COMPETITIVE BEHAVIOUR OF DIFFERENT LEGUMES GROWN AS INTERCROP WITH DIRECT SEEDED UPLAND RICE

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DECLARATION

I hereby declare that this thesis entitled "**Competitive behaviour of different legumes grown as intercrop with direct seeded upland rice**" 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.

Vellayani,
25-10-2002

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CERTIFICATE

Certified that this thesis entitled **"Competitive behaviour of different legumes grown as intercrop with direct seeded upland rice"** is a record of research work done independently by Srinivasan, K. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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LIST OF ABBREVIATIONS

@	at the rate of
kg	kilogram
ha	hectare
g	gram
mg	milligram
cm	centimetre
m	metre
%	per cent
N	nitrogen
P	phosphorus
K	potassium
DAS	days after sowing
LAI	leaf area index
CGR	crop growth rate
RGR	relative growth rate
RCC	relative crowding coefficient
LER	land equivalent ratio
LEC	land equivalent coefficient
CR	competition ratio
ATER	area time equivalent ratio
^0C	degree Celsius
Fig.	Figure

INTRODUCTION

1. INTRODUCTION

Rice is the most important food grain of Kerala. According to the report of Kerala Statistical Institute (1994), rice cultivation has been reduced to 58 per cent of the original area in the past three decades. Twenty four per cent of the original rice cultivating area is now occupied by perennial crops. This drastic reduction in area brought down the production of rice in Kerala to levels which have forced the state to depend on other states.

Upland rice is mainly grown in Kerala as a sole crop during the monsoon season. The establishment of the crop is often poor resulting in low productivity. It is very sensitive to scarce rains, which often occurs during the monsoon failure periods leading to instability in its production and economic returns. Under these adverse circumstances intercropping system provides insurance against failure of one crop. Besides, in a normal season, it increases the income of the farmer too.

The problems of underfeeding and malnutrition of people are primarily due to inadequate supply of protein. Hence, suitable agro techniques have to be developed in order to enable the cultivators to include pulses in the existing cropping systems without any additional land or heavy expenditure.

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

Intercropping is a term that is being widely used by agricultural scientists in recent years. In reality, intercropping is a practice of intensive land use to grow two or more crops simultaneously each year. This system not only increases the production from unit area per unit time but also provides additional work to the agricultural labourers besides giving them an additional income. Intercropping involves growing of two or more crop species simultaneously with the assumption that two or more species could exploit the resources better than one.

The intercrop selected should ensure maximum production or maximum returns per unit input to the farmer and should be compatible with the main crop. It should be able to utilize and harness efficiently the light that is filtered through the leaf canopy of the main crop. The rooting patterns of the intercrops should be such that they should not compete for water and nutrients with the main crop.

Intercropping provides substantial advantage in yield not by means of costly inputs but by growing crops together. Intercropping gives greater stability in yield during aberrant weather conditions and epidemics of disease and pests, which is of considerable importance to subsistent farmers.

Legumes have certain unique features, which together make them an indispensable component in sustainable agriculture. Legumes play an important role in the restoration and build up of soil fertility. The deep penetrating root system enables them to utilize the limited available moisture more efficiently. These crops serve as live mulch and effectively check soil and water loss apart from smothering weed growth.

The inclusion of quick growing leguminous crops like cowpea, blackgram and greengram may benefit the companion crop through current nitrogen transfer and the succeeding crop through residual effect. There are several reports to show that inclusion of legumes in the cropping system had indeed benefited the associated crop and improved the soil nitrogen status, thus reducing the nitrogen application to the succeeding crop (Mandal *et al.*, 1987; Mandal *et al.*, 2000).

By selecting suitable crop combinations and altering the row arrangement, intercropping can be made more profitable. Experiments have shown that intercropping pulses like blackgram, greengram and cowpea with cereals is successful without any adverse effect on the latter crop.

To increase and stabilize the productivity of rice, suitable intercropping systems have to be developed. The lack of relevant information about suitable and economical rice + legume intercropping system under agroclimatic conditions of Kerala prompted to conduct the present investigation with the following objectives.

(i) To find out the suitability of raising legumes as intercrop in upland rice.

(ii) To study the competitive behaviour of legumes grown as intercrop with upland rice

(iii) To find out an optimum row proportion of upland rice to legume combination.

(iv) To assess the soil fertility improvement resulting from legume intercropping

(v) To evolve an economically feasible legume intercropping system in upland rice.

REVIEW OF LITERATURE

2.REVIEW OF LITERATURE

The review of literature pertaining to various aspects of cereal + legume intercropping systems is presented in this chapter.

2.1 IMPORTANCE OF INTERCROPPING

The importance of intercropping has been recognized since long by the farming community and scientists. The intelligence of Indian farmers was appreciated in giving right place for mixed cropping and rotation in Indian agriculture. System of mixed cropping in India is successful and profitable method to uphold the fertility of soils.

Christidas and Harrison (1955) reported that economic advantage of intercropping system is by way of additional income from companion crop. Early maturity of companion crop helps to keep farm labourers fully engaged.

Trenbath (1976) observed that common characteristics of different forms of intercropping are that they can intensify crop production and exploit environments with potentially limiting growth resources more efficiently.

Reddy *et al.* (1977) found higher protein content in cereal mixed with pulse crop. Similarly nutritional improvement of cereals with respect to sorghum + pigeon pea association was noticed.

Gunasena *et al.* (1979) stressed the importance of intercropping system for subsistence farming of developing countries. Intercropping recorded higher yields in a given season and greater stability of yields in different seasons. Intercropping not only provides insurance against biotic and environmental stresses but also gives extra yield advantage by simple expedient of growing crops (Willey, 1979).

Rao *et al.* (1982) found that intercropping greengram and groundnut with rice and finger millet improved the total grain yield, land equivalent ratio and total monetary return when compared to sole crop of rice.

Mandal and Mahapatra (1990) reported that intercropping has improved the indigenous farming system in India and other parts of Asia by fully utilizing the growing season and increasing the yield per unit land, per unit time.

Angadi and Chittapur (1990) opined that rice based intercropping is useful in reducing the risks of monsoon and also in increasing productivity.

Intercropping is a potentially beneficial system, which shows substantial yield advantage over sole cropping and reduces risk (Singh *et al.*, 1992). Quayyam and Maniruzzadin (1995) reported that farmers prefer intercropping because this system provides satisfactory yield even in an adverse condition.

According to Mandal *et al.* (1996) intercropping is a possible way of increasing productivity of farms with low crop yields per unit area and limited resources.

Saha *et al.* (1999) concluded that the different rice + legume associations played an important role in influencing the yield performance of succeeding crops by their impact on nutrient status and moisture retentive capacity of the soil.

Sarkar *et al.* (2000) reported that intercropping might be a viable agronomic practice for stepping up production and productivity of crops.

2.2 CROP COMPATIBILITY IN INTERCROPPING SYSTEM

The major objectives in intercropping are to produce an additional crop without affecting too much yield of the base crop, to obtain higher economic returns, to optimize the use of natural resources including light, water and nutrients and to stabilize the yield of crop.

Legumes have an important role in intercropping system because of their potential to transfer the excreted nitrogen to the associated non-legumes (Ruschel *et al.*, 1979).

Reddy and Willey (1981) found that the advantage in pearl millet + groundnut intercropping was due to differences in the temporal and spatial characteristics of the crops.

Rao (1986) opined that the crops selected for intercropping are normally species differing in their duration, canopy structure, rooting habits, water, nutrients and solar radiation requirements.

Intercropping system is remunerative and gives yield advantage over sole crops provided it is properly planned and crops are not competitive to each other (Samui and Roy, 1990).

Holkar *et al.* (1991) opined that the success of an intercrop depends upon the proper choice of genotypes to assure stable production in the semiarid tropics.

According to Lal and Mishra (1996), improved variety of pulse crops intended to be grown as intercrops must possess erect and compact growth habit, early vigour, short maturity period, synchronous maturity, efficient photosynthetic system and non twining growth habit.

Mandal *et al.* (1996) reported that yield obtained from wheat and chickpea-intercropping system in 4: 2 ratio was higher than sole crops.

Selection of crops constitutes an essential ingredient of successful intercropping system (Rajasekhar *et al.*, 1997).

Verma and Warsi (1997) opined that the short duration intercrops did not cause much competition with main crop.

Mandal *et al.* (2000) concluded that intercropping of early maturing grain legumes with rice is advantageous.

2.3 COMPLEMENTARY AND COMPETITIVE EFFECTS IN INTERCROPPING SYSTEMS

An ideal intercropping system is one, which effectively shares the growth resources favourably among the component crops. Swaminathan (1980) stated that intercropping system should be based on complementary relation between the companion crops. Components of complementarity are efficient interception of sunlight, ability to tap the nutrients and moisture from different depths of soil, non-overlapping growth habits and introduction of legumes to promote biological nitrogen fixation and increase protein availability.

2.3.1 Complementary Effects

Biswas and Das (1957) noticed excretion of amino acid, from berseem into the rhizosphere and utilization by non-legumes grown in association or in sequence.

Chen and Peng (1961) found increase of phosphorus in soil due to root excretion of certain legumes like pea and cowpea. Dilz and Mulder (1962) reported that alfalfa, white clover and red clover transfer 16, 36 and 6 per cent of fixed nitrogen to rye grass respectively.

Kanwar and Katyal (1966) found that the total yield of wheat and gram were higher when grown in 1 : 1 proportion, compared to the sole crops with or without fertilizer. Mehrotra and Ali (1970) reported that legume after meeting their own requirement, supply a part of the fixed nitrogen to non-legume through sloughing of nodules which gradually degenerate and release nitrogen into the soil.

Morachan *et al.* (1977) revealed that the inclusion of blackgram and cowpea as intercrops in sorghum based intercropping system increases residual and total nitrogen content in soil. Legumes have an important role in intercropping owing to their potential for nitrogen fixation and possible nitrogen transfer to associated cereal crop (Lal *et al.*, 1978).

A significant increase in yield of maize when intercropped with a legume was noticed by Nair *et al.* (1979).

Mandal *et al.* (1986) reported that wheat + lentil and wheat + chickpea intercropping systems gave an additional yield without any significant reduction in wheat yield. The increase in yield was because of complementary relationship between wheat and grain legumes when grown in association.

Singh and Bajpai (1991) reported that the maize + legume intercropping systems recorded higher maize equivalent yield. The improvement in yield may be due to regular and timely availability of nitrogen fixed by associated legume plants.

Shah *et al.* (1991) found that the yield advantage in cereal + legume intercropping systems may possibly be attributed to the combined effect of better utilization of soil moisture, light and nutrients by component crops having differential rooting pattern, canopy distribution and nutrient requirement.

Singh and Singh (1993) recorded higher total grain equivalent when maize and french bean were grown at a ratio of 1:2. This also gave the highest net return and monetary advantage.

The increase in the grain yield of cereals in the cereal + legume intercropping systems may be attributed to the complementary effect of legumes in terms of biological nitrogen fixation (Pandita *et al.*, 2000).

2.3.2 Competitive Effects

In a system, component crops would compete for resources when the combined requirement is more than supply. Competition for moisture and nutrient is determined by rooting pattern while shoot development determines competition for light. Competition is stated as purely a physical process in which two or more organisms in proximity interact for a portion of environment, which is not available sufficiently to meet their combined demand.

Willey (1979) pointed out that the efficiency of production in cereal + legume intercrop systems could be improved by minimizing inter specific competition between the component crops for growth limiting factors.

No yield advantages were found in maize + cowpea and sorghum + cowpea intercropping systems in which components were of similar growth durations (Rees, 1986). Patra *et al.* (1990) reported that cereal crop was more competitive with the legumes in maize based intercropping systems.

2.3.2.1 Competition for Light

It is generally thought that light interception in mixture is more efficient. However excessive interception by one component crop leads to lower availability of light to the associated crop, thereby lowering photosynthetic rate and crop growth.

Trenbath (1976) recommended that ideal plant types in intercropping system consist of tall plants with erect and narrow leaves so that they do not shade the associate crop heavily and dwarf plants with broad and horizontal leaves are preferable so that utilize the available light completely.

The rate of dry matter production in crops depends on the efficiency of interception of photosynthetically active radiation (PAR) (Biscoe and Gallagher, 1977).

Sivakumar and Virmani (1980) observed that the higher biomass and grain production per unit area was obtained by better use of solar energy in intercropping. It was shown that an intercropping system will not intercept more light than sole crop, but intercropping system will have higher efficiency in converting the absorbed energy into dry matter than sole crops. Pearl millet + groundnut intercropping system was able to utilize light 28 per cent more efficiently than sole pearl millet. This was due to more evenly distributed light over more foliage (Reddy *et al.*, 1980).

Gardiner and Cracker (1981) maintaining a constant bean density of 220,000 plants ha^{-1}, found that varying maize density from 18,000 to 55,000 plants ha^{-1} progressively reduced the amount of light available to the beans. At the low maize density (18,000 plants ha^{-1}), bean received 50 per cent of the incident light, compared to 20 per cent at the highest maize density (55,000 plants ha^{-1}).

