (Table 4). The 50% nitrogen level recorded least spread of 77 cm. This proved that 75% was optimum for the canopy spread of bhindi plants under intercropping. Rajasree (1993) also reported that under coconut intercropping system, colocasia recorded maximum number of leaves at 75% nitrogen level.

Leaf area index of bhindi plant was not significantly influenced by nitrogen levels (Table 5). The 75 per cent nitrogen level recorded maximum leaf area index at all the growth stages which were 0.65, 1.97 and 1.56 at 30,60 and 90 DAS. Rajasree (1993) also found that colocasia plants intercropped in coconut garden recorded higher LAI at 75% nitrogen level.

Root length (Table 6) was also found to be influenced by nitrogen level at 90 DAS. The treatments 75% and 100% nitrogen level recorded more or less same root length of about 24 cm. But the lowest level of nitrogen recorded only 20.67 cm of root length.

Root spread of bhindi plants (Table 7) at 90 DAS was 66.67 cm, 71.16 cm, and 55.8 cm at 100%, 75% and 50% nitrogen levels. The higher levels of nitrogen might have increased the metabolic activities which lead to the quick growth of shoot and root production in plant. Kuruvilla Varughese (1991) also found almost similar increase in root length of maize at higher levels of nitrogen in maize + soybean intercropping system. At lowest level of nitrogen, the canopy spread and leaf development were less which inturn reduced the supplies of assimilates to the roots resulting in slow growth of roots as reported by Bray (1954). Many research workers found that the root and shoot activities were proportional to one another. (Luckwill, 1960; Troughton, 1960; Davidson, 1969; Hunt, 1973).

The effect of nitrogen levels on the dry matter production of bhindi was not appreciable. However, 75% nitrogen level recorded 5.6, 2.6 and 7.2 percent increased dry matter production over full package recommendation at 30,60 and 90 DAS respectively. Rajasree (1993) also found that colocasia intercropped in coconut garden recorded maximum dry weight of tubers at 75% nitrogen level.

At the highest dose of nitrogen, interference of cowpea plants (as observed from the bhusa yield of cowpea) with bhindi growth was much higher and the foliage caused shading of the main crop bhindi. The reduced dry matter production at the lowest level tried may be due to the inadequate availability of nitrogen for the proper growth and development.

Different computed parameters, like RGR, NAR and CGR were not influenced significantly by nitrogen levels. The CGR recorded under different levels of nitrogen was almost same which ranged between 0.95 to 0.97 mg^{-2} day-1 at the initial stage and 0.71 to 0.82 mg^{-2} day^{-1} at the final stage (Table 9). There was not much difference in RGR due to different levels of nitrogen. RGR value ranged between 66 to 67 mg day^{-1} at the initial stage and 17 to 18 mg day^{-1} at the final stage (Table 10). As in the case of other parameters, no significant difference was found in NAR also. The NAR (Table 11) for different nitrogen levels ranged between 0.91 to 0.97 and 0.43 to 0.52 mg cm^{-2} day^{-1}.

Ahamed (1989) noticed that different nitrogen levels had no effect on RGR, NAR and CGR of maize probably due to the high availability of soil nitrogen. However, the results are contradictory to the results of Bindu (1994) where a significant effect of nitrogen on growth analysis parameters were obtained in sole crop situation. It may be due to the fact that intercropping had a more depressive effect than nitrogen treatments particularly at the highest nitrogen rate as reported by Olasantan (1991).

From the results it can be concluded that bhindi plants need only 75% of the recommended nitrogen dose to produce maximum growth in bhindi + cowpea intercropping system.

b. Yield attributes and yield

The effect of nitrogen on the yield and yield attributes revealed that different levels of nitrogen produced more on less similar response to almost all the yield contributing parameters and yield.

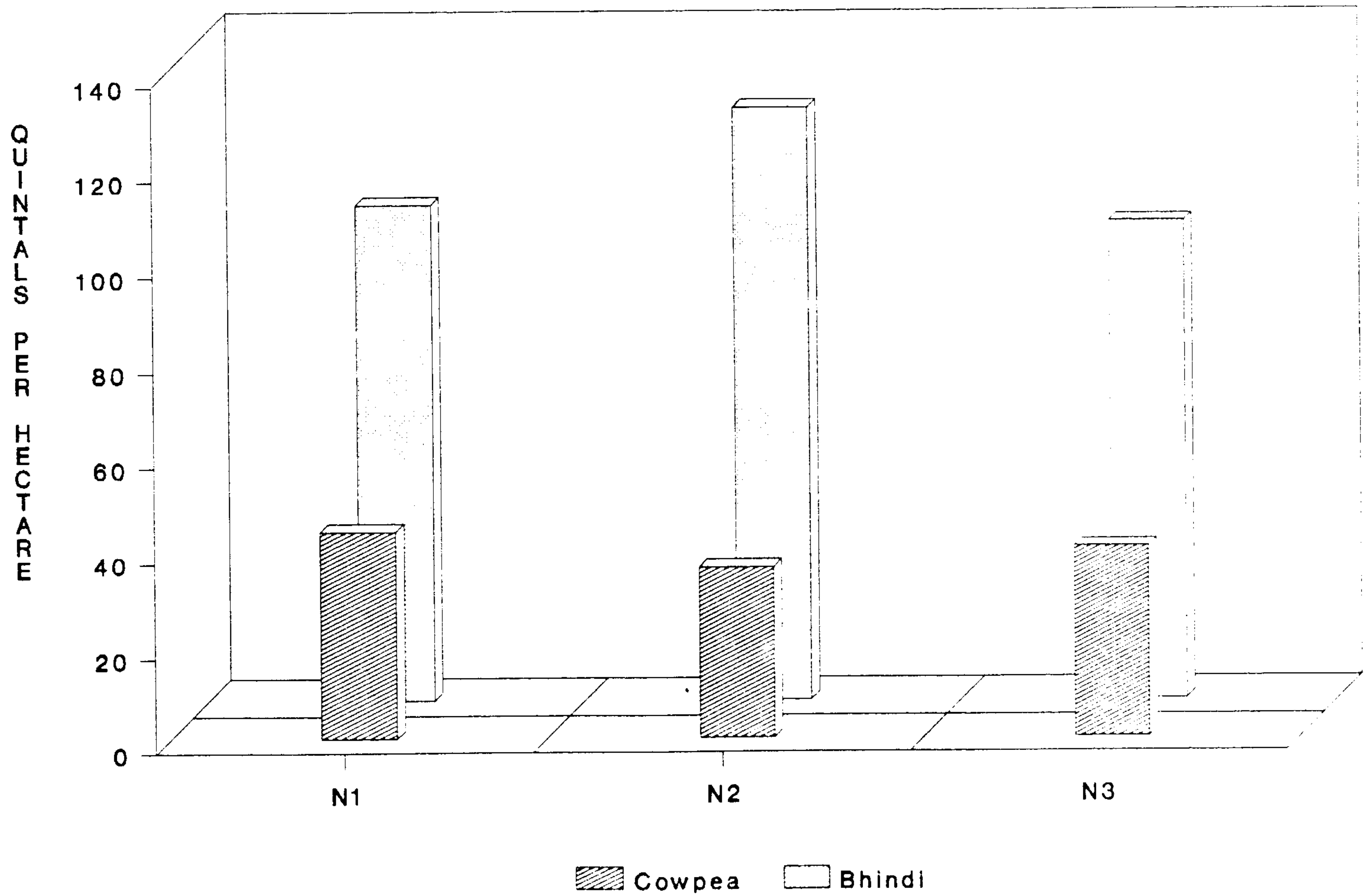
In days to 50 per cent flowering, number of fruits per plant, length and girth of fruits and fruit weight per plant, no significance was observed due to different levels of nitrogen (Table 12 and 13). But in all these parameters, a slight improvement was observed at 75% nitrogen level. Olasantan (1991) also found more or less similar effect of nitrogen on number of fruits and fruit weight per plant of bhindi in bhindi + cowpea intercropping system.

Maximum fruit yield was obtained under 75% (37.5 kg ha^{-1}) nitrogen level (Table 13) which was about 125 q ha^{-1}. It was followed by 100% nitrogen level (104.9 q ha^{-1}). The maximum fruit yield in 75% nitrogen level may be due to cumulative effect of higher fruit weight and higher number of fruits (Fig.9). The vigorous growth of cowpea plants at the highest nitrogen level might have caused some competition effect on the bhindi crop and this may be the reason for the low fruit yield at that level. A more or less similar effect of nitrogen in bhindi + cowpea intercropping was reported by Olasantan (1991) where application of medium level of nitrogen (30 kg N ha^{-1}) caused 20 to 35% gain in marketable fruit yield as compared to lowest level (0 kg ha^{-1}), but increasing the rate to 60 kg ha^{-1} caused depression in yield of bhindi. He opined that the highest nitrogen level inhibited nitrogen fixation and stimulated vegetative development and thus shading by cowpea. However, the peak vegetative development of both crops attained about the same time and there may be some competition in the mixture especially during the time of fruit production and this competition effect may be more at the highest level.

The lowest nitrogen level (50% nitrogen dose) recorded lowest fruit yield of about 100 q ha^{-1}. At this level, the crop received only 25 kg nitrogen ha^{-1} which may be insufficient for the proper growth and development of bhindi.

There were so many reports on different crops that under intercropping system, the nitrogen recommendation can be reduced for the main crop. Singh <u>et</u> <u>al</u>. (1993) found that in potato based intercropping system, 75% nitrogen dose showed

Fig.9. Fruit yield of bhindi and cowpea as affected by nitrogen levels



superiority over 100% nitrogen dose in tuber yield. Balyan and Jagdish Seth (1991) found that in pearl millet + clusterbean intercropping system, application of 40 kg N ha^{-1} was sufficient for maximum yield compared to 80 kg N ha^{-1}.

More than this, a 38 percent reduction in yield observed in intercropped bhindi revealed that the crop was not expressing its full genetic potential under the intercropping system. This also might have resulted in nonresponse to the highest level of nitrogen in the intercropping system.

