RESOURCE USE AND PLANT INTERACTION IN CHILLI INTERCROPPING SYSTEM IN SUMMER RICE FALLOW

By

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THESIS

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MY LOVING PARENTS

DECLARATION

I hereby declare that this thesis entitled "**RESOURCE USE AND PLANT INTERACTION IN CHILLI INTERCROPPING SYSTEM IN SUMMER RICE FALLOW**" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that this thesis entitled "RESOURCE USE AND PLANT INTERACTION IN CHILLI INTERCROPPING SYSTEM IN SUMMER RICE FALLOW", is a record of research work done independently by **Miss. ANITHA. 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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CONTENTS

LIST OF ABBREVIATIONS

N	-	Nitrogen
P	-	Phosphorus
K	-	Potassium
FYM	-	Farm yard manure
NL	-	Nutrient levels
NR	-	Normal row
PR	-	Paired row
DAP	-	Days after planting
DAS	-	Days after sowing
RGR	-	Relative Growth Rate
LER	-	Land Equivalent Ratio
LEC	-	Land Equivalent Coefficient
RCC	-	Relative Crowding Coefficient
ATER	-	Area Time Equivalent Ratio
CEY	-	Crop Equivalent Yield
s	-	5 per cent level of significance
ss	-	1 per cent level of significance
ns	-	Not significant
C.D	-	Critical difference
SE	-	Standard error
R.B.D.	-	Randomised Block Design
cc	-	Pure crop of chilli
ca	-	Chilli-amaranthus system

cf	-	Chilli-french bean system
aa	-	Pure crop of amaranthus
ff	-	Pure crop of french bean
Ycc	-	Pure crop yield of chilli
Yca	-	Intercrop yield of chilli in the presence of amaranthus
Ycf	-	Intercrop yield of chilli in the presence of french bean
Yaa	-	Pure crop yield of amaranthus
Yac	-	Intercrop yield of amaranthus in the presence of chilli
Yff	-	Pure crop yield of french bean
Yfc	-	Intercrop yield of french bean in the presence of chilli
Yci	-	Intercrop yield of chilli

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INTRODUCTION

1. INTRODUCTION

We have attained food security. Our country is now striving hard to achieve nutritional security. Vegetables, being excellent sources of roughages, carbohydrates, protein, vitamin A, vitamin B, vitamin C, calcium and iron, play a dominant role in safeguarding nutritional security. At present an alarming gap is existing between the requirement and production of vegetables in Kerala. The percapita consumption of vegetables in our state is only 30 g day^{-1} as against the requirement of 284 g. Even for this day to day requirement in vegetables, we depend heavily on the neighbouring states resulting in a substantial drain of money. Hence it is highly essential to step up our vegetable production. The area under vegetable cultivation is estimated to be 2.1 lakh ha (Farm guide, 1995) while the targeted area for achieving self sufficiency is 3.1 lakh ha. In Kerala there is little scope to increase the area under vegetable crops. Summer rice fallows have been identified as viable areas to cultivate vegetables where intercropping of different vegetables can be practised ie by intensifying cropping in spatiotemporal dimensions.

Importance of system approach in crop production is being realised by research workers. Intercropping system with vegetables have been found profitable because of the yield advantage (Prabhakar and Shukla, 1984, 1985). Thompson and Kelly (1959) opined that intercropping is advantageous from the point of view of economy of space, saving in tillage, complete utilization of surplus nutrients, better utilization of solar energy, soil moisture reserve and increased gross return from a unit area. Selection of suitable crop combinations (Marpaung, 1980) adoption of proper planting geometry (Ahlawat and Sharma, 1986) and proper nutrient management (Billore et al., 1992) help greatly in increasing the crop productivity as well as economic return from an intercropping system. Success of any cropping system depends on tailoring ways for maximising the complementarity and resource use and minimising the competition. Better use of resources can be achieved by proper selection of crops, ideal nutrient management and suitable planting geometry.

Chilli is taken as the base crop of this study considering its importance in our daily diet. The chilli cv Jwalamukhi was found ideal for cultivation in summer rice fallows. The morphology, growth habit and wider spacing recommended for this variety enable to grow some short duration vegetable crops along with Jwalamukhi without much adverse effect on the yield of this variety. Amaranthus is an important short duration leafy vegetable suitable for summer rice fallows. French bean, the most popular short duration vegetable is grown as an intercrop in many cropping systems. As the duration, critical stages and rooting pattern of amaranthus cv, Arun and french bean cv Contender being different from that of Jwalamukhi, they were selected as intercrops. Hence this study is taken to assess the possibility of raising an intercrop along with chilli.

Among the various agronomic factors, planting method and fertilizer management are the techniques which demand more research work. A modification in the planting pattern of the base crop could accommodate more intercrop and would make intercropping feasible and remunerative even in additive series. When two crops of dissimilar nutrient requirements are grown together it sometimes become operationally difficult to meet the nutrient needs of the two crops simultaneously. The nutrient requirement of crops when grown as intercrop differ from that of sole crop. There is meagre work on fertilizer allocation in this intercropping system. So the question was whether to apply recommended dose of fertilizer to all the crops or not.

With these views in front the present study is taken up with the following objectives.

1) Study the possibility of raising an intercrop along with chilli in summer rice fallow.

2) Standardize a nutrient dose for chilli based intercropping system.

3) Study the performance of chilli, french bean and amaranthus in chilli based intercropping system under normal and paired row methods of planting.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

An investigation was conducted at Rice Research Station, Kayamkulam to assess the suitability of raising intercrops with chilli, to formulate a nutrient schedule and ideal planting geometry for chilli intercropping system. Although in recent years researchers have started to evaluate the effect of intercropping on common vegetables there is still a dearth of information.

The relevant literature on the crop suitability, planting geometry and nutrient management of intercropping systems involving vegetables are reviewed here under. Research information on other crops are also reviewed whereever pertinent literature is lacking.

2.1 Crop suitability in vegetable intercropping system

Success of any intercropping system depends on the selection of suitable compatible crops. Vegetables deserve their due place in these systems because of their short duration, high returns and nutritional value. Natarajan (1992) reported that success of intercropping depends on crop suitability.

2.1.1 Performance of chilli in intercropping system

Since chilli is widely spaced and it remains in the field for about four months, the interspaces can be best utilized for growing short duration vegetables. Sayed (1979) opined that chilli could be very well intercropped with onion in red soils of Kovilpatti under irrigated condition. Kadali et al. (1988) reported that the interspaces of chilli could be best utilized for growing short duration vegetable like french bean. Prabhakar et al (1989) suggested that intercropping capsicum with beet root was beneficial. Natarajan (1992) reported that plant height and number of branches in chilli were affected due to intercropping with bhindi, onion, coriander, green gram, black gram and cowpea.

2.1.1.1 Biosuitability

Yield advantage of chilli intercropping system was reported by many workers. The yield of chilli was not affected by intercropping with french bean (Kadali et al., 1988). Chilli when intercropped with radish gave higher combined yield (AVRDC Programme Report, 1990). Hosmani (1990) reported that when chilli was intercropped with onion and cotton and the yield of these crops was more compared to sole crop. Mallanagouda (1991) also reported higher yields for chilli when intercropped with onion, garlic and coriander. Growing chilli or chilli along with onion, as mixed crop with Varalaxmi cotton did not reduce the yield of seed cotton compared to sole cotton (Kumaraswamy and Hosmani, 1978).

Patil (1981) reported that the growth and yield of chilli was reduced when intercropped with pulses. Elangoven et al. (1982) observed that onion as intercrop in chilli had significant effect on yield of chilli. The yield of chilli was significantly affected when intercropped with chinese cabbage and broccoli (AVRDC Programme Report, 1990). The yield of chilli was adversely affected by the intercrops (Natarajan, 1992). Ramamurthy et al. (1992) reported that chilli as pure crop gave higher yield than as an intercrop.

Ramachander et al. (1989) reported that LER was greater than one when chilli was intercropped with french bean (LER = 2.2) peas (LER = 1.9) knolkhol (LER = 1.1) and onion (LER = 1.8). LER of chilli and vegetable system had a combined yield advantage of LER greater than one (AVRDC Programme Report, 1990).

2.1.1.2 Economic suitability

Result of most of the trials conducted in chilli intercropping system showed that intercropping gave an additional income, over and above the income obtained from sole cropping of chilli.

Kadali et al. (1988) studied the economics of mixed cropping of chilli with different vegetables like onion, french bean and indicated that an additional net income of Rs.4952/- per ha was realised when chilli was interplanted with Kharif sown onion followed by french bean and gave 192 per cent higher income over chilli alone. Prabhakar and Shukla (1988) observed that intercropping capsicum planted at normal plant density of 50 x 30 cm with beet root gave the highest return. Chilli with cotton fetched higher gross income (Koraddi *et al*., 1990). Chilli with bhindi as intercrop under normal row system recorded the highest gross income of Rs. 29600/- per ha under semi dry condition. Also chilli with country onion under normal row system recorded more income than pure crop of chilli (Natarajan, 1992). Dodamani *et al*. (1993) suggested that intercropping chilli with cotton (full dose of fertilizer) and onion (half dose of fertilizer) gave higher net return of Rs. 29255/- per ha.

Results of most of these studies reveal the possibility of raising an intercrop along with chilli.

2.1.2 Performance of french bean in intercropping system

Being a short duration legume, bushy in nature, french bean can be grown as an intercrop. Prabhakar and Shukla (1984, 1985) had reported that french bean could be profitably intercropped with Okra. Kadali *et al*. (1988) suggested that short duration vegetables like french bean could be effectively intercropped with chilli. Some of the intercropping studies with cassava at the Central Tuber Crop Research Institute, Trivandrum had shown that french bean variety Contender could be taken as a successful intercrop with cassava (Thomas *et al*., 1982). Biju (1989) reported the suitability of french bean as an intercrop in cassava based cropping system in Kerala. Karnik *et al*. (1993)

opined that french bean, okra and cluster bean performed as better intercrops in a cassava based cropping pattern. Kushwaha and Masoodali (1991) revealed the suitability of french bean as an intercrop with potato. Suitability of french bean as intercrop with sugarcane was reported by Yadav and Prasad (1990) and Sharma et al (1992). The above studies show the suitability of french bean as an intercrop.

2.1.2.1 Biosuitability

Singh (1991) reported that tomato, french bean, onion combination gave significantly higher equivalent yield compared to pure crop of tomato. In french bean/potato intercropping system Kushwaha and Masoodali (1991) observed higher yield for both french bean and potato. Wilson and Adenisan (1976) observed that when cassava was intercropped with a sequence of three vegetables (tomato, okra and french bean) the yields of okra and french bean were suppressed. Prabhakar et al. (1979) observed that tuber yield of cassava was less when intercropped with french bean, amaranthus, cucumber, bhindi or cowpea. Andrade (1987) reported that maximum yield of french bean was obtained when the crop was sown with one line of bean between the single rows of cassava or with three lines between double rows of cassava. In a study on cassava - french bean intercropping system conducted at College of Agriculture, Vellayani, it was found that 50 per cent of the pure crop yield was realised from the intercropping situation for french bean (Biju, 1989). Yadav and Prasad (1990) concluded that french bean when intercropped in autumn sugarcane produced higher bean yield. Jayabal and Chockalingam (1990) reported that cane yield was not affected by intercropping sugarcane with french bean. Shah et al. (1991) found that intercropping gave additional seed yield in maize-french bean system. Reduction in yield due to intercropping was reported in wheat and french bean by Dahatonde et al. (1992).

Ramachander et al. (1989) reported that LER was more than one in okra intercropped with french been (LER = 2.21). Kushwaha and Masoodali (1991) reported that the LER was higher for french bean - potato intercropping system (LER 1.04 to 1.24). Shah et al. (1991) suggested an increased LER for french bean maize intercropping system. Sharma et al. (1992) reported that sugarcane french bean intercropping system gave higher sugarcane equivalent yield over sole crop of sugarcane. These results confirm the findings of Yadav and Prasad (1990). Dahatonde (1992) reported that intercropping french bean with wheat at doses of fertilizer for both crops recorded an LER more than one. French bean-maize intercropping system recorded an LER of 1.69 indicating the greater biological efficiency of intercropping system (Singh and Singh, 1993). All these studies show the biosuitability of french bean in an intercropping system.

2.1.2.2 Economic suitability

Economics of french bean intercropping system was reported by many workers. Thomas *et al.* (1982) reported that french bean intercropping system gave an additional income of Rs. 2400/- per ha over pure crop of cassava. Kadali *et al.* (1988) found that an additional income was reaslised from french bean intercropped with chilli. Biju (1989) reported that growing french bean as intercrop in cassava fetched an additional profit of Rs.7000/- per ha. Shah *et al.* (1991) reported that monetary advantage index was highest in intercropped stand of maize and french bean. Sharma *et al.* (1992) reported that an additional income of Rs.28771/- could be obtained by intercropping french bean 'VL 63' with sugarcane Singh and Singh (1993) noted that the highest net return of Rs.10032/- per ha and monetary advantage of Rs.11941/- per ha was realised by intercropping french bean with maize.

All these studies reveal that an additional profit can be obtained from an intercropping system involving french bean.

2.1.3 Performance of amaranthus in intercropping system

Suitability of amaranthus intercropping is reviewed hereunder. In banana based cropping system cucumber and amaranthus could be raised economically (KAU, 1983). Ikeorgu (1990) remarked that amaranthus performed better in mixtures than under sole cropping. He also reported that plant height and root length were more in intercropped amaranthus compared to sole crop. Amma and Ramadas (1991) reported that amaranthus when intercropped with bhindi, reduced the weed population. Dixit and Misra (1991) reported the suitability of amaranthus with sugarcane.

2.1.3.1 Biosuitability

Prabhakar et al. (1979) observed that tuber yield of cassava was reduced with amaranthus as intercrop. Krishnankutty (1983) concluded that the yield of amaranthus was drastically reduced when intercropped in coconut gardens.

Yield advantages of an intercropping system involving amaranthus was reported by many researchers. Ikeorgu (1990) concluded that amaranthus gave the highest vegetable and dry matter yield when intercropped with both celosia and corchorus compared to sole crop of amaranthus. Sugarcane with amaranthus recorded higher cane yield (71.2 ha^{-1}) over sole crop of sugarcane and an additional yield of 55q green vegetable per ha from amaranthus (Dixit and Misra, 1991). Amma and Ramadas (1991) reported that intercropping of amaranthus with bhindi recorded the highest yield for bhindi (10.36 t ha^{-1}) than pure crop of bhindi (9.66 t ha^{-1}).

Ikeorgu (1990) noted that when amaranthus was intercropped with celosia and corchorus LER was increased (2.0 to 3.8). Negative values under RCC showed that in most mixtures involving amaranthus, the yield of amaranthus was higher than its pure crop yield. Aggressivity value clearly showed that amaranthus was the dominant species. All these studies show the feasibility of an intercropping system involving amaranthus.

2.1.3.2 Economic suitability

Many workers reported that an additional income was realised by amaranthus intercropping. By paired row planting of banana with cucumber and amaranthus as intercrop, income would be increased by 40-60 per cent compared to square system (KAU, 1986). Amaranthus when intercropped with bhindi, fetched an additional income and resulted in higher economic return of Rs.9290/- per ha as against Rs. 5096/- per ha recorded by sole crop of bhindi (Amma and Ramadas, 1991) Dixit and Misra (1991) observed that a net return of Rs. 7016/- per ha could be obtained with amaranthus intercropping compared to the return of Rs.4065/- per ha for sole crop of sugarcane.

2.1.4 Performance of other vegetables in intercropping system

Several workers have reported that intercropping vegetables is profitable compared to sole cropping (Irullappan (1982); Prabhakar and Srinivas (1982); Randhawa and Sharma

(1972); Singh and Singh (1972)). Prabhakar and Shukla (1984, 1985) have reported that okra would be profitably intercropped with radish and french bean. Bhindi, cluster bean and french bean performed better as intercrops in cassava. Among the various intercrops like bhindi, brinjal, amaranthus, cluster been and vegetable cowpea, brinjal performed better in coconut gardens (Krishnankutty, 1983). Prabhakar et al. (1983) reported that the yield of short statured vegetables like beet root, knolkhol, onion and pea were superior when intercropped with okra and capsicum. Meenakshi et al. (1974) suggested that intercropping of bhindi, cowpea, radish, cluster bean, lab lab, beat root, knol-khol and carrot did not affect the yield of maize crop. Bhindi, cucumber, amaranthus, french bean and cowpea when intercropped in cassava reduced the tuber yield (Prabhakar et al. 1979). Intercropping tomato or okra with cowpea indicated that this system was more productive than sole cropping (Olasantan, 1985a; Olasantan and Aina, 1987). The yield of improved cultivars of tomato was significantly reduced by intercropping with okra, but the yield of a local variety was unaffected (Olasantan, 1985b). Yield of cassava or maize was not affected by intercropping with bhindi or melon as reported by Ikeorgu et al. (1989). Olasantan (1985b) also reported that the yield of okra when grown with tomato varieties was less than that of a sole crop and the combined yield of the two crops in mixtures was more than their pure crop yield. Jayabal and Chockalingam (1990) reported that when sugarcane was intercropped with bhindi, coriander, knolkhol, french bean, onion, radish, carrot and cowpea, cane yield was affected. Prabhakar and Shukla (1991) reported that okra and radish intercropping system gave higher return than their respective sole crop. The economics of chilli bhindi intercropping system revealed that bhindi was the best intercrop for chilli (Natarajan, 1992).

Shuo et al. (1980) reported the beneficial effect of intercropping *Brassica chinensis* with tomato. Shultz et al. (1982) found that polyculture of cucumber and tomato was beneficial over monoculture. Wilson and Adenisan (1976) reported that an intercropping system of cassava with a sequence of three vegetables, tomatoes, okra and french bean, was more efficient than any of the crops grown alone. Ojeifo and Lucas (1987) concluded that intercropping two rows of corchorus with one row of tomato gave the maximum yield of corchorus while one row of corchorus with two rows of tomato gave maximum economic return. Singh (1991) reported that radish as an intercrop reduced the yield and yield equivalent of tomato. He also reported that tomato – onion combination gave the highest net return of Rs.44046/- and maximum profit (390 per cent) and generated an additional income of Rs. 13379/- compared with pure tomato.

Intercropping vegetables such as broccoli, chinese cabbage and radish with chilli was a promising production system (AVRDC Programme Report, 1990). Vegetable legumes such as lablab, bean, cowpea and cluster bean can be remunerative and can form better component crop in intercropping system (Rao et al., 1983). Cowpea and onion gave higher yield than green gram, black gram and chilli in cotton based intercropping system (RRS, 1988). Intercropping of green gram, cluster bean, onion, beet root and wheat proved more profitable in cotton (Shanmugam and Basu, 1989). Intercropping of onion, lucern, chilli and groundnut with cotton was found more remunerative than growing cotton alone (AICCIP, 1980). Intercropping of onion and cotton under rainfed condition was the best (AICCIP, 1989). Patil and Sheelavanter (1986) reported that intercropping of peas with chilli and cotton mixed cropping system gave the highest net return of Rs.6,104/- per ha. Mishra et al. (1993) opined that returns increased significantly by intercropping arum (Colacasia esculanta) with a companion crop. The intercropping of either of arum with onion or arum with radish proved more remunerative than sole cropping of either of them. Mishra et al. (1985) also reported similar results. Leafy vegetables like coriander, fenugreek and safflower could be intercropped safely in maize crop (Jadhav et al. (1992). Chavan et al. (1985) suggested that radish and palak were found to be the most suitable intercrops for cabbage and cauliflower from the point of total vegetable yield. Advantage of intercropping different vegetable crops such as radish and suran in methi was reported by Koregave (1964) and radish and palak in cabbage by Kale et al. (1981). Okigbo and Greenland (1976) suggested that the vegetable yield from vegetable mixtures would be higher than in cereal/vegetable or root crop/vegetable mixtures. This indicated that a vegetable based cropping system could be developed.

2.2 Nutrient management in intercropping system

Formulating fertilizer requirement for an intercropping system consisting of more than one crop with different growth habit poses a problem of estimating the nutrient requirement of the component crops, as the uptake pattern of these crops are affected by their associate interaction. There is meagre work on fertilizer allocation in intercropping system. Nutrient management of some intercropping systems are reviewed hereunder.

Roy and Braun (1983) and Lira et al. (1983) reported higher fertilizer use efficiency in intercropping system compared to sole crops. Prabhakar and Shukla (1991) suggested that the intercropping system at all levels of fertiliser application was superior to sole crops indicating better utilization of fertilizer by the intercrops.

Prabhakar and Shukla (1991) were of opinion that returns from the vegetable intercropping systems, okra with french bean and okra with radish were significantly better with higher doses of fertilizer N and P. They also suggested that both okra and radish being exhaustive crops and having higher production potential, they responded to higher fertility level both as sole and intercrops compared with french bean or french bean-okra combination. Mallanagouda (1991) also recorded the highest yield with application of full recommended fertilizer dose and FYM to the main crop (chilli) as well as companion crops (onion, garlic and coriander). Jadhav et al. (1992) observed that in a maize vegetable cropping system, application of 120 kg N ha^{-1} produced significantly higher maize grain yield (79.7 and 11.1 per cent) and stover yield (56.3 and 9.0 per cent) than that of no nitrogen and 60 kg N ha^{-1} respectively and the yield of green leafy vegetables (coriander, fenugreek and safflower) also increased with increasing levels of N. The results were in confirmity with the results reported by Singh (1976); Gangwar and Kalra (1981); EL. Hatteb et al. (1980) and Wong and Kalpage (1981). Singh et al. (1993) showed that potato and onion seed crop when grown with 150 kg N ha^{-1} recorded maximum net return (Rs.29,043/-) followed by the same system with N @ 100 kg ha^{-1} (Rs.22,083/-). Dodamani et al. (1993) reported that among the fertilizer management treatments FH (full dose to cotton, half to onion) recorded higher yield of onion (743 q ha^{-1}), chilli (9.85 q ha^{-1}) and cotton (10.35 q ha^{-1}) and higher net return of Rs.49,255/- per ha when compared to rest of the fertilizer treatment followed by HH (half dose to cotton-half to onion).

When onion was supplied with no fertilizer there was significant reduction in the yield of chilli and cotton and similarly reducing the fertilizer level to half for cotton caused a reduction in yield of chilli and onion, as a result of severe competition for nutrients.

Tathode and Dhoble (1987) reported that the grain and stalk yield of pigeon pea intercropped with sorghum was increased significantly with 100 per cent recommended dose of fertilizer to pigeon pea but the net monetary return was not influenced significantly with the application of different fertilizer levels. Higher N levels based on soil test recommendation increased significantly all the yield attributes and grain and stover yield of maize when intercropped with greengram, blackgram soyabean and cowpea (Mohammed et al., 1990) Yadav and Prasad (1990) reported that in a french bean-sugarcane intercropping system, cane yield was not significant at different levels of N applied to french beans, but the yield of french bean obtained with 80 kg N ha^{-1} and 120 kg N ha^{-1} behaved similarly and it was significantly superior to the bean yield obtained with 0 kg N ha^{-1} and 40 kg N ha^{-1}. Billore et al. (1992) opined that nutrient application at 100 per cent to both wheat and linseed gave maximum grain yield and wheat equivalent yield compared to nutrient levels at 0, 50 and 75 per cent due to minimum competition between crops and higher relative crowding coefficient. Highest yields of sorghum (2938 kg ha^{-1}) and pigeon pea (1221 kg ha^{-1}) were obtained when both the crops were supplied with recommended dose of fertilizer, besides resulting in a maximum net return of Rs.11,817/- per ha (Pujari et al., 1992). Rafey and Prasad (1992) concluded that intercropping of maize and pigeon pea at 100 per cent recommended levels of nutrients was more remunerative. It gave the maximum grain yield, maximum LER, maximum monetory advantage and highest net return. Billore et al. (1993) concluded that an application of 100 + 75 per cent N to pigeon pea-soyabean intercropping was the most remunerative and had greater biological efficiency. Kumar (1993) opined that the highest grain yield of pigeon pea and blackgram was realised by the application of recommended dose of fertilizer to both the component crops. All these studies reveal that maximum benefit of the cropping system can be obtained when both the crops are given full recommended dose or with higher nutrient doses.

Olasantan (1991) reported that, when tomato and okra intercropped with cowpea, application of 30 kg N ha^{-1} significantly improved marketable fruit production of tomato plants by about 35 per cent and an increase of 30 per cent in marketable pod yield of okra compared with no nitrogen. Increasing the N rates to 60 kg ha^{-1}, however did not further increase yield significantly. The dry pod and grain yield of intercropped cowpea plants with 30 kg N ha^{-1} or with no nitrogen applied often yielded more than those with 60 kg N ha^{-1}. Balyan and Seth (1991) observed that in a pearlmillet-cluster bean intercropping system, N significantly increased the total production by 20 per cent at 40 kg N ha^{-1} compared with no N. But further increment of N dose upto 80 kg ha^{-1} did not show measurable improvement, either in growth or in yield of pearlmillet. Kushwaha and Masoodali (1991) reported that LER (1.24) of french bean-potato intercropping was higher when potato was given full dose of fertilizer and french bean with half dose compared to half dose and full dose to both crops.