Tsay (1985) observed that the amount of light intercepted by the component crops in an intercrop system depends on the geometry of the crops and foliage architecture. The reduction in light reaching the legume canopy when intercropped with a taller component crop has been clearly demonstrated in cassava-soybean intercrop system in southern Queens land.

Patra *et al.* (1990) reported that the shading and competition effects by maize plants on associated legumes might have suppressed the yield attributes of associated legume crops.

2.3.2.2 Competition for Nutrient and Water

The success of any crop species in competition with an associate plant depends on the competitive ability with which it can make use of the available nutrients and water.

Characteristic features of component crops for better competition for water and nutrients include early and fast penetration of roots in soil, high root density, root/shoot ratio, root length, root weight, proportion of actively growing root systems, long root hairs and high competitive potential for nutrients (Trenbath, 1976).

Hulugalle and Lal (1986) reported that water use efficiency (WUE) in maize-cowpea intercropping system was higher than the sole crops when soil water was not limiting. However under drought conditions, WUE in the intercropping system was lower compared to the sole maize.

Mallick *et al.* (1992) found that wheat and lentil intercropping system gave maximum water use efficiency (7.18 kg grain ha^{-1} mm^{-1}) and sole wheat recorded low water use efficiency. (6.56 kg grain ha^{-1} mm^{-1})

From the above, it may be concluded that cereal and legume intercrops use water equally and that the competition for water may not be an important factor in determining the efficiency of intercropping systems.

2.4 CEREAL + LEGUME INTERCROPPING SYSTEMS

One of the ways to meet the objective of increasing productivity of crops is by intercropping, the practice of growing together two or more crops with definite row spacing with the assumption that two species could exploit the environment better than one.

Legumes have been accorded from time immemorial a prominent place in intercropping, mainly by virtue of their nitrogen fixation property. *Lipman (1913) established the evidences of excretion of* nitrogen by legumes, which can be used by the associated non-legumes. Virtanen (1937) made extensive experiments, which provide apparently unassailable proof that legumes, at least under certain conditions are able to excrete nitrogen, which can be useful for the companion crop.

A row proportion of 4:1 for intercropping ragi with field beans gave more production than 2:1 row proportion or sole crop of ragi at Bangalore. In sorghum + pigeon pea intercropping with 4:2 row pattern was found ideal (Maheswari, 1973).

Beets (1977) showed that when maize was grown mixed with soybean, the mixture produced more total fat, protein and methionine yield per hectare.

In high rainfall areas of West Africa, a common crop combination is maize and cowpea (Okigbo and Greenland, 1976), whereas in south and central America, maize and different types of beans dominate (Francis *et al.*, 1976). In India, short duration sorghum and millet are intercropped with pigeon pea that mature 90 days later than the cereal (Willey, 1979).

Sivakumar and Virmani (1980) reported an increase in efficiency of dry matter production by intercropping of maize with pigeon pea. Combinations of rice and other cereals or legumes are also found in high rainfall areas with a single extended rainy season such as South East Asia (Ruthenberg, 1980).

Eaglesham *et al.* (1982) presented evidence for transfer of N from legume to an intercrop cereal using the ^{15}N labeled fertilizer method. Based on yield and N contents, Waghmare *et al.* (1982) found that sorghum crop was benefited from greengram, groundnut, soybean, fodder and grain cowpea intercrops.

Shankaralingappa (1982) reported that in ragi + legume intercropping system, monocrop had more productive tillers, higher grain weight and harvest index.

Legumes of indeterminate growth are more efficient in terms of nitrogen fixation than determinate types (Eaglesham *et al.*, 1982).

Herridge (1982) observed that the degree to which N from intercrop legume may benefit a cereal crop depends on the quantity and concentration of the legume N, microbial degradation of the legume residues, utilization of these residues, and the amount of nitrogen fixed by the legume.

Ladd *et al.* (1983) reported that the N in legume residues may be tied up in the soil organic N pool and may not be readily available to the cereal crop.

In a sorghum + groundnut intercrop system, partial defoliation of sorghum increased the amount of light for the associated legume and enhanced nitrogen fixation (Nambiar *et al.*, 1983).

Singh (1984) reported that there was less risk from the sorghum based intercropping with legumes where the difference in time between the harvests of component crops was 3 – 4 weeks.

Gawda *et al.* (1985) from their maize + soybean intercropping study, noticed that LAI of soybean got reduced by 9-15 per cent, dry matter production by 21-60 per cent, branches by 5-31 per cent and pods plant^{-1} by 23-54 per cent as a result of intercropping. An increase in cost benefit ratio by 56 per cent by intercropping maize with soybean compared to sole crop of maize was reported by Sarma and Kalita (1985).

Prasad *et al.* (1985) observed higher uptake of nitrogen, phosphorus and potash by ragi when intercropped with soybean. But Purushotham (1986) observed no difference in the total uptake of nitrogen by ragi between pure and intercrops. Patra *et al.* (1986) reported that nitrogen compounds are excreted by a nodulating legume and then assimilated by associating non-nitrogen fixing plants. They observed an increase in dry matter yield of maize and wheat grown with gram and cowpea respectively.

Mandal *et al.* (1986) opined that intercropping of cereals with legume is a recognized system for economizing the use of nitrogeneous fertilizers and increasing the production per unit area. The system usually gives higher combined yield than sole crops.

Growing legume as intercrop in cereals has been found economical and beneficial (Chatterjee, 1989).

Sarkar and Shit (1990) indicated a higher biological efficiency and LER of 1.41 when maize was intercropped with soybean. Yield advantage was probably due to compatible nature of the component crops in the system.

Ghosh *et al.* (1990) reported that blackgram, greengram and cowpea are popular compatible legume crops for cereal based intercropping systems. Introduction of legumes in cropping systems has been advocated as a source of nutrient economy (Balyan and Seth, 1991). Singh and Sarawgi (1995) conducted studies on intercropping chickpea with wheat and concluded that some of the fixed nitrogen by the chickpea is likely to be available to wheat at later stages of growth.

Intercropping of pulses with cereals provides insurance against crop failure in extremely dry years and fairly high yield is achieved in good rainfall years (Singh and Singh, 1995). Singh and Balyan (2000) reported that the introduction of legumes in the cropping system benefited the associated crops.

Upadhyay *et al.* (1998) reported that the intercropping of urdbean with maize or sorghum gave more combined grain yield than sole urdbean. The superiority of pearl millet + groundnut intercropping to increase the equivalent yield under rainfed conditions (Ramulu *et al.*, 1998).

When crops of different growth habits are put together in an inter or mixed cropping system, it provides greater opportunity to secure higher yield from the same piece of land. Further, intercropping of legumes with cereals offers scope for developing energy efficient and sustainable agriculture (Mandal *et al.*, 2000).

The studies cited have elucidated the following

(a) Excretion of nitrogen compounds or sloughing of nodules by legumes can be assimilated by the associating non-nitrogen fixing plants.

(b) Intercropping results in better exploitation of resources through the competition between crops for carbon dioxide, light, water and nutrients.

(c) Positive and negative responses in growth and yield parameters of crops depend on factors like type of crops grown together, planting, spacing adopted etc.

(d) Intercropping leads to higher total yields, yield stability and better economic returns.

2.5 EFFECT OF ROW RATIO ON CEREAL + LEGUME INTERCROPPING SYSTEM

Intercropping is an important approach to achieve maximum profit and stability in production under limited resources. Plant population and row ratio of component crops play an important role in maximizing the productivity of intercropping system.

The overall mixture densities and relative proportions of component crops are important in determining yield and production efficiency of cereal + legume intercropping systems (Willey and Osiru, 1972).

Mandal *et al.* (1990) reported that the rice grown at 4:1 planting ratio with legumes recorded significantly higher grain yield over rice + legumes grown at 2:1 planting ratio. Scope exists to improve and stabilize the productivity and profitability from wheat through proper choice of intercrops and adopting proper row ratios of the same (Jha *et al.*, 1991).

Sand and Thakuria (1993) observed that the total productivity in terms of rice grain equivalent yield was the highest with rice + cowpea having 3:1 row ratio (22.5 q ha^{-1}) followed by 2:1 (21.7 q ha^{-1}) and the lowest with both the sole crops.

Abbas *et al.* (1995) reported that the intercropping of maize with bean or greengram in the row ratio of 1:1, 2:1 and 3:1 indicated negative values of aggressivity index, whereas a reverse trend was observed in the row ratio of 1:2 and 1:3. The increase in the number of rows of legumes between the maize rows may have increased the competition between legume plants and thereby resulted in the increase in dominance power of maize.

The beneficial effect of a suitable row ratio for cereal + legume intercropping system can be assessed through various competition functions (Rafey and Prasad, 1996).

Ahmed and Prasad (1996) reported that the row ratio of 4:1 and 6:1 of little millet and groundnut gave higher LER (1.16) and advantageous crowding coefficient values.

Pandita *et al.* (1998) observed an increase in row proportions with cereal and legumes over 1:2 row ratio in the intercropping system greatly reduced the cereal equivalent yield.

Bora (1999) reported that the yield of each crop decreased gradually, as the sowing proportion of the crop decreased. Wheat + pea in 3:1 row proportion recorded higher wheat equivalent yield of 19.8 q ha^{-1} than wheat + pea in 2:1 row proportion (19.42 q ha^{-1}).

Rahman (1999) studied the effect of intercropping grass peas in wheat at different ratios. Maximum monetary advantage was recorded from wheat + grass pea in 3:1 row ratio followed by the same crops with 1:1 row ratio.

Pandita *et al.* (2000) observed that maize in association with greengram in row ratio of 1:3 gave significantly the highest total leaf area index at tasselling stage than other intercropping systems.

Plant population and spatial arrangement in intercropping have important effects on the balance of competition between component crops and their productivity (Sarkar *et al.*, 2000).

It seems that density of the cereal component determines the level of combined mixture yield, but the efficiency of cereal legume intercropping systems, measured in terms of LER, follows the trend of the legume component.

2.6 EFFECT OF INTERCROPPING ON GROWTH AND YIELD ATTRIBUTES

Rao and Willey (1980) opined that intercropping ensures adequate yield of one of the crops under aberrant weather conditions. In intercropping situation, even though the yield of both the crops compared to yield of their sole crops is low, the overall advantages over pure crops are higher (Willey and Rao, 1981).

Saraf and Chand (1981) reported that intercropping mungbean or urdbean in pigeonpea as compared with its monoculture increased the combined seed yield. The cultivation of pigeonpea on the ridges significantly decreased the rice yield mostly due to the effect of shading offered by pigeonpea (Sharma and Modgal, 1984).

Ghosh *et al.* (1986) found that in upland rice + legume intercropping systems, intercropping caused more incidence of tikka disease in groundnut.

Asokaraj and Ramaiah (1987) reported that intercropping treatments significantly influenced the leaf area index of redgram. Blackgram, greengram and cowpea as intercrops significantly increased the leaf area index of red gram (5.5 to 13.1 %) over sole redgram at all stages of crop growth.

Venkateswarlu and Balasubramanian (1990) observed that intercropping of redgram and groundnut in 1:3 row proportions in summer gives an additional yield of redgram (5.39 q ha^{-1}) without affecting the pod and oil yield of summer groundnut. Though the individual component crops of the different intercropping systems were less productive than sole crops, the component crops together produced more dry matter and economic yields per unit area (Venkateswarlu and Balasubramanian, 1990; Shinde *et al.*, 1991).

Mandal and Mahapatra (1990) opined that advantages from intercropping compared to sole cropping are often attributed to the fact that different crops can complement each other and make better use of resources when growing together rather than separately.

Mandal *et al.* (1990) conducted studies on intercropping legume with rice. It was concluded that monocropped rice produced significantly higher amount of grain than intercropping systems.

In pigeon pea-groundnut intercropping, the pigeon pea equivalent yield with 100 per cent plant density of groundnut was significantly more than with 50 per cent plant density (Pareek and Turkhede, 1991).

Reddy *et al.* (1991) found that in pigeonpea + groundnut intercropping systems, leaf area index and dry matter production of groundnut was very low because of competition from pigeonpea for available resources which decreased the pod yield to a larger extent.

Mallick *et al.* (1992) studied the effect of intercropping legumes and oil seeds in wheat. Intercropping system of wheat with grain legumes gave 40 per cent more protein yield than wheat alone. Intercropping systems removed significantly more N than that of wheat alone owing to differential rooting pattern of component crops as well as high root density per unit soil volume, which exploited different soil layers resulting more efficient utilization of N from soil when grown together.

Ramamoorthy *et al.* (1994) conducted studies on intercropping grain legumes in rice. At all the growth stages, leaf area index of rice recorded highest value under sole rice whereas the lowest was observed in 2:1 row ratio at rice + green gram intercropping system.

High LAI indicated high mobilizeable protein at the beginning of the reproductive stage, which helps the crop to put forth higher production (Boote *et al.*, 1986). Increased values of CGR, NAR and RGR of rice were noted from 4:1 ratio under blackgram intercropping system than under greengram and soybean.