The bhusa yield at different nitrogen levels (Table 14 and 14a) was found to be significant. The 75% nitrogen level recorded maximum bhusa yield of 230.36 q ha^{-1} which was 17 and 18 percent higher than 100% and 50% nitrogen level. The highest bhusa yield at 75% nitrogen level may be due to higher growth rate as observed from growth analysis parameters. As in the case of fruit yield, the enormous growth of cowpea might have depressed the bhusa production of bhindi at higher level of nitrogen.

The nutrient uptake under different nitrogen levels was more or less same. However, a slight increase in the nutrient uptake was observed in 75% nitrogen level compared with other levels of nitrogen. The nitrogen uptake of plant was maximum at 60 DAS and it varied from 30 to 31 kg ha^{-1} (Table 15). Phosphorus uptake was around 13 kg ha^{-1} and potassium uptake ranged between 44 to 46 kg ha^{-1} for all the levels of nitrogen (Table 16 and 16a). Non significant effect of nutrient uptake due to different levels of nitrogen was reported by Musande and Chavan (1987) in cotton based intercropping system.

In normal planting pattern at all the levels of nitrogen, canopy spread, dry matter production, crop growth rate and bhusa yield of bhindi were found to be more or less similar. But in paired planting pattern, 75% nitrogen dose was found to be superior to 50 and 100% nitrogen dose. It may be due to the reason that cowpea produced enormous vegetative growth in paired planting pattern with 100% and 50% nitrogen dose which might have resulted in some amount of competition and shading effect on bhindi.

From the results, it can be concluded that though the nitrogen level had no significant influence on growth, yield and yield attributes of bhindi the crop performed the best at 75% of the recommendation (37.5 kg N ha^{-1}) as compared with the normal recommendation of 50 kg N ha^{-1} or 50% of the recommendation (25 kg N ha^{-1}). So when bhindi is raised in bhindi + cowpea intercropping system, the nitrogen recommendation can be reduced by 25%. Similar saving of 25% nitrogen was reported by Morachan et al. (1977) by inclusion of a leguminous crop in the intercropping system.

5.2. Effect of intercropping in bhindi Vs sole cropping

In this section, the growth and yield performance of sole crop of bhindi is compared with bhindi plants in intercropping treatments.

Bhindi plants when grown as sole crop were taller than the plants in intercropping treatments. From the initial stage itself, the plants exhibited the enhanced growth rate and this continued upto the harvest stage which is clear from the plant height observations recorded at 30, 60 and 90 DAS (Table 2). In sole cropping, plant population was less as there was only the main crop of bhindi. But in intercropped plots, in addition to bhindi, there was cowpea plants also. Cowpea having a rapid initial growth might have interfered with the bhindi plants at the early stage in resource utilisation. This probably might have suppressed plant height at the initial stage. Cowpea is having the same maturity duration and the grand growth phase of these crops also coincide. Thus at each stage of growth of bhindi plant, the suppression effect of cowpea might have occurred resulting in a reduced plant height by bhindi in bhindi + cowpea intercropping system as compared to sole crop. The influence of intercrops in suppressing the growth of main crop was reported earlier by Soundararajan and Palaniappan (1979) in redgram, Sheela (1981) in tapioca + cowpea intercropping system and Olasantan (1992) in bhindi + cowpea intercropping system.

Canopy spread of sole crop bhindi was found significantly higher than intercropped plants at 60 and 90

DAS. The canopy spread of sole crop during those period was 91.27 cm and 82.27 cm which was 11.06 and 6.61 cm more than the mean value for intercropped treatments. The maximum canopy spread in sole crop bhindi might be due to more number of branches and leaves. Olasantan (1988) found that in melon + corchorus intercropping, sole crop of melon produced maximum number of branches. Olasantan (1991) also found that in bhindi + tomato and cowpea intercropping system, maximum number of branches and leaves were produced by sole crop of vegetables.

In the case of leaf area index, sole crop bhindi recorded significantly higher LAI at 60 DAS as compared to intercropped bhindi plants. In sole crop situation, each plant got more space and hence the mutual interference was less. But in intercropping, the close proximity of neighbouring plants caused suboptimal absorption of growth factors and hence per plant growth was reduced. So a general reduction in LAI was noticed. Several research findings are available in support of these views. In bhindi + cowpea intercropping system (Olasantan and Aina, 1987) and melon + corchorus intercropping system (Olasantan, 1988) maximum number of leaves and leaf area were reported by sole crop of bhindi and melon respectively.

Root development of bhindi measured as root length and root spread differed in sole cropping and intercropping. Root length was maximum under sole cropping as compared to intercropping. The sole crop bhindi recorded root length of

18.33 cm and 26.0 cm and that of intercropped plants were 15.14 and 22.61 cm at 60 and 90 DAS respectively. However, root spread of sole crop was lesser than intercropped plants upto 60 DAS. Bhindi plants in intercropping recorded a mean root spread of 44.17 cm and 56.72 cm and that of sole crop was 39 cm and 53.0 cm at 30 DAS and 60 DAS respectively. It might be due to the fact that during this stage, both the component crops were at the active growth phase utilising the resources to their maximum and for which both these crops spread their roots extensively. So more root spread upto 60 DAS in intercropping system was recorded. But after 60 DAS, leaf senescence and root decay of cowpea might have occurred and by which more nutrients were made available to bhindi plants in intercropping system. But in the case of sole crop bhindi, there was no nitrogen fixation and to meet its nutrient requirement, roots might have extended to deeper and wider layers.

The dry matter production of sole crop bhindi was found significantly higher than intercropped bhindi plants at 60 and 90 DAS. The sole crop recorded maximum dry matter production of 6736.78 kg ha^{-1} which were 7.8 and 36 per cent more than normal and paired planting pattern respectively. The highest dry matter production might be due to higher plant height, canopy spread and root development under sole cropping along with lesser competition. Similar reduction in dry matter production due to legume intercropping was reported by Sheela

(1981) in tapioca + cowpea/groundnut, Madhava Rao et al. (1986) in tapioca + cowpea and Sunitha (1990) in maize + cowpea intercropping system.

In the case of growth analysis parameters like RGR, NAR and CGR, sole crop recorded higher value for all the parameters though the effect was significant only for CGR.

CGR of sole crop bhindi was 1.15 and 0.93 mg^{-2} day^{-1} during the initial and final stage which were 19 and 23 percent more than intercropped plants. Intercropped bhindi plants recorded a mean CGR of 0.96 and 0.75 during the initial and final stage. The higher crop growth rate of sole crop was due to higher dry matter production and leaf area index. Adverse effect of different intercrops in the CGR of maize was reported by Prasad and Prasad (1989).

From the results it can be concluded that intercropping of bhindi with cowpea had a depressive effect on the growth of bhindi.

Yield and yield contributing factors of bhindi were also found to be adversely affected by intercropping with cowpea.

Sole crop and intercropped bhindi plants recorded more or less same days to 50 per cent flowering.

Number of fruits per plant in sole crop bhindi was found to be significantly higher than intercropped treatments. Sole crop bhindi produced about 23 fruits per plant while intercropped bhindi plants in normal row system and paired row system could produce only about 19 and 16 fruits per plant respectively. The maximum number of fruits in sole crop bhindi plants may be due to higher plant height and more plant spread which promote the plant to produce more flowers and fruits. A positive correlation between plant height and fruit yield per plant has been reported by Sajitharani (1993).

The results were in accordance with the findings of Olasantan (1991) in bhindi/tomato + cowpea intercropping system and Singh (1991) in tomato based intercropping system where maximum number of fruits were recorded by sole crop of vegetables.

Length and girth of bhindi fruits in sole cropping were 18.23 cm and 5.48 cm respectively. Fruit length of sole crop was significantly higher than intercropped plants. The lack of competition for space and nutrients in sole crop system might have contributed to the production of longer fruits in sole cropped plots. Geetha Kumari (1989) also found that in maize + cowpea intercropping system sole crop arrangement of maize produced longer cobs than the intercropped ones.

Sole crop bhindi recorded fruit weight of 582 g per plant which was about 22 per cent more than the mean fruit weight of intercropped plants (477.84 g per plant). The maximum fruit weight in sole crop bhindi was due to the increase in number of fruits per plant and increase in length and girth of fruits. The results are in accordance with the findings of Olasantan (1991) in bhindi + cowpea intercropping system, Singh (1991) in tomato based intercropping system where maximum fruit weight of vegetables were recorded under sole cropping.

The yield of a crop is a very complex competitive character resulting from different factors, the more important being yield per plant (Tanaka et al. 1964). This report almost reflect the result on fruit yield ha^{-1} of the present investigation also. Here fruit yield ha^{-1} was significantly higher in sole crop bhindi which recorded an yield of 150.87 q ha^{-1}. In intercropping, bhindi plants could produce only an yield of 128.27 and 91.12 q ha^{-1} under normal and paired planting pattern respectively. The yield contributing characters such as number of fruits per plant, length and girth of fruits, fruit weight per plant were more under pure crop system than under intercropping system. Further, vegetative growth characters such as height of the plant, canopy spread, leaf area, root spread, root length and CGR were also higher in sole cropping. The direct positive correlation of these parameters obtained with yield (Table 31) substantiate these results. Higher the leaf area, greater would be the photosynthetic rate, keeping other factors under optimum. In the case of pure crop of bhindi, the chances for increased rate of photosynthesis were more due to greater leaf area. Thus the photosynthates so produced would have been efficiently utilised in the production of more fruits. All the above factors together might have contributed to an increase in the yield under pure crop system when compared to intercropping system.

In intercropping system, yield advantage occur when the growth pattern of the component crops differ in time so that the crops make their major demands on resources at different time. The yield advantage occur only when there have been marked difference in the maturity periods of component crops. Baker and Yusuf (1976) estimated that no advantage would occur unless there was approximately a 30 to 40 day maturity difference. But in this experiment, both the crops had more or less same duration and their peak demand for resources might have occurred at the same period.