In a study conducted at Coimbatore it was found that application of recommended level of fertilizer to the base crop was sufficient and there was no need to apply extra dose to the intercrop (Palaniappan, 1988). Dahatonde et al. (1992) reported that application of recommended fertilizer dose to wheat crop sufficed the need of both wheat and french bean grown in a system and it was not necessary to give extra dose to french bean. These findings revealed that fertilizer recommendation of base crop was sufficient to meet the combined need of intercropping system and it was not necessary to apply fertilizer to the intercrop. However a judicious fertilizer treatment should be given to crops in intercropping system to fully enhance the species complementarity.

Most of the studies reveal that for realising maximum yield from the intercropping system, both the crops should be given the recommended dose of fertilizers. But the fertilizer recommendation varies with the nature of crop and N dose could be saved by intercropping with legume.

2.3 Effect of planting geometry on the performance of intercrops

A modification in the planting pattern of the base crop would make intercropping feasible and remunerative, due to the better utilization of available space, nutrients and light. Variation in base crop yield was nil when the orientation of rows were altered, while keeping the plant population per unit area constant (De et al., 1978). Paired row planting of crop facilitated the growing of intercrops since the interspaces available between the plant were more than that available in solid stand (Tarahalkar and Rao, 1975).

Natarajan (1992) reported that plant height of chilli was comparatively higher in paired row system than that in normal row system. He also reported that in chilli - coriander and in chilli-cowpea intercropping systems, height and branches of chilli were more under paired row technique than under normal row system.

Effect of planting geometry on yield and biosuitability was reported by many workers. Natarajan (1992) reported that chilli when intercropped with country onion, bhindi, coriander, green gram, black gram and cowpea the yield of intercrop was lower in paired row system than in normal row system. Dodamani *et al*. (1993) opined that onion planted 15 cm away from chilli resulted in higher yield of 71.79 q ha^{1} of onion and lower yield of chilli than planted at 30 cm away from chilli. Variation in plant population from single row to triple row increased the yield by 44.02 per cent in onion and 45.26 per cent in radish when intercropped with arum (*Colacasia esculenta*) (Mishra *et al*., 1993). Similar results were reported earlier by Umrani *et al*. (1984). Kushwaha and Masoodali (1991) noted that LER was higher for french bean-potato intercropping system with two rows of french bean planted between paired rows of potato (2:2 system). Intercropping system of paired rows of maize with french bean recorded the highest maize grain equivalent (Singh and Singh, 1993). He also reported that maize grown under paired planting combinations gave higher grain yield than normal maize intercropping system. Balyan and Seth (1991) suggested that grain yield and yield attributes of pearlmillet and yield of guar in pearlmillet 2:2 and 2:1 intercropping system were not significant. Dhingra *et al*. (1991) reported that when mung bean was intercropped with maize, higher yield of mung bean was recorded in paired row planting (2:2) followed by alternate row (1:1). Tathode and Dhoble (1987) reported that in a sorghum pigeon pea intercropping system paired row planting pattern with intercrop gave significantly higher yield for sorghum over normal planting pattern. Sarkar (1992) opined that sesame intercropped with mung bean at 2:2 row ratio of planting pattern was most productive with LER of 1.74 followed by sesame with mung bean in 1:1 ratio (LER 1.65). Paired row planting of gobhi sarson or Indian mustard decreased the leaves, tubers and tuber yield per plant compared with single row intercropping with potato (Narwal and Prakash, 1989). Venkateswarlu (1987) reported that total capsule and bean yield of castor obtained in uniform (1:1) and paired (2:2) row systems of castor and cluster bean were at par. Umrani et al. (1984) also reported that there was no difference in yield between planting patterns under well distributed rainfall condition in sorghum based intercropping system. Meera et al. (1992) reported that tuber yields of cassava intercropped with groundnut and cowpea were marginally higher under paired row planting compared to uniform planting. They also reported that the intercrop yield of cowpea was more under uniform planting than paired row planting but the intercrop yield of groundnut was more under paired row planting, though this difference in yield of three crops were not statistically significant. Koraddi et al. (1991) suggested that there was no significant difference between the two methods of planting but the seed cotton yield in paired row planting (1182 kg ha^{-1}) was 12.4 per cent higher than normal planting (1052 kg ha^{-1}) when intercropped with ground nut and the mean yield of ground nut in normal method of planting was 7.3 per cent higher than paired row planting.

Influence of planting geometry on the economics of intercropping systems is reviewed here. Biju (1989) reported that in a cassava-french bean intercropped system, intercropping in paired row system fetched an additional profit of Rs.5000/- per hectare compared to ordinary method. Natarajan (1992) suggested that chilli with bhindi under normal row system recorded the highest gross income of Rs. 29660/- per hectare compared to paired row system (Rs.25960/- per hectare), Chilli with country onion under normal row system also recorded more income than the pure crop of chilli. Meera et al. (1992) reported that the paired row planting of cassava with cowpea recorded the highest net income of Rs.11385/- per ha followed by uniform planting of cassava with cowpea with net income of Rs.10,433/- per hectare.

Literature reviewed here indicates that paired row system of planting is an ideal method for certain crops like chilli, french bean, coriander, cowpea, etc. while for certain other crops like bhindi, country onion etc. no advantage is observed for paired row system of planting.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The investigation entitled "Resource use and plant interaction in chilli intercropping system in summer rice fallow" was carried out with the objective of assessing the possibility of intercropping in chilli based cropping system. The materials used and the method adopted for the study are briefly described below.

3.1 Experimental site

The experiment was conducted at Rice Research Station, Kayamkulam located at 9°30' north latitude and 76°20' east longitude at an altitude of 3.05 meters above mean sea level.

3.2 Soil

The soil of the experimental site comes under the taxonomical order Entisols. The initial data on the mechanical and chemical analysis of the soil are given below.

Table 3.1 Physico-chemical properties of soil

A. Mechanical composition

Sl. No.	Parameters	Content in soil (%)	Method used
1.	Coarse sand	56.50	International pipette method (Piper, 1950)
2.	Fine sand	16.10	
3.	Silt	20.35	
4.	Clay	5.80	
5.	Soil type	Loamy sand	

B. Chemical composition

Sl. No.	Parameters	Content kg ha^{-1}	Rating	Method used
1.	Available N	177.8	Low	Alkaline potassium permanganate method (Subbiah and Asija, 1956)
2.	Available P_2O_5	31.8	Medium	Bray colorimetric method (Jackson, 1973)
3.	Available K_2O	124.0	Low	Ammonium acetate method (Jackson, 1973)
4.	pH	5.8	Acidic	1:2 soil water suspension using pH meter

3.3 Season

The experiment was conducted during the summer season of 1993-94.

3.4 Weather condition during the cropping period

The meteorological parameters recorded are rainfall, maximum and minimum temperatures, relative humidity and number of rainy days. The average weekly values and their variation from the average of past 5 years (normal values of these parameters from sowing to harvest) are collected from the observatory attached to CPCRI Kayamkulam and presented in Appendix I and illustrated graphically in Figure 1.

During the cropping period a mean maximum temperature of 32.18°C was observed while the mean minimum temperature was 22.85°C. The average relative humidity recorded was 91.33 per cent. A total of 1412 mm rainfall was received distributed over 17 rainy days.

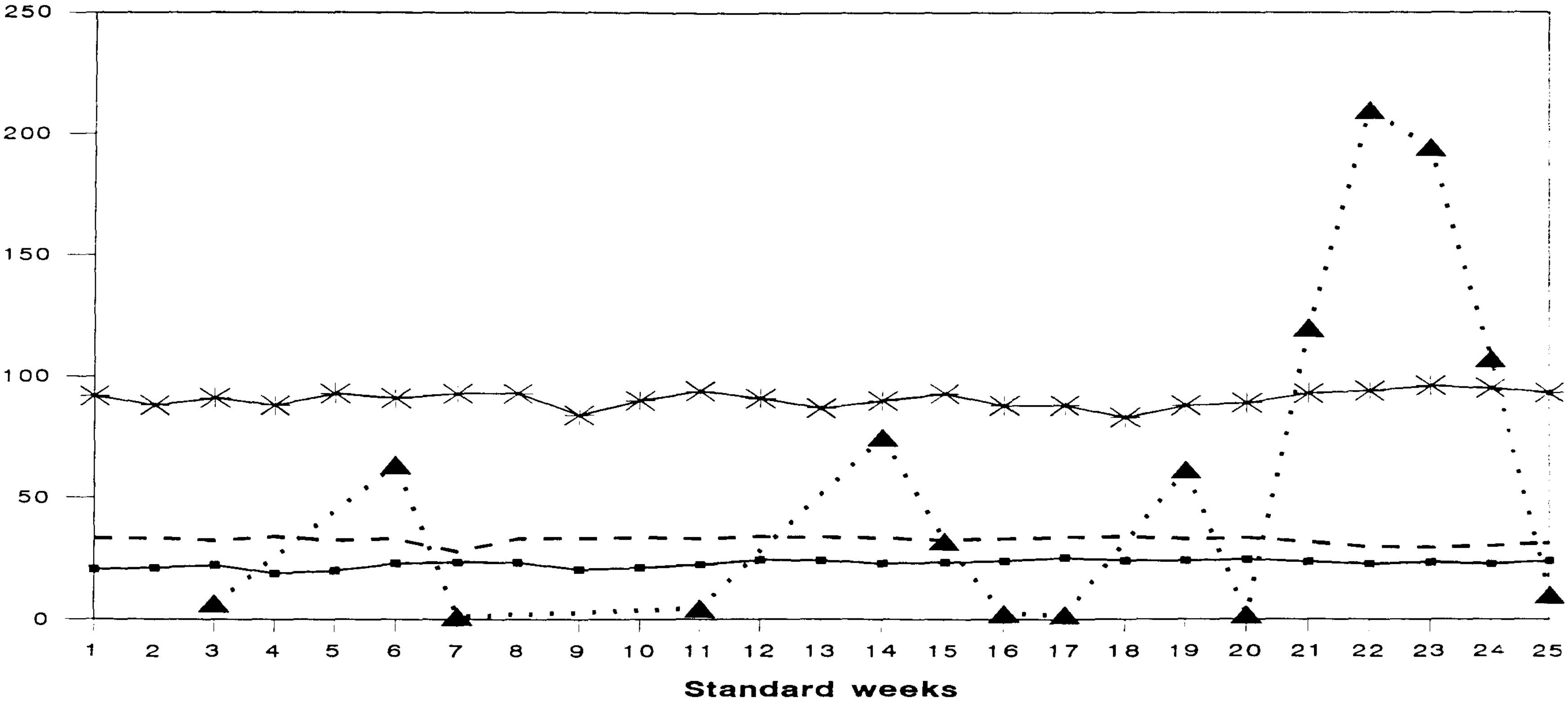


Fig. 1. Weather data during the crop period

3.5 Materials

3.5.1 Crop characters and source of seed materials are given in Table 3.2

Table 3.2 Crop characters and source of seed materials

Crop	Variety	Duration (days)	Height (cm)	Maximum growth (day)	Root spread (cm)	Remarks	Seed materials collected from
Chilli	Jwalamukhi	120	50	60-80	20	A green chilli variety evolved by crossing Vellanotchi with Pusajwala. It is an annual plant with branching habit and suitable for all seasons. The green fruit yield is 315 g per plant.	Instructional Farm, College of Agriculture, Vellayani.
French bean	Contender	60	40	30-45	40	A variety suited for cultivation in the plains throughout the year. It is bush type variety. The green pod yield is 150 g per plant. Green pods are excellent vegetable.	Pocha Seeds Pune
Amaranthus	Arun	100	40	30-40	35	A multicut variety with purple leaves evolved by mass selection. It is photoinsensitive and can be cultivated throughout the year and suitable for rice fallows. The green leaf yield is 210 g per plant	Instructional Farm, College of Agriculture Vellayani.

3.5.2 Fertilizer

Fertilizers analysing the following nutrient contents were used

Urea	-	46.1% N
Mussorie Rock Phosphate	-	27.8% P_2O_5
Muriate of Potash	-	59.5% K_2O

3.6 Method

3.6.1 Design and layout

The experiment was laid out in a Randomised Complete Block Design with three replications. The lay out plan of the experiment is given in Figure 2.

Treatments

The treatments consisted of 2 intercrops, 2 planting geometry and 3 nutrient levels.

Base crop - Chilli

Intercrops (2)

1. French bean
2. Amaranthus

Planting geometry (2)

1. Normal row planting
2. Paired row planting

Nutrient levels (3)

1. NL 100 - 100% NPK recommendation for both crops
2. NL 75 - 75% NPK recommendation for both crops
3. NL 50 - 50% NPK recommendation for both crops

Absolute controls

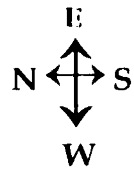
Sole crop of chilli Sole crop of french bean Sole crop of amaranthus	KAU Package of practices recommendations

Treatment combinations 2 x 2 x 3 + 3 = 15

3.7 Plot size

The gross plot size was 3.6 m x 3.6 m. For intercropped treatments the net plot size was calculated after leaving one row each of chilli and intercrop all around the plot. In pure crop of chilli, french bean and amaranthus respectively the net plot size was calculated after leaving two rows of respective crop all around the plot. The net plot size and plant population are given in Table 3.3.

Fig. 2. LAYOUT PLAN OF THE EXPERIMENT



T_4	T_{11}	T_6	T_8	T_1
T_{13}	T_{10}	T_{14}	T_7	T_2
T_{15}	T_5	T_9	T_{12}	T_3
T_1	T_6	T_{11}	T_5	T_{10}
T_7	T_{12}	T_{15}	T_{13}	T_4
T_2	T_8	T_3	T_9	T_{14}
T_{10}	T_5	T_6	T_{14}	T_7
T_4	T_{11}	T_{13}	T_{12}	T_8
T_{15}	T_3	T_9	T_2	T_1

T_1 - Chilli + French bean - Normal row - NL 100
T_2 - Chilli + French bean - Paired row - NL 100
T_3 - Chilli + French bean - Normal row NL 75
T_4 - Chilli + French bean - Paired row - NL 75
T_5 - Chilli + French bean - Normal row NL 50
T_6 - Chilli + French bean - Paired row - NL 50
T_7 - Chilli + Amaranthus - Normal row NL 100
T_8 - Chilli + Amaranthus - Paired row - NL 100
T_9 - Chilli + Amaranthus - Normal row NL 75
T_{10} - Chilli + Amaranthus - Paired row - NL 75
T_{11} - Chilli + Amaranthus - Normal row NL 50
T_{12} - Chilli + Amaranthus - Paired row - NL 50
T_{13} - Chilli Pure crop - Package of Practices recommendations
T_{14} - French bean Pure crop - Package of Practices recommendations
T_{15} - Amaranthus Pure crop - Package of Practices recommendations

Table 3.3 Net plot size and plant population of chilli and intercrops

Crop	Net plot size	Plant population/ha	
		Chilli	Intercrop
Chilli	2.25 m x 2.7 m	74074	-
Intercrops (Frenchbean/ Amaranthus)	2.7 m x 3.0 m	-	166666
Chilli (NR) + Intercrop	2.7 m x 3.3 m	74074	83333
Chilli (PR) + Intercrop	3.0 m x 3.3 m	74074	111111

3.8 Cultural operations

3.8.1 Nursery

Chilli and amaranthus seedlings were raised in seed beds of 4m x 1m x 0.15m size. Farm yard manure was applied @ 2.5 kg m^{-2} and was thoroughly mixed with the soil.

Chilli seedlings were transplanted at 4 weeks growth stage and amaranthus seedlings at 25 days after sowing.

3.8.2 Field preparation

The land was prepared by two ploughings. Stubbles were removed, clods were broken and laid out into 3 blocks. The blocks were then subdivided into 15 plots and each plot was separated with channels of 50 cm width. The individual plots were thoroughly dug and levelled.

3.8.3 Manures and fertilizer application

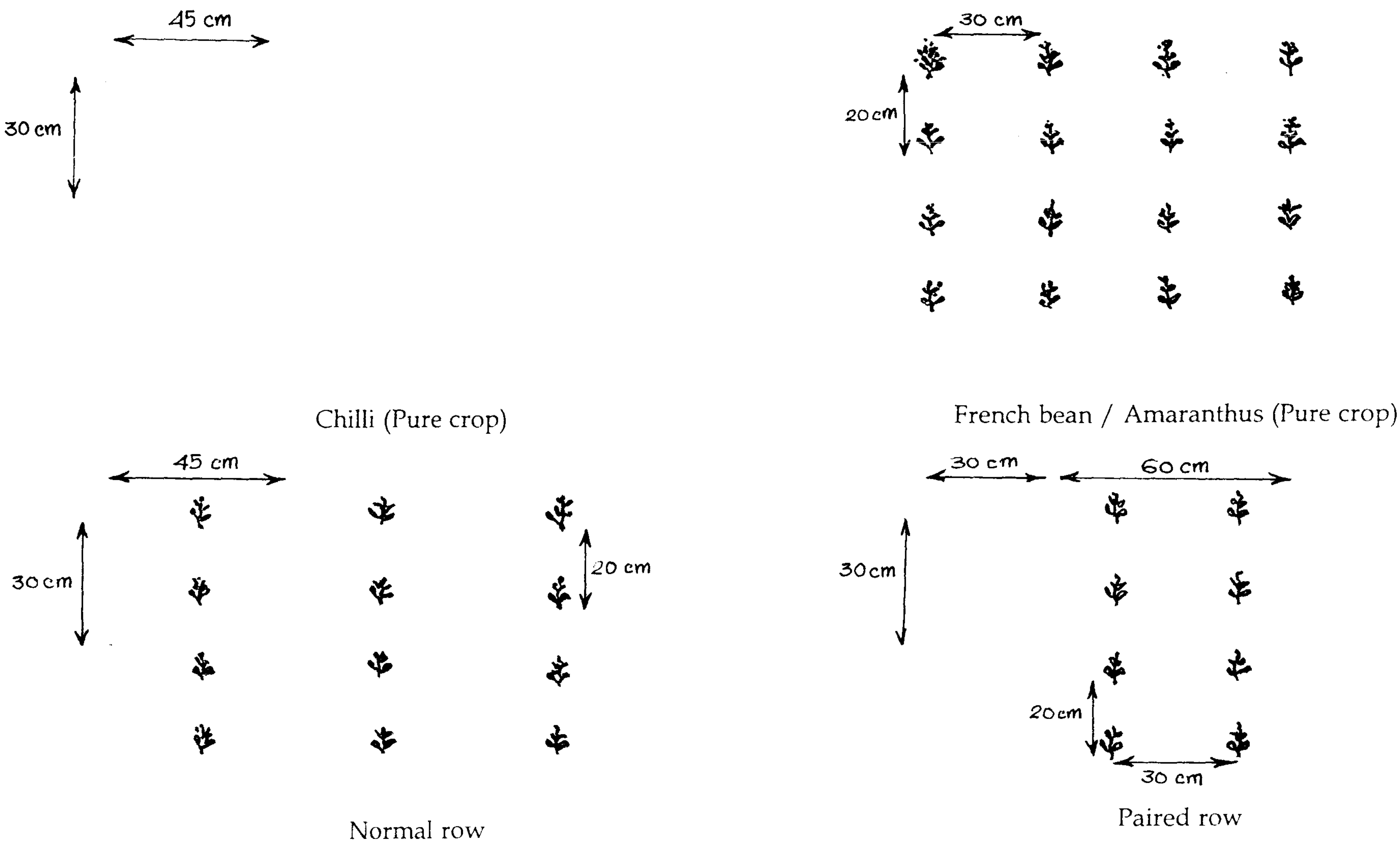
Well decomposed farm yard manure was applied in each plot @ 2.5 kg m^{-2}. Different doses of N, P and K were applied according to the treatment schedule. Recommended fertilizer doses (Package of practices recommendations of Kerala Agricultural University 1993) and schedule of fertilizer application are given in Table 3.4.

Table 3.4 Fertilizer recommendation and schedule of fertilizer application

Crop	Recommendation (kg ha^{-1}) N	P	K	Schedule of application
Chilli	75	40	25	1/2 N,Full P & 1/2 K basal 1/4 N & 1/2 K 20 DAP 1/4 N 45 DAP
French bean	60	40	60	1/2 N,Full P & K basal 1/2 N 20 DAP
Amaranthus	50	50	50	1/2 N,Full P and K basal 1/2 N 20 DAP

3.8.4 Method of transplanting and sowing

The details of planting geometry is furnished in Table 3.5 and Figure 3.



Intercropping system

Fig. 3. PLANTING GEOMETRY

Table 3.5 Planting geometry

Crop		Spacing
Chilli Normal row (Pure and Intercrop)	-	45 cm x 30 cm
Chilli Paired row (Intercrop)	-	30/60 cm x 30 cm
French bean (Pure and Intercrop)	-	30 cm x 20 cm
Amaranthus (Pure and Intercrop)	-	30 cm x 20 cm

Normal row - One row of intercrop (french bean or amaranthus) was planted in between two rows of chilli. (Plates 1, 3 & 5)

Paired row - Two rows of intercrop (french bean and amaranthus) were planted in between two adjacent paired rows. (Plates 2, 4 & 6)

3.8.5 After cultivation

In both pure and intercropped plots, weed problem was severe only during the initial growth stages. Three weedings were given at 10 days interval. In pure cropped plots two more weedings were given. Daily irrigation was given to the crop.

3.8.6 Plant protection

Prophylatic drenching of the soil with bordeaux mixture (1%) was done to control the seedling blight of chilli and french bean. Aphid infestation was observed in chilli and french bean and was controlled by spraying dimecron (0.05%). Dithane M-45 (0.2%) was sprayed at two weeks interval to control leaf blight of amaranthus and leaf spot and fruit rot of chilli.

3.8.7 Harvesting of chilli

Chilli green fruits were picked as and when they matured at an interval of 14 days. First harvest was taken 50 days after transplanting. Altogether four pickings were done and in the last picking all the green fruits were picked to complete the harvesting.

3.8.8 Harvesting of french bean

The crop flowered 45 days after sowing but the pod set was very poor and only 1-2 pods were produced per plant. The green pods of french bean were harvested at tender stage.

3.8.9 Harvesting of amaranthus

First harvest was done 40 days after transplanting. Two more harvests were taken at an interval of 20 days.

3.9 Observations recorded

Observations on growth characters, yield components and yield were recorded.

Sampling procedure

For recording various observations, five plants each of chilli, french bean and amaranthus were tagged at random from the net plot area in each plot. The observations on growth characters of chilli were taken 30 and 60 days after transplanting and at harvest. For amaranthus and french bean observations were recorded 30 days after transplanting/sowing and at harvest.

Chilli

3.9.1 Plant height

The height of five plants at 30 days interval was measured from the base of the plant to the growing tip. The average was taken and expressed as cm.

3.9.2 Number of leaves per plant

Total number of leaves produced was recorded from all the tagged plants at 30 days interval and the average was taken and furnished.

3.9.3 Leaf area per plant

Leaf area per plant was calculated by length x breadth x factor method. (Factor : 0.59).

3.9.4 Number of branches per plant

Number of primary and secondary branches were recorded on all tagged chilli plants at 30 days interval and the average was taken.

3.9.5 Total dry matter production per plant

Total dry matter production at flowering and harvest was calculated. Five plants were selected randomly, uprooted and air dried. Later the samples were dried in hot air oven to a constant weight at 70-75°C and the total dry weight was recorded and expressed as kg ha^{-1}.

3.9.6 Root spread

Plants were carefully uprooted washed and placed on a graph paper. The maximum width and depth were recorded and expressed in cm.

3.9.7 Relative growth rate (RGR)

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

$$RGR = \frac{\log_e w_2 - \log_e w_1}{t_2 - t_1}$$

w_1 - Dry weight of the plant at time t_1

w_2 - Dry weight of the plant at time t_2.

3.9.8 Time of 50 per cent flowering

Date on which 50 per cent of plants flowered was noted and time of 50 per cent flowering was computed.

3.9.9 Number of fruits per plant

The number of chilli fruits harvested from the five tagged plants was taken at each picking. Total number of chilli fruits harvested from all pickings was calculated and the average of five plants was taken as the number of fruits per plant.

3.9.10 Length, girth and volume of the fruits

From different pickings, ten fruits were selected randomly from each treatment and their length was measured from tip to the stalk end of the fruit. The average was computed and expressed in cm. Their diameter was measured and the average was computed and expressed as girth in cm. Volume of the fruits was measured by water displacement method and expressed in cubic cm.