Quayyam and Maniruzzadin (1995) found that the reduction in yield was 58 per cent in rice when maize or blackgram was grown in inter and strip crop situations due to less area occupied by rice than sole rice.

Singh *et al.* (1996) reported that the plant height and dry matter accumulation of rice was the highest in sole crop of rice. The dry matter accumulation by rice plants was significantly reduced when intercropped with soybean, urdbean and sesame. All the yield attributes of rice *viz.*, effective tillers per metre row length, length of panicles, grains panicle^{-1} and seed index had higher values under sole crop of rice and reduced to significant level under intercropped conditions.

The combined yield of rice-groundnut intercropping system was significantly higher than each of the component crops, which indicated that the intercropping resulted in greater productivity per unit of land area than monoculture (Mandal *et al.*, 1997).

Ramamoorthy *et al.* (1997) reported that the highest rice grain equivalent yield was observed in rice and blackgram intercropping at 4:1 ratio followed by rice and blackgram in 3:1 ratio, rice and greengram 4:1 ratio and rice and soybean in 2:1 ratio.

Verma and Warsi (1997) observed that the plant height of pigeon pea was higher in intercropping systems than pure crop.

Significantly higher plant height, branches plant^{-1} and total drymatter accumulation were recorded under pure crop of soybean than rice-soybean intercropping treatment. Among the intercropping higher plant height, branches plant^{-1}, total dry matter were recorded in rice-soybean in 2:1 row ratio (Sarawgi *et al.*, 1999).

Mandal *et al.* (2000) reported that rice + blackgram intercropping system gave significantly higher number of effective tillers of rice per unit area over rice + pigeon pea intercropping system. The legumes had some beneficial effect on the number of filled grains panicle^{-1} in comparison with sole rice.

Pandita *et al.* (2000) observed maize and legume in 1:2 row ratio gave the higher number of cobs plant^{-1}, higher number of grains cob^{-1} and higher thousand grain weight than sole maize.

Singh and Balyan (2000) conducted studies on intercropping blackgram with sorghum. They observed that intercropping systems recorded higher sorghum equivalent yield, panicle weight and grain weight than their sole crops. Sorghum and blackgram intercropping systems gave higher protein content (9.47 %), dry weight plant^{-1} (84.54 g), LAI (3.31) and plant height (151.44 cm) of sorghum. Sole sorghum recorded lower protein content (9.32 %), dry weight plant^{-1} (81.81 g), LAI (3.05) and plant height (149.44 cm).

Maitra *et al.* (2001) reported that intercropping of finger millet with legumes showed higher leaf area index. The finger millet and green gram intercropping system at 4: 1 row ratio recorded higher number of pods plant^{-1} (11.3), number of seeds pod^{-1} (5.8) and test weight of grains (23.19 g). Sole greengram recorded lower number of pods plant^{-1} (11.2), number of seeds pod^{-1} (5.7) and test weight (23.03 g).

From the above literature, it is clear that in intercropping system, growth and yield attributes varied according to planting pattern and component crops.

2.7 ECONOMIC EFFICIENCY OF THE INTERCROPPING SYSTEM

The ultimate aim of intercropping is to increase the monetary returns per unit area. So economic evaluation becomes a necessity to assess how best an intercropping system is economically viable.

Kunasekharan *et al.* (1980) opined that intercropping of blackgram with sorghum gave the higher net returns. They also reported that growing of pulses as sole crops was not remunerative.

Hunshell and Malik (1983) reported that intercropping maintained superiority to sole cropping in term of monetary gain.

In upland rice + legume intercropping system, in addition to the yield advantage, the intercropping cuts down the cost of one weeding also (Ghosh *et al.*, 1986).

Mandal *et al.* (1990) conducted studies on rice + legume intercropping system. It was concluded that rice + mungbean, rice + soybean, rice + peanut and rice + blackgram inter cropping systems were all economically advantageous. The highest net return was realized under the rice + blackgram intercropping system.

Rathore (1992) conducted experiments under dryland agriculture on intercropping systems and stated that the productivity in terms of base crop equivalent increased in the order of 7to 26 q ha^{-1} thereby achieving additional monetary returns by 15 to 100 per cent.

Sand and Thakuria (1993) studied the effect of intercropping of cowpea with rice in different row proportions under rainfed conditions. Highest total production, monetary returns and net returns per rupee invested were recorded with rice and cowpea in 3:1 row ratio intercropping system.

Gadhia *et al.* (1993) conducted intercropping studies in pearl millet with grain legumes. He reported that intercropping pearl millet and pigeonpea in 2: 1 row proportion recorded significantly the highest grain equivalent yield of pearl millet which was due to high price ratio of pigeon pea to pearlmillet and higher yield of pigeonpea in intercropping system. Pearlmillet and pigeon pea gave the highest net return, which was significantly higher than all the other treatments. The increase in net return under this treatment was 83 per cent more than sole pearlmillet.

Ramamoorthy *et al.* (1994) observed that intercropping of blackgram in rice (1:4 row ratio) gave highest gross returns per hectare as compared to sole crop of rice. The increase in net return under rice and blackgram (4:1 ratio) was 32 per cent compared to sole rice. The mean net return (Rs. 9042 ha^{-1}) was proved to be superior in intercropping over sole rice (Rs. 6862 ha^{-1}).

Sarkar *et al.* (1995) reported that intercropping pulse crops in upland cotton increases total productivity and monetary advantage in the system. It was concluded that intercropping of greengram gave higher cotton equivalent yield (2408 kg ha^{-1}) than sole cropping of upland cotton (1393 kg ha^{-1}).

Quayyam and Maniruzzadin (1995) conducted studies on intercropping of blackgram with upland rice. Rice (67 %) and blackgram (33 %) combination gave higher net return per hectare and higher net return per rupee invested (0.97) compared with pure crop of rice (0.65).

Mandal *et al.* (1996) studied the economics of chickpea + wheat intercropping system and found that two rows of chickpea between four rows of wheat recorded the highest net return of Rs. 9,034 ha^{-1}, net return per rupee invested (1.13) and highest wheat equivalent yield (3614 kg ha^{-1}).

The intercropping of upland rice with legumes were more productive and advantageous on a system basis. The cost of cultivation decreased in rice + urdbean system compared with respective sole crop of rice or urdbean (Ghosh *et al.*, 1986; Prasad *et al.*, 1989). Singh *et al.* (1996) studied the production potential and economics of intercropping of sesamum, urdbean and soybean with upland rice.

Mandal *et al.* (2000) reported that intercropping of blackgram with rice gave the highest rice equivalent yield and the highest net return (Rs. 4683 ha^{-1}) over the respective sole crops. It was concluded that growing of greengram, blackgram and pigeon pea between rice rows was profitable as the values of relative net returns of rice exceeded unity in all intercropping systems.

Pandita *et al.* (2000) observed that intercropping of greengram with maize in 1:2 row ratio gave higher net returns. He found that maize + beans intercropping gave highest benefit cost ratio (1.87) closely followed by maize + green gram in same proportion (1.74). Hence it was concluded that intercropping of maize with bean in 1:2 row ratio is a biologically and economically sustainable intercropping system for rainfed conditions.

Sarkar *et al.* (2000) reported that intercropping of chickpea and safflower in 1:1 ratio proved to be the most efficient system resulting in maximum chickpea equivalent yield (12.76 q ha^{-1}), gross returns (Rs. 10,846 ha^{-1}) and net monetary returns (Rs. 5, 346 ha^{-1}).

Singh and Singh (2001) studied the economics of maize + soybean intercropping system. Maize + soybean 2:1 row ratio intercropping system produced the maximum net returns (Rs.10,740 ha^{-1}) and benefit cost ratio (2.27) over sole maize net returns (Rs. 5,760 ha^{-1}) and benefit cost ratio (1.79).

From the above literature it can be concluded that intercropping systems are economically more beneficial than sole crops.

2.8 BIOLOGICAL EFFICIENCY OF THE INTERCROPPING SYSTEMS

Francis *et al.* (1976) reported that land utilization efficiency increased with intercropping systems. The land equivalent ratio (LER) is an indicator of efficient land utilization for intercropping systems (Jha and Chandra, 1982).

Rao and Willey (1980) indicated that distinct difference in maturity periods of the component crops usually results in large yield advantages. The type of combination clearly allows the better use of resources over time, which has clearly been noticed particularly in cereal and legume intercropping.

In a field study Mohta and De (1980) reported that maize yields were not affected by intercropping with soybean, but soybean yields were reduced. However the combined grain yield of the two crops in the intercropping system was more than the individual components.

Ghosh *et al.* (1986) conducted studies on intercropping of groundnut and blackgram in rice. The study revealed that the land equivalent ratio increased by 29 per cent in rice + groundnut 2:2 alternated row system to 74 per cent in rice + blackgram 2:2 alternated row system.

Sarkar and Shit (1990) indicated that the higher biological efficiency and LER of 1.4 when maize was intercropped with soybean. Yield advantage was probably due to compatible nature of the component crops in the intercropping system.

Mandal and Mahapatra (1990) studied the effect of intercropping barley with lentil and linseed on yield and net returns. In both intercropping systems, LER exceeded unity indicating greater biological efficiency of intercropping over sole cropping.

The LER values suggest that intercropping is more efficient in utilizing resources than sole cropping of component crops resulting in higher productivity per unit space (Holkar *et al.*, 1991).

Saha and Patro (1993) reported that the little millet + blackgram intercropping system in 2:1 ratio registered the highest little millet equivalent yield (39.4 q ha^{-1}) than their sole crops. The LER and monetary advantage index were also found to be highest with 2:1 row ratio of little millet and blackgram, which indicated superiority of intercropping system to sole cropping system.

The LER value recorded in rice + blackgram intercropping in 4:1 row proportion was highest (1.34) indicating on an average of 34 per cent yield advantage. It was concluded that the yield increase was due to extra yield obtained from intercrop making the combination higher yielding (Ramamoorthy *et al.*, 1994).

Mandal *et al.* (1996) studied the effect of intercropping of chickpea with wheat. The LER worked out from combined intercrop yields was always greater compared to sole crops. The highest LER was recorded with 4:2 row ratio in wheat + chickpea. It was found that on an average, yield advantage up to 9 per cent was achieved from wheat + chickpea intercropping system as compared to monoculture.

Barik (1997) studied the comparison of maize based intercropping systems. The LER of these intercropping treatments varied from 1.22 to 1.45 giving a yield advantage of 22 to 45 per cent over sole cropping. The combination of maize-groundnut and maize + blackgram were found to be advantageous to the other intercropping system giving a yield advantage of 41 per cent and 40 per cent respectively.

In sorghum + ground nut intercropping system, LER was greater than unity, which clearly indicated the yield advantage of the system (Barik *et al.*, 1998).

Pandita *et al.* (2000) reported that the intercropping of maize with legume resulted in higher LER and area time equivalent ratio (ATER) indicating better land utilization efficiency than their sole crops.

Mallick *et al.* (1992) reported that the intercropping of wheat with grain legumes did not affect the energy productivity of wheat. Among the intercropping systems wheat + lentil gave 20 per cent more energy output than wheat alone. Significant increase in productivity under wheat + lentil was because of more total grain production.

Sand and Thakuria (1993) conducted studies on intercropping of fodder cowpea in rice with different row ratios. The studies revealed that the product of relative crowding coefficient (K) were more than one in all the intercropping systems and the highest K value (6.56) was observed with 3:1 row ratio of rice and fodder cowpea. The aggressivity values were also highest with rice-cowpea in 3:1 row ratio indicating the bigger difference in competitive abilities between the component crops and clearly indicated that rice was the dominant companion to cowpea.

Mandal *et al.* (1997) reported that in the rice + groundnut intercropping system ATER, LER, relative value total, relative crowding coefficient and competitive ratio were found to be greater than unity indicating that each species gave more yield than expected.

From the review cited above, it is evident that intercropping systems have higher biological efficiency than sole crops.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

A field investigation was carried out during the kharif season of 2001 to find out the optimum row proportion of upland rice to legume combination, to assess the soil fertility improvement and to evolve an economically feasible legume intercropping system in upland rice.

The materials used and methods adopted for the study are detailed below.

3.1 MATERIALS

3.1.1 Experimental Site

The experiment was conducted in the Instructional Farm, attached to the College of Agriculture, Vellayani. The farm is located at $8^0 18'$ N latitude and $76^0 57'$ E longitude at an altitude of 29 m above MSL.

3.1.2 Soil

The soil of the experimental area comes under the textural class of sandy clay loam, belonging to the taxonomical order oxisol. The data on the mechanical and chemical properties of the soil are presented in Table 1 and 2 respectively.

3.1.3 Cropping History of the Field

The experimental area was cultivated with a bulk crop of chillies during the previous season, adopting the normal package of practices recommendations.