It was said that plants having different heights were suitable for intercropping, which accounts for bhindi + cowpea intercropping system of the present investigation also. However, yield advantage does not occur in all cases. Osiru (1974) found that some yield advantage resulted from intercropping sorghum genotypes of different height, but the maximum increase was only nine per cent.

There are so many reports to show the superiority of sole cropping over intercropping. Olasantan (1991) found that in bhindi + cowpea intercropping system intercropping caused 45 per cent loss in marketable fruit yield. Similarly, Kadalli et al. (1988) found that yield of chilli was maximum under sole cropping in chilli based cropping system. Sheela (1981) in cassava + cowpea intercropping system, Singh (1991) in tomato based intercropping system, Natarajan (1992) in chilli based intercropping system also found similar effect.

Total bhusa yield of sole crop bhindi was found significantly higher than intercropped treatments. Sole crop bhindi produced bhusa yield of 253.53 q ha^{-1} and the mean value of bhusa yield of intercropped bhindi plants were 207.64 q ha^{-1}. The increased plant height, leaf area, wider canopy spread, root length and root spread along with the cumulative effect of all these parameters increased the bhusa yield in pure crop system. Madhava Rao et al. (1986) found that in cassava + cowpea intercropping system, cowpea lowered the stem thickness and vegetative yield of cassava. Similarly, Sheela (1981) also observed a higher bhusa yield for sole crop cassava compared with cassava + cowpea/groundnut intercropping system.

Total nitrogen uptake by sole crop bhindi was higher than the intercropped bhindi plants at the later phase of the crop and the effect was significant only at 90 DAS.

During the initial stages of growth, uptake was more or less same by both sole crop and intercropped bhindi plants. At the young stage, both sole crop and intercrops were very small and their zone of depletion was also less. Hence all the plants both in intercropping as well as sole cropping were getting optimum land area and also all other resources for their growth. At this stage, no mutual competition was experienced. This probably may be the reason for the similar uptake of nutrients by both the sole crop and intercrop at young stage.

At 90 DAS, the difference in uptake of nutrient was significant. Due to the higher dry matter production and fruit yield in sole cropping, the uptake of all the three nutrients was maximum under sole cropping. Increased uptake of nutrient (phosphorus) by sole crop of cassava was reported by Sheela (1981) as compared with intercropping.

Thus the comparison of bhindi + cowpea intercropping system with bhindi sole crop revealed a general reduction in almost all the growth and yield parameters of base crop bhindi. But even under intercropping, the base crop could produce about 85 and 60 per cent of the yield of sole crop under normal and paired row planting pattern respectively. Since the yield of base crop is more than 50% in intercropping system, the intercropping of bhindi with cowpea can be considered as advantageous as reported by Adetiloye et al. (1983).

5.3.1. Effect of planting pattern on growth and yield of intercrop cowpea

The results of the experiment indicated little difference in the vegetative growth parameters like plant height, plant spread and root spread of cowpea due to planting geometry. But the yield of pod and total bhusa productions on the contrary, showed significant difference and paired row planting recorded maximum value for both these attributes.

It is evident from the results that eventhough the growth parameters were not showing any significant difference, plants in the paired row performed better, with regard to plant height (Table 18) and plant spread (Table 19). The plant height as observed from the data is 43.96 cm for paired planting and 42.6 cm for normal planting pattern. In paired planting pattern, modification of spacing of bhindi plants has resulted in better availability of space and radiant energy by photosynthetic surface of the intercrop cowpea (Table 30). This is in accordance with the results of Biju (1989) in cassava + french bean intercropping system where french bean produced taller plants in paired row system.

Plant spread was also more for paired row plants and the higher plant spread always indicates higher production of branches, higher number of leaves and more bhusa yield which was always reported to be directly correlated with pod yield (Magie Mereena, 1989). The higher plant spread of cowpea in paired planting pattern was due to the availability of more space between two pairs of rows of bhindi plants. Increased number of branches and leaves due to paired row technique as compared to normal row technique was reported by Biju (1989) in groundnut in cassava + groundnut intercropping system and in mungbean by Dhingra et al. (1991) in maize + mungbean intercropping system.

Root spread of cowpea was also found to be significantly influenced by planting pattern recording the maximum value by paired technique indicating a less interspecific competition. At the harvest stage, the root spread of cowpea was 41.44 cm in paired planting pattern and 36.78 cm in normal planting pattern.

Thus the superiority of all the above growth expressions by the plants in paired row technique had made the cowpea plants significantly higher yielders in both pod and bhusa yield.

The paired planting pattern recorded pod yield of 47.46 q ha^{-1} which was 49% more than normal planting pattern (31.78 q ha^{-1}). In the case of bhusa yield, paired row technique produced 78.03 q ha^{-1}, whereas, that for normal row technique was only 50.61 q ha^{-1} (Table 21).

In paired row technique, the spacing was so adjusted that each bhindi plant got the same space in both the system. At the same time, between pairs, a larger land area of 75 cm was given for intercropping cowpea as compared with 60 cm in normal row planting. Hence this modification of spacing of bhindi plants resulted in better availability of space and solar energy by the cowpea crop. The data on the incident solar radiation also clearly substantiate this result where the incident solar radiation over cowpea canopy was 31.55 per cent of that in open for normal row and 71.77 per cent for paired row arrangement at the peak growth stage (60 DAS) (Table 30).

There are so many reports to show that paired planting pattern was best for the component crop in intercropping system. Singh et al. (1992) in wheat + chickpea intercropping system and Dhingra et al. (1991) in maize + mungbean intercropping system reported maximum yield under 2:2 planting pattern as compared to normal row arrangement.

Studies on the nitrogen, phosphorus and potassium uptake by cowpea revealed that only potassium uptake was significantly influenced by planting pattern (Table 22). The paired planting pattern recorded maximum nitrogen, phosphorus and potassium uptake of 38.58, 17.16 and 29.31 kg ha^{-1} which was 15.89, 1.4 and 26 per cent more than normal planting pattern respectively. Higher nutrient uptake in paired planting pattern might be due to better growth of cowpea plants which resulted in more root spread and thereby increased nutrient uptake. Biju (1989) found that in cassava + groundnut intercropping system, lowest nitrogen and potassium uptake by groundnut was recorded under normal planting of cassava.

Thus from the results, it can be concluded that a modification in the planting pattern of the main crop and arranging the crop in pairs of rows leaving a wider spacing between two pairs and growing an intercrop adds significant improvement in the yield of the intercrop. Thus for the better performance of intercrop in bhindi based cropping system, a modification in the planting pattern of main crop bhindi to paired method and growing cowpea in between the pairs of rows is advantageous.

5.3.2. Effect of nitrogen on the growth and yield of intercrop cowpea

The effects of different levels of nitrogen on the growth and yield of cowpea in bhindi + cowpea intercropping system are discussed below.

Different levels of nitrogen (50,75 and 100% of the recommended dose) could not exert significant influence on any of the growth and yield contributing parameters of cowpea. This indicates that a 50 per cent of the nitrogen recommendation as that for open condition is sufficient for meeting the requirement of cowpea when grown as intercrop in bhindi + cowpea intercropping system. Such a performance of cowpea may be due to the general reduction in growth as well as yield of cowpea under intercropped situation as compared with sole cropping (Figure 9). General reduction in growth and yield of cowpea plants under partial shade situation was reported by Rajesh Chandran (1983) and Krishnankutty (1987) in vegetable cowpea, Sansamma George (1982) in grain cowpea.

The plant height of cowpea ranged from 41.77 cm for 75% nitrogen to 44.93 cm for 100% nitrogen. The cowpea plants were shortest and the roots were less vigorous at 75% nitrogen level as compared to 50 and 100% nitrogen level. At 75%

nitrogen level, the bhindi plants were more vigorous, casting more shade over the cowpea canopy and thus resulting in a poor performance of cowpea crop at this nutrient level. But at 50% nitrogen level, the bhindi plants were less vigorous and hence the shade effect was also lesser which favoured the growth of cowpea. At full recommendation (100% nitrogen), the cowpea plants were the tallest as compared to other treatments at all the growth stages, though the effects were not significant. The height increase is a general response to nitrogen application. Similar observation was reported by Olasantan (1991) in bhindi + cowpea intercropping system.

The root spread of cowpea was also not significantly influenced by nitrogen levels (Table 20). However, at 75% nitrogen level, the spatial distribution of roots was less (37.33 cm) as compared with 50 and 100% nitrogen level (40 cm). As reported earlier, the poor spread of root is also due to the interference of vigorous bhindi roots (Table 6).

As in the case of growth characters, the pod yield and bhusa yield were also not significantly influenced by nitrogen levels. The enhanced growth of plants at 100% nitrogen level is reflected on the yield of cowpea and the highest pod yield of 43.44 q ha^{-1} was obtained for this level. It was about 21% and 9.2% more than that obtained for medium and low levels of nitrogen respectively. As in the case of growth characters the pod yield was also least for 75% nitrogen level, due to the heavy shading of bhindi plants.

Ofori and stern (1987) reported that shading of the legume by the non-legume will reduce the growth of legume and nitrogen fixation. This stands in agreement with the present finding.

The trend in bhusa yield was similar to that of pod yield. The highest bhusa yield (Fig.8) at highest level of nitrogen may be due to better growth of plant as evidenced from the data on plant height, plant spread and root spread. Sunitha (1990) also reported same effect of nitrogen in the bhusa yield of cowpea in maize + cowpea intercropping system.

Uptake of nutrients was also not influenced by nitrogen levels appreciably. However, at 100% nitrogen level, the uptake of all the nutrients was higher than that of other two levels. The increased availability of nitrogen at the highest level might have favoured the uptake of phosphorus and potassium also, thus resulting in a higher total uptake value. Sunitha (1990) also reported similarly.

The combined effect of planting pattern and nitrogen levels was found to be significant on the plant spread of cowpea. The normal row planted cowpea with 50% nitrogen was significantly inferior to all the other treatments. It may be due to the severe competition faced by cowpea crop in that treatment.