3.9.11 Fresh weight and dry weight of hundred fruits

The fresh chilli fruits obtained at each picking were mixed and hundred fruits were drawn randomly from pooled sample for each of the treatment and its weight was recorded and expressed in g. The fresh chilli fruits from each picking were dried for a week and then dried in hot air oven to constant weight at a temperature of 70-75°C and the dry weight was recorded for 100 fruits and expressed in g.

3.9.12 Yield per hectare

The fresh chilli fruit yield obtained from the net plot was recorded at different pickings. The yield of fresh chillies obtained at each picking was summed up to get the yield per plot. On the basis of which yield per hectare was computed and expressed in kg ha^{-1}.

3.9.13 Harvest index

Harvest index was worked out based on the fruit yield and total plant yield using the following formula as suggested by Donald (1962)

$$\text{Harvest index} = \frac{\text{Economic yield}}{\text{Biological yield}}$$

Amaranthus

3.9.14 Plant height

In each plot five plants were tagged randomly and plant height was recorded from the ground level to the growing tip of the plant on 30th day and at harvest.

3.9.15 Number of leaves per plant

The number of total green leaves per sample plant was recorded 30 DAP and at harvest.

3.9.16 Leaf area per plant

Leaf area per plant was worked out by length x breadth x constant method. (Constant : 0.6).

3.9.17 Root spread at harvest

Plants were carefully uprooted and after washing were placed on a graph paper and maximum width and depth were recorded and expressed in cm.

3.9.18 Total dry matter production

Five plants were selected randomly from the net plot area and uprooted at first harvest and kept for air drying. Later the samples were dried in hot air oven to constant weight at 70-75°C and the total dry weight was recorded and expressed in kg ha^{-1}.

3.9.19 Yield per hectare

The yield of amaranthus obtained from the net plot area was recorded at different cuts. The yield obtained at each harvest was summed up to get the yield per plot. On the basis of which yield per hectare was computed and expressed in t ha^{-1}.

French bean

3.9.20 Plant height

In each plot five plants were tagged randomly and plant height was recorded from the ground level to the growing tip of the plant 30 days after sowing and at harvest expressed in cm.

3.9.21 Number of leaves per plant

The number of total green leaves per sample plant was recorded 30 days after sowing and at harvest.

3.9.22 Leaf area per plant

Leaf area was calculated by length x breadth x constant method. (Constant : 0.52)

3.9.23 Root spread at harvest

Plants were carefully uprooted and after washing were placed on a graph paper and the maximum width and depth were recorded and expressed in cm.

3.9.24 Total dry matter production

Five plants were selected randomly from the net plot area, uprooted at harvest and air dried. Later the samples were dried in hot air oven to constant weight at 70-75°C and the total dry weight was recorded.

3.9.25 Yield per hectare

The pod set was very poor and pods produced were harvested 60 days after sowing. On the basis of which yield per hectare was computed and expressed in kg ha^{-1}.

3.10 Parameters for evaluation of cropping systems

Biosuitability

3.10.1 Land Equivalent Ratio (LER)

In this study LER for the chilli based intercropping system was calculated using the formula proposed by Willey and Osiru (1972).

$$LER = \frac{Yab}{Yaa \times Zab} + \frac{Yba}{Ybb \times Zba}$$

Yab and Yba are the individual crop yields in intercropping and Yaa and Ybb are their yields as sole crop. Zab and Zba are the proportion of land area occupied in intercropping when compared to sole crop for species a and b respectively

a - Chilli, b - Intercrop (french bean/amaranthus)

3.10.2 Land Equivalent Coefficient (LEC)

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

LEC = LER of base crop x LER intercrop

3.10.3 Relative Crowding Coefficient (RCC)

RCC was calculated using the formula proposed by de Wit (1960).

$$Kab = \frac{Yab}{(Yaa-Yab)Zab} \qquad Kba = \frac{Yba}{(Ybb-Yba)Zba}$$

Kab and Kba are Relative crowding coefficient for species a and b respectively

K = product of coefficient of species a and b respectively (Kab x Kba)

3.10.4 Aggressivity

Aggressivity was calculated using the formula proposed by Mc Gilchrist (1965).

$$Aba = \frac{Yab}{Yaa \times Zab} - \frac{Yba}{Ybb \times Zba}$$

3.10.5 Area Time Equivalent Ratio (ATER)

ATER was calculated using the formula proposed by Hiebsch (1978).

$$ATER = \frac{(RYa \times ta) + (RYb \times ts)}{T}$$

RY = relative yield of species a and b

$$= \frac{\text{Yield of intercrop/ha}}{\text{Yield of monocrop/ha}}$$

t = duration (days) for species a and b

T = duration (days) of the intercrop system

3.10.6 Crop Equivalent Yield (CEY)

CEY was calculated using the formula proposed by Verma and Modgal (1983).

$$CEY = \sum_{i=1}^{n} (Yiei)$$

Where CEY - Chilli Equivalent Yield (kg ha^{-1})

Y - the economic yield of 1 to n number of crops (kg ha^{-1})

e - the crop equivalent factor

which can be calculated as $\frac{Pc}{Pa}$ where Pc is the price of a unit weight of concerned crop and Pa is the price of unit weight of chilli

i = 1 to n number of crops.

Economic suitability

3.10.7 Monetary Advantage Based on LER

Monetary advantage was calculated using the formula proposed by Willey (1979).

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

3.10.8 Gross Return

The total monetary value of the economic produce obtained from the crop raised in the cropping system is calculated based on the local market prices of the produce and expressed on per hectare basis.

3.10.9 Net Return

This is calculated by substracting total cost of cultivation for the cropping system from gross return.

3.10.10 Return per rupee invested

Return per rupee invested was calculated using the formula. (Palaniappan, 1988).

$$\text{Return per rupee invested} = \frac{\text{Gross return}}{\text{Total (variable) cost of cultivation}}$$

3.10.11 Per Day Return

Per day return was calculated using the formula

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

(Palaniappan, 1988)

3.11 Analytical procedures

3.11.1 Plant analysis

Plant samples were dried in the oven at 75°C till constant weights were achieved. The samples were then ground to pass through a 0.5 mm mesh sieve in a Wiley mill. Then 0.5 g of samples were weighed out and analysis was carried out as per standard procedures.

3.11.1.1 Uptake of nitrogen

Total nitrogen content was estimated by modified microkjeldhal method (Jackson, 1973) and the values were expressed as percentage. Uptake of nitrogen was calculated by multiplying the nitrogen content of the plant with the total dry weight of the plant. The uptake values were expressed in kg ha^{-1}.

3.11.1.2 Uptake of phosphorus

Phosphorus content was estimated colorimetrically (Jackson, 1973) by developing colours by vanado molybdophosphoric acid method. The yellow colour developed was read using klett summerson photoelectric colorimeter. Phosphorus content was multiplied with total dry weight of the plants to give the uptake of phosphorus by the plant in kg ha^{-1}.

3.11.1.3 Uptake of potassium

Total potassium content in the plants were estimated by the flame photometric method. Total potassium uptake was calculated by multiplying the dry weight and the total potassium content and the uptake values were expressed in kg ha^{-1}.

3.11.2 Soil analysis

Soil samples were taken from the experimental area before the start of the experiment and after the experiment. Available nitrogen status of the soil was estimated using alkaline potassium permanganate method (Subbiah and Asija, 1956), available phosphorus by Bray colorimetric method (Jackson, 1973) and available potassium by ammonium acetate method (Jackson, 1973) respectively.

3.11.3 Statistical analysis

Data relating to different characters were analysed statistically by applying the technique of analysis of variance for R.B.D. and significance was tested by F test (Snedecor and Cochran, 1967). Important correlations were also worked out.

3.11.4 Nutrient balance sheet

Nutrient balance sheet was prepared based on the procedure suggested by (Sadanandan and Mahapatra, 1973).

Plate 1. Normal row planting of chilli

Plate 2. Paired row planting of chilli

Plate 3. Amaranthus intercropped with chilli planted in normal row system.

Plate 4. Amaranthus intercropped with chilli planted in paired row system

Plate 5. French bean intercropped with chilli planted in normal row system

Plate 6. French bean intercropped with chilli planted in paired row system

RESULTS

4. RESULTS

An investigation was conducted at Rice Research Station, Kayamkulam to study the possibility of intercropping in chilli based cropping system. The experimental data collected were statistically analysed and the results obtained are presented under the following sections.

4.1 Growth and yield characters

Chilli

4.1.1 Plant height

Effects of intercrop, nutrient levels and planting geometry on the height of chilli at different growth stages are presented in Table 4.1. Intercropping and planting geometry did not influence the height of chilli in all the different growth stages. Nutrient levels had a significant influence on plant height at all growth stages except 30 DAP. At later two stages of plant growth the maximum and significant height was recorded by the highest level of nutrient (40.9 cm 60 DAP and 49.5 cm 90 DAP). Pure crop recorded the lowest height 30 DAP and 60 DAP. After 90 day of planting except with NL 50 all other treatments recorded superior plant height .

After 60 and 90 days of planting none of the interaction was found significant but 30 DAP interaction effect

Table 4.1 Effect of intercrops, nutrient levels and planting geometry on the height of chilli at different growth stages

Height (cm)

Treatments	30 DAP	60 DAP	90 DAP
Intercrops			
French bean	23.6	38.6	46.8
Amaranthus	23.4	35.9	43.7
$F_{1, 24}$	0.05^{ns}	2.63^{ns}	2.3^{ns}
SE	0.68	1.20	1.54
Nutrient levels			
NL 100	24.3	40.9	49.5
NL 75	24.8	35.7	43.4
NL 50	22.8	35.2	42.4
$F_{2, 24}$	0.93^{ns}	4.53^{s}	4.18^{s}
SE	0.83	1.47	1.89
C.D (0.05)	-	4.29	5.51
Planting geometry			
Normal row	22.8	36.0	44.3
Paired row	24.2	38.5	45.9
$F_{1, 24}$	2.15^{ns}	2.10^{ns}	0.52^{ns}
SE	0.68	1.20	1.54
Treatment vs control	21.9	33.7	43.0

Table 4.1.1 Interaction effect of intercrops and nutrient levels on the height of chilli at 30 DAP

Height (cm)

	NL 100	NL 75	NL 50
French bean	22.4	24.4	24.0
Amaranthus	26.3	22.3	21.5
$F_{2, 24}$	4.66^{s}		
SE	1.76		
C.D (0.05)	3.43		

between nutrient levels and intercrop revealed significance (Table 4.1.1). Thirty days after planting, maximum plant height (26.3 cm) was recorded when chilli was intercropped with amaranthus and was fertilized with 100 per cent of the nutrient dose. It was on par with the height obtained when chilli was intercropped with french bean at NL 75 and was significantly superior to all other treatments. At this stage also other interactions failed to show significance.

4.1.2 Number of leaves per plant

Effects of intercrops, nutrient levels and planting geometry on the leaf number of chilli at different growth stages are presented in Table 4.2.

Intercrops had significant influence on the leaf number of chilli at all growth stages. French bean intercropping recorded significantly higher leaf number. The nutrient levels significantly influenced the leaf number only after 60 days of planting. At the stage of 60 DAP the highest leaf number (103) was recorded by NL 100 compared with the lower levels and the lower two levels behaved similarly. At the stage of 90 DAP NL 100 recorded a leaf number of 114. It was on par with NL 75 and significantly superior to NL 50 while the lower two doses behaved similarly. Planting geometry did not influence the leaf number at any growth stage. At the stages of 60 and 90 DAP pure crop

Table 4.2 Effect of intercrops, nutrient levels and planting geometry on the leaf number and leaf area of chilli at different growth stages

	Number of leaves			Leaf area (sq.cm)		
Treatments	30 DAP	60 DAP	90 DAP	30 DAP	60 DAP	90 DAP
Intercrops						
French bean	43	113	124	366.9	1808.1	1528.8
Amaranthus	34	67	81	295.5	664.6	858.9
$F_{1,\ 24}$	13.56^{s}	57.02^{s}	46.90^{s}	6.10^{s}	38.40^{s}	27.10^{s}
SE	1.86	4.33	4.49	20.57	73.35	90.89
C.D (0.05)	5.44	12.65	13.09	60.05	214.10	265.29
Nutrient levels						
NL 100	41	103	114	376.5	1271.9	1453.2
NL 75	38	87	100	319.9	868.4	1105.5
NL 50	38	81	93	296.6	818.8	1022.8
$F_{2,\ 24}$	0.63^{ns}	4.63^{s}	3.77^{s}	2.60^{ns}	7.65^{s}	4.21^{s}
SE	2.28	5.31	5.49	25.19	89.84	111.13
C.D (0.05)	-	15.49	16.03	-	262.23	324.92
Planting geometry						
Normal row	38	89	101	324.4	969.9	1176.9
Paired row	39	91	104	337.6	1002.9	1210.8
$F_{1,\ 24}$	0.10^{ns}	0.08^{ns}	0.18^{ns}	0.20^{ns}	0.10^{ns}	0.26^{ns}
SE	1.86	4.33	4.49	20.57	73.35	90.89
Treatment vs control	40	124	137	313.8	1051.9	1422.9

recorded maximum leaf number compared with all other treatments. At the stage of 30 DAP french bean intercropping and NL 100 produced more leaf number than pure crop. Interaction effects had no significant influence on this character at different growth stages.

4.1.3 Leaf area per plant

Effects of intercrop, nutrient levels and planting geometry on the leaf area of chilli at different growth stages are presented in Table 4.2. Intercrops had significant effect on leaf area. Chilli recorded significantly superior leaf area when intercropped with french bean at all the different growth stages. Maximum leaf area was observed with highest nutrient dose at later two stages of growth. It was significantly superior to the lower doses at the later two growth stages. Planting geometry had no significant effect on the leaf area of chilli. At the stage of 30 DAP amaranthus intercropping and the lowest nutrient dose recorded the lowest leaf area than pure crop. At later two stages, french bean intercropping and NL 100 recorded superior leaf area than pure crop. Interaction effects did not significantly influence the leaf area of chilli at different growth stages.

4.1.4 Number of branches

Effects of intercrops, nutrient levels and planting geometry on the number of primary and secondary branches of chilli at different growth stages are presented in Table 4.3.

Table 4.3 Effect of intercrops, nutrient levels and planting geometry on the number of primary and secondary branches of chilli at different growth stages

	Primary branches			Secondary branches		
Treatments	30 DAP	60 DAP	90 DAP	30 DAP	60 DAP	90 DAP
<u>Intercrops</u>						
French bean	5.2	7.5	8.0	11.4	31.3	37.1
Amaranthus	4.5	6.0	6.7	8.7	19.8	26.4
F1, 24	4.03^{ns}	13.55^{s}	9.57^{s}	11.60^{s}	52.20^{s}	19.85^{s}
SE	0.26	0.27	0.31	0.56	1.13	1.69
C.D (0.05)	-	0.80	0.89	1.63	3.30	4.93
<u>Nutrient levels</u>						
NL 100	4.9	7.5	8.1	10.2	28.3	39.1
NL 75	5.1	6.7	7.2	10.0	24.2	31.3
NL 50	4.5	6.0	6.8	9.8	24.2	29.9
F2, 24	0.65^{ns}	4.60^{s}	3.25^{ns}	0.12^{ns}	2.90^{ns}	1.06^{ns}
SE	0.32	0.34	0.38	0.69	1.39	2.07
C.D (0.05)	-	0.9	-	-	-	-
<u>Planting geometry</u>						
Normal row	4.9	6.7	7.3	10.3	25.9	31.9
Paired row	4.8	6.7	7.4	9.7	25.2	31.6
F1, 24	0.16^{ns}	0.02^{ns}	0.01^{ns}	0.56^{ns}	0.23^{ns}	0.12^{ns}
SE	0.26	0.28	0.31	0.56	1.13	1.69
Treatment vs control	5.4	6.4	7.4	12.2	31.2	27.6

Intercropping significantly influenced the number of primary branches of chilli at later two growth stages but had a significant influence on the number of secondary branches at all the growth stages. French bean intercropping recorded significantly superior number of primary and secondary branches of chilli compared with amaranthus intercropping. Nutrient doses significantly influenced the number of primary branches at the stage of 60 DAP only. NL 100 recorded significantly superior number of primary branches (7.5) compared with NL 50. It was on par with NL 75 and significantly superior to NL 50 and lower two levels behaved similarly. Nutrient level, had no significant effect on the number of secondary branches produced by chilli. Planting geometry had no significant influence on the number of primary and secondary branches of chilli. At the stage of 30 DAP pure crop recorded the highest number of primary and secondary branches. At the stage of 60 DAP amaranthus intercropping and NL 50 produced lower number of primary branches compared with the pure crop and only french bean intercropping recorded more number of secondary branches than pure crop. At the stage of 90 DAP french bean intercropping, NL 100, and paired row planting system produced more number of primary branches than pure crop and except amaranthus intercropping all other treatments produced more number of secondary branches compared with pure crop.

Interaction had not significantly influenced the number of primary and secondary branches produced by chilli at different growth stages.

4.1.5 Total dry matter production

Effect of intercrops, nutrient levels and planting geometry on the total dry matter production of chilli at different growth stages is presented in Table 4.4.

Intercrops had a significant effect on the total dry matter production. Chilli with french bean produced significantly superior dry matter at flowering (450 kg ha^{-1}) and harvest (1202 kg ha^{-1}). Nutrient doses had no significant effect on the total dry matter production of chilli at flowering but had a significant effect at harvest. Total dry matter produced (1182 kg ha^{-1}) was the maximum with the highest nutrient dose and it was significantly superior to the total dry matter produced with lower nutrient doses. Planting geometry had no significant effect on the total dry matter production. At flowering stage the total dry matter produced by the pure crop was less compared with all the other treatments. At harvest french bean intercropping, NL 100 and paired row planting recorded higher total dry matter than pure crop. Interactions had no significant effect on the total dry matter production of chilli at flowering and harvest.

Table 4.4 Effect of intercrops, nutrient levels and planting geometry on the total dry matter production of chilli at different growth stages

Total dry matter kg ha^{-1}

Treatments	Flowering	Harvest
Intercrops		
French bean	450	1202
Amaranthus	250	637
F1, 24	38.18^{s}	23.92^{s}
SE	22.89	74.34
C.D (0.05)	66.83	217.00
Nutrient levels		
NL 100	353	1182
NL 75	376	833
NL 50	322	742
F2, 24	0.95^{ns}	6.51^{s}
SE	28.04	91.05
C.D (0.05)	-	265.77
Planting geometry		
Normal row	372	851
Paired row	328	988
F1, 24	1.85^{ns}	1.69^{ns}
SE	22.89	74.34
Treatment vs control	220	933

4.1.6 Root spread at harvest

Effect of intercrops, nutrient levels and planting geometry on the root spread of chilli at harvest is presented in Table 4.5. Intercrops, nutrient levels and planting geometry had no effect on the root spread of chilli at harvest. Pure crop recorded the lowest root spread compared with all other treatments.

4.1.7 Relative growth rate (g g^{-1} day^{-1})

Effect of intercrops, nutrient levels and planting geometry on the relative growth rate of chilli is given in Table 4.5.

Neither the main effects nor the interaction effects revealed any significant effect in RGR.

4.1.8 Time of 50 per cent flowering

Effect of intercrops, nutrient levels and planting geometry at the time of 50 per cent flowering of chilli is given in Table 4.6. Time of 50 per cent flowering when intercropped with amaranthus (23 days) was significantly superior to intercropping with french bean. Nutrient doses and planting geometry had no significant effect on the time of 50 per cent flowering of chilli. Chilli plants, only in amaranthus intercropped plots flowered earlier than pure crop. Interaction effects had no significance on the time of 50 per cent flowering.

Table 4.5 Effect of intercrops, nutrient levels and planting geometry on the root spread and RGR of chilli at harvest stage

Treatments	Root spread (cm)	RGR ($g\ g^{-1}\ day^{-1}$)
Intercrops		
French bean	78.9	0.016
Amaranthus	77.4	0.026
F1, 24	0.28^{ns}	1.08^{ns}
SE	1.91	0.01
Nutrient levels		
NL 100	79.6	0.036
NL 75	78.2	0.013
NL 50	76.8	0.015
F2, 24	0.37^{ns}	2.51^{ns}
SE	2.34	0.01
Planting geometry		
Normal row	76.6	0.023
Paired row	79.7	0.019
F1, 24	1.33^{ns}	0.22^{ns}
SE	1.91	0.01
Treatment vs control	73	0.026

Table 4.6 Effect of intercrops, nutrient levels and planting geometry on time of 50 per cent flowering, number, length, girth and volume of fruits of chilli.

Treatments	Time of 50 per cent flowering	Number of fruits $plant^{-1}$	Length (cm)	Girth (cm)	Volume (cm^3)
Intercrops					
French bean	21	45	8.9	5.2	8.7
Amaranthus	23	23	8.4	4.9	7.5
F1, 24	29.8^{s}	36.88^{s}	21.7^{s}	3.6^{ns}	9.23^{s}
SE	0.23	2.56	0.087	0.079	0.285
C.D (0.05)	0.67	7.49	0.25	-	0.82
Nutrient levels					
NL 100	22	37	8.8	5.1	8.8
NL 75	22	35	8.7	5.1	7.8
NL 50	22	30	8.5	5.1	7.8
F2, 24	0.81^{ns}	1.56^{ns}	1.49^{ns}	0.018^{ns}	3.01^{ns}
SE	0.28	3.14	0.106	0.097	0.34
Planting geometry					
Normal row	22	32	8.7	5.1	7.8
Paired row	22	36	8.6	5.1	8.4
F1, 24	0.116^{ns}	0.87^{ns}	1.72^{ns}	0^{ns}	2.12^{ns}
SE	0.230	2.56	0.087	0.079	0.28
Treatment vs Control	22	44	9.5	5.0	7.9

4.1.9 Number of fruits per plant

Effect of intercrops, nutrient levels and planting geometry on the number of fruits of chilli is given in Table 4.6.

Intercrops had significant effect on the number of fruits of chilli. Chilli with french bean as intercrop produced significantly superior number of fruits (45). Nutrient level and planting geometry had no significant effect on the number of fruits of chilli. Interaction effect did not influence the number of fruits of chilli. French bean as intercrop recorded more number of fruits than pure crop.

4.1.10 Length, girth and volume of fruits

Effect of intercrops, nutrient levels and planting geometry on the length, girth and volume of chilli fruit is shown in Table 4.6.

Intercrops had significant influence on the length and volume of chilli fruits and had no influence on the girth. Length and volume of chilli fruits with french bean as intercrop were significantly superior to that of amaranthus as intercrop. Nutrient levels and planting geometry did not influence the length, girth and volume of chilli fruits. Interaction effects had no significance on the length, girth and volume of chilli fruits. Length of fruits with all treatments was less than pure crop. Amaranthus as intercrop recorded lesser girth than pure crop. Volume of fruits obtained with french bean as intercrop, NL 100 and paired row planting was more than that of pure crop.

4.1.11 Fresh and dry weight of 100 chilli fruits

Effect of intercrops, nutrient levels and planting geometry on the fresh and dry weight of 100 chilli fruits is given in Table 4.7. Intercrops had significant effect on the fresh and dry weight of 100 chilli fruits. French bean intercropping recorded significantly superior fresh and dry weight of chilli fruits (460 g and 60 g respectively). Nutrient levels had significant effect on the fresh and dry weight of chilli fruits. NL 100 recorded significantly superior fresh weight (459 g) and dry weight (60 g) of chilli fruit. Planting geometry and interaction effects did not influence the fresh and dry weight of 100 chilli fruits. Amaranthus intercropping and NL 50 recorded lesser fresh weight of fruits compared with pure crop. French bean intercropping, NL 100 and normal planting recorded more dry weight of chilli fruits than pure crop.

4.1.12 Yield per hectare

Effect of intercrop, nutrient levels and planting geometry on the yield of chilli is presented in Table 4.7.