3.1.4 Season

The experiment was conducted during the kharif season of 2001. The rice crop was sown on 20-06-2001 and harvesting was completed by 13-10-2001. The legume crops were sown on 20-06-2001 and harvesting of blackgram was completed by 1-09-2001. Harvesting of cowpea was

Table 1. Mechanical analysis of the soil of the experimental site

Sl. No.	Parameters	Content in soil (%)	Method used
1.	Coarse sand	37.20	Bouyoucos Hydrometer method (Bouyoucos, 1962)
2.	Fine sand	15.00	
3.	Silt	17.50	
4.	Clay	30.15	

Table 2. Chemical properties of the soil of the experimental site

Sl. No.	Parameters	Content	Rating	Methods used
1.	Available N (kg ha^{-1})	278.00	Medium	Alkaline potassium permanganate method (Subbiah and Asija, 1956)
2.	Available P_2O_5 (kg ha^{-1})	42.00	Medium	Bray colorimetric method (Bray and Kurtz, 1945)
3.	Exchangeable K_2O (kg ha^{-1})	118.00	Medium	Ammonium acetate method (Jackson, 1973)
4.	pH	4.8	Acidic	1:2:5 soil solution ratio using pH meter with glass electrode (Jackson, 1973)
5.	Organic carbon (%)	0.47	Low	Walkely and Black rapid titration method (Jackson, 1973)

completed by 15-09-2001 and harvesting of greengram was completed by 20-09-2001.

3.1.5 Weather Conditions

The weekly averages of temperature, evaporation, relative humidity and rainfall during the cropping period collected from the meteorological observatory at the College of Agriculture, Vellayani are presented in Appendix – I and illustrated graphically in Fig. 1.

The weather conditions during the period was favourable for the satisfactory growth of the crop.

3.1.6 Crop Characters and Source of Seed Material

Sl. No.	Crop	Variety	Source of seed materials	Characteristics
1.	Upland rice	Matta-triveni	Krishi Bhavan, Navaikulam, Thiruvananthapuram	95 – 105 days duration, variety released by RARS, Pattambi. Grains are red, long and bold. This is tolerant to BPH and susceptible to blast and sheath blight.
2.	Blackgram	T9	National seeds corporation (NSC) Thiruvananthapuram	Pureline selection, 65-70 days duration with the average yield of 1000 kg ha^{-1}.
3.	Greengram	CO2	TNAU, Coimbatore	Variety released by TNAU, Coimbatore. The average yields are 910 $kgha^{-1}$ and 1550 $kgha^{-1}$ under rainfed and irrigated conditions respectively.
4.	Cowpea	Pusa-Komal (K 1552)	NSC, Thiruvananthapuram	High yielding vegetable cowpea. Bushy habit with shallow root system and is suitable for intercropping. The duration ranges from 85 – 90 days.

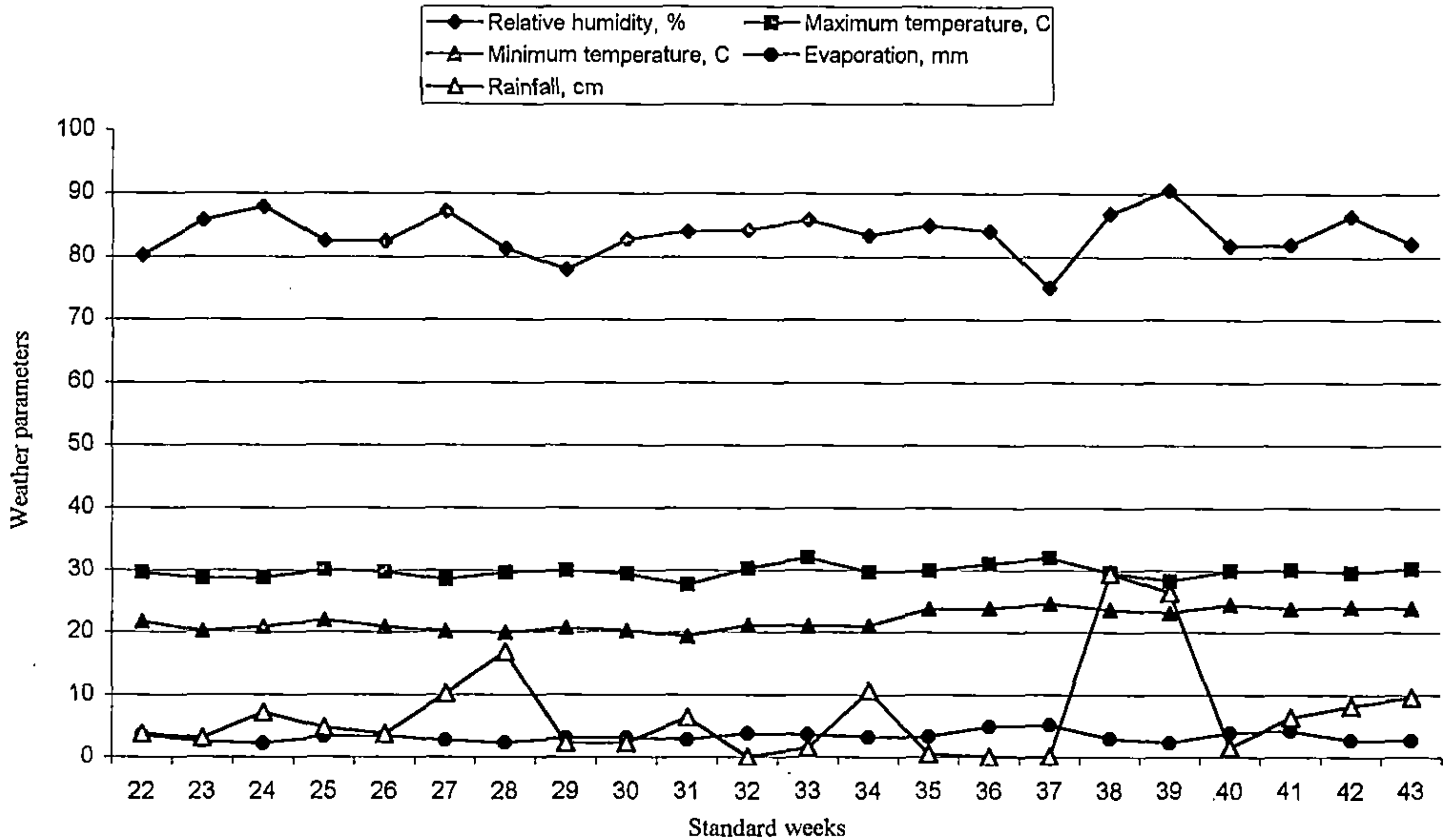

Fig. 1. Weather parameters during the experimental period (June to October, 2001)

3.1.7 Manures and Fertilizers

Farmyard manure (FYM) analysing to 0.5 per cent N, 0.3 per cent P_2O_5 and 0.2 per cent K_2O obtained from local source was used in the study. Urea (46 % N), mussoriephos (18 % P_2O_5) and muriate of potash (60 % K_2O) were used as sources of nitrogen (N), phosphorus (P) and potassium (K) respectively.

3.2 METHODS

3.2.1 Design and Layout

The field experiment was laid out in randomized block design (Snedecor and Cochran, 1967). The experiment consisted of ten treatments with three replications. The layout plan of experiment is given in Fig. 2. The details of the layout are given below.

Number of treatments	: 10
Number of replications	: 3
Gross plot size	: 5 m x 4 m
Net plot size	: 4.6 m x 3.8 m
Spacing	: 20 cm x 15 cm
Total number of plots	: 30

3.2.2 Treatments

T_1 – Upland rice sole

T_2 – Blackgram sole

T_3 – Greengram sole

T_4 – Cowpea sole

T_5 – Upland rice + black gram (2 : 1)

T_6 – Upland rice + greengram (2 : 1)

T_7 – Upland rice + cowpea (2 : 1)

T_8 – Upland rice + blackgram (3 : 1)

T_9 – Upland rice + greengram (3 : 1)

T_{10} – Upland rice + cowpea (3 : 1)

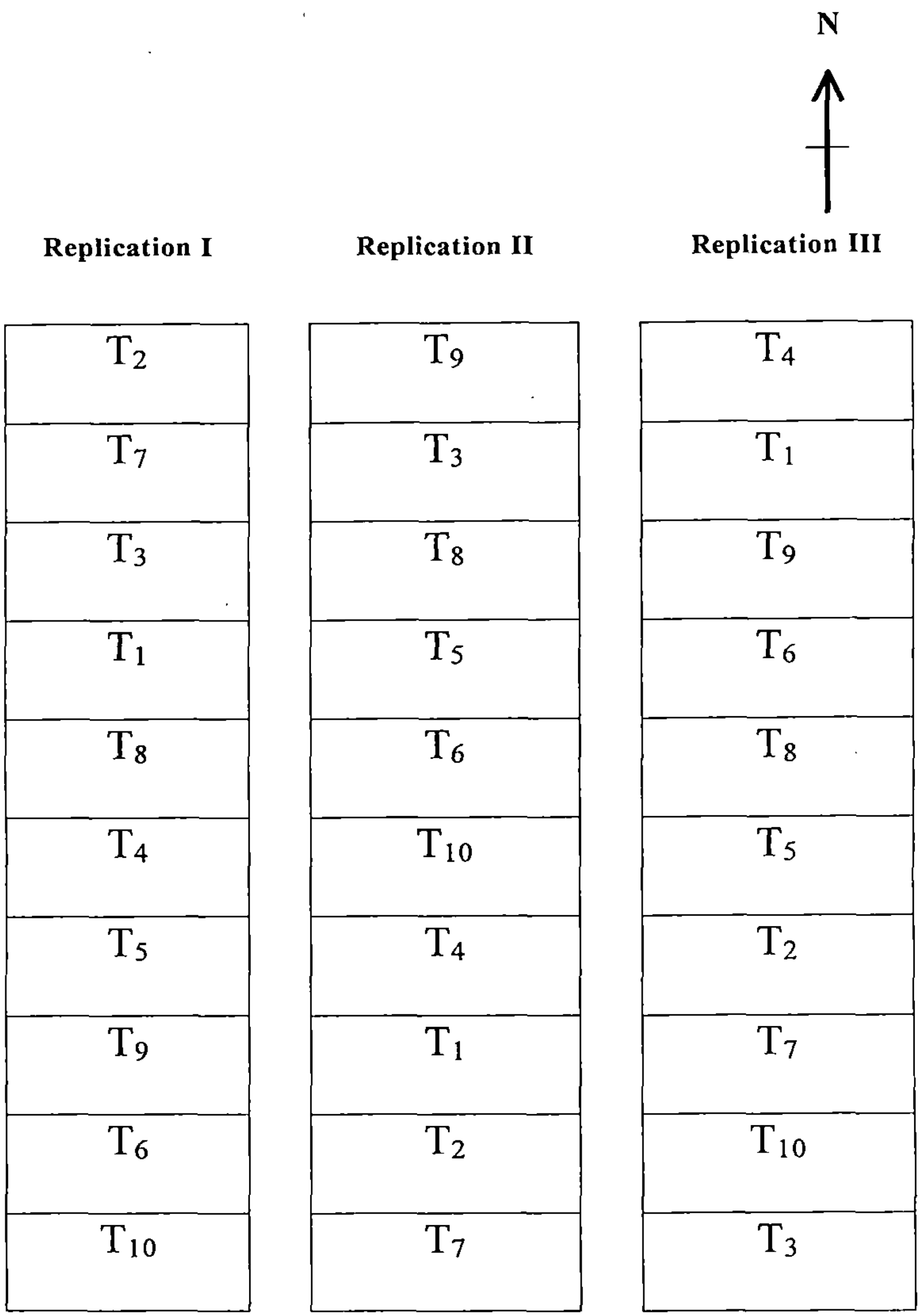

Fig. 2. Layout plan of the experimental site

Plate 1. General view of the experimental site

Plate 2. Performance of rice as sole crop

Plate 3. Rice + blackgram intercropping in 2 : 1 ratio

Plate 4. Rice + greengram intercropping in 2 : 1 ratio

Plate 5. Rice + cowpea intercropping in 2 : 1 ratio

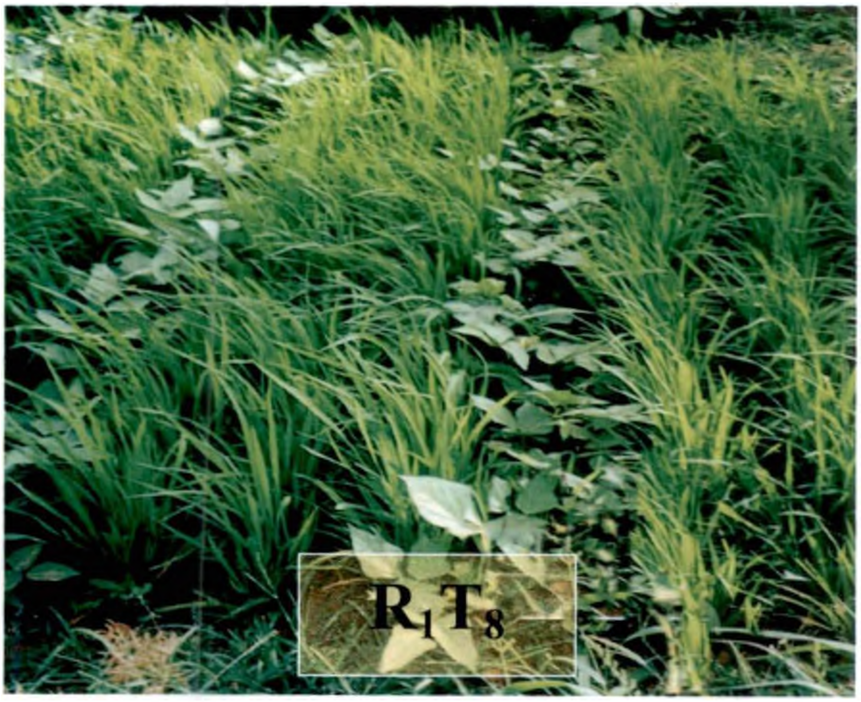

Plate 6. Rice + blackgram intercropping in 3 : 1 ratio

Plate 7. Rice + greengram intercropping in 3 : 1 ratio

3.2.3 Land Preparation

The experimental area was ploughed with power tiller, clods were broken and weeds and stubbles of previous crop were removed. The plots were laid out according to the design of the experiment. The plots were levelled and FYM was applied as per the package of practices recommendations (Kerala Agricultural University, 1996) and incorporated into the soil.