Thus the non significant effect of nitrogen on the growth and yield parameters of intercropped cowpea lead to the conclusion that when cowpea is raised under intercropping system, nitrogen level can be reduced to 50% level without remarkable decrease in the production. Only about 9% reduction in pod yield is observed in this investigation due to the curtailing of 50% nitrogen. Kushwah and Masood Ali (1991) reported that in french bean + potato intercropping system, french bean with 50% nitrogen dose was quite productive.

5.4. Effect of intercropping of cowpea vs. sole cropping

The data on growth and yield parameters clearly revealed the superiority of sole crop cowpea over intercrop cowpea. Sole crop cowpea recorded maximum plant height (46.87 cm) and plant spread (51.33 cm) as compared with intercrops (Table 18 and 19). In sole cropping, the solar radiation received by cowpea canopy was 51% more than that for intercropping (Table 30). Moreover, the interspecific competitions for the resources like nutrients and moisture was nil here. But under intercropping, the crop had to compete with the taller bhindi plants which caused considerable shade over the cowpea canopy resulting in poor growth performance. This is in accordance with the observations of Rajesh Chandran (1987) and Sansamma George (1982) where a reduction in plant height and leaf number was reported for cowpea grown under partial shade situation.

As in the case of above ground parts, the below ground part of the crop as observed from the data on root spread (Table 20) is also seen influenced by intercropping.

From the very initial stage itself, the root spread of sole crop cowpea was more than that of intercrop. At the time of harvest, the root spread of sole crop cowpea was 46 cm while that of intercropped cowpea was only 37 and 41 cm under normal and paired row system respectively. In intercropped treatments, the intermingling of roots of cowpea and bhindi might have resulted in some competition for the available resources like plant nutrients and moisture. This intermingling and the more aggressive nature of bhindi roots might have restricted the spread of cowpea roots in intercropping.

The pod yield and bhusa yield also showed significant reduction in intercropped situation. This was actually a reflection of poor growth performance of cowpea under intercropping (Table 21). The total pod yield of sole crop was 89.29 q ha^{-1} and the average pod yield under intercropping was only 39.62 q ha^{-1}. The yield increase in sole cropping of cowpea was due to higher plant population and absence of interspecific competition. The interspecific competition between bhindi and cowpea was so high that it caused 55% reduction in yield of cowpea due to intercropping though the population reduction was only 40%. The bhindi crop in intercropping system might have exerted some adverse competitive effect on the component cowpea crop for solar radiation, moisture and nutrients. For more yield advantages, greater canopy differences between component crops should be there (Patil, 1990). That is taller component should be with a high light requirement and the bottom component with a low light requirement. But in this case, both the crops are having high light requirements and more than that the peak period of requirement for resources of bhindi and cowpea were almost similar and hence at the grand growth phase, the competition was more resulting in reduced yield. Similar reduction in cowpea yield due to intercropping was reported by Ofori and Stern (1986) and Morgado (1986).

As in the case of pod yield, the bhusa yield of cowpea was maximum in solecropping. The sole crop produced bhusa yield of 176.66 q ha^{-1} and the average bhusa yield of intercropped cowpea was 64.32 q ha^{-1}. The higher bhusa yield in sole cropping was due to the increased plant height and canopy spread coupled with the higher plant population. The result is in accordance with the observation of Sunitha (1990) in maize + cowpea intercropping system, Prasad and Srivastava (1991) in Pigeonpea + Soybean intercropping systems.

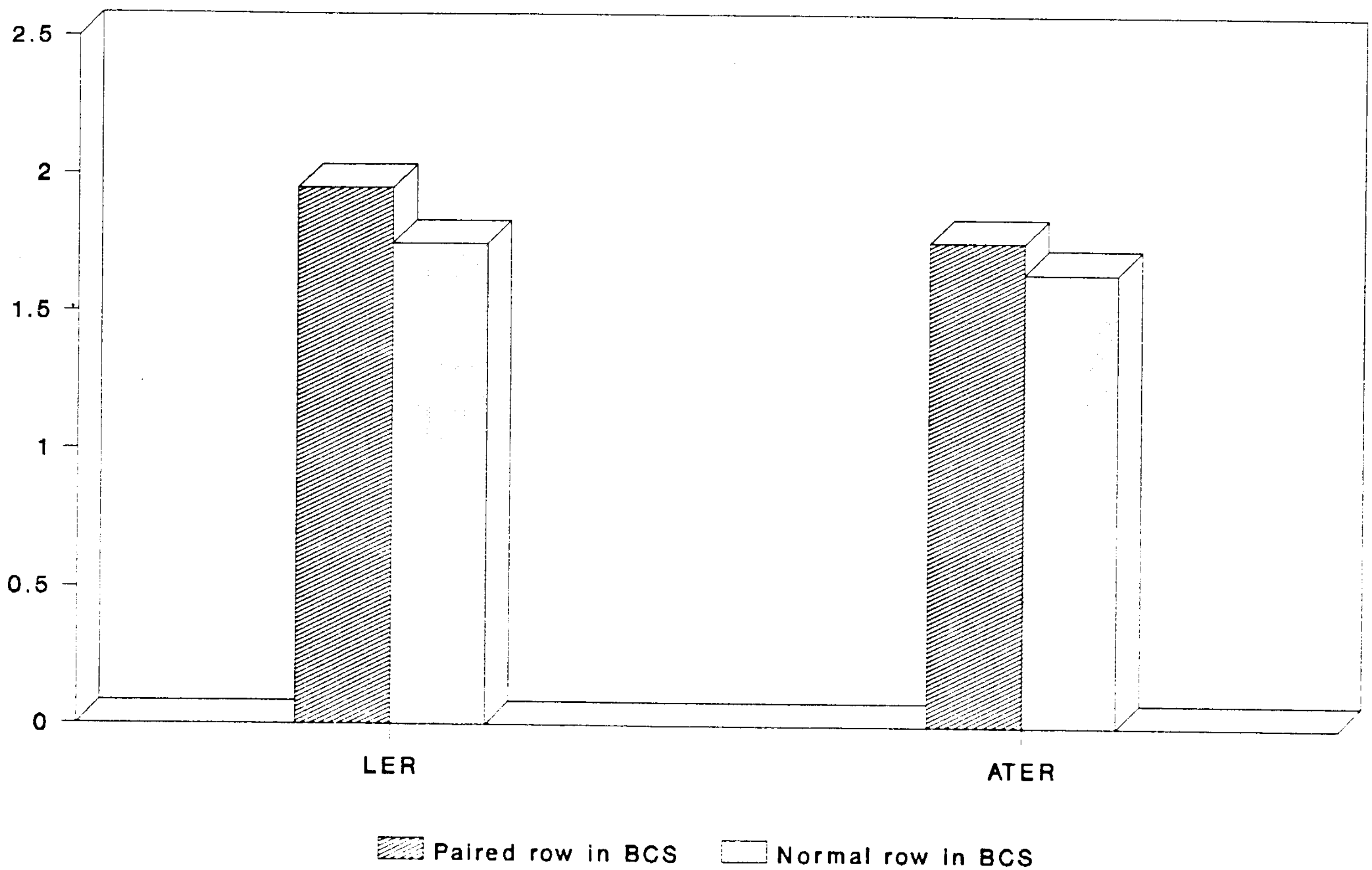
The nitrogen, phosphorus and potassium uptake by sole crop cowpea (Table 22) was found to be significantly higher than that of intercropped plants. The nitrogen, phosphorus and potassium uptake of sole crop cowpea was 76.30, 36.04 and 62.98 kg ha^{-1}. The higher bhusa production coupled with higher root spread resulted in enhanced absorption of nutrients and thus resulted in higher uptake values. Sunitha (1990) also found that in maize + cowpea intercropping system, maximum nutrient uptake of cowpea was in sole cropping than in intercropping treatments. Patra et al. (1986) also found that nitrogen uptake by cowpea was reduced in mixed cropping as compared to pure cropping.

The foregoing results clearly indicate that intercropping of cowpea with bhindi resulted in substantial yield reduction of cowpea as compared to sole cropping. But even then it satisfies the requirement in such a way that without much additional input, a 45% yield as that of sole cropping is obtained due to this type of intercropping.

5.5. Biological efficiency of the intercropping system

Based on the results till discussed it is understood that intercropping of bhindi with cowpea resulted in the yield reduction of both bhindi and cowpea as compared to their respective sole cropping. But for any intercropping system, evaluation of the competitive relations of component crops and their yield advantages in intercropping situation provides a useful basis to describe different competitive situations (Sheelavantar, 1990). Biological efficiency parameters are used for evaluating the competitive relation between component crops in intercropping. Willey (1979) concluded that the most generally used single index for expressing the yield advantage is LER, defined as the relative land area required by sole crops to produce the same yield as in intercropping.

Fig.12. Biological efficiency of the intercropping system as affected by planting pattern



From the results, it is clear that the total LER of bhindi + cowpea intercropping system were not appreciably modified by the planting pattern. However, the paired planting pattern proved its superiority by producing an LER of 1.95 over normal planting pattern which recorded a value of 1.75 (Table 23). In both the planting patterns, the total LER was more than unity, indicating the higher biological efficiency of this intercropping system (Fig.12).

In paired planting pattern, the LER value of 1.95 indicate that 95% more land would be required as sole crops to produce the same yield as intercropping ie. it was 95% more efficient than respective sole crops. Similarly in normal row technique, a 75% more efficiency as compared with sole cropping was obtained. Geetha Kumari (1989) also reported a higher biological efficiency in terms of LER for maize + cowpea intercropping system as compared with their sole cropping.

The increased efficiency of paired row technique is due to the better performance of the intercrop cowpea in this system as observed from the LER value of cowpea (1.35). This indicates that cowpea produced more yield per unit area in paired row intercropping. Thus the lower yield and lesser LER value of bhindi is compensated by the better performance of cowpea in paired row technique resulting in more efficiency and more productivity per unit space. The results are in accordance with the findings of Olasantan (1988) in maize +

melon intercropping system, Venkateswarlu (1989) in castor + clusterbean intercropping system, and Sarkar and Pramanik (1992) in sesamum + mungbean intercropping system where paired planting recorded maximum LER value.