Intercrops and nutrient levels had significant effect on the yield of chilli. Planting geometry had no significant

Table 4.7 Effect of intercrops, nutrient levels and planting geometry on the fresh weight and dry weight of 100 fruits, yield and harvest index of chilli

Treatments	Fresh weight (g)	Dry weight (g)	Yield kg ha^{-1}	Harvest index
<u>Intercrops</u>				
French bean	460	60	8371	0.87
Amaranthus	403	52	4550	0.87
F1, 24	21.14^{s}	15.5^{s}	42.87^{s}	0.01^{ns}
SE	8.78	1.44	412.66	0.01
C.D (0.05)	25.62	4.20	1204.52	-
<u>Nutrient levels</u>				
NL 100	459	60	8917	0.88
NL 75	422	52	5598	0.87
NL 50	414	55	4865	0.86
F2, 24	5.10^{s}	5.13^{s}	18.25^{s}	0.80^{ns}
SE	10.75	1.76	505.40	0.01
C.D (0.05)	31.38	5.15	1475.23	-
<u>Planting geometry</u>				
Normal row	433	57	6155	0.87
Paired row	430	56	6765	0.87
F1, 24	0.03^{ns}	0.01^{ns}	1.09^{ns}	0.15^{ns}
SE	8.78	1.44	412.66	0.01
Treatment vs control	422	56	6718	0.87

effect on the yield of chilli. French bean intercropping recorded significantly superior yield (8371 kg ha^{-1}) for chilli compared with amaranthus intercropping. NL 100 recorded significantly superior yield (8917 kg ha^{-1}) compared with NL 75 and NL 50. French bean intercropping, NL 100 and paired row planting produced more yield compared with pure crop. Yield of chilli was not affected by the interaction effects.

4.1.13 Harvest index

Effect of intercrops, nutrient levels and planting geometry on the harvest index of chilli is given in Table 4.7. Neither the main effects nor the interaction effect revealed any significance on the harvest index of chilli. Harvest index obtained with NL 50 was less than that of pure crop.

Amaranthus

4.1.14 Plant height

Effect of nutrient levels and planting geometry on the height of intercropped amaranthus at different growth stages is given in Table 4.8.

Nutrient levels, planting geometry and their interaction had no significant effect on the height of amaranthus at different growth stages. Pure crop of amaranthus recorded lesser height compared with other treatments at both stages except NL 50 at harvest.

Table 4.8 Effect of nutrient levels and planting geometry on the height, leaf number, leaf area and root spread of intercropped amaranthus at different growth stages.

Treatments	Height (cm)		Number of leaves		Leaf area (sq.cm.)		Root spread (cm)
	30 DAP	harvest	30 DAP	harvest	30 DAP	harvest	harvest
Nutrient levels							
NL 100	32.7	51.1	18.2	28.9	1673.6	3588.1	40.1
NL 75	26.1	41.2	17.1	27.2	1454.4	2572.7	38.0
NL 50	25.7	31.2	18.6	30.4	1119.0	2733.9	38.9
F2, 12	1.92^{ns}	3.20^{ns}	0.13^{ns}	0.58^{ns}	3.18^{ns}	2.46^{ns}	0.14^{ns}
SE	2.84	3.77	2.02	2.07	156.61	347.77	2.71
Planting geometry							
Normal row	26.4	42.1	19.1	29.5	1371.7	3023.5	41.0
Paired row	29.9	44.8	16.8	28.2	1459.7	2906.2	37
F1, 12	1.09^{ns}	0.42^{ns}	0.99^{ns}	0.29^{ns}	0.23^{ns}	0.08^{ns}	1.6^{ns}
SE	7.16	9.47	1.65	1.69	127.87	283.95	2.21
Treatment vs control	22.89	34.9	15.2	26.4	1328.1	2787.4	33.6

4.1.15 Number of leaves per plant

Effects of nutrient levels and planting geometry on the number of leaves of intercropped amaranthus at different growth stages are given in Table 4.8.

Nutrient levels, planting geometry and their interactions did not influence the number of leaves of amaranthus at different growth sages. Number of leaves produced by pure crop of amaranthus was less compared with other treatments both at 30 DAP and at harvest.

4.1.16 Leaf area per plant

Effect of nutrient levels and planting geometry on the leaf area of intercropped amaranthus at different growth stages is presented in Table 4.8. Nutrient levels, planting geometry and their interaction had no significant effect on the leaf area of amaranthus at different growth stages. At the stage of 30 DAP NL 50 recorded lower leaf area than pure crop. At harvest stage, the leaf area obtained with NL 75 and NL 50 was less than pure crop of amaranthus.

4.1.17 Root spread at harvest

Effect of nutrient levels and planting geometry on the root spread of intercropped amaranthus at harvest is given in Table 4.8.

Root spread of amaranthus was not affected by nutrient level, planting geometry and their interaction. Root spread of pure crop of amaranthus was less compared with other treatments.

4.1.18 Total drymatter production

Effect of nutrient levels and planting geometry on the total drymatter production of intercropped amaranthus is given in Table 4.9. Nutrient doses did not influence the total dry matter produced by amaranthus. Planting geometry revealed significance in the total dry matter production of amaranthus. Paired row planting recorded significantly higher total dry matter production (2663 kg ha^{-1}). Interaction effect also had no significance on the dry matter production. Total dry matter produced by pure crop of amaranthus was more than all other treatments.

4.1.19 Yield per hectare

Effect of nutrient levels and planting geometry on the yield of intercropped amaranthus is presented in Table 4.9.

Nutrient doses had significant influence on the yield of amaranthus. Significantly higher yield (23.6 t ha^{-1}) was obtained with NL 100. It had a similar effect on the yield obtained with NL 75 and higher two levels were significantly superior to NL 50. Planting geometry and interaction effects had

Table 4.9 Effect of nutrient levels and planting geometry on the total dry matter production and yield of intercropped amaranthus.

Treatments	Total dry matter kg ha^{-1}	Yield t ha^{-1}
Nutrient levels		
NL 100	2486	23.7
NL 75	2285	23.4
NL 50	1986	16.5
F2, 12	1.31^{ns}	3.9^{s}
SE	219.75	2.06
C.D (0.05)	-	6.33
Planting geometry		
Normal row	1902	19.1
Paired row	2603	23.4
F1, 12	7.63^{s}	3.29^{ns}
SE	179.40	1.68
C.D (0.05)	552.90	-
Treatment vs control	2605	18.81

no significant influence on the yield of ameranthus. Only the yield obtained with NL 50 was less when compared with pure crop yield.

French bean

4.1.20 Plant height

Effect of nutrient levels and planting geometry on the height of intercropped french bean at different growth stages is given in Table 4.10. Height of french bean was not affected by nutrient levels, planting geometry and their interaction. Pure crop recorded less plant height compared with other treatments.

4.1.21 Number of leaves per plant

Effect of nutrient levels and planting geometry on the number of leaves of intercropped french bean at different growth stages is presented in Table 4.10. Nutrient levels, planting geometry and their interaction did not influence the number of leaves produced by french bean. Pure crop of french bean recorded higher number of leaves at both growth stages than other treatments.

4.1.22 Leaf area per plant

Effect of nutrient levels and planting geometry on the leaf area of intercropped french bean at different growth stages

Table 4.10 Effect of nutrient levels and planting geometry on the height, leaf number, leaf area and root spread of intercropped french bean at different growth stages.

Treatments	Height (cm)		Number of leaves		Leaf area (sq.cm.)		Root spread (cm)
	30 DAP	harvest	30 DAP	harvest	30 DAP	harvest	harvest
<u>Nutrient levels</u>							
NL 100	23.0	29.2	24.8	31.7	545.6	828.3	33.7
NL 75	18.7	23.7	20.5	28.0	353.3	494.8	36.5
NL 50	18.1	27.6	20.8	26.7	346.5	468.3	33.3
F2, 12	1.52^{ns}	0.96^{ns}	0.93^{ns}	0.92^{ns}	2.24^{ns}	3.04^{ns}	0.36^{ns}
SE	2.17	2.85	2.49	2.69	75.57	114.88	8.82
<u>Planting geometry</u>							
Normal row	20.5	25.6	23.3	29.6	464.2	615.0	28.6
Paired row	19.3	28.0	20.8	28.0	366.0	579.2	40.4
F1, 12	0.23^{ns}	0.54^{ns}	0.79^{ns}	0.25^{ns}	1.27^{ns}	0.07^{ns}	12.94^{s}
SE	1.77	2.33	2.04	2.20	61.70	93.80	2.34
C.D (0.05)	-	-	-	-	-	-	7.20
Treatment vs control	16.3	23.3	26.9	37	373.4	560.3	35.3

is given in Table 4.10. Nutrient levels, planting geometry and their interaction did not influence the leaf area of french been. At the stage of 30 DAS leaf area obtained by NL 100 and normal planting system was more than pure crop. At the stage of 60 DAP NL 75 and NL 50 recorded lesser leaf area than pure crop.

4.1.23 Root spread at harvest

Effect of nutrient levels and planting geometry on the root spread of intercropped french bean at harvest is shown in Table 4.10. Planting geometry revealed significance in the root spread of intercropped french bean. Root spread (40.4 cm) obtained with paired row planting was significantly superior to that of normal row planting. Nutrient doses and interaction had no significance on the root spread. Only paired row planting recorded higher root spread than pure crop.

4.1.24 Total dry matter production

Effect of nutrient levels and planting geometry on the total dry matter production of intercropped french bean is given in Table 4.11.

Nutrient levels and planting geometry had significant influence on the total dry matter production. NL 100 produced significantly superior dry matter (433 kg ha^{-1}). It was on par with NL 75 and superior to NL 50. Lower two doses behaved

Table 4.11 Effect of nutrient levels and planting geometry on the total dry matter production and yeild of intercropped french bean

Treatments	Total dry matter (kg ha^{-1})	Yield (kg ha^{-1})
<u>Nutrient levels</u>		
NL 100	433	13.8
NL 75	317	12.1
NL 50	292	8.4
F2, 12	3.97^{S}	38.22^{S}
SE	37.78	0.45
C.D (0.05)	116.44	1.38
<u>Planting geometry</u>		
Normal row	281	10.5
Paired row	414	12.3
F1, 12	9.36^{S}	13.34^{S}
SE	30.85	0.37
C.D (0.05)	95.07	1.13
Treatment vs control	632	17.1

similarly. Total dry matter produced by paired row planting (414 kg ha^{-1}) was significantly superior to that of normal row planting. Interaction had no significant effect on total dry matter production. Pure crop recorded higher total dry matter than other treatments.

4.1.25 Yield per hectare

Effect of nutrient levels and planting geometry on the yield of french bean is given in Table 4.11.

Nutrient levels and planting geometry significantly influenced the yield of french bean. NL 100 recorded highest yield (13.8 kg ha^{-1}). It was significantly superior to lower two nutrient doses. NL 75 was significantly superior to NL 50. Paired row planting recorded significantly superior yield (12.3 kg ha^{-1}) compared with normal planting. Interaction effect had no significance on yield. Pure crop of french bean produced more yield than other treatments.

4.1.26 Correlation of yield between yield attributing and growth characters

The simple correlation coefficient of different growth and yield component with yield are presented in Table 4.17.

It was observed that yield contributing characters like number of fruits, length, girth, volume, fresh and dry weight of fruits showed significant positive correlation with yield. The yield was significantly and positively correlated with height and primary branches at the stages of 60 and 90 DAP and leaf number, leaf area and secondary branches at the stages of 30, 60 and 90 DAP.

4.2 Parameters for evaluating the suitability of chilli based intercropping system

Biosuitability

4.2.1 Land Equivalent Ratio

The data on LER were analysed statistically and the mean values are presented in Table 4.12.

Intercrops and nutrient levels had significant influence on LER. Chilli with amaranthus recorded significantly superior LER (2.74) compared with chilli in cf system. NL 100 recorded significantly superior LER (3.1) compared with NL 75 and NL 50. LER (2.6) obtained with NL 75 was significantly superior to NL 50. Planting geometry and interactions had no significant effect on the LER of intercropped system.

4.2.2 Land Equivalent Coefficient

The data on LEC were analysed statistically and given in Table 4.12.

Table 4.12 Effect of intercrops, nutrient levels and planting geometry on parameters for evaluating the suitability of chilli based intercropping system

Treatments	LER	LEC	RCC	Aggressivity	ATER	CEY kg ha^{-1}	Monetary advantage based on LER Rs.
Intercrops							
French bean	2.35	1.41	-12.94	0.16	1.57	8380	72570
Amaranthus	2.74	1.52	245.88	-1.32	1.61	10421	97801
$F_{1,22}$	6.31^{s}	0.29^{ns}	0.01^{ns}	68.56^{ss}	0.13^{ns}	8.78^{s}	7.74^{s}
SE	0.11	0.16	181.77	0.13	0.08	491.22	6413.83
C.D (0.05)	0.32	-	-	0.37	-	1429.01	18811.40
Nutrient levels							
NL 100	3.10	2.27	363.89	-0.43	2.03	11998	121399
NL 75	2.60	1.35	-11.76	-0.82	1.55	9131	83744
NL 50	1.93	0.78	-2.77	-0.50	1.21	7073	50411
$F_{2,22}$	18.94^{ss}	15.89^{s}	0.93^{ns}	1.87^{ns}	16.53^{s}	17.8^{s}	20.44^{ss}
SE	0.14	0.19	222.16	0.15	0.09	601.62	7854.94
C.D (0.05)	0.40	0.56	-	-	0.29	1750.17	23039.16
Planting geometry							
Normal row	2.57	1.45	252.82	-0.73	1.47	8702	79538
Paired row	2.52	1.48	-19.90	-0.44	1.72	10099	908.38
$F_{1,22}$	0.09^{ns}	0.01^{ns}	1.13^{ns}	2.6^{ns}	4.84^{s}	4.11^{ns}	1.55^{ns}
SE	0.11	0.16	181.77	0.13	0.08	491.22	6413.53
C.D (0.05)	-	-	-	-	0.234	-	-

The effect due to nutrient level was significant on LEC. NL 100 record the highest value of LEC (2.27) and NL 50 recorded the lowest value of LEC. Intercrops, planting geometry and interaction had no significant effect on LEC values.

4.2.3 Relative Crowding Coefficient

The data on RCC were analysed statistically and the mean values are presented in Table 4.12.

Intercrops, nutrient levels, planting geometry and their interactions had no significant effect on the RCC of intercropping system.

4.2.4 Aggressivity

The data on aggressivity were analysed statistically and the mean values are presented in Table 4.12.

Intercrops significantly influenced the aggressivity. Aggressivity value 0.16 of french bean intercropped plots of chilli showed the dominant nature of chilli. But the aggressivity value of -1.32 of chilli amaranthus intercropped system showed that amaranthus was the dominant species. Nutrient levels, planting geometry and interactions did not significantly influence the aggressivity of intercropped system.

4.2.5 Area Time Equivalent Ratio

The data on ATER were analysed statistically and given in Table 4.12.

Nutrient levels and planting geometry significantly influenced the ATER. NL 100 recorded significantly superior ATER value (2.01) than the lower two doses. ATER (1.55) with NL 75 was significantly superior to NL 50. Paired row system recorded a significantly higher value of ATER (1.72) compared with normal row planting system. Intercrops and interaction effects had no significant influence on ATER.

4.2.6 Crop Equivalent Yield

The data on CEY were analysed statistically and given in Table 4.12.

Intercrops and nutrient levels significantly influenced the crop equivalent yield. Chilli intercropped with amaranthus recorded significantly higher value of CEY (10421 kg ha^{-1}) than that of chilli and french bean. NL 100 recorded signi-ficantly superior value of CEY compared with NL 75 and NL 50. NL 50 recorded significantly inferior value of CEY. Planting geometry and interactions did not significantly influence the crop equivalent yield.

Economic suitability

4.2.7 Monetary advantage based on LER

The data on monetary advantage based on LER were statistically analysed and shown in Table 4.12.

Monetary advantage based on LER was significantly influenced by intercrops and nutrient levels. Monetary return was significantly superior when chilli was intercropped with amaranthus. NL 100 recorded significantly higher value for monetary advantage based on LER (Rs.121390/-). It was significantly superior to NL 75 and NL 50. Significantly inferior value of monetary return was obtained with NL 50. Planting geometry and interactions did not influence the monetary advantage based on LER.

4.2.8 Gross Return

The data on gross return was statistically analysed and presented in Table 4.13.

Gross return was significantly influenced by intercrops and nutrient levels. Chilli-amaranthus system recorded highest gross return of Rs.156246/- compared with chilli french bean system (Rs.125704/-) NL 100 recorded significantly superior gross return (Rs.179956/-) compared with lower two levels and the lower two levels behaved similarly. Planting geometry and interactions had not significantly influenced the gross return. NL 50 recorded a gross return less than pure crop of chilli. All other treatments had a gross return more than that of pure crop of chilli. Gross return of sole crop chilli was also less and french bean recorded the lowest gross return.

Table 4.13 Effect of intercrops, nutrient levels and planting geometry on economics of chilli based croppingsystem

Treatments	Gross return ha^{-1} (Rs.)	Net return ha^{-1} (Rs.)	Return per rupee invested	Per day return (Rs.)
<u>Intercrops</u>				
French bean	125704	91799	3.68	1148
Amaranthus	156246	119926	4.37	1499
F1, 28	5.93^{s}	5.19^{s}	3.14^{ns}	4.82^{s}
SE	8868.52	8727.50	0.28	113.17
C.D (0.05)	25685.99	25277.65	-	327.77
<u>Nutrient levels</u>				
NL 100	179956	144263	5.12	1803
NL 75	136902	101837	3.86	1273
NL 50	106069	71487	3.10	894
F2, 28	11.67^{s}	11.70^{s}	8.99^{s}	0.009^{ns}
SE	10861.68	10689.01	0.34	138.6
C.D (0.05)	31458.79	30958.68	0.98	-
<u>Planting geometry</u>				
Normal row	130520	96374	3.82	1205
Paired row	151431	115351	4.23	1442
F1, 28	2.78^{ns}	2.36^{ns}	1.13^{ns}	2.19^{ns}
SE	8868.52	8727.50	0.28	113.17
<u>Pure crops</u>				
Chilli	100772	72465	3.57	906
French bean	213	-24909	0.008	-415
Aamaranthus	75247	45455	2.53	568

4.2.9 Net return

The data on net return was analysed statistically and shown in Table 4.13.

Planting geometry and interaction had no significant influence on the net return. Intercrop and nutrient levels significantly influenced the net return. Net return of chilli with amaranthus (Rs.119926/-) was significantly superior to that of chilli with french bean (Rs.91799/-). NL 100 recorded a net return of Rs.144263/- which was significantly superior to the lower two doses and the lower levels behaved similarly. Net return of NL 50 was less than pure crop of chilli. Sole crop amaranthus also had a lesser net return (Rs.45455/-). The pure crop of french bean recorded a net loss of Rs.24909/-.

4.2.10 Return per rupee invested

The data on return per rupee invested were statistically analysed and given in Table 4.13.

Nutrient levels had marked influence on the return per rupee invested. Return per rupee invested (5.12) with NL 100 was significantly superior to that of lower nutrient doses. NL 75 and NL 50 had a similar effect on the return per rupee invested. Intercrops, planting geometry and interaction had no significant influence in the return per rupee invested. Return per rupee with NL 50 (3.10) was less than pure crop of chilli (3.57). Sole crop french bean (.008) and amaranthus (2.53) also had lesser return per rupee invested.

4.2.11 Per day return

The data on per day return were analysed statistically and given in Table 4.13.

Intercrop had a significant influence on the per day return. Per day return of amaranthus intercropped chilli (Rs.1499/-) was significantly superior to that of french bean intercropped chilli. Nutrient levels, planting geometry and interaction had no significant effect on per day return. Only NL 50 had less per day return than pure crop of chilli.

4.3 Plant analysis

Chilli

4.3.1. Uptake of N

Effect of intercrops, nutrient levels and planting geometry on the N uptake of chilli is shown in Table 4.14.

N uptake of chilli was found significantly affected by intercropping and nutrient levels. Uptake of N (38.7 kg ha^{-1}) was superior when chilli was intercropped with french bean. NL 100 recorded significant N uptake of chilli (40.1 kg ha^{-1})

Table 4.14 Effect of intercrops, nutrient levels and planting geometry on the NPK uptake of chilli

Treatments	N uptake ($kg\ ha^{-1}$)	P uptake ($kg\ ha^{-1}$)	K uptake ($kg\ ha^{-1}$)
<u>Intercrops</u>			
French bean	38.7	13.1	23.1
Amaranthus	20.8	7.1	10.7
F1, 24	23.14^{s}	24.29^{s}	37.05^{s}
SE	2.63	0.86	1.44
C.D (0.05)	7.67	2.51	4.22
<u>Nutrient levels</u>			
NL 100	40.1	14.1	22.5
NL 75	26.1	8.9	15.4
NL 50	23.1	7.1	12.7
F2, 24	7.95^{s}	11.63^{s}	8.08^{s}
SE	3.22	1.05	1.77
C.D (0.05)	9.39	3.08	5.17
<u>Planting geometry</u>			
Normal row	27.8	9.5	15.7
Paired row	31.7	10.6	18.1
F1, 12	1.09^{ns}	0.71^{ns}	1.33^{ns}
SE	2.63	0.86	1.44
Treatment vs control	26.9	9.5	18.2

compared with lower two nutrient doses. The lower two levels behaved similarly. Planting geometry did not show any significance on N uptake. French bean as intercrop, NL 100 and paired row planting showed more N uptake compared with pure crop. Interaction effects had no significance on N uptake of chilli.

4.3.2 Uptake of P

Effect of intercrops, nutrient levels and planting geometry on the P uptake of chilli is given in Table 4.14.

Intercrops and nutrient levels showed significance on P uptake of chilli. French bean intercropping recorded significantly higher P uptake (13.1 kg ha^{-1}). NL 100 recorded significantly superior P uptake (14.1 kg ha^{-1}) to that of NL 75 and NL 50. Lower two doses behaved similarly. Planting geometry and interaction effect did not show any significance on P uptake. French bean intercropping, NL 100 and paired row planting recorded higher P uptake than pure crop of chilli.

4.3.3 Uptake of K

Effect of intercrops, nutrient levels and planting geometry on the K uptake of chilli is given in Table 4.14.

K uptake was found significantly influenced by intercrops and nutrient levels. French bean intercropping showed significant uptake of K (23.1 kg ha^{-1}) compared with amaranthus intercropping. The highest uptake of K (22.5 kg ha^{-1}) was observed with NL 100 and it was significantly superior to that of lower two nutrient doses. The lower two levels behaved similarly. Planting geometry and interaction effects had no significance on K uptake of chilli. French bean intercropping and NL 100 recorded higher K uptake than pure crop of chilli.

Amaranthus

4.3.4 Uptake of N

Effect of nutrient levels and planting geometry on the N uptake of intercropped amaranthus is shown in Table 4.15.

Planting geometry showed significant influence on N uptake of amaranthus. N uptake of amaranthus (88.3 kg ha^{-1}) was more under paired row planting and it was significantly superior to that of normal planting. Nutrient levels and interactions were not found significant on N uptake. Only NL 100 recorded higher N uptake than pure crop.

4.3.5 Uptake of P

Effect of nutrient levels and planting geometry on P uptake of intercropped amaranthus is given in Table 4.15.

P uptake was found influenced by nutrient doses and planting geometry. NL 100 recorded significantly superior P

Table 4.15 Effect of nutrient levels and planting geometry on the NPK uptake of intercropped amaranthus.

Treatments	N uptake ($kg\ ha^{-1}$)	P uptake ($kg\ ha^{-1}$)	K uptake ($kg\ ha^{-1}$)
<u>Nutrient levels</u>			
NL 100	91.4	25.6	65.8
NL 75	75.0	22.8	62.5
NL 50	65.7	16.1	49.0
F2, 12	2.70^{ns}	3.95^{s}	2.22^{ns}
SE	7.9	2.44	5.97
C.D (0.05)	-	7.53	-
<u>Planting geometry</u>			
Normal row	66.4	18.3	49.4
Paired row	88.3	24.7	68.8
F1, 12	5.74^{s}	5.15^{s}	7.98^{s}
SE	6.46	1.99	4.87
C.D (0.05)	19.9	6.15	14.9
Treatment vs control	90.5	27.6	65.7

uptake (25.6 kg ha^{-1}). NL 75 also behaved similarly NL 50 was significantly inferior in P uptake. P uptake obtained with paired row planting (24.7 kg ha^{-1}) was significantly superior to that of normal planting. Interaction effect did not significantly influence the uptake of P. Uptake of P by amaranthus was more when grown as a pure crop.

4.3.6 Uptake of K

Effect of nutrient levels and planting geometry on K uptake of intercropped amaranthus is shown in Table 4.15.

K uptake was significantly influenced by planting geometry. K uptake (68.8 kg ha^{-1})was significantly higher under paired row planting system. Nutrient doses and interaction had no significant affect on K uptake. Paired row planting and NL 100 recorded more K uptake than pure crop of amaranthus.

4.4 Soil analysis

The mean values of the nutrient contents of soil after the experiment are presented in Table 4.16.

4.4.1 Available nitrogen content of the soil

Intercrops, nutrient levels, planting geometry and interaction had no significant effect on the available nitrogen content of the soil.