3.2.4 Fertilizers Application

Urea, mussoriephos and muriate of potash were applied as per the package of practices recommendations (Kerala Agricultural University, 1996).

3.2.5 Seeds and Sowing

Rice seeds were dibbled in lines at the rate of 3 – 5 seeds per hole at a depth of 4 cm. Crop management was followed according to the treatment schedule. Legume seeds were sown in lines at the rate of two seeds per hole.

3.2.6 After Cultivation

In rice, gap filling and thinning were done at 10 DAS to secure a uniform stand of the crop. Legumes were also thinned at 10 DAS. According to the POP recommendation, periodic hand weedings were done in all the plots.

3.2.7 Plant Protection

Prophylatic sprays of plant protection chemicals were given to protect the crops from pests and diseases. During flowering, malathion 50 EC @ 1 l ha^{-1} was applied to control earhead bug in rice.

3.2.8 Harvesting

Harvesting of vegetable cowpea started from the 50^{th} day onwards (10-08-2001). Altogether eleven harvests of cowpea were done, over the entire cropping period. Harvesting of blackgram and greengram were started on 23-08-2001 and 12-09-2001 respectively. The pods were picked by hand and beaten with sticks to separate the seeds. The harvesting operation of rice was taken on 13-10-2001.

The bhusa of legumes was incorporated into the soil *in situ* after the final harvest.

3.3 OBSERVATIONS RECORDED

Observations on growth characters, yield and yield attributing characters of rice, blackgram, greengram and cowpea were recorded and the mean values were worked out.

Five plants each of upland rice and legumes were selected at random as observational plants in each plot after eliminating the border rows and all the biometric observations were recorded from these plants at various growth stages. At harvest, observational plants were used for drymatter estimation and chemical analysis.

Parameters considered and methods followed are briefly described here under.

3.3.1 Growth Characters

3.3.1.1 Upland Rice

3.3.1.1.1 Height of the plant

The height of the plant (cm) was recorded on 30, 60 DAS and at harvest. Five plants were selected diagonally in each plot for measuring the height. Height was measured from the base of the plant to the tip of the longest leaf or to the tip of the longest earhead whichever was taller.

3.3.1.1.2 Plant and root spread

3.3.1.1.2.1 Plant spread

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

3.3.1.1.2.2 Root spread

Roots of each hill after washing were placed as such on a plain paper and maximum width of the root system was measured and expressed in cm.

3.3.1.1.3 Tiller number per hill

Tiller number was counted at 30, 60 DAS and at harvest from the sample plants, the mean values were worked out and recorded.

3.3.1.1.4 Leaf area index

Leaf area index was recorded by using the length and width method, according to which the leaf area = k x l x w, where k is the crop factor (0.75), l is the length and w is the maximum width. Leaf area index was calculated using the formula suggested by Watson (1958).

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

3.3.1.1.5 Dry matter production

At harvest, the sample plants were dried at 70^0C for 48 hours, weighed and expressed as drymatter production in t ha^{-1}.

3.3.1.2 Legumes

3.3.1.2.1 Height of the plant

The height of the plant (cm) was recorded at 30 DAS and at harvest. The height was measured from the base to the growing point and the average was worked out.

3.3.1.2.2 Plant and root spread

3.3.1.2.2.1 Plant spread

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

3.3.1.2.2.2 Root spread

Roots of each plant after washing were placed as such on a plain paper and maximum width of the root system was measured and expressed in cm.

3.3.1.2.3 Number of branches per plant

Number of branches were counted from five sample plants and the mean number was worked out.

3.3.1.2.4 Leaf area index

Leaf area was calculated by using the graphical method. LAI was calculated using the formula suggested by Watson (1958).

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

3.3.1.2.5 Dry matter production

Dry matter production was recorded at harvest. The sample plants were dried at $70^{O}C$ for 48 hours, weighed and expressed in t ha^{-1}.

3.3.2 Yield and Yield Attributing Characters

3.3.2.1 Rice

3.3.2.1.1 Days to 50 per cent flowering

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

3.3.2.1.2 Number of productive tillers per hill

At harvest, productive tillers were counted in five sample hills and the mean number was worked out.

3.3.2.1.3 Length of panicle

Ten panicles were separately weighed from each plot, the mean weight was worked out and expressed in grams.

3.3.2.1.4 Number of spikelets per panicle

The spikelets were removed from ten panicles, counted and the mean number of spikelets was recorded.

3.3.2.1.5 Number of filled grains per panicle

The filled grains were separated from ten panicles, counted and the mean number was recorded.

3.3.2.1.6 Chaff percentage

The chaff percentage was worked out using the formula

$$\text{Chaff percentage} = \frac{\text{Number of unfilled grains}}{\text{Total number of grains}} \times 100$$

3.3.2.1.7 Thousand grain weight

The weight of one thousand grains from the cleaned produce drawn from each plot was recorded in grams.

3.3.2.1.8 Grain yield

The grains harvested from each net plot area were cleaned, dried, weighed and expressed in kg ha^{-1}.

3.3.2.1.9 Straw yield

The straw harvested from each net plot area was dried under sun and weight was expressed in kg ha^{-1}.

3.3.2.1.10 Harvest index

Harvest index (HI) was calculated using the formula

$$HI = \frac{\text{Economic yield}}{\text{Biological yield}}$$

3.3.2.2 Legumes

3.3.2.2.1 Days to 50 per cent flowering

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

3.3.2.2.2 Number of pods per plant

Pods were collected from five sample plants and the mean number was worked out.

3.3.2.2.3 Length of pod

Ten pods were collected from each plot, length was measured from one end to another and the average was expressed in cm.

3.3.2.2.4 Weight of pod

Ten pods were collected from each plot. Weight was recorded and the average was worked out and expressed in grams.

3.3.2.2.5 Number of filled grains per pod

The filled grains were separated from each pod, counted and the mean number of ten pods was recorded.

3.3.2.2.6 Hundred-grain weight

The weight of one hundred grains from the cleaned produce drawn from each plot was recorded in grams.

3.3.2.2.7 Grain yield

The grains harvested from each net plot area was dried to constant weight under sun, cleaned, weighed and expressed in kg ha^{-1}.

3.3.2.2.8 Stover yield

The plants pulled out from each net plot area were dried to constant weight under sun and the weight was expressed in kg ha^{-1}.

3.3.2.2.9 Harvest Index

Harvest Index [HI] was calculated using the formula

$$HI = \frac{\text{Economic yield}}{\text{Biological yield}}$$

3.4 CHEMICAL ANALYSIS

3.4.1 Soil Analysis

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

3.4.2 Plant Analysis

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

The plants were chopped and dried in air-oven at 70 ± 5^0C separately till constant weight was obtained. Samples were ground to pass through a sieve of 0.5 mm mesh. The required quantity of samples was then weighed accurately in electronic balance and analysed.

3.4.3 Nutrient Uptake Studies

3.4.3.1 Uptake of Nitrogen

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

3.4.3.2 Uptake of Phosphorus

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

3.4.3.3 Uptake of Potassium

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

3.4.4 Protein Content of Grains

Protein percentage was estimated by multiplying the nitrogen content of the grain with 6.25.

3.5 PEST AND DISEASE INCIDENCE

Plants were scored for pest attack and disease incidence. In all cowpea plots, fusarium wilt incidence was noted. The disease was scored based on per cent disease incidence using the formula suggested by Horsfall and Heuburger (1942).

$$\text{Per cent disease incidence} = \frac{\text{No. of disease infected plants}}{\text{Total number of plants observed}} \times 100$$

3.6 PARAMETERS FOR EVALUATION OF CROPPING SYSTEM

3.6.1 Biosuitability

3.6.1.1 Land Equivalent Ratio (LER)

LER was calculated using the formula suggested by Mead and Willey (1980).

$$\text{LER} = \frac{\text{Intercrop yield of 'a'}}{\text{Pure crop yield of 'a'}} + \frac{\text{Intercrop yield of 'b'}}{\text{Pure crop yield of 'b'}}$$

Where 'a' and 'b' are component crops.

3.6.1.2 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 of intercrop

3.6.1.3 Competition Ratio

The competition ratio of intercrop components was calculated using the formula suggested by Willey and Rao (1981).

Competition ratio for component a

$$\frac{LER_a}{LER_b} \times \frac{Z_{ba}}{Z_{ab}}$$

Where LER_a and LER_b are the land equivalent ratio of 'a' and 'b' component crops. Z_{ba} and Z_{ab} are the sown proportion of component 'b' in combination with 'a' and sown proportion of component 'a' in combination with 'b'.

3.6.1.4 Aggressivity

The aggressivity was calculated as per the following formula given by Mc Gilchrist (1965).

$$\text{Aggressivity (Aab)} = \frac{\text{Mixture yield of 'a'}}{\text{Expected yield of 'a'}} - \frac{\text{Mixture yield of 'b'}}{\text{Expected yield of 'b'}}$$

3.6.1.5 Relative Crowding Coefficient (RCC)

The relative crowding coefficient was calculated using the formula proposed by de Wit (1960).

$$\text{Relative crowding coefficient} = \frac{\text{Mixture yield of 'a'}}{\text{Pure stand yield of 'a'} - \text{mixture yield of 'a'}}$$

3.6.2 Economic Efficiency

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

3.6.2.1 Cost of Cultivation

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

3.6.2.2 Gross Return

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

3.6.2.3 Net Return

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

3.6.2.4 Benefit-Cost Ratio (BCR)

Benefit-cost ratio was worked out as per the formula given below.

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

3.6.2.5 Rice Equivalent Yield (REY)

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

$$\text{REY} = \frac{\text{Yield of legume(kg ha}^{-1}\text{)}}{\text{Market price of rice(Rs.kg}^{-1}\text{)}} \times \text{Market price of legume(Rs.kg}^{-1}\text{)}$$

3.7 STATISTICAL ANALYSIS

The analysis of variance technique (ANOVA) was applied to draw inferences from the data (Gomez and Gomez, 1984). Wherever the effects were found to be significant, critical differences were calculated for effecting comparison among the means. Correlation studies were also carried out between yield and yield attributes.

RESULTS

4. RESULTS

The experiment was conducted to assess the production potential and economics of upland rice + legume intercropping systems, to assess the soil fertility improvement and to find out an optimum row proportion of upland rice to legume combination at the Instructional farm, College of Agriculture, Vellayani. The field experiment was conducted during the period from June 2001 to October 2001.

The experimental data collected were statistically analysed and the results obtained are presented below.

4.1 GROWTH CHARACTERS

The plant growth was measured in terms of plant height, plant and root spread, tiller number $hill^{-1}$, leaf area index and dry matter production.

4.1.1. Rice

4.1.1.1 Height of Plants

The average height of plants at 30 DAS, 60 DAS and at harvest are presented in Table 3.

At 30 DAS, the maximum height of 38.51 cm was recorded by the sole rice and it was on par with the treatment combination of rice + blackgram (3:1) and rice + cowpea (3:1) ratios. The lowest height (33.15 cm) was noticed in the rice + greengram (2:1) which was on par with rice + greengram (3:1) and was inferior to all other treatments.

At 60 DAS, eventhough the maximum height (66.92 cm) was found in the sole rice plot, it was on par with all other treatments except rice intercropped with greengram. The lowest height was found in rice + greengram (2:1) ratio which was on par with rice + greengram at 3 : 1 ratio.