Nitrogen levels did not influence the total LER significantly. However, it increased with increasing levels of nitrogen recording the highest value of 1.90 for 100% nitrogen. This is in accordance with the results of Zada et al. (1988) that an increase in nitrogen levels tend to increase the LER values in maize + soyabean intercropping system. LER was least for 50% nitrogen level (1.80). As in the case of planting pattern, at all the levels of nitrogen also biological efficiency of intercropping system was higher than sole cropping. Even at 50% N level, 80% more efficiency is observed by intercropping. Prabhakar and Vishnu Shukla (1991) in bhindi + french bean intercropping system and Olasantan (1985) in bhindi + tomato intercropping system also found that intercropping system was biologically efficient in terms of LER recording higher total LER than sole cropping.

The interaction effect of planting pattern and nitrogen levels failed to modify the total LER significantly. However, that in paired row planting technique, the LER of bhindi was very much reduced at 100 and 50% nitrogen level. But at the same time, the LER of cowpea for these treatments was very high and thus resulted in a higher total LER. Hence the reduction in yield of bhindi due to paired row technique in intercropping system was not reflected in the total LER.

Hence, eventhough LER is generally considered as the most efficient index for measuring the biological efficiency of intercropping,it fails to indicate the minimum level of yield that is expected from each component crop. That is, in this case, eventhough the LER of bhindi was the least for paired row with 100% Nitrogen (0.49) the total LER was the highest for that treatment (2.09) simply because of a higher LER of cowpea (1.6). This indicates that the total LER was approximating to the LER of the dominant species and failed to show the competitive effects.

In this context, the use of LEC is advantageous. It considers the LERs of the the individual crop being the product of LER of component crops in the intercropping system. For any intercropping system (involving 2 crops) to be advantageous, the LEC must be above 0.25 indicating that each component crop in the system should give atleast 50% of the their sole crop yield or the yield of either of the component should be more than expected. LEC values of this experiment revealed a nonsignificant influence of planting pattern and nitrogen levels. In both the planting pattern, the LEC was 0.76 and the value ranged from 0.7 to 0.83 for different levels of nitrogen. When LEC is more than 0.25, but less than unity, the neighbourhood effects involves competitive complementarity (Adetiloye <u>et</u> <u>al</u>., 1983). In the present study, all the intercropping arrangements fall in this category which indicate that they are in the same situation.

In the Calculation of LER, time is not considered. But Area x time equivalent ratio (ATER) as proposed by Hiebsch and McCollum (1987) considers the land occupancy period of the crops also.

The land occupancy period of bhindi and cowpea in this experiment was 90 days and 80 days respectively. Considering these periods,the ATER was calculated for the system and the results indicated a non significant effect of planting pattern and nitrogen level on this efficiency parameter.

However, ATER of paired planting pattern was slightly higher than that of normal planting pattern. Thus even with the consideration of duration, the biological efficiency was 76% and 65% more for paired and normal planting pattern respectively as compared with sole cropping (Table 23). This is in accordance with the result of Geetha Kumari (1989) for maize + cowpea intercropping system.

ATER value ranged from 1.62 to 1.76 for different levels of nitrogen exhibiting an increasing efficiency with increased levels of nitrogen.

For assessing the competition between component crops in intercropping, calculation of aggressivity was proposed by Mc Gilchrist (1965). He suggested that numerical value of aggressivity will be same for both the component crops, but the sign of the dominant component will be positive and the dominated negative. The greater the numerical value, the bigger is the difference in the competitive abilities.

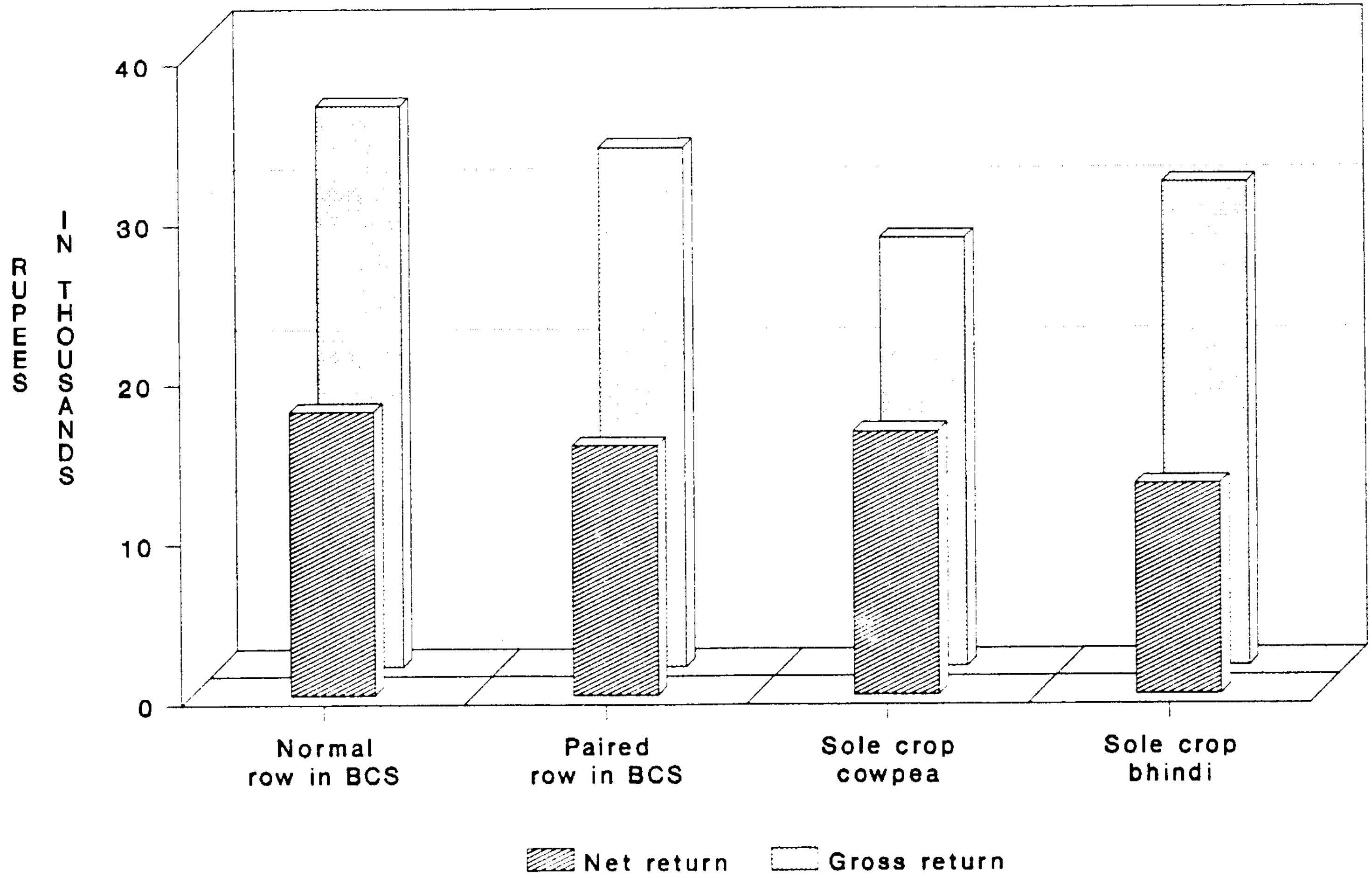
Here the planting pattern modified the aggressivity significantly. Cowpea was found to be more aggressive than bhindi as observed from the positive value. In normal planting pattern, the aggressivity value was 0.061 and in paired planting pattern, it was 0.741 indicating a higher competitive ability (Table 24). In paired planting pattern, cowpea canopy received more solar radiation (Table 30) as compared to normal row method and as such the crop was able to express better growth and yield performance. The nitrogen level did not show any significant difference in the aggressivity of both the crops. At all levels, cowpea was more aggressive.

Thus the biological efficiency parameters clearly indicate that bhindi + cowpea intercropping system is biologically efficient under both the planting pattern and at all levels of nitrogen.

5.5.2. Economic suitability of the intercropping system

But from the farmers' point of view, any system to be efficient, has to be economically profitable. Economic feasibility was tested using various efficiency parameter like gross return, net return, benefit cost ratio, return per rupee invested on labour and fertiliser, per day return, monetary advantage based on LER and bhindi equivalent yield and the

Fig.10. Economic suitability of the intercropping system



results are discussed here.