Table 4.16 Effect of intercrops, nutrient levels and planting geometry on the N P K content of soil

Tretments	Available N kg ha^{-1}	Available P_2O_5 kg ha^{-1}	Available K_2O kg ha^{-1}
Intercrops			
French bean	270	32.7	118.8
Amaranthus	285	32.4	117.9
F1, 28	0.95^{ns}	2.69^{ns}	0.05^{ns}
SE	11	0.19	2.81
Nutrient levels			
NL 100	283	32.1	116.3
NL 75	263	32.4	124.0
NL 50	243	32.2	114.9
F2, 28	2.24^{ns}	2.79^{ns}	2.01^{ns}
SE	13	0.24	3.45
Planting geometry			
Normal row	262	32.6	115.4
Paired row	263	32.5	121.4
F1, 28	0.01^{ns}	0.15^{ns}	2.29^{ns}
SE	11	0.19	2.81
Pure crops			
Chilli	290	32.6	113.7
French bean	257	31.8	108.5
Aamaranthus	260	33.2	127.5

4.4.2 Available phosphorus content of the soil

The results revealed that there was no significant difference in the available phosphorus content of soil due to intercrop, nutrient levels, planting geometry and their interactions.

4.4.3 Available potassium content of the soil

No significant difference was indicated due to intercrops, nutrient levels, planting geometry and their interactions with regard to the available potassium content of the soil.

4.5 Nutrient balance sheet

Nutrient balance sheet for chilli-amaranthus cropping system was worked out and given in Table 4.18.

Both under pure and intercropped plots, there was a positive build up of nitrogen and phosphorus status of soil. For potassium status of soil also a positive balance was observed, except with the intercropped plots receiving 50 per cent of the nutrient dose under both planting system and with 75 per cent nutrients under paired row planting system.

Compared with pure crop of chilli, N and K status of soil of intercropped plots were also less except at the highest dose. Nutrient status of soil of intercropped plots at the

Table 4.17 Values of simple correlation coefficient

Sl.No.	Characters correlated	Correlation coefficient
1.	Yield x Height (60 DAP)	0.4575
2.	Yield x Height (90 DAP	0.4924
3.	Yield x Primary branches (60 DAP)	0.6723
4.	Yield x Primary branches (90 DAP)	0.5784
5.	Yield x Secondary branches (30 DAP)	0.3892
6.	Yield x Secondary branches (60 DAP)	0.5900
7.	Yield x Secondary branches (90 DAP)	0.4622
8.	Yield x Number of leaves (30 DAP)	0.5108
9.	Yield x Number of leaves (60 DAP)	0.6203
10.	Yield x Number of leaves (90 DAP)	0.5679
11.	Yield x Leaf area (30 DAP)	0.4951
12.	Yield x Leaf area (60 DAP)	0.7097
13.	Yiled x Leaf area (90 DAP)	0.6409
14.	Yield x Number of fruits	0.6265
15.	Yield x Length of fruit	0.5774
16.	Yield x Girth of fruit	0.3421
17.	Yield x Volume of fruit	0.5771
18.	Yield x fresh weight of fruit	0.6319
19.	Yield x dry weight of fruit	0.6355

Table 4.18 Nutrient balance sheet of chilli - amaranthus cropping system

	Total nutrient uptake kg ha^{-1}			Applied nutrients kg ha^{-1}			Soil balance kg ha^{-1}			Soil test data after the experiment kg ha^{-1}		
	N	P	K	N	P	K	N	P	K	N	P	K
T_7	102.74	30.07	68.41	180	125	90	77.26	94.93	21.59	260	32.0	129.16
T_8	136.58	41.71	93.31	188	133	98	51.42	91.29	4.87	310	31.9	113.66
T_9	73.63	23.45	53.01	135	93	67.5	61.37	69.7	14.49	250	32.3	108.55
T_{10}	114.48	34.24	91.45	141	99	73.5	26.52	65.51	-17.95	230	31.96	129.16
T_{11}	78.71	20.15	54.89	90	62.5	45	11.83	42.35	-9.89	220	32.53	113.60
T_{12}	82.91	21.68	57.71	94	66.5	49	11.81	44.82	-8.1	260	33.7	113.60
T_{13}	26.87	9.50	18.21	155	100	65	128.2	90.5	46.79	290	32.56	113.60
T_{15}	90.54	27.55	65.71	130	110	90	39.46	82.45	24.30	260	33.16	127.5

Initial soil test data - N kg ha^{-1} P kg ha^{-1} K kg ha^{-1}

N - 177.8 P- 31.8 K - 124

lowest nutrient dose was found to be less than the nutrient status of soil of pure cropped amaranthus plot. The same trend was observed in paired row system supplied with 75 per cent nutrient dose. All other treatments recorded higher values of N and P compared with pure crop of amaranthus. Except at 100 per cent nutrient dose under normal planting system, K status of soil was found to be reduced by intercropping compared with pure crop of amaranthus. Though a depletion of K status of soil was seen in the theoretical values, the actual nutrient status of the soil was not found to be affected by both pure and intercropping ie, a positive balance of all the nutrient was observed in all the treatments.

DISCUSSION

5. DISCUSSION

An investigation entitled "Resource use and plant interaction in chilli intercropping system in summer rice fallow" was conducted at Rice Research Station, Kayamkulam to assess the suitability of raising amaranthus/french bean as intercrop in chilli at different nutrient levels under normal and paired row systems of planting. The data collected on various growth and yield characters, nutrient uptake and soil nutrient status were analysed statistically and the results are discussed in this chapter in five sections.

1. Performance of crops in chilli based intercropping system.
2. Nutrient management in chilli based intercropping system.
3. Effect of planting geometry on the performance of crops in chilli based intercropping system.
4. Soil nutrient status as influenced by intercropping.
5. Evaluation of chilli based intercropping system.

5.1 Performance of crops in chilli based intercropping system.

5.1.1 Effect of french bean / amaranthus on the performance of intercropped chilli.

Intercropping involves growing two or more crops or varieties simultaneously in the same area of land. In Kerala the emphasis has mostly been in having the full population of a main crop and to accommodate some population of the other species, ie. an additive series approach. When plants are grown in association, interaction between component species occur. Hence selection of compatible crops is a factor that determines the success of any cropping system. In intercropping situation, crops should be chosen so as to make the best use of resources with minimum competition. Yield advantage occurs when component crops differ in the use of growth resources ie, they are able to complement each other and so make an overall better use of resources than when grown separately. Maximising intercropping advantage is therefore a matter of maximising the degree of complementarity between the component crops and minimising intercrop competition. The main way that complementarity can occur is by growing crops that are having temporal difference and having difference in morphology and rooting habit. In this investigation the suitability of raising french bean or amaranthus as intercrop with chilli was studied. The result of these studies showed that the yield of intercropped chilli was not affected by french bean, but when intercropped with amaranthus, chilli recorded an yield lesser than that of pure crop of chilli. Chilli cv Jwalamukhi in association with french bean cv Contender, recorded an intercrop yield (Ycf) of 8371 kg ha^{-1} which was 84 per cent more than the yield (Yca 4550 kg ha^{-1}) realised in association with amaranthus cv Arun in summer fallows. It was observed that the growth parameters of intercropped chilli were all superior in cf system. All the growth parameters were positively and significantly correlated with yield (Table 4.17). Chilli in cf system produced more number of leaves (50 per cent) leaf area (78 per cent) and branches (40 per cent) than ca system (Figure 4). Olasantan (1991) also reported an increase in plant height, number of leaves and branches in cowpea intercropped with tomato or okra. Better branching of chilli coupled with higher leaf area helped in tapping more solar radiation and that have resulted in better dry matter production in chilli by intercropping with french bean ie 450 and 1202 kg ha^{-1} at flowering and harvest respectively which was 80 and 89 per cent more than the total dry matter production of chilli in ca system. This better performance in growth characters might be due to the higher uptake of nutrients by intercroped chilli in cf system. N, P and K uptake of chilli in cf system was 86, 86 and 117 per cent more than the uptake of chilli in ca system. Better uptake of nutrients by chilli (cf system) is due to poor competition for nutrients between chilli and french bean because of the temporal difference and variation in the rooting habit of chilli and french bean. According to Baker (1975) to have yield advantages in a cropping system, there should be minimum 25 per cent difference in duration of crops. In the present study also there is about 25 per cent difference

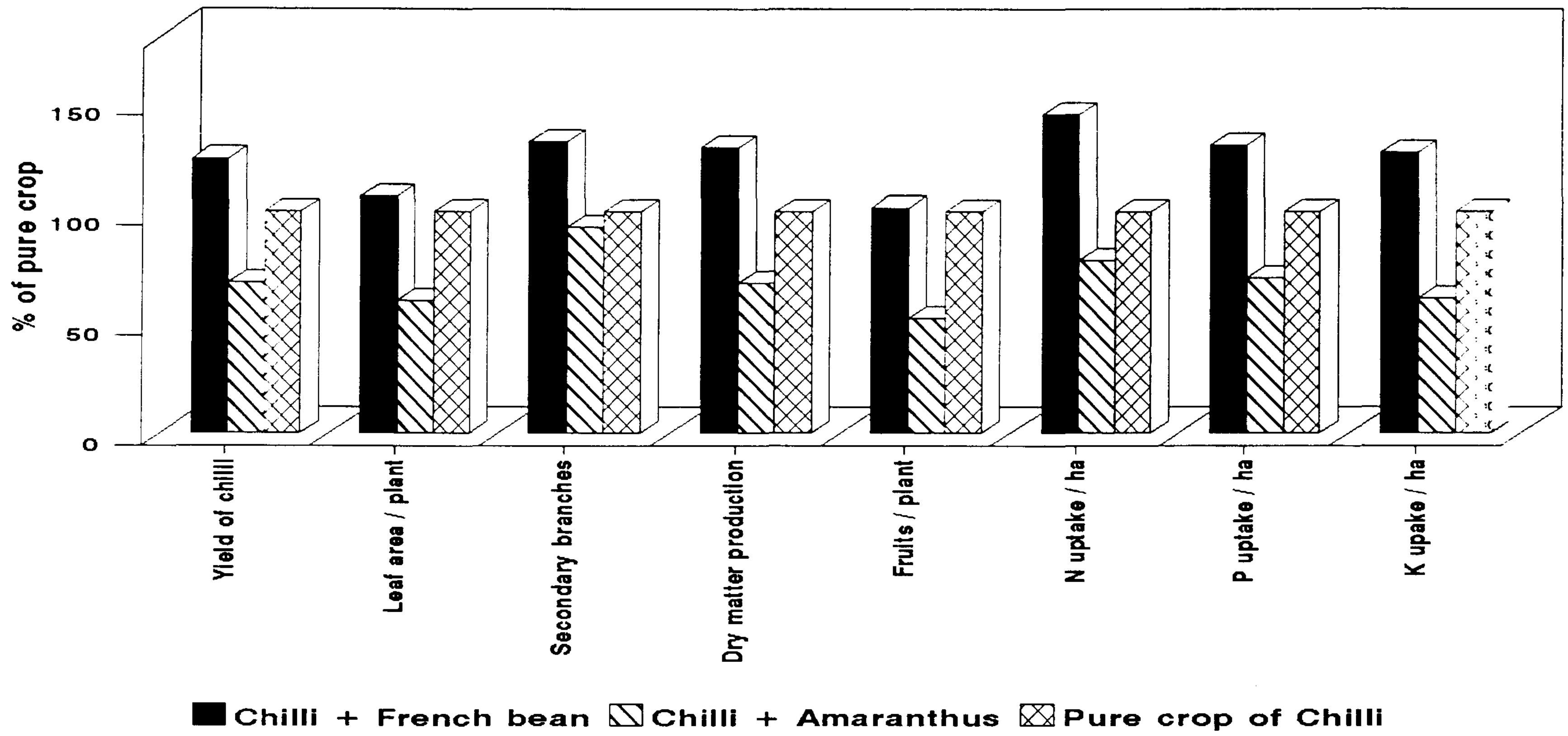


Fig. 4. Performance of pure and intercrop of chilli in chilli based cropping system

between the duration of chilli (80 days) and french beans (60 days). Since the duration of the crops differed, critical growth stages did not coincide with each other and might have reduced the competition for various resources. Differences in the rooting pattern also must have resulted in better use of nutrients and water. The competition between chilli and french bean for resources were also much less, probably because, chilli is a transplanted crop and french bean is a direct sown crop. Chilli had attained certain morphological development before transplanting into the field. Within 30 days of transplanting chilli crop attained the reproductive stage. Data furnished in Table 4.6 revealed this. At this time the french bean canopy did not develop fully. Similar results were reported by Olasantan (1991) in tomato cowpea intercropping system. He has reported beneficial effect by intercropping tomato (transplanted crop) with cowpea (direct sown crop). Better growth parameters had a positive reflection on yield contributing characters like number of fruits per plant (43) Length (8.9 cm) and volume of fruits (8.7 cm) of chilli in cf system (Table 4.6). All these yield attributes were positively correlated with yield. Better performance of growth and yield contributing characters have resulted in higher yield of chilli when intercropped with french bean. Positive and significant correlation was obtained between yield and growth and yield attributes of chilli (Table 4.17).

Higher LER (1.25) for chilli in cf system also registered 25 per cent advantage in yield of chilli (Figure 10). Ramachandar *et al*. (1989) also reported a yield advantage of chilli in chilli-french bean system.

Poor performance of chilli in chilli-amaranthus intercropping system might be due to the aggressive nature of amaranthus compared to french bean. Aggressivity of chilli recorded a negative value (-1.32) in ca system (Table 4.12) revealing the suppressed nature of chilli. Ikeorgu (1990) too reported the dominant nature of amaranthus in amaranthus-corchorus (*Corchorus olitorius*) and amaranthus-celosia intercropping systems. LER of chilli (0.71) was also reduced by amaranthus intercropping compared to french bean intercropping (LER = 1.25). Intercropping with amaranthus reduced the number of leaves of chilli by 38 per cent, leaf area by 44 per cent and number of fruits by 49 per cent compared to french bean intercropping (Figure 4). Uptake of nutrients by chilli was less in chilli-amaranthus system compared to chilli-french bean system (Table 4.14). The depressive effect of amaranthus on the growth and yield characters of chilli resulted in poor yield of chilli in chilli-amaranthus system.

5.1.2 Intercrop of chilli vs. Pure crop of chilli

Intercrop yield of chilli in chilli-french bean system (Ycf) was not only higher than intercropped yield of chilli in chilli-amaranthus system (Yca) but higher than pure crop yield of chilli (Ycc). Hosmani (1990) and Mallanagouda (1991) reported higher yields for chilli when intercropped with onion. Pure crop of chilli recorded a lesser plant height (43 cm) and leaf area (1423 cm^2) than plant height (47 cm) and leaf area (1529 cm^2) of intercropped chilli in chilli french bean system. Thus the poor development of photosynthetic surface resulted in poor expression of yield contributing characters like number of fruits per plant, girth and volume of fruits compared with chilli in cf system. N P K uptake of pure crop of chilli was 30, 27 and 21 per cent less than the respective uptake of N, P and K by intercropped chilli in cf system. All these have resulted in 22 per cent reduction in dry matter production and 20 per cent reduction in yield of pure crop of chilli compared with Ycf.

Pure crop yield of chilli (Ycc) was better than the intercrop yield of chilli (Yca) grown with amaranthus. Kadali et al. (1988) and Natarajan (1992) had reported higher pure crop yield than intercrop yield for chilli. This is because the growth and yield attributes and nutrient uptake of intercropped chilli in ca system was much less than that of pure crop (Figure 4). Natarajan (1992) had found that the growth of chilli was affected by the intercrops. He had also noticed a reduction in plant height of chilli by intercropping. This showed that competition for nutrients existed between chilli and amaranthus. This may be due to the dominant nature of amaranthus as suggested by Ikeorgu (1990). Negative aggressivity values of chilli also revealed the dominated nature of chilli (Table 4.12 and Plates 7 & 8). Olasantan (1991) suggested that in bhindi cowpea intercropping system there was a competition for growth resources because of the simultaneous growth of both crops. Chilli and amaranthus, both being transplanted crops, due to the concurrent growth, have resulted in a competition for nutrients and moisture. Better branching, better leaf production as well as higher leaf area ie, 34, 69 and 65 per cent increase respectively were observed in pure crop of chilli compared with intercropped chilli in ca system. All these growth parameters were positively correlated with yield. This better development of photosynthetic surface had resulted in the production of more fruits. Not only the number of fruits but the quality of fruits was also better in pure crop of chilli compared with intercrop of chilli grown with amaranthus as shown in Table 4.6. Similar results were reported by Natarajan (1992) and Kadali et al. (1988). It is observed in the present study that the better growth and yield attributes resulted in better performance of pure crop of chilli compared with chilli in chilli-amaranthus system.

Plate 7. Dominant growth of intercropped amaranthus under normal row system

Plate 8. Dominant nature of intercropped amaranthus under paired row system

5.1.3 Intercrop of amaranthus vs pure crop of amaranthus

Yield of amaranthus was not affected by intercropping. Higher LER of amaranthus indicated this (Figure 10). Ikeorgu (1990) reported higher LER for intercropped amaranthus. None of the growth and yield characters were adversely affected by intercropping. Data presented in Table 4.8 support this. Ikeorgu (1990) had reported that sole crop of amaranthus gave the lowest vegetable and dry matter yield. This showed that intraspecific competition in amaranthus was higher than interspecific competition. Negative values under RCC of most mixtures involving amaranthus revealed the better performance of intercropped amaranthus. This again confirms that intraspecific competition was greater than interspecific competition in amaranthus. Grubben (1976) reported that all species of amaranthus had C-4 carboxylic acid photosynthetic pathway. All C-4 plants possess some characteristics which give them better environmental adaptation than C-3 plants. According to Black (1973), some of these characteristics include better use of light energy, low photorespiration and hence higher dry matter production than C-3 plants. By making better use of micro environmental factors amaranthus dominated the companion crop. This shows that by growing C-4 and C-3 plants together, in most cases C-4 plants take an upper hand. The variety used for this study is a multicut variety. From the figure 5 it is seen that

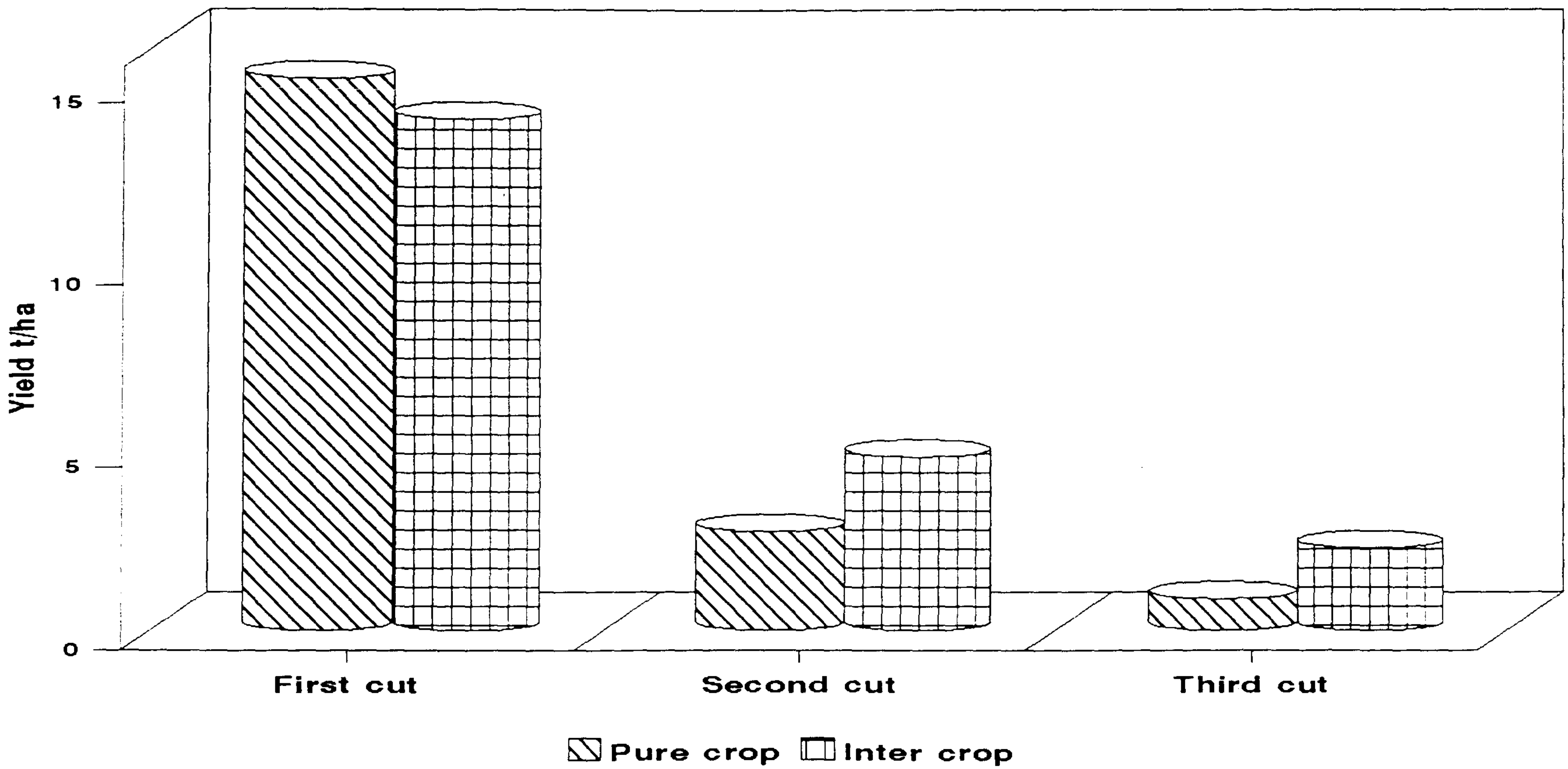


Fig. 5. Yield of amaranthus at different harvests

the yield of pure crop from second and third cut was much less than that of intercropped amaranthus. This might be due to the fact that after the first harvest, the intercropped plots received the second top dressing given to chilli but the pure crop of amaranthus did not receive this benefit. The higher yield obtained from second and third cuts of intercropped amaranthus (Yac) also resulted in higher yield of intercropped amaranthus compared to pure crop (Yaa).

5.1.4 French bean as pure and intercrop

Performance of both pure and intercrop of french bean was very poor. This showed that french bean is not an ideal crop for summer rice fallow. Since the crop was very poor not much observations could be recorded. From the data collected it was seen that intercropping did not affect the yield of french bean. French bean (Yfc) recorded an LER more than one when intercropped with chilli which showed that french bean is an ideal intercrop with chilli (Figure 10). These results are in accordance with the findings of Ramachander et al. (1989); Shah et al. (1991); Dahatonde (1992) and Singh and Singh (1993). The yield of french bean being very low, it could not be recommended for summer rice fallows.

5.2. Nutrient management in chilli based cropping system

5.2.1 Effect of nutrient levels on intercropped chilli

Fertilizer recommendation for multiple cropping system have been so far based on the schedule recommended for sole crop. But the nutrient requirement of crops when grown as intercrop differs from that of sole crop due to crop interference. In this study the effect of different doses of nutrients on the performance of chilli, french bean and amaranthus in an intercropping system is discussed.

Chilli recorded higher yield when both the chilli and the intercrop were given 100 per cent nutrient dose. Naturally when more than one crop is grown in the same field competition for nutrients will occur, so application of nutrients at higher doses ie, 100 per cent recommended dose might have helped in avoding the competition for nutrients, the key factor in crop production. The yield of intercroped chilli was 8917, 5598 and 4865 kg ha^{-1} at 100, 75 and 50 per cent nutrient doses respectively. Mallanagouda (1991) recorded the highest yield with application of full recommended fertilizer dose to the main crop of chilli and companion crops. Uptake of NPK by chilli was superior at 100 per cent of the nutrient dose. The N, P and K uptake of chilli at NL100 was 40, 14 and 224.8 kg ha^{-1} respectively. It was significantly higher than the NPK uptake of chilli (26, 9 and 154 kg ha^{-1}) and (23, 7 and 127 kg ha^{-1}) respectively at NL 75 and at NL 50. Data presented in Table 4.14 revealed this. It was observed that the growth paramters like height (49.5 cm) leaf number (114) and leaf area (1453 cm^2) produced by chilli at NL 100 was significantly superior to that at lower doses. It was also noticed that yield was positively correlated to these growth parameters. The data furnished in Table 4.1, 4.2 and 4.17 support this. Olasantan (1991) had reported that branches, leaves and plant height of intercropped tomato and okra with cowpea was higher at 60 kg N ha^{-1} than at 0 or 30 kg N ha^{-1}. This better performance of growth parameters at 100 per cent nutrient dose helped in better use of solar radiation which might have resulted in better dry matter production (1182 kg ha^{-1}). Higher nutrient uptake along with better photosynthetic efficiency resulted in more number of fruits (Figure 6), appreciable length, girth and volume. These yield attributes were positively correlated with yield. Favourable effect on growth and yield characters resulted in higher yield of intercropped chilli at 100 per cent of nutrient dose.