Table 3. Height of rice at different days after sowing, cm

Treatments	30 DAS	60 DAS	Harvest
T_1	38.51	66.92	82.95
T_5	36.24	64.82	81.53
T_6	33.15	58.75	72.40
T_7	36.10	65.17	79.44
T_8	36.52	65.21	81.74
T_9	34.33	61.11	76.49
T_{10}	36.45	65.55	80.53
$F_{6, 12}$	5.762*	7.662**	61.800**
SE	0.715	1.046	0.468
CD	2.203	3.224	1.442

* Significant at 5 % level

** Significant at 1 % level

DAS – Days after sowing

At harvest also, the maximum height (82.95 cm) was found in sole rice. It was significantly superior to all other treatments except when intercropped with blackgram. The treatment combination of rice with greengram in 2:1 ratio recorded the lowest height (72.40 cm).

4.1.1.2 Plant and Root Spread

The mean plant and root spread recorded at harvest are given in Table 4.

4.1.1.2.1 Plant spread

The maximum plant spread of 6.87 cm observed in rice + blackgram in 2:1 ratio was on par with all other treatments except when intercropped with greengram. The lowest plant spread (6.33 cm) was recorded by the treatment rice + green gram in 2:1 ratio.

4.1.1.2.2. Root spread

The root spread was significantly influenced by the treatment combinations. Sole rice recorded the highest root spread of 3.27 cm and was superior to all other treatments When rice was intercropped with greengram in 2:1 ratio, it resulted in the lowest root spread (3.03 cm).

4.1.1.3 Tiller Number Hill^{-1}

The mean number of tillers hill^{-1} recorded at 30 DAS, 60 DAS and at harvest are presented in Table 5.

The different intercropping treatments did not significantly influence the number of tillers hill^{-1} when observed at 30 DAS, 60 DAS and at harvest. The number of tillers hill^{-1} for the sole rice was 9.20, 10.20 and 10.10 at 30 DAS, 60 DAS and at harvest respectively.

4.1.1.4 Leaf Area Index

The mean LAI of plants observed at 60 DAS are presented in Table 6.

At 60 DAS, rice intercropped with blackgram in 2:1 ratio recorded the maximum LAI of 4.24. It was significantly superior to all other

Table 4. Plant and root spread of rice at harvest, cm

Treatments	Plant spread	Root spread
T_1	6.79	3.27
T_5	6.87	3.16
T_6	6.33	3.03
T_7	6.80	3.15
T_8	6.83	3.21
T_9	6.44	3.10
T_{10}	6.84	3.17
$F_{6, 12}$	31.883**	12.023**
SE	0.038	0.022
CD	0.120	0.069

** Significant at 1 % level

Table 5. Tiller number hill^{-1} of rice at different days after sowing

Treatments	30 DAS	60 DAS	Harvest
T_1	9.20	10.20	10.10
T_5	7.90	8.70	8.60
T_6	7.60	8.83	8.73
T_7	8.43	9.40	9.46
T_8	8.16	9.10	9.30
T_9	9.00	9.86	9.80
T_{10}	8.53	9.46	9.63
$F_{6, 12}$	0.883^{NS}	0.831^{NS}	0.821^{NS}
SE	0.608	0.593	0.604
CD	-	-	-

NS-not significant
DAS – Days after sowing

treatments except rice intercropped with cowpea in both 2:1 and 3:1 ratios and rice intercropped with blackgram in 3:1 proportion. The rice + greengram intercropping in 2:1 proportion recorded the lowest leaf area index (3.42).

4.1.1.5 Dry Matter Production

The dry matter production recorded at harvest are given in Table 6.

Sole crop of rice recorded significantly higher dry matter production (7931.19 kg ha^{-1}) as compared to other intercropping treatments. The dry matter production of rice when intercropped with blackgram in 2:1 and 3:1 ratios were 5128.17 and 5571.68 kg ha^{-1} respectively. On the other hand, when greengram was the intercrop, the dry matter productions were 2454 and 3758 kg ha^{-1} in 2:1 and 3:1 ratios respectively. The lowest dry matter production (2454 kg ha^{-1}) was recorded when rice and greengram were grown in 2:1 ratio.

4.1.2 Blackgram

4.1.2.1 Height of the Plant

The mean height of plants recorded at 30 DAS, 60 DAS and at harvest are given in Table 7.

The treatment combination of rice and blackgram in 3:1 ratio recorded the maximum height at 30 DAS (16.58 cm) and at harvest (42.92 cm), which was on par with the treatment combination of rice and blackgram in 2:1 ratio. It was significantly superior to other treatments at 30 DAS and at harvest. At 60 DAS, the height was not significantly influenced by various treatments.

The sole blackgram showed lesser height at 30 DAS (13.50 cm), 60 DAS (35.39 cm) and at harvest (38.93 cm).

4.1.2.2 Plant and Root Spread

The data on plant and root spread are given in Table 8

Table 6. Leaf area index (LAI) at 60 DAS and dry matter production at harvest of rice

Treatments	LAI	Drymatter production ($kg\ ha^{-1}$)
T_1	3.88	7931
T_5	4.24	5128
T_6	3.42	2454
T_7	4.20	5117
T_8	4.09	5571
T_9	3.54	3758
T_{10}	4.14	5040
$F_{6,\ 12}$	40.671**	328.660**
SE	0.051	92.769
CD	0.160	285.87

** Significant at 1 % level
LAI – Leaf area index

Table 7. Height of blackgram at different days after sowing, cm

Treatments	30 DAS	60 DAS	Harvest
T_2	13.50	35.39	38.93
T_5	16.50	37.62	42.49
T_8	16.58	38.18	42.92
$F_{2,\ 4}$	64.478*	3.010^{NS}	511.078**
SE	0.218	0.851	0.096
CD	0.858	-	0.379

* Significant at 5 % level
** Significant at 1 % level
NS-not significant
DAS – Days after sowing

4.1.2.2.1 Plant spread

At harvest, the plant spread was significantly influenced by the treatments. The treatment combination of rice and blackgram in 2:1 ratio recorded the maximum plant spread (13.11 cm) and it was significantly superior to all other treatments. The lowest plant spread (8.16 cm) was recorded by the sole blackgram.

4.1.2.2.2 Root spread

The maximum root spread (8.30 cm) was found in blackgram intercropped with rice in 1:3 ratio and was significantly superior to other treatments. The lowest root spread (7.59 cm) was observed in the sole blackgram.

4.1.2.3 Number of Branches Plant^{-1}

The data on mean number of branches are given in Table 9.

In blackgram, branching was initiated one month after sowing. At harvest, the maximum number of branches (5.64) was produced by blackgram intercropped with rice in 1:2 ratio, which was significantly superior to all other treatments. The lowest number of branches (3.49) was observed in the sole blackgram.

4.1.2.4 Leaf Area Index

The mean LAI is presented in Table 9.

The leaf area index of blackgram was significantly influenced by the different treatments.

The blackgram intercropped with rice in 1:3 ratio recorded the highest LAI (3.83). It was on par with blackgram and rice grown in 2:1 ratio. The lowest leaf area index (3.09) was recorded by the sole blackgram.

4.1.2.5 Dry matter Production

The data on dry matter production are given in Table 9.

Table 8. Plant and root spread of blackgram at harvest, cm

Treatments	Plant spread	Root spread
T_2	8.16	7.59
T_5	13.11	7.96
T_8	12.02	8.30
$F_{2, 4}$	834.790**	42.280*
SE	0.090	0.054
CD	0.353	0.215

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

Table 9. Number of branches at harvest, leaf area index at 60 DAS and drymatter production at harvest of blackgram

Treatments	No. of branches	LAI	Drymatter production (kg ha^{-1})
T_2	3.49	3.090	2412
T_5	5.64	3.677	1071
T_8	5.40	3.833	710
$F_{2, 4}$	396.898**	73.494*	768.580**
SE	0.059	0.045	32.362
CD	0.232	0.179	127.05

* Significant at 5 % level
** Significant at 1 % level
LAI – Leaf area index

At harvest, the sole blackgram recorded significantly the highest drymatter production (2412 kg ha^{-1}). The dry matter productions of blackgram when rice and blackgram were grown in 2:1 and 3:1 ratios were 1071 kg ha^{-1} and 710 kg ha^{-1} respectively.

4.1.3 Greengram

4.1.3.1 Height of the Plant

The data on mean height of plants are given in Table 10.

At 30 DAS, the maximum height (23.96 cm) was recorded in greengram intercropped with rice in 1:3 ratio which was significantly superior to other treatments. The lowest height (22.29 cm) was recorded by sole greengram.

At 60 DAS and harvest also, the rice + greengram in 3:1 ratio recorded the highest plant height of 55.28 cm and 77.91 cm respectively, which was significantly superior to other treatments. Sole greengram recorded the lowest height of 51.87 cm and 74.33 cm, at 60 DAS and harvest respectively.

4.1.3.2 Plant and Root Spread

The data on plant and root spread are given in Table 11.

4.1.3.2.1 Plant spread

The treatment combinations significantly influenced the plant spread. At harvest the greengram intercropped with rice in 1:3 ratio recorded significantly the highest plant spread (16.29 cm) and sole greengram recorded significantly the lowest plant spread of 15.12 cm.

4.1.3.2.2. Root spread

At harvest, there was significant difference in the average root spread of greengram.

The root spread of 13.16 cm recorded by the treatment combination of greengram with rice 1:3 ratio was significantly the

Table 10. Height of greengram at different days after sowing, cm

Treatments	30 DAS	60 DAS	Harvest
T_3	22.29	51.87	74.33
T_6	23.55	54.35	76.91
T_9	23.96	55.28	77.91
$F_{2, 4}$	86.316*	61.682*	61.32*
SE	0.093	0.224	0.235
CD	0.367	0.880	0.926

* Significant at 5 % level
DAS – Days after sowing

Table 11. Plant and root spread of greengram at harvest, cm

Treatments	Plant spread	Root spread
T_3	15.12	11.68
T_6	15.97	12.64
T_9	16.29	13.16
$F_{2, 4}$	106.814**	149.463**
SE	0.058	0.061
CD	0.228	0.240

** Significant at 1 % level

highest. The lowest root spread of 11.68 cm was recorded by sole greengram.

4.1.3.3 Number of Branches Plant^{-1}

The data on mean number of branches are given in Table 12.

Effect of various treatments on branching was significant. The highest number of branches produced by greengram intercropped with rice in 1:3 ratio was 7.26 and that was on par with greengram intercropped with rice in 1:2 proportion. The sole greengram produced the lowest number of branches (6.11) and was inferior to all other treatments.

4.1.3.4 Leaf Area Index

The mean LAI is presented in Table 12.

The treatments did not significantly influence the LAI. The highest LAI (4.48) was found in greengram intercropped with rice in 1:3 ratio and the lowest LAI (4.36) was recorded by the greengram intercropped with rice in 1:2 ratio.

4.1.3.5 Dry matter Production

The data on drymatter production are given in Table 12.

The maximum drymatter (1923 kg ha^{-1}) was produced in the sole greengram plot. It was significantly superior to other treatments. Intercropping of green gram with rice in 1:2 ratio and 3:1 ratio produced 902 kg ha^{-1} and 698 kg ha^{-1} respectively.

4.1.4 Cowpea

4.1.4.1 Height of the Plant

The mean height of the plant recorded at 30, 60 DAS and at harvest are given in Table 13.

The cowpea intercropped with rice in 1:3 ratio recorded the maximum height at all stages such as 30 DAS (16.94 cm), 60 DAS (44.41

Table 12. Number of branches at harvest, leaf area index at 60 DAS and drymatter production at harvest of greengram

Treatments	No. of branches	LAI	Drymatter production (kg ha^{-1})
T_3	6.11	4.37	1923
T_6	7.20	4.36	902
T_9	7.26	4.48	698
$F_{2, 4}$	136.66**	0.327^{NS}	455.188**
SE	0.055	0.116	30.766
CD	0.218	-	120.785

* Significant at 5 % level

** Significant at 1 % level

NS – not significant

LAI – Leaf area index

cm) and at harvest (54.64 cm), it was significantly superior to other treatments at 30 DAS, 60 DAS and at harvest.

The plants showed lesser height in sole cowpea plots at 30 DAS (15.64 cm), 60 DAS (41.10 cm) and at harvest (51.54 cm).

4.1.4.2 Plant and Root Spread

The data on plant and root spread are given in Table 14.

4.1.4.2.1 Plant spread

The highest plant spread of 9.62 cm was recorded by cowpea intercropped with rice in 1: 3 ratio which was on par with cowpea intercropped with rice in 1 : 2 ratio. The lowest plant spread (9.11 cm) was observed in sole cowpea which was significantly inferior to all other treatments.

4.1.4.2.2 Root spread

Cowpea intercropped with rice in 1 : 3 ratio recorded significantly the highest root spread of 9.32 cm. The root spread recorded by cowpea intercropped with rice in 1 : 2 ratio and sole cowpea were 9.14 and 8.72 cm.

4.1.4.3 Number of Branches Plant^{-1}

The data on mean number of branches are given in Table 15.

At harvest, the number of branches was significantly influenced by the treatments. The maximum number of branches (6.37) was recorded by cowpea intercropped with rice in 1:2 ratio and was on par with rice + cowpea intercropping 3:1 ratio.