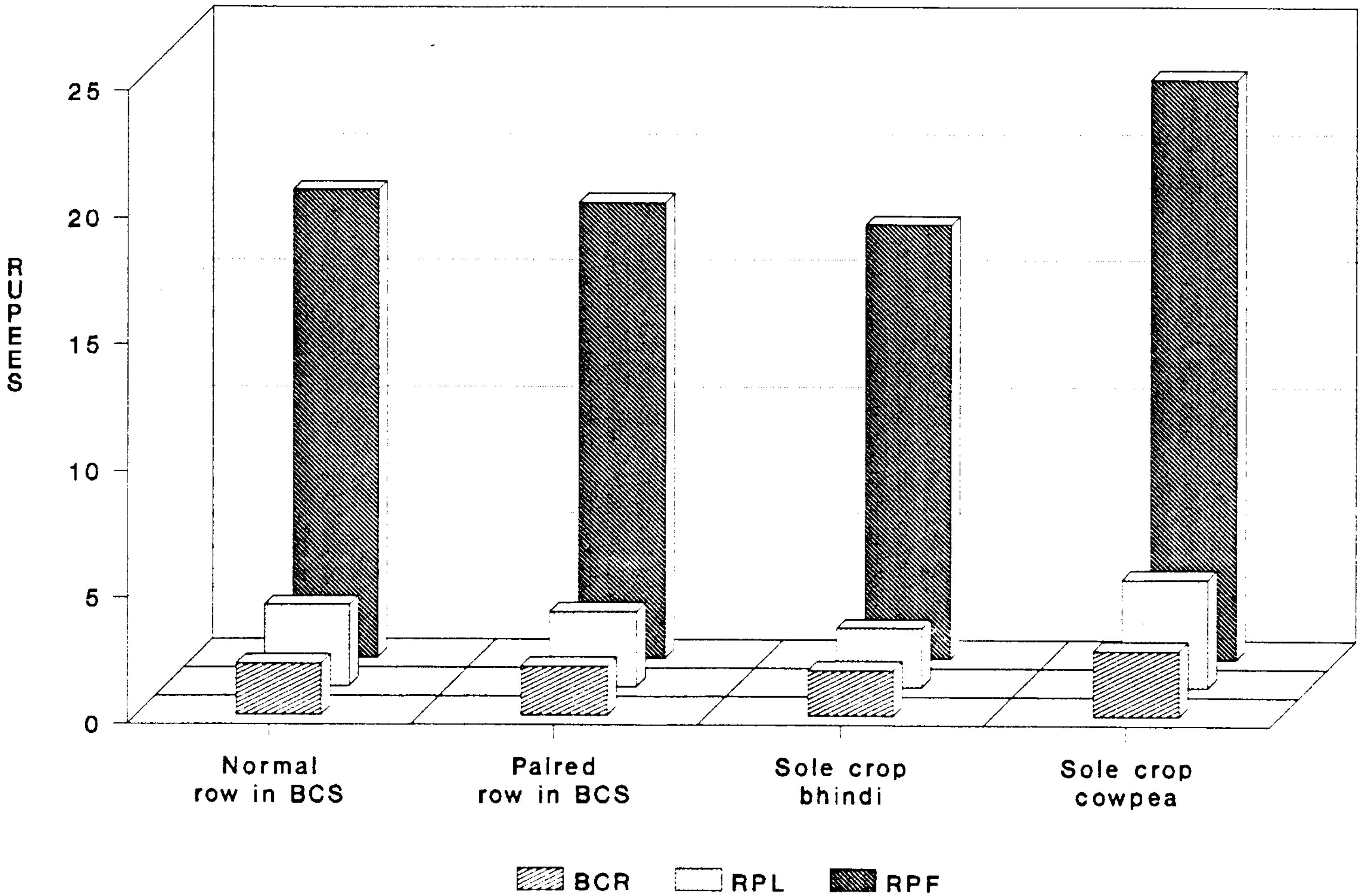
The results revealed that economics of the intercropping system was not significantly influenced either by planting pattern, nitrogen level or their interaction.

However, maximum gross and net return of Rs. 35096.33 and Rs. 17754.24 respectively were obtained in normal planting pattern while paired row method gave only Rs. 32461.67 and Rs. 15575.20 as gross and net return respectively (Table 25). This indicates that modification of planting pattern to paired row system is not beneficial as far as intercropping in bhindi is considered. This modification actually results in yield reduction of main crop even though it benefits the intercrops. By this modification, the wider space between the row provides ample space and resources for the intercrop. But at the same time, within the row, the spacing is narrow and hence the main crop is badly affected resulting in the poor performance of the crop. This poor performance of the main crop is not compensated by the additional benefit obtained from the intercrop. As a result the return from the whole system is reduced. Thus the paired row techniques resulted in a loss of Rs. 2634.66 and Rs. 2179.04 as gross and net return respectively compared to normal row technique. Hence as far as the net return to the farmer is considered, intercropping with cowpea in the normal system is beneficial.

The effect of different levels of nitrogen was not significant. But gross and net return were maximum at 75% nitrogen level (Fig.10). The difference of about Rs. 1873.83 and Rs. 2040.49 were obtained as gross and net return as compared to 100% nitrogen level. This increased net return was due to the highest combined yield from both the crops at that level. A similar response of normal row intercropping in Chilli + bhindi intercropping system was reported by Natarajan (1992). The net return from sole crop bhindi was Rs 13158.2 and that of cowpea was Rs. 16437. The combined gross and net return from the intercropped plots were Rs. 33779 and Rs. 16664.72 respectively. The difference in net return due to intercropping as compared with sole cropping was Rs. 3506.5 and Rs. 227.52 for bhindi and cowpea respectively. Similar result of increased gross and net return from intercropping as compared with sole cropping was reported by Prasanna Kumari and Seemanthini Ramdas (1989) in bhindi + amaranthus intercropping system and Prabhakar and Vishnu Shukla (1991) in bhindi + radish and bhindi + french bean intercropping system.

Benefit cost ratio (BCR) provides an estimate of the benefit the farmer derives for the expenditure he incurred in adopting a particular cropping system. There was not much difference in BCR due to planting pattern and nitrogen levels. However, return from normal row planting pattern was slightly higher than that of paired planting pattern. Similarly an increase was observed for 75% nitrogen level as compared with

Fig.11. Economic suitability of the intercropping system



50% and 100% nitrogen level. This is almost similar to the results obtained by Geetha Kumari (1989) in maize + cowpea intercropping system. Sole crop of cowpea recorded the highest BCR of 2.54 and that of bhindi was only 1.77. Since in the present situation labour is a very costly input, an estimate on labour utilisation efficiency is also highly needed while going for an intercropping practice. Hence, in this experiment the return per rupee invested on labour was also calculated for getting the correct estimate of the production efficiency of a particular treatment with regard to the amount spent on labour. From the result, it is clear that the return per rupee invested on labour was higher for normal planting pattern (Rs. 3.22) as compared with paired planting pattern (Rs. 2.95). In the intercropping treatments maximum labour efficiency was obtained for 75% nitrogen level (Rs. 3.31) followed by 100 % nitrogen level (Table 26). These results are almost in accordance with the results of Geetha Kumari (1989) in maize + cowpea intercropping system. But where sole cropping and intercropping were compared, labour efficiency was also maximum for sole crop of cowpea (Fig.11). This is due to the lesser number of labourer required for sole cropping of cowpea.

Since about 13 per cent of the total cost involved in cost of cultivation is accounted for fertiliser, the return per rupee invested on fertiliser also seek importance. The results revealed that the modification in the planting pattern could not exert any significant influence on the cost spent on fertilisers (Table 26). In contrast to the other economic parameters the return per rupee invested on fertilizer was least for 100% nitrogen level (Rs. 15.76). It was maximum for 75% level of nitrogen (Rs. 20.69). Return per rupee invested on fertiliser was also maximum for sole crop cowpea. Compared to the intercropping situation, the fertiliser requirement for cowpea sole crop was less and hence this enhancement in return was observed. Bhindi being a crop requiring more nutrients, more amount has to be spent on the input per unit area of cropping when bhindi is raised as a sole crop. More than that the net return was also less.

The observations on per day return (Table 26) also revealed non significant difference due to planting pattern. However, as in the other economic parameters it was also maximum for normal planting pattern (Rs. 197.27). Though the effect of nitrogen level was not significant, the per day return value from 50% nitrogen was very less as compared with other two levels. It was only Rs. 144.89, whereas, for 75% and 100% level, per day return was Rs.205.69 and Rs. 183.01 respectively. When sole cropping and intercropping treatments were compared, the per day return from sole crop bhindi was only Rs. 146.2 and that for intercropping plots was Rs. 185.66 Thus in the per day return an increase of about Rs. 38.96 was obtained when intercropping was practiced as compared with sole cropping of bhindi.

The calculation of monetary advantage based on LER assume that the appropriate economic assessment of intercropping should be in terms of increased value per unit area of land. In the present investigation, monetary advantage based on LER remained unaffected by different planting pattern and nitrogen level. Maximum monetary advantage of Rs. 15590 was recorded under paired planting pattern (Table 24). It may be due to higher total LER value at paired planting. This is contradictory with the results of other economic parameters. But this is the only efficiency parameter that considers the land also as a resource. Hence it can be said that for maximum efficiency in the land utilisation paired row technique of intercropping is best. In the case of nitrogen, 75% of recommended nitrogen recorded maximum monetary advantage (Rs. 16028.5) based on LER.

In intercropping it is very difficult to compare the economics of produce with different nature. Hence equivalent yield was calculated by converting the intercrop yield into base crop yield by considering the market rates of both the crops (Table 24). In the present investigation it was found that planting pattern significantly influenced the equivalent yield. It was maximum under paired planting pattern which recorded 7118.63 kg ha^{-1} of bhindi equivalent yield while the equivalent yield under normal planting was only 4767.0 kg ha^{-1} In paired planting pattern cowpea recorded maximum yield and when this was converted to bhindi equivalent yield, 7118.12 kg

ha^{-1} was obtained. This was the reason for higher equivalent yield under paired planting pattern. However, nitrogen level had no significant influence on equivalent yield. 100% nitrogen level recorded maximum bhindi equivalent yield of 6516.0 kg ha^{-1}. It was followed by 50% nitrogen level (5968.26 kg ha^{-1}). The maximum equivalent yield at highest level of nitrogen may be due to highest yield at that level.

This based on the economic parameters, it can be concluded that though BCR, return per rupee invested on fertiliser and labour were higher far sole crop cowpea, the gross and net return were maximum in bhindi + cowpea intercropping system in normal row arrangement.

5.7. Effect of summer cropping on succeeding crop

For understanding the residual effect of previous cropping, one crop of rice was raised in all those plots with a uniform dose of 75% of the nutrient recommendation as per pop recommendation.

The yield of rice was not appreciably influenced by nitrogen level. The results clearly indicated that the performance of rice in these plots were satisfactory and for all the treatments an average grain yield of more than 3.75t ha^{-1} and straw yield of around 3 to 3.5 t ha^{-1} were obtained. This suggests that, though rice crop is raised with a lesser quantity of fertilizer than is recommended, it does not adversely affect the rice yield if it is raised in plots where some vegetables were cultivated previously. The enrichment of nutrients through the cropping might have resulted in the better performance of the rice crop.