LER of chilli alone (1.33), LER of intercropping system (3.1), ATER (2.01), LEC (2.27) and chilli equivalent yield (11998 kg ha^{-1}) furnished in Table 4.12 revealed the advantage at the highest nutrient dose. The lower two doses had a similar effect and were significantly inferior to the higher dose ie. the lower doses of nutrients were not sufficient to meet the demand of both the crops. NPK uptake was also low with lower doses (Table 4.14). These resulted in poor expression of growth and yield contributing characters and thereby lesser yield of chilli with 75 and 50 per cent of the nutrient dose.

5.2.2 Chilli as pure and intercrop at different nutrient levels

Pure crop yield of chilli (Ycc 6718 kg ha^{-1}) was more than intercrop yield of chilli realised at NL 75 and NL 50. But at NL 100 Yci was more than Ycc. From figure 6 it is evident that pure crop recorded more number of leaves and leaf area than intercrop at NL 75 and NL 50. This better development of leaf area resulted in better expression of yield contributing characters like number of fruits, length and volume of fruits (Table 4.6). All these have resulted in better dry matter production (933 kg ha^{-1}) at harvest and resulted in better yield of pure crop of chilli. These better parameters of chilli may be due to the higher uptake of nutrients by pure crop of chilli. (26.5 kg N ha^{-1}, 15 kg P ha^{-1} and 182 kg K ha^{-1}) compared with intercrop at NL 75 and at NL 50. The reduced uptake of NPK by intercropped chilli at NL 75 and NL 50 may be due to competition for nutrients at these levels. This showed that 75 and 50 per cent nutrient doses were not sufficient to meet the demands of the intercropping system.

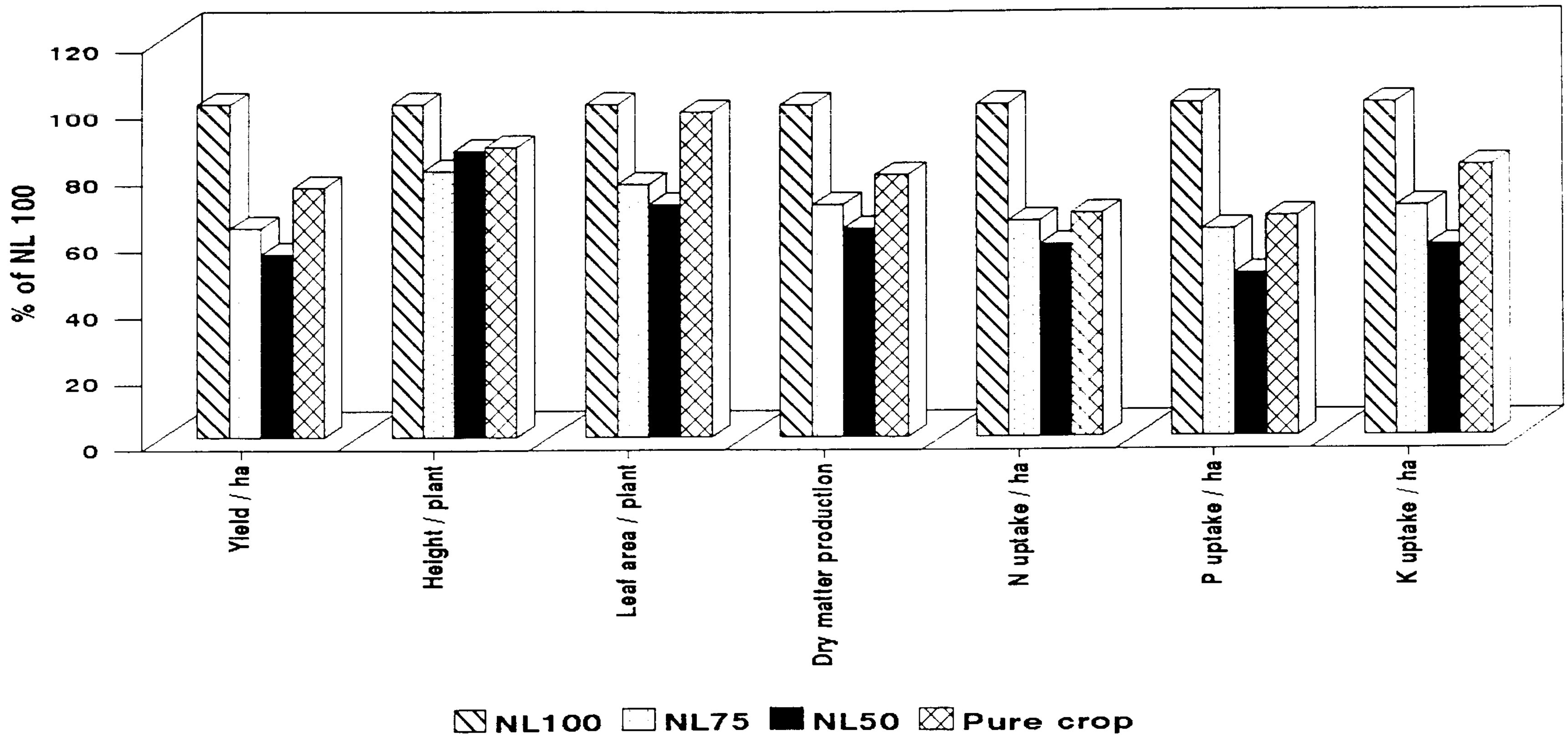


Fig. 6. Effect of nutrient levels on growth, yield and NPK uptake of intercropped chilli

5.2.3 Effect of nutrient levels on intercropped amaranthus

Nutrient levels significantly influenced the intercrop yield of amaranthus (Yac). Yield was more at NL 100 and NL 75 (23.6 and 23.4 t ha^{-1}) respectively and these higher doses had a similar effect on yield. This showed that 75 per cent of the recommended dose might be enough for intercropped amaranthus. But this does not imply that 75 per cent of the recommended dose is sufficient for intercropped amaranthus. We may recall the dominant nature of amaranthus at 75 and 50 per cent nutrient levels. This better performance of intercropped amaranthus compared with chilli is due to better exploitation of nutrients and other resources by amaranthus. Amaranthus crop might have utilized a good share of nutrients supplied to chilli crop at lower levels of nutrient dose. This competition effect was not reflected at NL 100 since nutrient supply was more or less adequate. The data presented in Table 4.8 showed the better growth parameters at NL 100 and NL 75. Increase in nutrient uptake of intercropped amaranthus was observed with increase in nutrient levels (Table 4.14). The better expression of growth parameters along with higher uptake of nutrients resulted in better yield (Figure 7).

LER more than one for amaranthus at 100, 75 and 50 per cent of the recommended doses showed the superiority of intercrop at all nutrient doses over pure crop. (Figures 11). Even the

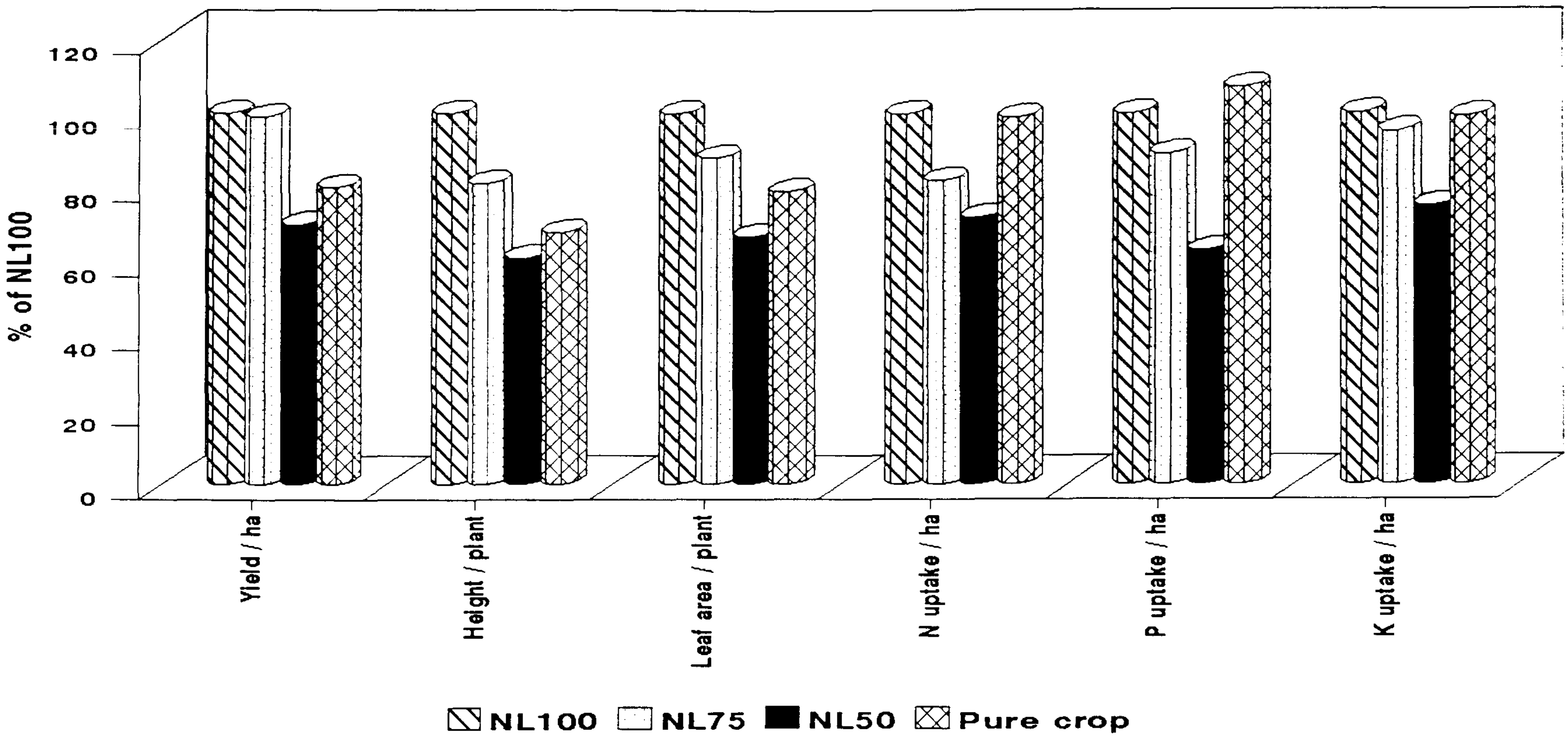


Fig. 7. Effect of nutrient levels on growth, yield and nutrient uptake of intercropped amaranthus

yield (Yac) realised from the lowest dose of nutrients was better than the pure crop yield of amaranthus (Yaa) that received 100 per cent of the recommended dose. This shows the dominant nature of amaranthus in an intercropping system. Better performance even at the lower doses may be due to the higher competant nature of amaranthus compared with chilli (Plates 7 & 8).

5.2.4 Effect of nutrient levels on intercropped french bean

Nutrient levels significantly influenced the yield of french bean. The yield of french bean (Ycf 13.7 kg ha^{-1}) was more at 100 per cent nutrient dose. Though the growth parameters were not significantly different, the data depicted in figure 8 revealed that height, number of leaves and leaf area of french bean at NL 100 were appreciable compared with the growth at NL 75 and NL 50. This better growth parameters resulted in better tapping and assimilation of solar radiation and nutrients and resulted in more dry matter production and better yield (Yfc) at NL 100 followed by NL 75 and NL 50. Yadav and Prasad (1990) reported that in a french bean-sugarcane intercropping system the yield of french bean at 80 and 120 kg N ha^{-1} were similar and was significantly superior to the yield at 0 and 40 kg N ha^{-1}.

From the figure 11, it becomes clear that LER was higher at NL 100 followed by NL 75 and NL 50. The higher LER values revealed the yield advantage at 100 per cent nutrient dose over the other two doses. Kushwaha and Masoodali (1991) reported high LER (1.24) for french bean in potato-french bean system when potato was given full dose of fertilizer and french bean was given half the dose.

Higher LER (0.71) of intercropped french bean at 75 and 100 per cent nutrient levels showed the respective yield advantage of 32 and 15 per cent by intercropping (Figure 11). But at NL 50 Yff performed better than Yfc (Figure 8). The data furnished in Table 4.10 showed better development of leaves in pure crop compared with intercrop at this nutrient dose. Pure crop being supplied with full recommended dose, chance for competition on nutrient was less. At NL 50 both the crops being given only 50 per cent of the recommended dose, chance for competition was more and thus resulted in reduced expression of growth and yield characters which reflected in Yfc also.

5.3 Effect of planting geometry on the performance of crops in chilli based cropping system

5.3.1 Effect of planting geometry on intercropped chilli

Introduction of another plant species without reducing the population of the first species from the optimum (additive series) causes complex interference between the species. A modification in the planting pattern of base crop helps to

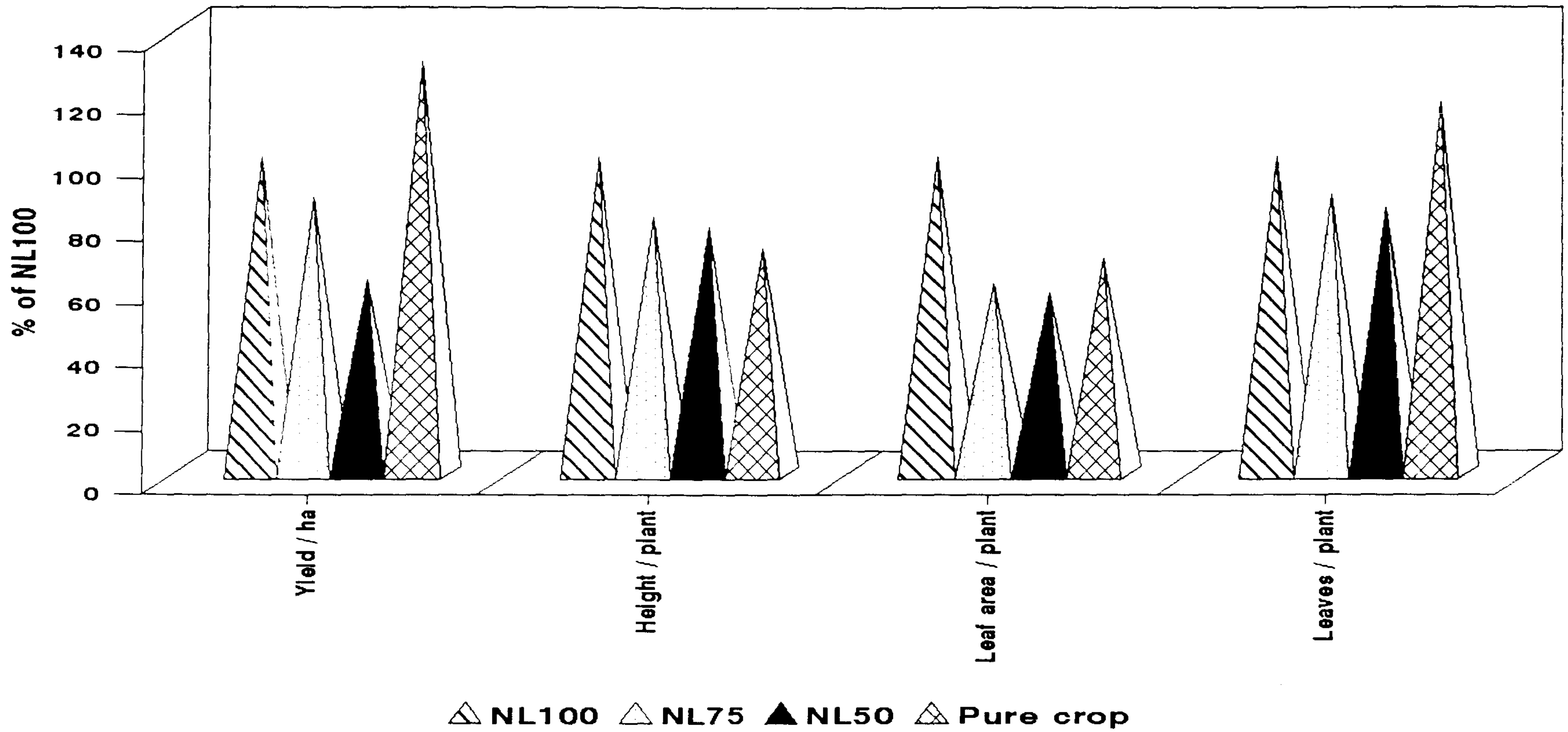


Fig. 8. Effect of nutrient levels on growth, yield and nutrient uptake of intercropped french bean

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accommodate intercrops. Paired row system of planting was found an ideal method for accommodating a companion crop along with base crop without reducing the plant population of base crop. In this investigation an intercrop was raised along with chilli planted under both normal and paired planting systems. In between normal row, one row of intercrop was grown (Plates 3 & 5) but in between paired rows of chilli, two rows of intercrops were accommodated (Plates 4 & 6).

The yield of chilli (Yci) was not significantly influenced by planting geometry. De et al. (1978) observed that variation in base crop yield was nil when the orientation of rows were altered, while keeping plant population per unit area constant. Planting geometry had no significant effect on the growth and yield contributing characters of chilli. Growth characters like height (Table 4.1), number of leaves and leaf area (Table 4.2), number of branches (Table 4.3), total dry matter production (Table 4.5) and yield contributing characters like number of fruits, length, girth and volume of fruits (Table 4.6) fresh and dry weight (Table 4.7) of intercropped chilli were similar under both the systems of planting. There was no significant difference noticed in the yield of intercropped chilli due to differences in planting geometry.

The yield of chilli (Yci) under paired row planting was more than that of pure crop. In cassava intercropped system Biju

(1989) reported higher yield for intercropped cassava under paired row system than pure crop. Initial leaf area development being more in paired row system which might have contributed significantly to the initial higher yield ie. at the stage of 30 DAP, chilli under paired row system of planting produced 7.5 per cent more leaf area than pure crop (Table 4.2). Figure 9 showed that the first two harvests contributed 56 per cent of the total yield. This better leaf area development during the initial stage had resulted in better development of source and thereby increased the yield of the first two harvests.

The NPK uptake of chilli under paired row planting system (31.7, 10.6, 180 kg ha^{-1}) was more than the NPK uptake of pure crop of chilli (26.9, 9.5, 182 kg ha^{-1}). This might be due to the better root spread of intercropped chilli under paired row system (79.7 cm) compared with pure crop of chilli (73 cm). This could be due to competition for soil nutrient and moisture or as a bid to avoid the roots of closely planted chilli in paired row planting. Ikeorgu (1990) reported that root spread of amaranthus was more in intercrop compared with pure crop. The better photosynthetic efficiency coupled with better nutrient uptake resulted in higher yield of chilli under paired row system of planting. Higher LER (1.03) of chilli under paired row system also revealed the yield advantage of intercropped chilli under paired row planting (Figure 12).

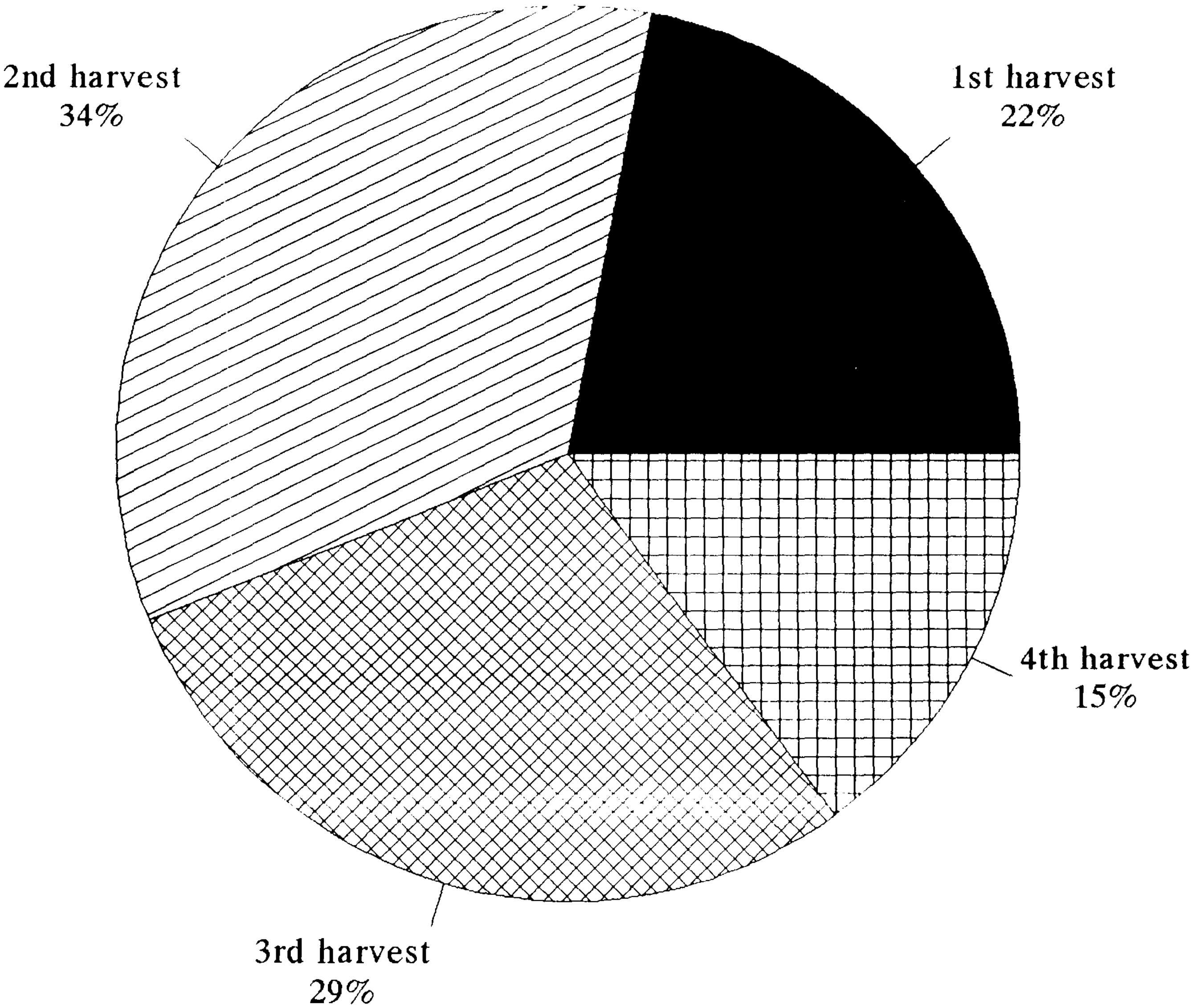

Fig. 9. Yield of Chilli at different harvest (% of total yield)

5.3.2 Effect of planting geometry on intercropped amaranthus

Planting geometry did not influence the yield of amaranthus (Yac). The data presented in Table 4.8 showed that the growth characters of amaranthus under both planting system behaved similarly. Hence there was no significant difference in yield under normal and paired systems.

The yield of inter cropped amaranthus under normal and paired row planting system was more than the yield of pure crop amaranthus. Higher LER for intercropped amaranthus (LER (NR) - 2.13 and LER (PR) - 1.93) under both systems of planting (Figure 12) revealed the advantage of intercropping.

5.3.3 Effect of planting geometry on intercropped french bean

French bean produced more yield (Yfc) under paired row system. Kushwaha and Masoodali (1991) noted the yield advantage of french bean potato intercropping system with two rows of french bean planted between paired rows of potato. Singh and Singh (1993) also reported similar result in maize - french bean intercropping system. The growth characters of intercropped french bean under paired and normal row systems behaved similarly (Table 4.10). Though the french been expressed similar growth characters population of french bean under paired row system was 32 per cent more than that of normal planting and that may be the reason for increased yield under paired row system compared with normal system.

Suitability of french bean to be raised as an intercrop with chilli had been evident from LER above unity observed in both normal and paired row systems of planting (Figure 12) but the yield being very low, this crop could not be recommended for summer rice fallows.

5.4 Soil nutrient status as influenced by intercropping

A positive build up of N and P were observed because the quantity of nutrient absorbed by plant was less than quantity applied. But in the case of K a negative balance was seen in some plots, that may be due to the phenomenon of luxury consumption exhibited in respect of potassium. The soil test data after the experiment indicated a positive build up of all the nutrients. This showed the sustainable nature of these cropping systems. Even thoguh a depletion in the status of K was observed that was not reflected in the final soil test data. This is due to the cumulative effect of initial nutrient status of the soil.

5.5 Evaluation of cropping system

To achieve higher productivity from intercropping the component crops are to be evaluated and chosen for better compatibility. Therefore, knowledge of techniques of evaluation of competitive relation of component crops and their yield advantages in intercropping situation is basic and would be helpful in future for tailoring suitable intercropping system for any specific agro-ecological situation. There are many competition functions proposed to describe competitive relationship and which give some indications of yield advantages.