The sole cowpea recorded the lowest number of branches (5.28) and was inferior to all other treatments.

4.1.4.4 Leaf Area Index

The mean LAI is presented in Table 15.

The treatments significantly influenced the LAI.

Table 13. Height of cowpea at different days after sowing, cm

Treatments	30 DAS	60 DAS	Harvest
T_4	15.64	41.10	51.54
T_7	16.57	43.65	54.09
T_{10}	16.94	44.41	54.64
$F_{2,4}$	50.603*	249.783**	226.54**
SE	0.093	0.109	0.109
CD	0.368	0.430	0.430

* Significant at 5 % level

** Significant at 1 % level

DAS – Days after sowing

Table 14. Plant and root spread of cowpea at harvest, cm

Treatments	Plant spread	Root spread
T_4	9.11	8.720
T_7	9.57	9.140
T_{10}	9.62	9.327
$F_{2,4}$	40.874*	703.03**
SE	0.043	0.011
CD	0.171	0.046

* Significant at 5 % level

** Significant at 1 % level

The cowpea intercropped with rice in 1:2 ratio recorded the highest LAI of (3.85) and was on par with rice + cowpea in 3:1 ratio.

Among the treatments, the lowest value of LAI (3.28) was observed in sole cowpea.

4.1.4.5 Dry matter Production

The data on dry matter production are given in Table 15.

At harvest, the sole cowpea produced the maximum dry matter (2004 kg ha^{-1}), which was significantly superior to other treatments. The dry matter production of cowpea when rice and cowpea were grown in 2:1 and 3:1 ratios were 1175 and 849 kg ha^{-1} respectively.

4.2 YIELD AND YIELD ATTRIBUTING CHARACTERS

4.2.1 Rice

4.2.1.1 Days to 50 per cent Flowering

The mean number of days taken for 50 per cent flowering are given in Table 16.

There was no significant difference in the number of days taken for 50 per cent flowering with respect to the various treatments.

4.2.1.2 Number of Productive Tillers $Hill^{-1}$

The mean number of productive tillers $hill^{-1}$ are given in Table 16.

The number of productive tillers $hill^{-1}$ was significantly influenced by treatments.

The maximum number of productive tillers $hill^{-1}$ (8.76) was observed in rice + cowpea intercropping in 3:1 ratio. It was on par with all other treatments except when grown with greengram.

The rice intercropped with greengram in 2:1 ratio recorded the lowest number of productive tillers $hill^{-1}$ (5.06) which was on par with rice intercropped with greengram in 3:1 ratio.

4.2.1.3 Length of Panicle

The data on mean length of panicle are presented in Table 16.

Table 15. Number of branches at harvest, leaf area index at 60 DAS and drymatter production at harvest of cowpea

Treatments	No. of branches	LAI	Drymatter production (kg ha^{-1})
T_4	5.28	3.28	2004
T_7	6.37	3.85	1175
T_{10}	6.21	3.83	849
$F_{2, 4}$	82.089*	36.511*	993.877**
SE	0.065	0.053	18.880
CD	0.256	0.208	74.150

* Significant at 5 % level

** Significant at 1 % level

The length of panicle was significantly affected by treatments. The length of panicle was maximum (22.43 cm) when rice was intercropped with blackgram in 3:1 ratio. It was on par with sole rice and rice + cowpea intercropping in 2:1 and 3:1 ratios. The lowest length of panicle (18.80 cm) was observed in rice + greengram intercropping in 2:1 ratio.

4.2.1.4 Weight of Panicle

The results observed on weight of panicle are presented in Table 16.

The rice intercropped with cowpea in 3:1 ratio produced the maximum weight of panicle (12.58 g) and was on par with the rice intercropped with cowpea in 2:1 ratio and with blackgram in 2:1 and 3:1 ratios. The lowest weight of panicle was observed in rice + greengram intercropping in 2:1 ratio.

4.2.1.5 Number of Spikelets Panicle^{-1}

The data on mean number of spikelets panicle^{-1} are presented in Table 17.

The number of spikelets panicles^{-1} was maximum (110.00) in rice + cowpea intercropping in 2:1 ratio and was on par with the rice intercropped with blackgram in both 2:1 and 3:1 ratios and with cowpea in 3:1 ratio. The number of spikelets produced by sole rice (90.66) and rice+greengram intercropping in 3:1 ratio (84.66) were on par. The rice+greengram in 2:1 ratio recorded the lowest number of spikelets panicle^{-1} (72.66) and was inferior to all other treatments.

4.2.1.6 Number of Filled Grains Panicle^{-1}

The data on mean number of filled grains panicle^{-1} are presented in Table 17.

The number of filled grains panicle^{-1} was significantly influenced by the treatments. Rice + cowpea intercropping in 3:1 ratio recorded the

Table 16. Yield attributes of rice

Treatments	Days to 50 % flowering	Number of productive tillers hill^{-1}	Length of panicle (cm)	Weight of panicle (g)
T_1	67.00	7.80	21.92	11.79
T_5	68.00	7.13	21.44	12.45
T_6	68.00	5.06	18.80	6.83
T_7	68.00	7.86	22.12	12.44
T_8	67.66	8.03	22.43	12.39
T_9	67.33	5.70	19.63	7.70
T_{10}	67.66	8.76	22.10	12.58
$F_{6, 12}$	2.795^{NS}	5.750*	41.728**	253.39**
SE	0.230	0.558	0.218	0.156
CD	-	1.720	0.674	0.483

* Significant at 5 % level

** Significant at 1 % level

NS-not significant

maximum number of filled grains panicle^{-1} (92.00) and was on par with rice intercropped with blackgram in 2:1 and 3:1 ratios and with cowpea in 2:1 ratio. The rice intercropped with greengram in 2:1 combination recorded the lowest number of filled grains panicle^{-1} (31.66) and was inferior to all other treatments.

4.2.1.7 Chaff Percentage

The results on chaff percentage are given in Table 17.

The chaff percentage recorded by rice + greengram intercropping in 2:1 ratio was significantly the highest (56.53 per cent). The lowest chaff percentage (15.03) was recorded by the rice intercropped with blackgram in 2:1 ratio and was on par with all other treatments except when rice was intercropped with greengram in both 2:1 and 3:1 ratios.

4.2.1.8 Thousand Grain Weight

The data on mean 1000 grain weight are presented in Table 17.

The 1000 grain weight was found to be significantly influenced by the treatments. The highest 1000 grain weight of 23.10 g was recorded by rice, when it was intercropped with blackgram in 3 : 1 ratio. It was on par with the intercropped rice with blackgram in 2 : 1 ratio and with cowpea in 3 : 1 ratio. The intercropped rice with greengram in 2 : 1 ratio produced the lowest 1000 grain weight of 21.14 g and was on par with rice + greengram intercropping in 3 : 1 ratio.

4.2.1.9 Protein Content

The data on protein content of grains are presented in Table 18.

Various treatments significantly influenced the protein content of grains. The highest protein content (4.96 %) was recorded by rice + greengram intercropping in 2:1 ratio. Sole rice recorded the lowest protein content (3.84 %).

4.2.1.10 Grain Yield

The effect of treatments on the grain yield are given in Table 18.

Table 17. Number of spikelets panicle^{-1}, number of filled grains panicle^{-1}, chaff percentage and thousand grain weight of rice

Treatments	Number of spikelets panicle^{-1}	Number of filled grains panicle^{-1}	Chaff percentage	1000-grain weight (g)
T_1	90.66	74.33	17.95	22.43
T_5	108.33	92.00	15.03	22.79
T_6	72.66	31.66	56.53	21.14
T_7	110.00	92.00	16.36	22.51
T_8	109.66	91.33	20.02	23.10
T_9	84.66	46.33	48.69	21.32
T_{10}	109.66	92.00	16.05	22.85
$F_{6, 12}$	20.006**	119.150**	57.03**	48.55**
SE	3.410	2.314	2.324	0.110
CD	10.510	7.132	7.16	0.340

** Significant at 1 % level

The sole crop of rice recorded the maximum grain yield of 2436 kg ha^{-1} and was significantly superior to all other treatments. In the case of rice + blackgram intercropping, the yield of rice was 1633 kg ha^{-1} for 2:1 ratio and 1896 kg ha^{-1} for 3:1 ratio.

The yield of rice when intercropped with greengram in the ratio of 2:1 and 3:1 were 565 and 972 kg ha^{-1} respectively. Rice intercropped with greengram in 2:1 ratio recorded the lowest grain yield.

The yield of rice when intercropped with cowpea in the ratio of 2:1 and 3:1 were 1596 and 1795 kg ha^{-1} respectively. The decrease in yield in 2:1 and 3:1 ratio were 35 and 27 per cent respectively when compared with sole rice.

4.2.1.11 Straw Yield

The results observed on straw yield are presented in Table 18.

Sole crop of rice recorded significantly higher straw yield (5218 kg ha^{-1}) as compared to intercropping treatments. The yield of rice when intercropped with blackgram in 2:1 and 3:1 ratio were 3249 and 3428 kg ha^{-1} respectively. On the other hand, when greengram was the intercrop, the yields were 1633 and 2523 kg ha^{-1} in 2:1 and 3:1 ratio respectively. The straw yield of rice when intercropped with cowpea in 2:1 and 3:1 ratio were 3297 and 3341 kg ha^{-1} respectively. Thus the minimum straw yield was recorded when rice and greengram were grown in 2:1 ratio.

4.2.1.12 Harvest Index (HI)

The results on HI are presented in Table 18.

The highest HI of 0.356 was obtained when rice was grown with blackgram in 3:1 ratio and was on par with rice intercropped with cowpea in 3:1 ratio. It was superior to all other treatments.

The rice intercropped with greengram in 2:1 recorded the lowest HI of 0.257 and was significantly inferior to other treatments. The sole rice recorded the harvest index of 0.318.

Table 18. Grain yield, straw yield and harvest index of rice

Treatments	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index	Protein content (%)
T_1	2436.66	5218.57	0.318	3.84
T_5	1633.33	3249.27	0.334	4.82
T_6	565.00	1633.45	0.257	4.96
T_7	1596.33	3297.70	0.326	4.93
T_8	1896.66	3428.35	0.356	4.71
T_9	972.33	2523.39	0.277	4.80
T_{10}	1795.43	3341.56	0.349	4.56
$F_{6, 12}$	499.388*	231.536**	202.049**	60.03**
SE	27.304	71.252	0.002	0.026
CD	84.148	219.56	0.008	0.153

* Significant at 5 % level

** Significant at 1 % level

4.2.2 Blackgram

4.2.2.1 Days to 50 per cent Flowering

The data on days to 50 per cent flowering are given in Table 19.

Treatments did not have any significant effect on number of days to 50 per cent flowering.

4.2.2.2 Number of Pods Plant^{-1}

The mean number of pods plant^{-1} is presented in Table 19.

The number of pods plant^{-1} was not affected significantly by the various treatments.

4.2.2.3 Length of Pod

The mean length of pod is presented in Table 19.

The treatments did not significantly affect the length of pod.

4.2.2.4 Weight of Pod

The mean weight of pod is given in Table 19.

No significant difference of weight of pod was observed with respect to the various treatments.

4.2.2.5 Number of Filled Grains Pod^{-1}

The mean number of filled grains pod^{-1} is presented in Table 20.

The number of filled grains was significantly influenced by the treatments effect.

The blackgram intercropped with rice in 1:2 ratio recorded the maximum number of filled grain pod^{-1} (8.43) and was on par with the blackgram intercropped with rice in 1:3 ratio. The sole crop of blackgram gave the lowest number of filled grains pod^{-1} (7.45).

4.2.2.6 Hundred Grain Weight

The results on hundred grain weight are presented in Table 20.

Table 19. Yield attributes of black gram

Treatments	Days to 50 % flowering	Number of pods plant^{-1}	Length of pod(cm)	Weight of pod (g)
T_2	38.33	7.50	4.98	0.571
T_5	38.66	8.85	5.37	0.629
T_8	38.66	8.64	5.14	0.628
$F_{2, 4}$	18.508^{NS}	15.731^{NS}	5.155^{NS}	4.773^{NS}
SE	0.069	0.183	0.086	0.015
CD	-	-	-	-

NS -not significant

There was no significant influence on hundred grain weight by various treatments.

*4.2.2.7 **Protein Content***

The mean values of the protein content of seeds in percentage are given in Table 20.

The sole crop of blackgram recorded the highest percentage of protein content (22.44 %) and was significantly superior to all other treatments. The lowest percentage of protein content (21.79 %) was observed when blackgram was intercropped with rice in 1:3 ratio.

*4.2.2.8 **Grain Yield***

The results on grain yield are presented in Table 21.

The sole crop of blackgram recorded the highest seed yield (675 kg ha^{-1}) and it was significantly superior to other intercropping treatments.

Among the intercropping treatments, 2:1 row proportion gave significantly higher yield (323.33 kg ha^{-1}) than 3:1 proportion.