From the result, it may be concluded that there is a possibility of reducing the nutrients to 75% level for rice crop succeeding a vegetable crop.

When intercropping and sole cropping were compared, the grain and straw yield from sole crop bhindi plot was 3.94 and 3.22 t ha^{-1} respectively and the corresponding value for sole crop cowpea was 3.56 and 3.34 t ha^{-1} (Table 28). Under intercropping treatments, a grain and straw yield of 3.79 and 3.35 t ha^{-1} respectively were obtained. This proves that raising of bhindi as previous crop improves the following rice yield. Reports of CSRC, Karamana show that rice succeeding bhindi crop give higher yield (Annual Report, AICARP, 1978).

On the other hand, studies at Port Blair had shown that maximum rice yield was recorded under the treatment where cowpea was raised for vegetable purpose which was closely followed by rotation where bhindi and maize were the previous crops (Annual Report, CARI, Port Blair, 1990-'91).

5.6. Soil analysis

The data on soil analysis revealed that only the phosphorus content was significantly influenced by planting pattern. The nitrogen levels and their interaction had no significant influence on soil nitrogen, phosphorus and potassium content.

The nitrogen and phosphorus status of soil, in general reported a higher value in paired planting pattern which were 359.23 and 60.12 kg ha^{-1} respectively. It may be due to reduced nutrient uptake by bhindi plants coupled with higher nitrogen fixation and addition of more leaves by cowpea plants as evidenced from the bhusa yield of cowpea.

Different nitrogen level had no significant influence on soil nitrogen status. There was a slight reduction in nitrogen content of soil at 75% level. Bhindi plants recorded maximum uptake under this level of nitrogen. More than that due to higher shading effect in normal row system might have reduced the capacity of nitrogen fixation. Ofori and Stern (1987) reported that if cowpea plants were shaded, nitrogen fixation will be reduced.

Sole crop of cowpea recorded maximum soil nitrogen status which was maximum in sole crop cowpea plot (393.84 kg ha^{-1}). The superiority of cowpea was due to its nitrogen fixing capacity and higher addition of plant residues. Singh et al. (1981) found that cowpea was able to fix about 198 kg nitrogen ha^{-1}. Singh (1991) also found that inclusion of cowpea in a rotation had always higher soil nitrogen status.

The soil nitrogen status in the plot of sole crop of cowpea was followed by intercrop treatments. The intercropped treatments on an average recorded soil nitrogen content of 335.60 kg ha^{-1}. On the other hand, the nitrogen status of soil was the least in bhindi plots.

Soil potassium was almost same in both the planting pattern which was around 149 kg ha^{-1}.

5.6.a. Nutrient Balance Sheet

The balance sheet of major plant nutrients (Table 29) at the end of the field experiment was worked out on the method followed by Nambiar and Ghosh (1994) in the All India coordinated research project on long term fertiliser experiment (ICAR).

The data shows that all the treatments had a positive nitrogen and phosphorus balance, whereas, that of potassium had a negative balance. The increase can be attributed to the balanced amount of nutrients from the applied fertiliser and the residues returned to the soil. This is in agreement with the findings of Biswas et al. (1977) and Palaniappan (1985).

There was a reduction in available potassium in the soil after cropping compared to the initial potassium status (182 kg ha^{-1}). It may be due to the fact that plants might have absorbed potassium in excess of that required for the optimum growth, thereby reducing the content of these nutrients in the soil. The results are in agreement with the findings of Sharma and Choubey (1991) in maize + legume intercropping system.

The nutrient balance arrived at after deducting the uptake of nutrients from the quantity applied under various treatments does not show any relationship with the final soil test value after the harvest. The available nitrogen and phosphorus content of the soil after the experiment indicates that it is higher than the balance obtained. The decrease in potassium status can be due to the soluble and leachable nature of the potash as plant nutrient in the soil especially under low land condition and heavy rainfall during the later stage of the experiment.

FUTURE LINE OF WORK

From the present study it is seen that normal row arrangement of bhindi + cowpea intercropping system gave better returns than intercropping of cowpea between paired rows of bhindi. In the intercropping system, maximum yield was recorded under 75% nitrogen level. Alternative suggestions that may be proposed are trying different row arrangements of component crops and different combinations of fertilisers to bhindi and cowpea. It is also advisable to try other vegetables like amaranthus, french bean, chilli etc. as an intercrop in bhindi.

SUMMARY

SUMMARY

An experiment was conducted in the summer rice fallows of the Instructional Farm attached to the College of Agriculture, Vellayani during March 1993 with the objective of assessing the possibility of raising cowpea as intercrop in bhindi and evaluating the crop association effects in different planting patterns and varying levels of nitrogen. This study also aims to evaluate the biological efficiency and economic feasibility of the bhindi + cowpea intercropping system. The different planting pattern tried were normal row planting (G_1) of bhindi at 60 x 45 cm and paired row planting of bhindi (G_2) at 45/75 x 45 cm. In normal row planting technique, one row of cowpea was intercropped in between one row of bhindi and in paired planting technique, two rows of cowpea were intercropped in between pairs of rows of bhindi (Fig.2) The nitrogen levels tried were 100% nitrogen (N_1) as per pop recommendation, 75% of nitrogen (N_2) and 50% of nitrogen (N_3). Full dose of phosphorus and potassium was applied uniformly in all the plots. In addition to these treatments, sole crop of bhindi and cowpea were raised as control treatments.

The experiment was laid out in factorial RBD with three replications. Observations were made on growth characters, yield and yield attributes, and nutrient content of plants. The calculation on nutrient uptake, biological

efficiency and economic suitability were worked out using different indices. The results obtained in this study are summarised below.

Intercropping of cowpea was practiced by adopting normal and paired row technique in the main crop of bhindi.

Planting pattern influenced the growth parameters like plant height, canopy spread, root length, total dry matter production and crop growth rate of bhindi significantly. All the growth expressions were maximum for normal row technique.

Height of first bearing node, root spread and growth analysis parameters like LAI, RGR and NAR of bhindi were not significantly influenced by planting pattern.

Paired planting pattern took significantly higher number of days for 50 per cent flowering for bhindi.

Number of fruits per plant and fruit weight per plant of bhindi was significantly higher in normal planting pattern as compared to paired planting pattern.

Length and girth of the fruits of bhindi, on the other hand, were not influenced by planting pattern.

Planting pattern influenced the fruit yield and bhusa yield of bhindi significantly. The normal planting pattern recorded maximum fruit yield of 128.27 q ha^{-1}, whereas, that for paired row planting pattern was only 91.12 q ha^{-1}.

Maximum bhusa yield of 244.24 q ha^{-1} was reported by normal planting pattern.

Total uptake of nitrogen, phosphorus and potassium by bhindi plants was significantly higher in normal planting pattern than in paired planting pattern.

Thus the performance of the main crop bhindi was better in normal planting pattern.

The performance of intercrop cowpea, on the other hand, was better in paired row planting pattern.

There was significant difference in the plant height and canopy spread of cowpea due to planting pattern. The value was maximum for paired row method.

Plant height and plant spread of cowpea at 60 and 75 DAS and root spread at all growth stages were not markedly influenced by planting pattern.

The paired planting pattern recorded maximum pod yield of 47.46 q ha^{-1} and bhusa yield of 78.03 q ha^{-1}.

Uptake of nitrogen and phosphorus of cowpea was not significantly influenced by planting pattern. There was significant difference only in the uptake of potassium.

The effect of different levels of nitrogen on growth and yield of bhindi and cowpea was also evaluated in this experiment.

Nitrogen levels could not exert any significant influence on any of the growth parameters like plant height, height of the first bearing node, root length, root spread, dry matter production, LAI, RGR NAR, and CGR of bhindi.

The effect was significant only on the canopy spread of bhindi at 60 DAS and root length at 90 DAS. At this stage 75% nitrogen level recorded maximum value.

Though the effect was not significant, all the growth characters of bhindi were higher for 75% nitrogen level as compared with other levels.

Days to 50% flowering of bhindi was not significantly influenced by nitrogen levels. However, 100% nitrogen took more days to reach 50 per cent flowering.

Yield contributing characters like number of fruits per plant, length and girth of fruits and fruit weight per plant of bhindi were not significantly influenced by nitrogen levels.

Total fruit yield of bhindi was not significantly influenced by nitrogen levels. But it was maximum at 75% nitrogen which recorded an yield of 124.52 q ha^{-1}. It was followed by 100% nitrogen (104.19 q ha^{-1}).

There was significant difference in bhusa yield by nitrogen levels. It was maximum under 75% nitrogen followed by 100% nitrogen.

Non significant effect of nitrogen on total uptake of nitrogen, phosphorus and potassium was also observed due to different levels of nitrogen.

The combined effect of nitrogen and planting pattern was significant on canopy spread of bhindi at 60 DAS, total dry matter production and CGR at 60 and 90 DAS and bhusa yield.

Nitrogen levels could not exert any significant influence on any of the growth parameters of cowpea like plant height, plant spread and root spread.

The fruit yield and bhusa yield of cowpea were also not significantly influenced by nitrogen levels. However, fruit yield was maximum under 100% nitrogen which was 43.44 q ha^{-1}. The bhusa yield at this level was 69.64 q ha^{-1}.

Total nitrogen, phosphorus and potassium uptake of cowpea plants were not significantly influenced by planting pattern.

The combined effect of nitrogen and planting pattern was significant only on the plant spread of cowpea at 30 and 60 DAS.

The biological efficiency indices like aggressivity, LER, LEC and ATER were worked out for the system in both planting pattern and different nitrogen levels.

Total LER was not seen influenced either by planting pattern or nitrogen levels. However, LER of individual crops was significantly influenced by planting pattern.

LEC and ATER were not significantly influenced by planting pattern.

Value of LER and ATER for all the treatments were above 1.5 and this indicated that the intercropping of bhindi + cowpea is biologically efficient. LEC value is around 0.75 for all the treatments also implies the competitive complementarity.