Biosuitability

5.5.1 Land Equivalent Ratio (LER)

LER is an ideal parameter for evaluating an intercropping system. No intercropping situation can be fully analysed without combining the crop in some fashions. Willey and Osiru (1972) have given the most widely accepted parameter for assessing a cropping system ie LER. This is defined as the relative land area under sole crops that is required to produce the yields achieved in intercropping. If the LER is unity there is neither gain nor loss by intercropping. Value less than unity denotes disadvantage and value more than unity represents advantage.

The LER of both chilli-french bean system and chilli-amaranthus systems were above unity. This showed that there was an advantage in land use by intercropping chilli with amaranthus or french bean. Among the two crops tried as intercrops regarding land use, amaranthus is considered more ideal. Chilli amaranthus system recorded an LER of 2.74 as against 2.35 in chilli-french bean system (Figure 10). The higher LER recorded

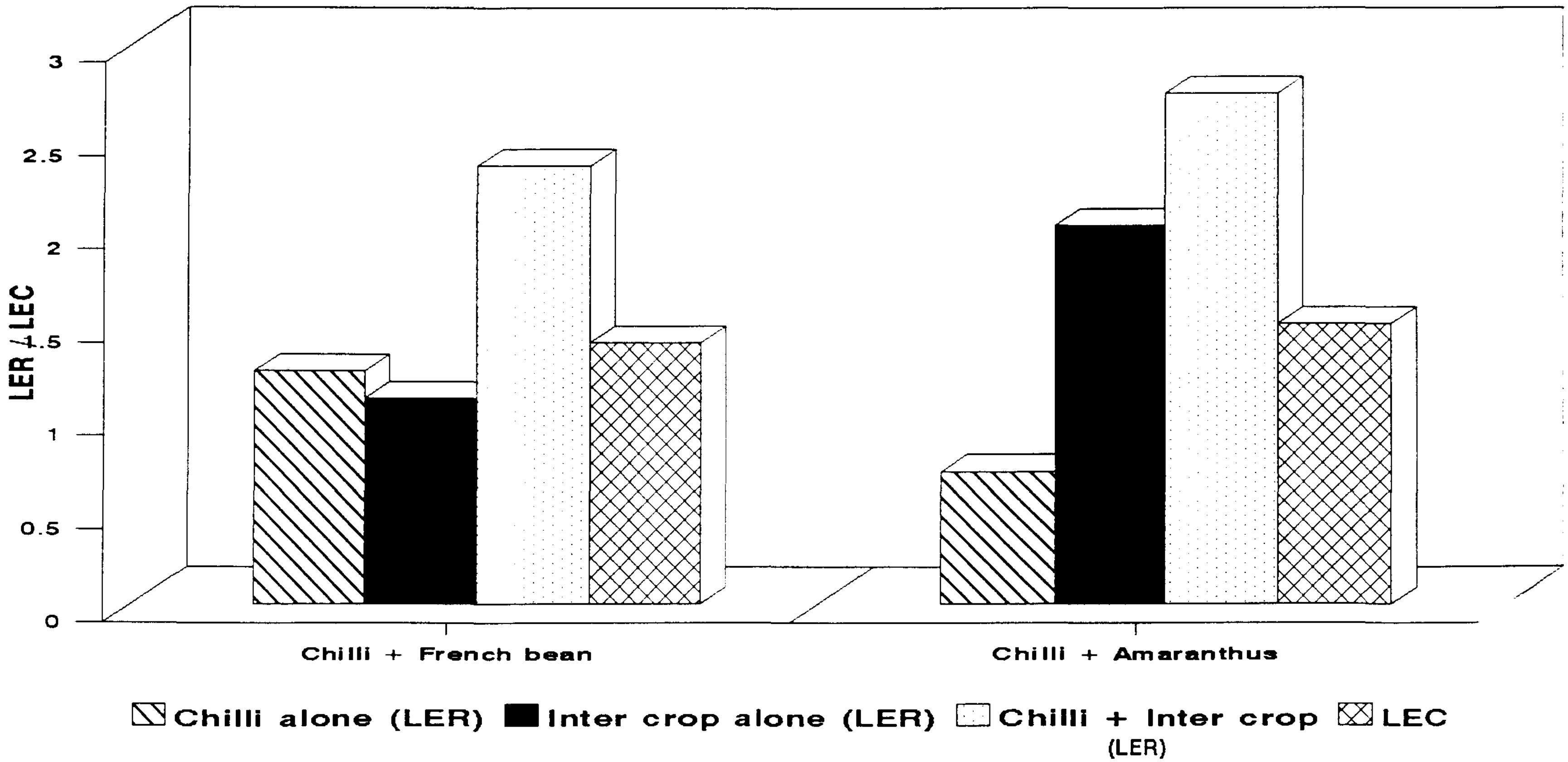

Fig. 10. LER and LEC of component crops in chilli based cropping system

by chilli-amaranthus system was mainly due to the higher intercrop yield of amaranthus. Even though the performance of chilli was poor (LER = 0.71) the system was found beneficial due to higher LER of amaranthus (2.03). There was 174 per cent advantage in land use by raising amaranthus with chilli where as by raising french bean with chilli the advantage is only 135 per cent. Ramachander et al. (1989) reported an LER greater than one when chilli was intercropped with french bean, peas and onion.

Maximum LER was obtained at NL 100 (Figure 11). Similar results were observed by Rafey and Prasad (1992) in a maize-pigeon pea intercropping system. This is due to the higher intercrop yield of all the component crops realised at this level of nutrients. There was an advantage of 210 per cent of land use at the highest level of fertilizer recommendation. Not only at maximum nutrient level, but also at lower levels, intercropping was found beneficial than pure cropping. Even though the yield of chilli was low at 75 and 50 per cent of the recommended dose, this was compensated by the intercrop yield of the component crop.

Systems of planting failed to show any significance on LER. Same trend in yield was observed in chilli and amaranthus.

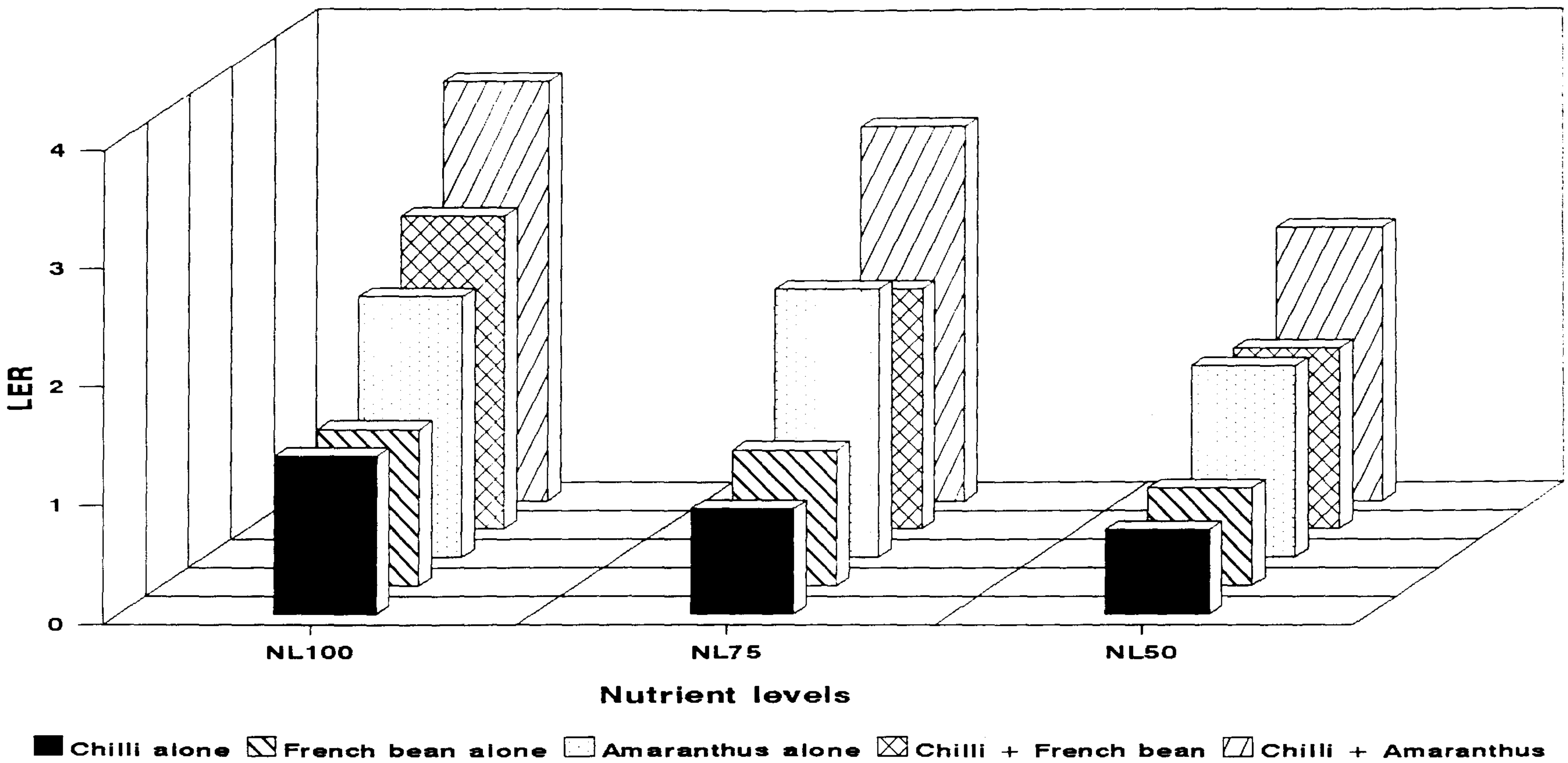

Fig. 11. LER at varying nutrient levels

5.5.2 Land Equivalent co efficient (LEC)

LEC has been found to be very effective in deciding the mixture yield as well as the intercrop proportion that gave agronomic advantage. According to Willey (1979) one criteria for assessing the yield advantage of cropping system is to realise full yield from the base crop and to get some extra yield from the component crop. In this study 100 per cent of the pure crop population was maintained in the intercropping system for base crop chilli. Hence expected LER was one, assuming interspecific competition was equal to intraspecific competition. And for intercrop 50 per cent of the pure crop population was maintained in the intercropping system. Here the expected maximum LER was 0.5. Hence the standard LEC of this system was 0.5. Here all LEC were more than 0.5 and hence the combined intercrop yield realised from all the treatments was more than the expected yield.

Any intercropping system to become beneficial, should have an LER of more than one or the LEC of more than 0.25. In this study also all treatments recorded LEC of more than 0.25. This again confirmed the suitability of intercropping in chilli based cropping system. Chilli amaranthus system recorded an LEC of 1.52 even though the LER of chilli was less than one. This loss in yield was compensated by the higher LER of amaranthus

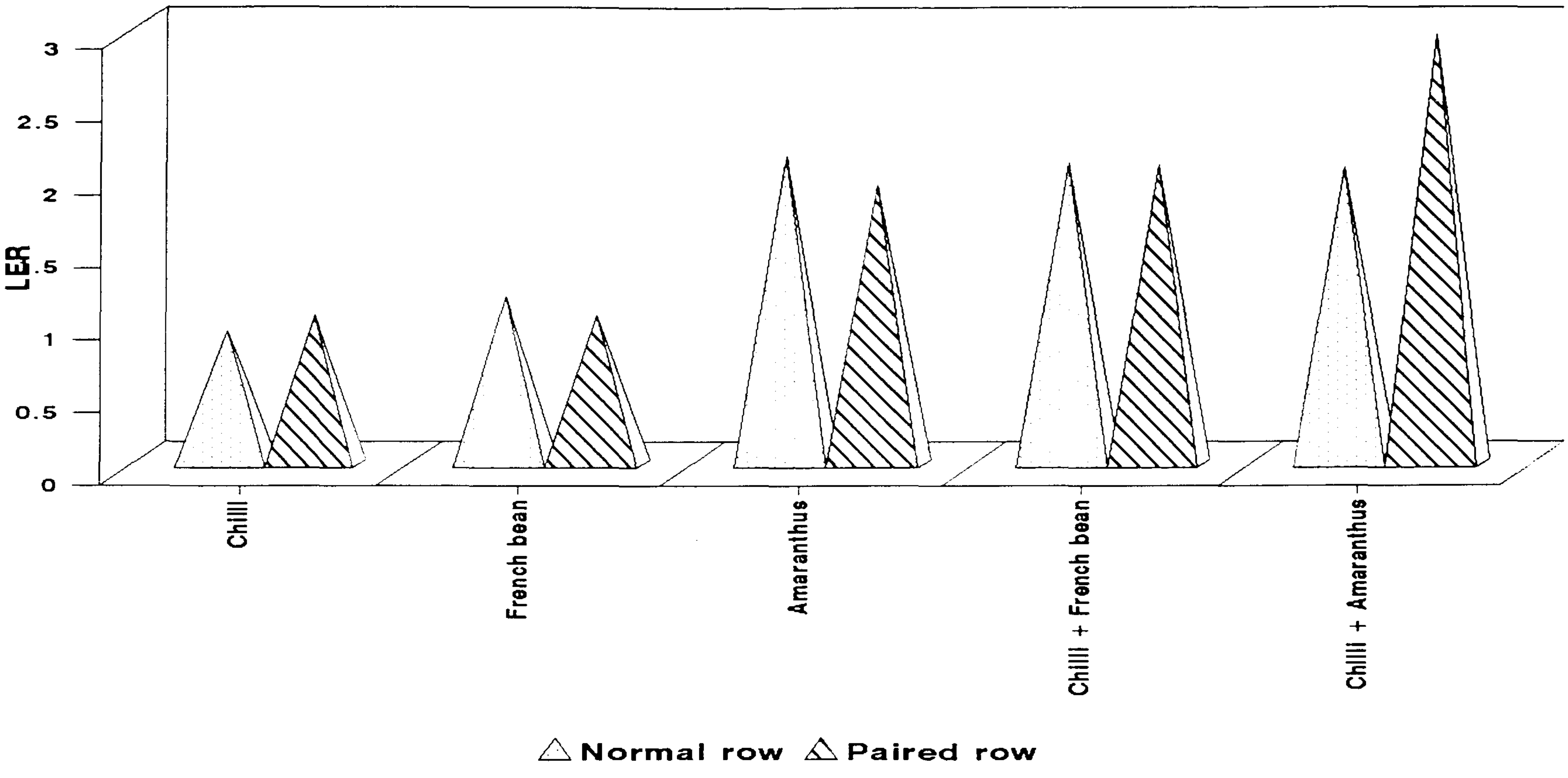

Fig. 12. LER at different planting geometry

(2.08) and thus resulted in higher LEC (Figure 10). Chilli-french bean system gave an LEC of 1.41. In this system the intercrop yield of both the crops was more than expected and have resulted in higher LEC (Figure 10).

Application of 100 per cent nutrients for both the crops recorded maximum LEC of 2.27 followed by 75 and 50 per cent of the recommended dose (LEC = 1.35 and 0.78 respectively). This higher LEC at the highest level of nutrient was a direct reflection of the higher LER of chilli and intercrop at this level of nutrient. Planting geometry failed to give any significant effect on LEC.

5.5.3 Aggressivity

Aggressivity is a parameter that helps to assess the competitive nature of the component crops. This is calculated by the formula suggested by Mc Gilchrist (1965). Positive aggressivity value of a crop indicates that it is more aggressive than the component crop and negative aggressivity value indicates its dominated nature. Chilli in cf system recorded positive aggressivity value where as french bean recorded negative value (Figure 13) which showed that in chilli-french bean system chilli was the dominant crop and french bean the dominated one. Ycf revealed this dominant nature of chilli in chilli - french bean system. But in chilli-amaranthus system chilli recorded negative

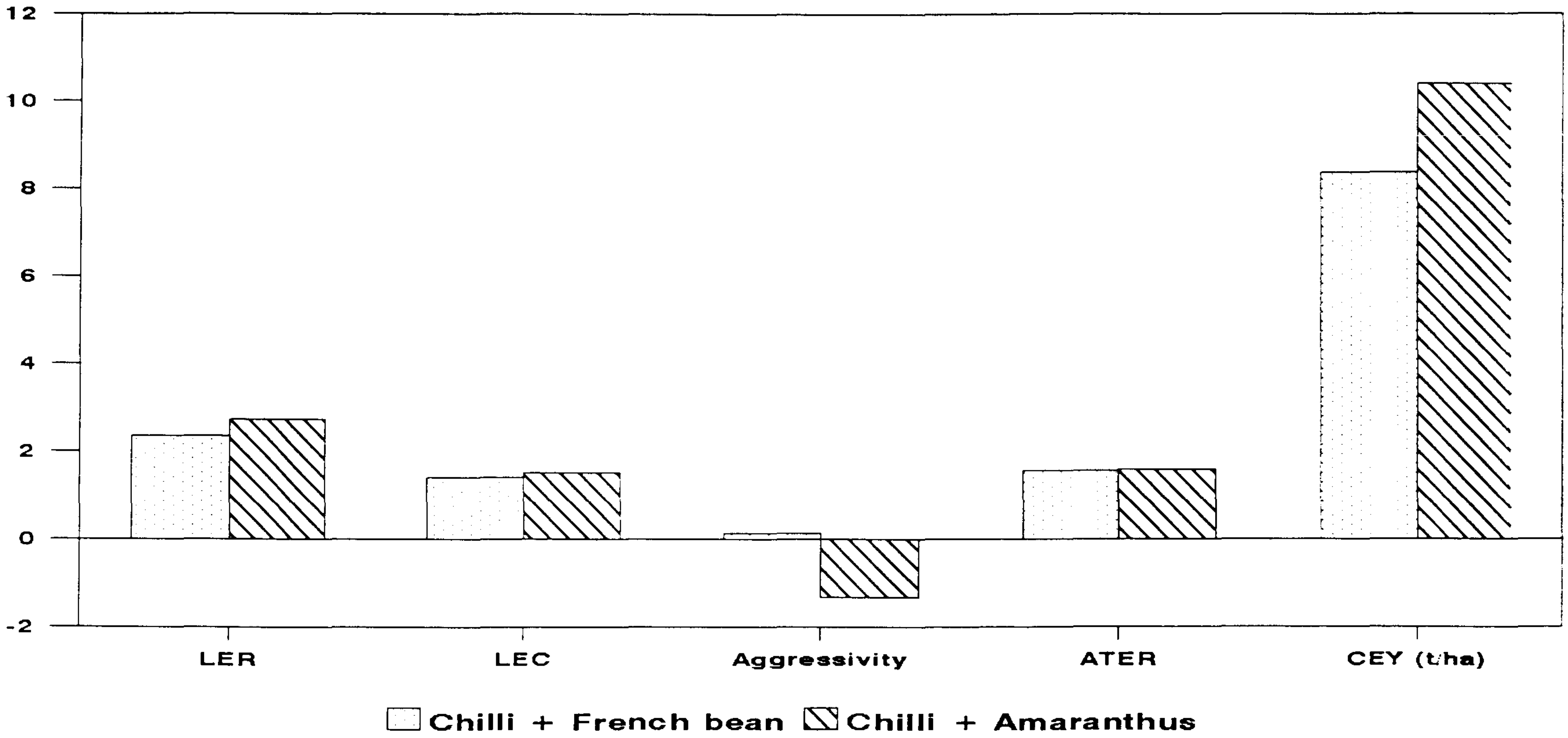

Fig. 13. Biosuitability of intercropping system as affected by intercrops

value and amaranthus recorded positive value that is the base crop yield was suppressed by the component crop. C-4 nature of the component crop resulted in better utilisation of resources and hence resulted in positive aggressivity values. This is in confirmity with the findings of Ikeorgu (1990).

Negative aggressivity values of chilli at all nutrient levels showed that chilli was suppressed by the component crops (Figure 14). This might be due to the better utilisation of nutrients by the companion crops. The lowest competition was observed at the highest nutrient level. This might be due to the better supply of nutrients which resulted in minimum competition. Under both the systems of planting the component crops expressed dominant nature. So the result of this study showed that even under all levels of nutrients supplied and under both the methods of planting, component crops compete with base crops. So the possibility to rule out competition is very less under chilli-french bean and chilli-amaranthus systems of planting. Though competition existed, both the systems of cropping were found better than pure cropping of chilli.

5.5.4 Area Time Equivalent Ratio (ATER)

In the calculation of LER, the time the field was dedicated to production is not included. Hiebsch (1978) proposed an area time equivalent ratio (ATER) with a view to correcting

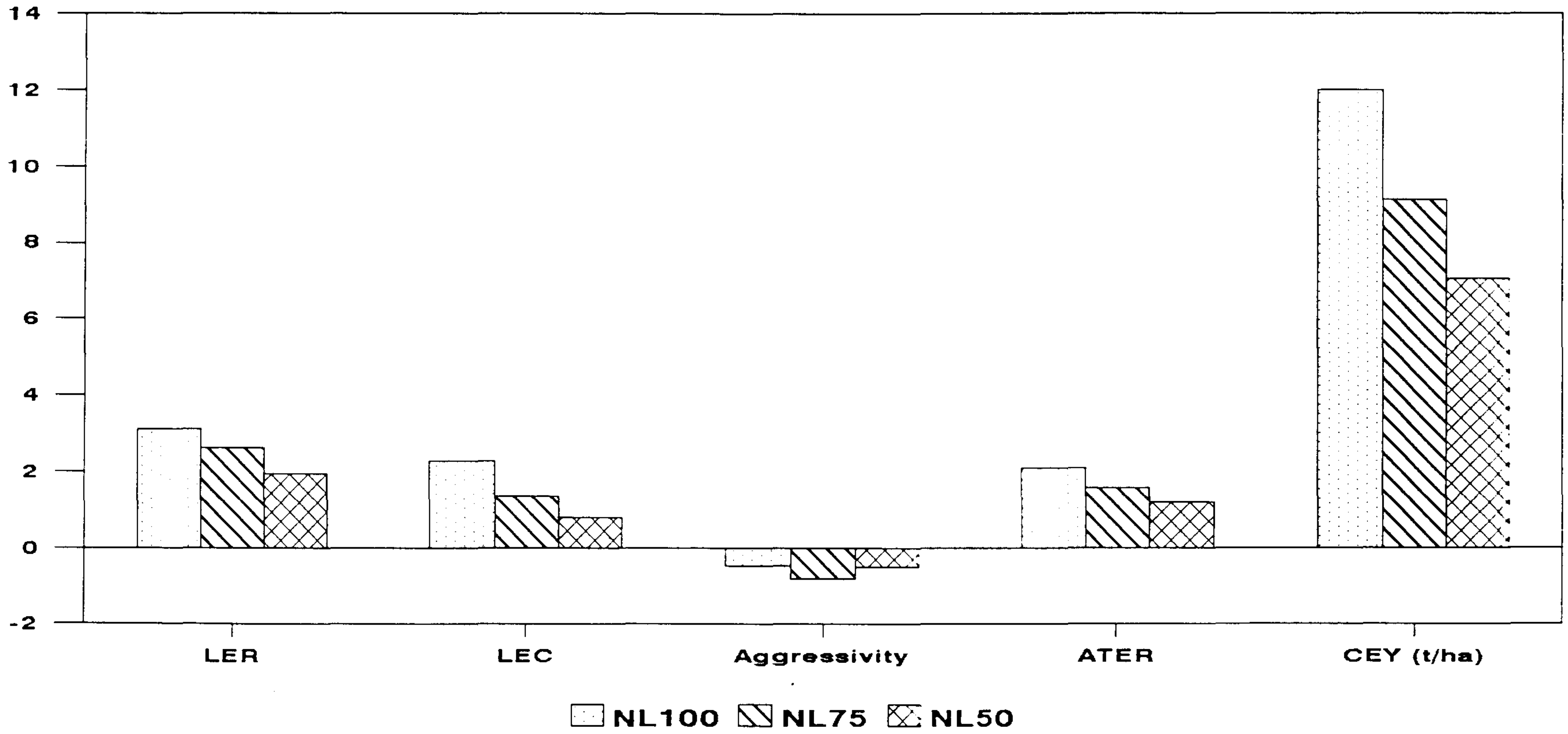

Fig. 14. Biosuitability of intercropping system as affected by nutrient levels

the conceptual inadequacy in LER by including the duration of land occupancy in the intercrop vs monoculture. ATER is a parameter which gives us an idea of utilisation of area and time by component crops of the cropping system. ATER showed that by intercropping with both french bean and amaranthus, there is a combined net saving of 55 to 60 per cent in use of space and time (Figure 13) compared to pure cropping. The better ATER is due to better combined intercrop yield and temporal difference existed between the crops.

Maximum utilisation of space and time was observed at the highest level of nutrient applied (Figure 14). This is due to the higher combined intercropped yield at this level of nutrient. As the nutrient level was reduced advantage also diminished due to reduction in the combined intercrop yield. Paired row system of planting recorded higher ATER compared with normal system of planting, indicating better use of the resources by the component crop under this system of planting.