The aggressivity value was positive for cowpea at both the planting pattern and nitrogen levels indicating that cowpea is significantly more aggressive than bhindi in bhindi + cowpea intercropping system.

For assessing the monetary advantage, economic parameters like gross return, net return, benefit/cost ratio, return per rupee invested on fertiliser, return per rupee invested on labour, per day return, bhindi equivalent yield and monetary advantage based on LER were worked out at both the planting pattern and at varying levels of nitrogen in bhindi + cowpea intercropping system.

Gross return and net return were maximum for normal planting pattern. There was an increase of Rs. 2179.04 of net return for normal planting pattern over paired planting pattern. Similarly, all the other parameters were maximum in normal planting pattern. Return per rupee invested on fertilisers and labour, benefit cost ratio and per day return were higher for normal planting pattern.

Monetary advantage based on LER was not significantly influenced by planting pattern. But it was maximum in paired planting pattern.

The bhindi equivalent yield was significantly influenced by planting pattern. Paired row planting recorded significantly higher equivalent yield than normal planting pattern.

All the economic parameters like gross return, net return, Benefit/cost ratio, return per rupee invested on labour and fertiliser, monetary advantage based on LER were maximum under 75% nitrogen level. Bhindi equivalent yield was maximum under 100% nitrogen level. By considering the economic parameters, thus for intercropping cowpea in bhindi plots normal row planting with 75% N level was found profitable. The effect of intercropping cowpea in bhindi vs. sole cropping bhindi or cowpea is summarised below.

The pure crop of bhindi recorded maximum plant height, height of first bearing node, canopy spread, root length and root spread as compared to intercropped bhindi plants.

Growth analysis parameters like LAI, RGR, CGR, NAR and dry matter production were also maximum under sole cropping of bhindi than intercropping treatments.

Fruit yield and yield contributing characters like number of fruits per plant, fruit weight per plant, length and girth of fruits were maximum in sole crop of bhindi. The bhusa production was also maximum under sole cropping.

In the case of cowpea also, pure crop of cowpea recorded maximum plant height, plant spread and root spread as compared to intercrop.

Pod yield and bhusa yield were also maximum for sole crop cowpea.

But the economic analysis revealed that in terms of gross return and net return, intercrop treatments proved their superiority over sole cropping of either of the crops. There was an increase of Rs. 3506.52 and Rs. 227.7 of net return from bhindi + cowpea intercropping system over that of sole crop bhindi and sole crop cowpea respectively.

Soil nitrogen and potassium contents were not significantly influenced by planting pattern. But soil phosphorus was significantly influenced by planting pattern. Paired planting pattern recorded maximum nitrogen phosphorus and potassium contents in soil.

Different nitrogen levels had no significant influence on soil nutrient status. The sole crop plot of cowpea recorded maximum soil nutrient status. It was followed by intercropping treatments. The soil nitrogen was lowest in sole bhindi plots.

The succeeding rice crop yield was not significantly influenced by planting pattern, different nitrogen levels of previous crop. Different nitrogen levels recorded grain yield of around 3.75 t ha^{-1} and straw yield around 3-3.5 t ha^{-1}. According to Willey (1979), for getting yield advantage from intercropping, (i) the intercrop yield must give full yield of a main crop and some yield of a second crop or (ii) combined intercrop yield must exceed the higher sole crop yield or (iii) combined intercrop yield must exceed combined sole crop yield.

In the present investigation, the second criteria was satisfied in normal planting pattern of bhindi. The combined intercrop yield was 160.05 q ha^{-1} and higher sole crop yield was only 150.87 q ha^{-1}. Based on the foregoing discussions, it can be concluded that though yield reduction was observed in individual crops due to intercropping, when the system as a whole is taken, there was both yield advantage and monetary advantage as observed from gross and net return and the LER value of above unit.

Planting bhindi at 60 x 45 cm spacing and growing one row of cowpea in between the row spacing of bhindi was the best planting pattern.

Application of 75% of the recommended dose of N for both bhindi and cowpea along with the recommended dose of phosphorus and potassium gave maximum profit.

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* Originals not seen

APPENDIX

Weather data during the cropping period

Standard week	Period from	Period to	Rainfall (mm)	Maximum temp. (°C)	Minimum temp. (°C)	Relative humidity Av. (%)	Relative humidity Max. (%)	Relative humidity Min. (%)
12	19.3.93	25.3.93	6.4	32.3	23.7	74.55	86.0	63.1
13	26.3.93	1.4.93	1.1	32.2	24.0	75.65	82.8	68.5
14	2.4.93	8.4.93	1.8	31.9	24.6	81.55	91.4	71.7
15	9.4.93	15.4.93	0.0	32.3	24.4	81.65	91.1	72.1
16	16.4.93	22.4.93	1.8	32.7	24.6	81.75	87.7	75.7
17	23.4.93	29.4.93	0.9	33.2	25.1	83.47	87.8	79.14
18	30.4.93	6.5.93	0.0	33.3	25.8	84.57	90.7	78.43
19	7.5.93	13.5.93	7.3	32.9	25.9	36.77	90.7	82.7
20	14.5.93	20.5.93	0.2	32.2	25.0	78.75	86.1	71.4
21	21.5.93	27.5.93	10.6	31.6	24.0	83.7	92.4	75.0
22	23.5.93	3.6.93	17.3	30.3	24.1	85.17	89.5	80.7
23	4.6.93	10.6.93	29.6	28.7	23.2	87.55	91.7	83.4
24	11.6.93	17.6.93	5.9	30.0	24.2	85.77	93.3	78.1
25	18.6.93	24.6.93	4.1	30.5	25.1	84.15	89.5	78.8
26	25.6.93	1.7.93	13.3	29.8	23.7	88.2	90.0	86.4
27	2.7.93	8.7.93	10.0	28.9	22.6	90.05	92.1	88.0
28	9.7.93	15.7.93	3.4	29.4	22.6	85.55	89.1	82.0
29	16.7.93	22.7.93	4.5	28.6	23.0	87.55	91.4	83.7
30	23.7.93	29.7.93	3.0	28.4	23.1	86.65	93.0	80.3
31	30.7.93	5.8.93	2.4	29.1	23.2	85.35	91.6	79.1
32	6.8.93	12.8.93	0.0	29.4	24.1	84.75	93.4	76.1
33	13.8.93	19.5.93	0.0	28.8	23.8	80.7	88.4	73.0
34	20.8.93	26.8.93	0.0	30.0	23.6	82.0	90.3	73.7
35	27.8.93	2.9.93	0.0	25.4	23.4	84.2	91.7	76.7
36	3.9.93	9.9.93	0.0	29.8	23.1	82.7	88	77.4
37	10.9.93	16.9.93	0.0	31.2	24.1	79.37	87.8	70.8
38	17.9.93	23.9.93	4.8	30.7	24.0	79.97	85.4	74.4

ABSTRACT

An experiment was conducted in the summer rice fallows of the Instructional Farm attached to the College of Agriculture, Vellayani during March 1993 with the objective of assessing the possibility of raising cowpea as intercrop in bhindi and evaluating the crop association effects in different planting patterns and varying nitrogen levels. The study also aims to evaluate the biological efficiency and economic feasibility of bhindi + cowpea intercropping system. The treatments consisted of two planting patterns viz. normal row planting (G_1) of bhindi at 60 x 45 cm and paired row planting (G_2) of bhindi at 45/75 x 45 cm. In normal row planting technique, one row of cowpea was intercropped in between one row of bhindi and in paired planting technique two rows of cowpea were intercropped in between pairs of rows of bhindi. Three levels of nitrogen were other treatments. The nitrogen levels tried were 100% dose of nitrogen (N_1), 75% dose of nitrogen (N_2) and 50% dose of nitrogen (N_3). Full dose of phosphorus and potassium were applied uniformly in all these plots. In addition to these treatments, sole crop of bhindi and cowpea were raised as control plots.

The results revealed that planting pattern significantly influenced most of the growth and yield contributing characters and yield of bhindi. Growth characters like plant height, canopy spread, root length, total dry

matter production and CGR and yield contributing characters like days to 50 per cent flowering, number of fruits per plant, fruit weight per plant, total yield of fruits and bhusa yield of bhindi were significantly higher in normal planting pattern than in paired planting pattern.

The bhusa yield and pod yield of cowpea were also significantly influenced by planting pattern recording the higher value for paired row technique.

Tne crop arrangements also influenced the nitrogen, phosphorus and potassium uptake of bhindi and cowpea. Nutrient uptake of bhindi was maximum under normal planting pattern, whereas, that of cowpea was maximum under paired planting pattern.

The biological indices like land equivalent ratio, area x time equivalent ratio, aggressivity and economic indices like gross return, net return, benefit/cost ratio return per rupee invested on labour and fertilizer were maximum under normal planting pattern though the effect was not significant.

The soil nutrient status was maximum under paired planting pattern.

Application of nitrogen could not appreciably influence most of the growth and yield contributing characters and yield of bhindi. Nitrogen level significantly influenced canopy spread and root length and bhusa yield. Maximum growth and yield of bhindi were recorded under 75% nitrogen recommendation.

Nitrogen levels had no significant influence on growth and yield of cowpea. However, maximum growth and yield of cowpea were recorded under 100% nitrogen level.

The nutrient uptake by bhindi and cowpea was not influenced by nitrogen level.

Land equivalent ratio and area x time equivalent ratio and land equivalent coefficient were not significantly influenced by nitrogen levels.

The economic parameters revealed that 75% nitrogen dose to the intercropping system was the best.

The available nitrogen, phosphorus and potassium content in the soil after the experiment were not influenced by nitrogen levels.

As pure crops, bhindi and cowpea recorded maximum growth and yield contributing characters and yield as compared to the intercropping treatments. However, the economic analysis revealed that intercropping of bhindi with cowpea is advantageous than their respective sole crops.

Raising a summer crop resulted in a saving of 25% nitrogen for the succeeding rice crop. The different treatments of summer cropping did not cause any variation in the yield of rice.