5.5.5 Crop Equivalent Yield (CEY)

In intercropping more than one species are involved, hence it is difficult to compare the produce with different nature and hence efforts have been made to convert the yield of component crops into equivalent yield. Chilli equivalent yield was more in ca system. This is because of the better intercrop yield of amaranthus compared with inter crop yield of french bean. Sharma et al. (1992) and Yadav and Prasad (1990) also reported higher sugarcane equivalent yield in a sugarcane intercropping system compared with sole crop of sugarcane. Application of the highest dose of nutrients recorded maximum chilli equivalent yield (Figure 14). Billore et al. 1992 opined that nutrient application at 100 per cent to both crops gave higher equivalent yield due to minimum competition between crops. Higher CEY was a direct reflection of the higher yield of the intercrops ie the LER of both the intercrops were more than one. Seventy five per cent of the recommended dose resulted in a chilli equivalent yield of 9731 kg ha^{-1} which was significantly superior to chilli equivalent yield realised under the lowest dose. This higher chilli equivalent yield was due to the higher LER of french bean and amaranthus under these levels of nutrient supply.

Economic suitability

Intercropping being a system involving cultivation of crops of dissimilar nature it is very difficult to compare the produce of different nature. Any system to be recommended to the farmer should be economically viable. Hence the produce of different crops are converted in terms of returns and is compared to assess the economic suitability.

Chilli - amaranthus system was found more economically feasible than chilli-french bean system. The former recorded a higher net return of Rs.119926/- which was 31 per cent more than the net return of Rs.91799/- realised from chilli-french bean system. High benefit cost ratio of 4.4 and high per day return of Rs.1499/- revealed the superiority of chilli-amaranthus system (Figure 15). Economic feasibility of chilli intercropping system due to higher net return was reported by Kadali et al. (1988), Prabhakar and Shukla (1988) and Koraddi et al. (1990). Monetary return based on LER showed a similar trend. The better return from chilli-amaranthus system is due to the better gross return realised from this system. This is a direct reflection of higher combined intercrop yield from chilli-amaranthus system.

Highest nutrient dose recorded maximum values of net return (Rs.144263/-), per day return (Rs.1803/-), benefit cost ratio (5.12) and monetary advantage based on LER (Rs.121399/-). (Figure 16). At this higher nutrient level there was little competition for nutrients and that resulted in higher production of component crops. Singh et al. (1993) reported higher net return of potato-onion system at the higher level of nutrients. Similar results were obtained by Dodomani et al. (1993) in chilli-cotton-onion intercropping system. Planting geometry failed to give any influence on economic return.

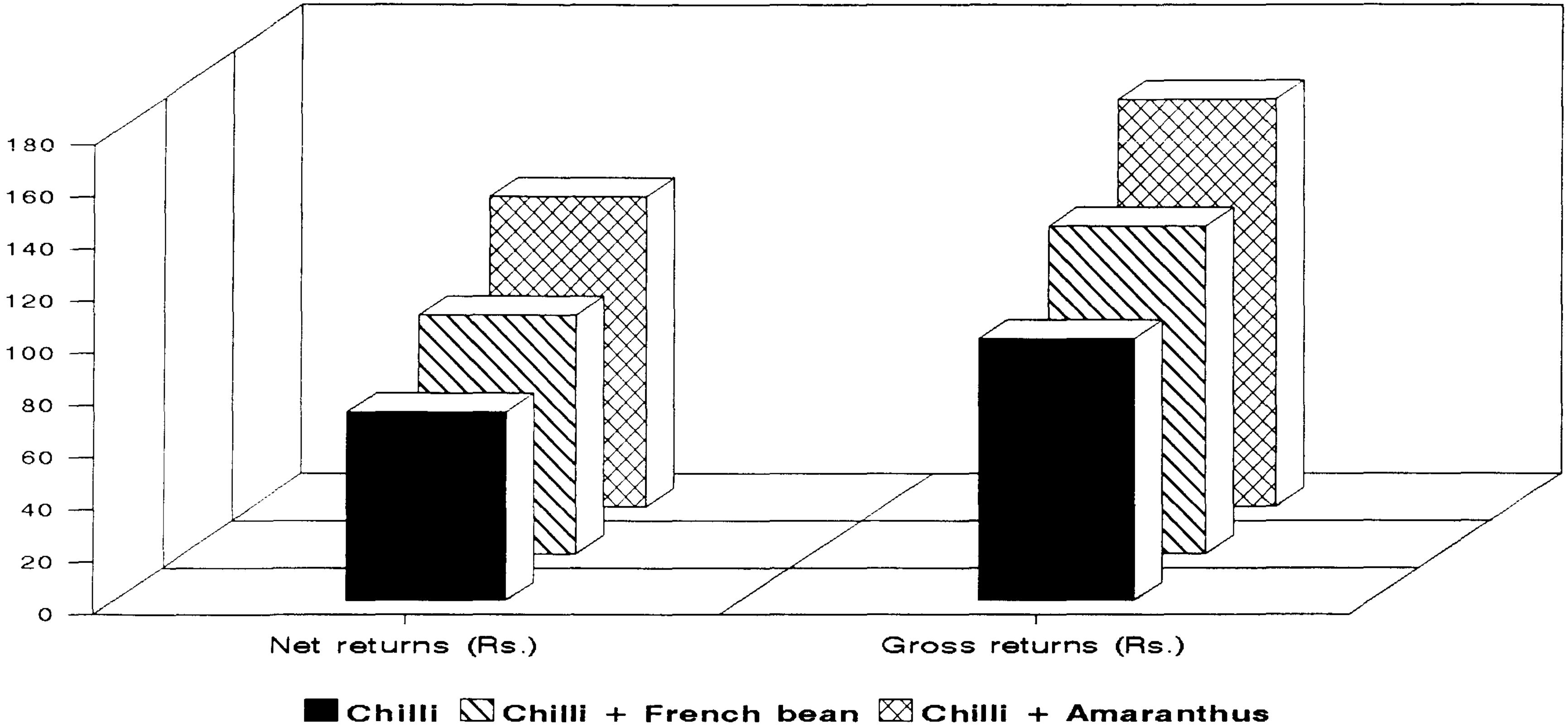

Fig. 15. Economic suitability of cropping systems as affected by intercropping

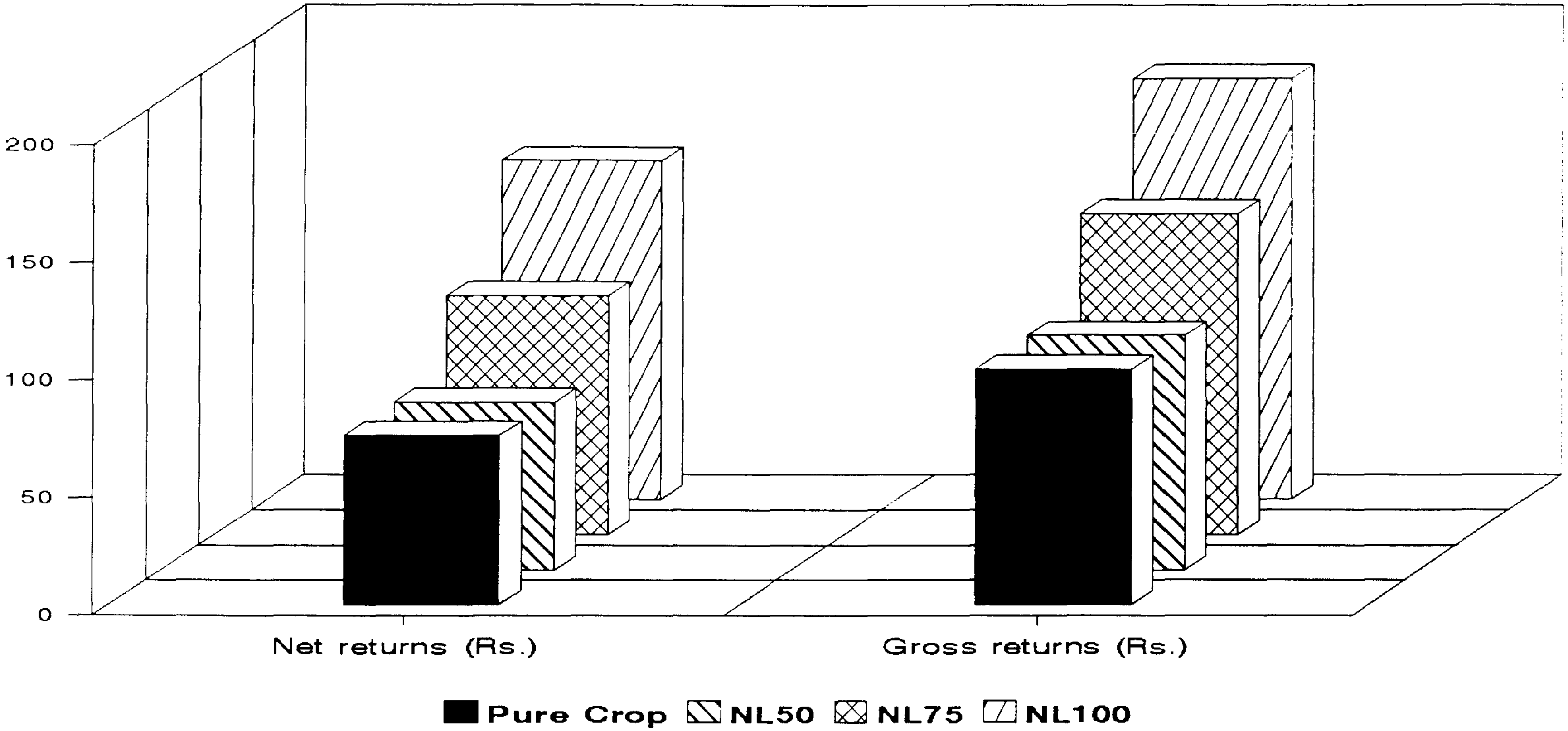

Fig. 16. Economic suitability of cropping systems as affected by nutrient levels

Compared with pure crop yield of any of the crops studied the monetary return was higher from intercropping system. (Figure 16). Pure crop of chilli gave a net return of Rs.72465/- per ha, but when intercropped with french bean the return increased to 126 per cent, with amaranthus it further shoot up to 165 per cent. NL 100 and NL 75 recorded a net return of 20 per cent and 4 per cent more than the net return of pure crop (Rs.72465/-). Even though extra cost was involved for nutrients the benefit derived was much more than the expenditure incurred.

For evaluating the advantages of intercropping three different situations were distinguished (Willey, 1979).

1. Where intercropping must give full yield of a main crop and some yield of a second crop.

2. Where combined intercrop yield must exceed the higher sole crop yield.

3. Where combined intercrop yield must exceed a combined sole crop yield.

From the results of this study, it could be seen that, the first two criteria were satisfied by chilli intercropping system, which showed the advantage of intercropping in chilli. The parameters studied for analysing the bio and economic suitability of chilli-french bean and chilli-amaranthus intercropping systems showed that chilli-amaranthus system is an economically viable practice which results in better biomass production as well as higher profit for summer rice fallows (Figure 17).

At 50 per cent recommendation the net return realised by chilli-amaranthus intercropping system was 13 per cent higher than the net return obtained from pure crop of chilli (Rs.72465/-) that further increased to 63 and 150 per cent with 75 and 100 per cent recommended dose (Figure 17). Even at the lowest nutrient dose net return was higher than pure crop of amaranthus. At the lowest level of the recommended dose itself, combined intercrop yield was higher than the sole crop yield of both chilli as well as amaranthus (Willey criteria I). At higher per cent of the recommended dose this system satisfies the second criteria proposed by Willey.

Both in terms of production as well as economics chilli-amaranthus intercropping is a system that could be recommended for summer rice fallows of Kerala.

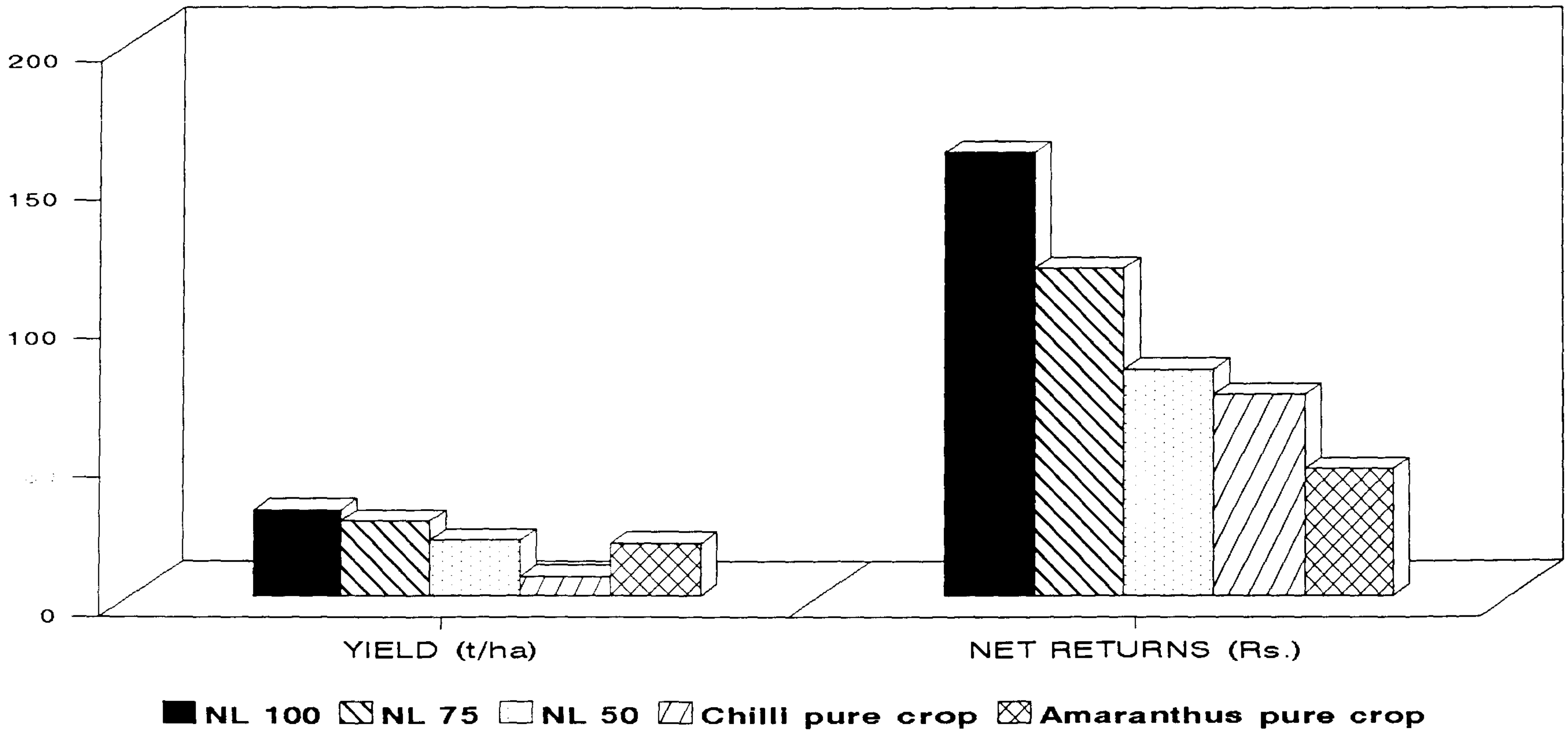

Fig. 17. Bio-Economic suitability of chilli - amaranthus intercropping system

SUMMARY

6. SUMMARY

An investigation was undertaken at the Rice Research Station, Kayamkulam to find out the suitability of raising french bean or amaranthus as intercrop in chilli and also to study the effect of nutrient levels and planting geometry in chilli based intercropping system. The results of the study are summarised below.

Performance of chilli under three systems of cropping chilli-french bean (cf) system, chilli-amaranthus (ca) system and pure crop system (cc) was studied. Performance of chilli was better under cf system than other two systems. Chilli in cf system recorded significantly higher leaf number, leaf area, branches, dry matter production, fruit number, length, girth and volume of fruits, fresh and dry weight of fruit and uptake of nutrients compared with ca and cc systems. Chilli in cf system recorded a yield (Ycf) of 8371 kg ha^{-1} which was significantly superior to Yca and Ycc, but Yca was less than Ycc.

Performance of intercropped chilli under 3 levels of nutrient was assessed and the results showed that all growth and yield attributes significantly increased with increasing levels of nutrients. Maximum plant height, leaf number, leaf area, number of branches, dry matter production, number of fruits,

length, girth and volume of fruits, fresh and dry weight of fruits and uptake of N, P and K were observed at NL 100. Yci was also maximum at NL 100 (8917 kg ha^{-1}). Even though Yca was less than Ycc, with 100 per cent of nutrient doses Yca was more than Ycc.

Intercrop yield of chilli was not influenced by planting geometry.

Growth characters of intercropped amaranthus was not significantly influenced by nutrient levels and planting geometry. Uptake of nutrients by amaranthus was maximum at NL 100 and under paired row planting.

Intercrop yield of amaranthus (Yac) significantly increased with nutrient levels. Maximum yield (Yac) was recorded at NL 100 (23660 kg ha^{-1}) and at NL 75 (23431 kg ha^{-1}). Yac at NL 100 and NL 75 was significantly higher than Yac at NL 50 and Yaa.

Growth characters of french bean was not influenced by nutrient levels and planting geometry. Intercrop yield of french bean (Yfc) was significantly influenced by nutrient levels and planting geometry. Yfc was maximum at NL 100 and among the systems of planting, paired row system recorded better yield than normal row system. But in general the performance of french bean was very poor hence this crop could not be recommended for summer rice fallow.

Interaction effects were not found significant except for plant height of chilli at the stage of 30 DAP.

The bio and economic suitability of system was studied. Higher LER (2.74), LEC (1.52) ATER (1.61) and CEY (10421 kg ha^{-1}) were observed in ca system. This revealed the biosuitability of ca system compared with cf system and cc system. Monetary return based on LER (Rs.97801/-) gross return (Rs.156246/-), net return (Rs.119926/-) per day return (Rs. 1499/-) were also high in ca system compared to cf, cc, aa and ff systems and thus indicate the economic superiority of this system. Thus we can summarise that chilli-amaranthus system is a biologically suitable and economically viable system for summer rice fallow.

Nutrient levels had significant influence on the biological and economic parameters of chilli intercropped system. Higher LER (3.10), LEC (2.27), ATER (2.03), CEY (11998 kg ha^{-1}), monetary return based on LER (Rs.121399/-), gross return (Rs.179956/-), net return (Rs.144263/-) and return per rupee invested (5.12) were obtained at NL 100. Bio and economic suitability of chilli intercropping system was maximum when both crops were given 100 per cent of the nutrient dose.

Nutrient content in the soil after the experiment was not significantly influenced by intercropping, nutrient levels and planting geometry. Positive build up for N, P and K (except

T10, T11 and T12) status was observed after the experimentation but final soil test data revealed an enrichment in this status of soil N. There was not much difference between the initial and final P status of the soil. Compared with the initial status of K a slight depletion was observed.

This study indicated that intercropping is feasible in chilli and by raising amaranthus along with chilli an additional yield as well as profit can be realised compared with pure crops of chilli and amaranthus in summer rice fallow.

Maximum yield and profit from the intercropping system was obtained when, both the crops were given 100 per cent of the recommended dose. French bean was not found ideal for summer rice fallows. Combined intercrop yield was not affected by system of planting.

By raising amaranthus with chilli in summer rice fallow, not only the resources can be utilized to the maximum extent but also better returns can be realised. To reap the maximum biological and economic advantage, both the crops should be supplied with 100 per cent of the recommended nutrient dose. Chilli-amaranthus intercropping system can be recommended as an economically viable, biologically suitable and a sustainable cropping system for summer rice fallows of Kerala.

Future line of work

In this study only two crops were tried as intercrop along with chilli. The compatibility of other vegetable crops can also be studied under chilli based cropping system. Since a linear response was obtained for nutrient levels, it was not possible to draw the economic and optimum dose for intercropping system. Hence higher doses of nutrients can be tried. Possibility of reducing the use of chemical fertilizer by supplementing with organic manure is an area that demand more investigation. Pest and disease incidence in the intercropping system under different levels of nutrients in the form of organics and inorganics and planting geometry form another area for future research.

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APPENDICES

APPENDIX - I

Weather data during the crop period in comparison with the corresponding average values for the past 5 years

Standard weeks	Average Temperature °C				Average Relative Humidity (Per cent)		Rainfall (mm)	
	Maximum		Minimum				Crop period (Total)	Past 5 years (Average)
	Crop period	Past 5 years	Crop period	Past 5 years	Crop period	Past 5 years		
1	33.2	33.01	20.6	15.34	92	90.2	-	4.7
2	33.1	33.06	21.0	14.9	88	91.8	-	1.86
3	32.5	32.96	22.2	14.86	91	90	6.5	-
4	33.9	33.18	18.8	16	88	90	-	-
5	32.4	38.58	20.0	16.42	93	89.4	-	1.84
6	33.0	33.8	22.9	17.08	91	89.6	63.5	-
7	27.9	33.74	23.6	17.66	93	91.2	1.2	0.52
8	33.2	33.54	23.4	18.36	93	91.0	-	0.72
9	33.4	33.86	20.6	18.48	84	90.8	-	-
10	33.8	33.8	21.3	19.0	90	90.8	-	16.4
11	33.2	34.42	22.6	19.8	94	90.8	46	9.2
12	33.9	34.62	24.4	20.42	91	91.0	-	8.78
13	33.8	34.84	24.2	20.1	87	90.8	-	0.96
14	33.2	33.44	22.9	20.64	90	90.8	75.0	3.84
15	32.4	35.56	23.5	21.18	93	90.0	32.10	12.42
16	33.3	34.02	24.1	21.04	88	93.2	2.5	22.42
17	33.8	33.56	25.3	20.88	88	89.2	1.8	46.92
18	33.5	34.06	24.1	20.72	83	89.0	-	40.18
19	32.4	83.76	24.2	20.72	88	90.8	61.4	83.38
20	33.6	32.80	24.6	20.8	89	90.0	1.8	69.90
21	31.7	31.44	23.7	20.5	93	92.2	119.9	56.4
22	29.7	32.02	22.8	19.9	94	93	209.7	91.4
23	29.7	30.30	23.5	19.28	96	94.8	194.4	286.76
24	30.2	30.24	22.8	20.02	95	95	107.2	107.92
25	31.3	31.54	24.0	20.02	93	93.2	10.2	87.56

RESOURCE USE AND PLANT INTERACTION IN CHILLI INTERCROPPING SYSTEM IN SUMMER RICE FALLOW

By

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ABSTRACT OF THE THESIS

Submitted in partial fulfilment of the requirement for the degree

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ABSTRACT

An investigation entitled "Resource use and plant interaction in chilli intercropping system in summer rice fallow" was conducted at Rice Research Station, Kayamkulam to assess the bio and economic suitability of chilli intercropping system. The experiment consisted of two intercrops (french bean and amaranthus), three nutrient levels (NL 100, NL 75 and NL 50) and two planting methods (normal row planting and paired row planting).

Among the three cropping systems viz. chilli-french bean, chilli-amaranthus and pure crop system, performance of chilli in chilli-french bean system was the best. All the growth and yield attributes, nutrient uptake and yield of chilli in chilli-french bean system was superior to chilli-amaranthus system and pure crop system.

Better growth and yield performance of chilli was observed at 100 per cent of the nutrient dose for both the crops. The maximum benefit from chilli intercropping system was also realised at this level of nutrient.

Intercrop yield of chilli was not influenced by planting geometry.

Intercrop yield of amaranthus significantly increased with nutrient levels. Intercrop yield of amaranthus at 100 and

75 per cent nutrient dose was significantly higher than intercrop yield of amaranthus at 50 per cent nutrient dose and pure crop yield.

Performance of both pure and intercropped french bean was very poor hence this crop could not be recommended for summer rice fallow.

Higher LER, LEC, ATER, CEY, monetary return based on LER, gross return, net return, return per rupee invested and per day return revealed the bio and economic suitability of chilli-amaranthus system. Bio and economic suitability of chilli intercropping system was maximum when both crops were given 100 per cent of the nutrient dose.

Nutrient status of the soil was not affected by intercrops, nutrient levels and planting geometry. A positive build up of all the nutrients in the soil revealed the sustainable nature of these systems.

The results indicated that, french bean was not ideal for summer rice fallows. To reap the maximum biological and economic advantage, both the crops should be supplied with 100 per cent of the recommended dose. Chilli-amaranthus intercropping system can be recommended as an economically viable, biologically suitable and a sustainable cropping system for summer rice fallows of Kerala.