*4.2.2.9 **Stover Yield***

The results are presented in Table 21.

The sole crop of blackgram recorded significantly higher biological yield (1741.75 kg ha^{-1}) as compared to intercropping treatments. The lowest yield (474.68 kg ha^{-1}) was recorded when it was intercropped with rice in 1:3 ratio, which was significantly inferior to all other treatments.

*4.2.2.10 **Harvest Index***

The results are given in Table 21.

The treatments did not have any significant effect on HI.

Table 20. Number of filled grains pod^{-1}, hundred grain weight, protein content of seeds of blackgram

Treatments	No.of filled grains pod^{-1}	Hundred grain weight (g)	Protein content (%)
T_2	7.45	4.58	22.44
T_5	8.43	4.79	21.82
T_8	8.37	4.83	21.79
$F_{2, 4}$	68.057*	5.824^{NS}	38.139*
SE	0.066	0.055	0.059
CD	0.260	-	0.232

* Significant at 5 % level

NS-not significant

Table 21. Grain yield, stover yield and harvest index of blackgram

Treatments	Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Harvest index
T_2	675.00	1741.75	0.279
T_5	323.33	740.57	0.304
T_8	208.33	474.68	0.306
$F_{2, 4}$	1021.374**	524.069**	4.970^{NS}
SE	7.607	29.186	0.006
CD	29.866	114.580	-

** Significant at 1 % level

NS-not significant

4.2.3 Greengram

4.2.3.1 Days to 50 per cent Flowering

The data on mean values are given in Table 22.

The number of days taken for 50 per cent flowering was not significantly influenced by the treatments.

4.2.3.2 Number of Pods Plant^{-1}

The mean number of pods plant^{-1} is prescribed in Table 22.

In greengram, the number of pods remained unaffected by the treatments.

4.2.3.3 Length of Pod

The mean length of pod is presented in Table 22.

In greengram, length of pod was significantly influenced by the treatments. The maximum length of pod (9.23 cm) was noticed in intercropping of rice and greengram in 2 : 1 and 3 : 1 ratios. The sole crop produced the lowest pod length of 8.63 cm.

4.2.3.4 Weight of Pod

The mean weight of pod is given in Table 22.

No significant difference in weight of pod was observed with respect to the various treatments.

4.2.3.5 Number of Filled Grains Pod^{-1}

The mean number of filled grains pod^{-1} is presented in Table 23.

The number of filled grains was not significantly influenced by the various treatments.

4.2.3.6 Hundred Grain Weight

The results on 100 grain weight are presented in Table 23.

Hundred grain weight did not show any variation among the treatments.

Table 22. Yield attributes of greengram

Treatments	Days to 50 % flowering	Number of pods $plant^{-1}$	Length of pod(cm)	Weight of pod (g)
T_3	43.33	6.65	8.63	0.685
T_6	43.66	6.93	9.23	0.757
T_9	43.66	6.99	9.23	0.757
$F_{2, 4}$	10.913 ^{NS}	1.651 ^{NS}	26.65*	6.329 ^{NS}
SE	0.086	0.140	0.067	0.016
CD	-	-	0.264	-

* Significant at 5 % level
NS-not significant

4.2.3.7 Protein Content

The mean values of the protein content of seeds in percentage are given in Table 23.

The percentage of protein content was significantly influenced by the treatments. The sole crop produced the maximum of protein content (22.88 %) and the lowest (22.14 %) was noticed when rice and greengram were intercropped in 3 : 1 ratio. The protein content of 22.47 per cent was obtained with the treatment combination of rice and greengram in 2 : 1 ratio.

4.2.3.8 Grain Yield

The results on seed yield are given in Table 24.

The sole crop of greengram recorded the highest seed yield (442.30 kg ha^{-1}) and it was significantly superior to all other treatments. Among the intercropping treatments, 2:1 row proportion gave significantly the highest yield (218 kg ha^{-1}). The yield of greengram when rice and greengram were grown in 3 : 1 ratio was 170.6 kg ha^{-1}.

4.2.3.9 Stover Yield

The data on stover yield are given in Table 24.

The sole crop of greengram recorded significantly higher stover yield (1479.87 kg ha^{-1}) as compared to intercropping treatments. The lower yield (518.11 kg ha^{-1}) was recorded when it was intercropped with rice in 1 : 3 ratio, which was 35 per cent of the sole crop yield. It was significantly inferior to all other treatments.

4.2.3.10 Harvest Index

The results are given in Table 24.

The treatments did not exhibit significant differences.

4.2.4 Cowpea

4.2.4.1 Days to 50 per cent Flowering

The data on days to 50 per cent flowering are given in Table 25.

Table 23. Number of filled grains pod^{-1}, hundred grain weight, protein content of seeds of greengram

Treatments	No.of filled grains pod^{-1}	Hundred grain weight (g)	Protein content (%)
T_3	10.53	3.62	22.88
T_6	11.59	3.96	22.47
T_9	11.35	3.85	22.14
$F_{2, 4}$	7.963 ^{NS}	3.971 ^{NS}	26.629*
SE	0.192	0.087	0.071
CD	-	-	0.282

* Significant at 5 % level

NS-not significant

Table 24. Grain yield, stover yield and harvest index of greengram

Treatments	Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Harvest index
T_3	442.30	1479.87	0.230
T_6	218.00	669.48	0.245
T_9	170.60	518.11	0.247
$F_{2, 4}$	201.655**	281.88**	4.99 ^{NS}
SE	10.219	30.801	0.004
CD	40.121	120.92	-

** Significant at 1 % level

NS-not significant

The number of days taken for 50 per cent flowering was not significantly influenced by the treatments.

4.2.4.2 Number of Pods Plant^{-1}

The mean number of pods plant^{-1} is listed in Table 25.

The number of pods was significantly influenced by the treatments. The maximum number of pods (8.86) was noticed in the treatment combination of rice with cowpea in 2:1 ratio which was on par with the cowpea intercropped with rice in 1:3 ratio. The sole cowpea produced significantly the lowest number of pods (7.72).

4.2.4.3 Length of Pod

The mean length of pod is presented in Table 25.

The treatments did not significantly influence the length of pod. Cowpea intercropped with rice in 1:2 ratio recorded the maximum pod length of 22.61 cm and the lowest length of pod (21.47 cm) was observed in sole cowpea.

4.2.4.4 Weight of Pod

The mean weight of pod is given in Table 25.

The weight of pod was not significantly affected by the treatments.

4.2.4.5 Number of Filled Grains Pod^{-1}

The mean number of filled grains pod^{-1} is presented in Table 26.

The number of filled grains pod^{-1} was not significantly influenced by the treatments.

4.2.4.6 Hundred Grain Weight

The results on hundred grain weight are presented in Table 26.

The hundred grain weight did not show any variation among the treatments.

Table 25. Yield attributes of cowpea

Treatments	Days to 50 % flowering	Number of pods plant^{-1}	Length of pod (cm)	Weight of pod (g)
T_4	39.33	7.72	21.47	3.61
T_7	39.66	8.86	22.61	3.86
T_{10}	39.33	8.82	22.46	3.79
$F_{2, 4}$	6.285^{NS}	90.36*	17.15^{NS}	18.93^{NS}
SE	0.071	0.068	0.149	0.030
CD	-	0.267	-	-

* Significant at 5 % level

^{NS}-not significant

4.2.4.7 Protein Content

The mean values of the protein content of the seed is presented in Table 26.

The treatments significantly influenced the protein content of grains.

The sole cowpea recorded the highest protein content of 22.68 per cent and was significantly superior to all other treatments. Cowpea intercropped with rice in 1:2 and 1:3 ratios recorded 22.16 and 22 per cent of protein content respectively.

4.2.4.8 Vegetable Yield

Table 27 shows the results on vegetable yield.

The sole crop of cowpea produced highest vegetable yield of 4071 kg ha^{-1} and it was found to be significantly superior to all other treatments. The yield of cowpea when rice and cowpea were grown in 2:1 and 3 : 1 ratio were 2458 and 1788 kg ha^{-1} respectively.

4.2.4.9 Stover Yield

The data on stover yield are given in Table 27.

The sole crop of cowpea recorded the highest yield of 1439 kg ha^{-1} and was found to be significantly superior to other treatments. The yield of cowpea, when rice and cowpea were intercropped in 2:1 and 3:1 ratios were 805 and 596 kg ha^{-1} respectively.

4.2.4.10 Harvest Index

The result of harvest index are given in Table 27.

The treatments did not exhibit significant differences with respect to harvest index.

4.3 BIOLOGICAL EFFICIENCY OF THE INTERCROPPING SYSTEM

4.3.1 Rice Equivalent Yield

The data on rice equivalent yield are given in Table 28.

Table 26. Number of filled grains pod^{-1}, hundred grain weight, protein content of seeds of cowpea

Treatments	No.of filled grains pod^{-1}	Hundred grain weight (g)	Protein content (%)
T_4	12.80	10.54	22.68
T_7	13.91	11.30	22.16
T_{10}	13.37	11.15	22.00
$F_{2, 4}$	6.437 ^{NS}	7.057 ^{NS}	37.54*
SE	0.219	0.151	0.058
CD	-	-	0.228

* Significant at 5 % level

NS-not significant

Table 27. Vegetable yield, stover yield and harvest index of cowpea

Treatments	Vegetable yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Harvest index
T_4	4071.66	1439.99	0.268
T_7	2458.33	805.01	0.287
T_{10}	1788.33	596.35	0.286
$F_{2, 4}$	1028.54**	3823.324**	6.202 ^{NS}
SE	36.596	7.106	0.001
CD	143.674	27.898	-

** Significant at 1 % level

NS-not significant

Table 28. Rice equivalent yield of different treatments, kg ha^{-1}

Treatments	Rice equivalent yield
T_1	2436.66
T_2	2855.33
T_3	1871.33
T_4	4384.66
T_5	3001.39
T_6	1487.30
T_7	4244.09
T_8	2778.07
T_9	1685.04
T_{10}	3599.63
$F_{9, 18}$	320.334**
SE	56.579
CD	168.11

** Significant at 1 % level

The rice equivalent yield showed significant differences among the treatments. The sole crop of cowpea recorded the highest rice equivalent yield (4384 kg ha^{-1}) and was superior to other treatments.

Among the intercropping combinations, rice + cowpea in 2:1 ratio recorded the highest rice equivalent yield (4244 kg ha^{-1}) which was on par with sole cowpea and superior to other intercropping treatments. The rice equivalent yield produced by rice + blackgram in 2:1 ratio was 3001.39 kg ha^{-1} and was on par with sole blackgram.

The rice equivalent yield (1487.3 kg ha^{-1}) recorded by rice + greengram in 2:1 ratio was significantly inferior to all other treatments.

4.3.2 Land Equivalent Ratio (LER)

The mean values of LER are presented in Table 29.

The LER of the intercropping systems was significantly influenced by the treatments. In all intercropping systems LER excelled unity except in greengram intercropping system indicating greater biological efficiency of intercropping over sole cropping. Cowpea intercropped with rice in 1:2 ratio gave the highest LER value (1.24). The LER values recorded by blackgram intercropped with rice in 1 : 2 and 1 : 3 ratios and cowpea intercropped with rice in 1:3 ratio were 1.13, 1.07 and 1.12 respectively. In both the greengram intercropping systems LER values were less than one.

4.3.3 Land Equivalent Coefficient (LEC)

The mean values of the LEC are given in Table 29.

The value of LEC differed significantly by the treatments. The maximum value (0.38) was noticed when rice and cowpea were grown in 2:1 row ratio and it was significantly higher than all other values. The LEC values recorded by rice + blackgram intercropping in 2:1 ratio (0.31) and rice + cowpea intercropping in 3:1 ratio (0.29) were on par with each other. Rice + greengram in 2:1 ratio registered significantly the lowest value of LEC.

Table 29. Land equivalent ratio and land equivalent coefficients of intercropping systems

Treatments	LER	LEC
T_1	1.00	0.25
T_2	1.00	0.25
T_3	1.00	0.25
T_4	1.00	0.25
T_5	1.13	0.31
T_6	0.71	0.11
T_7	1.24	0.38
T_8	1.07	0.23
T_9	0.77	0.14
T_{10}	1.12	0.29
$F_{9, 18}$	105.17**	113.42**
SE	0.015	0.007
CD	0.046	0.021

** Significant at 1 % level

LER – Land equivalent ratio LEC – Land equivalent coefficient

Table 30. Competition ratio of rice and legumes

Treatments	Rice	Legumes
T_5	0.697	1.430
T_6	0.236	4.265
T_7	0.541	1.847
T_8	0.850	1.173
T_9	0.342	1.936
T_{10}	0.521	1.918
$F_{5, 10}$	307.055**	7.630*
SE	0.012	0.400
CD	0.040	1.261

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

4.3.4 Competition Ratio

The results on competition ratio are given in Table 30.

The treatment effects significantly influenced the competition ratio of rice and legumes. In rice, the highest value of competition ratio (0.850) was observed when rice and blackgram were grown in 3:1 ratio and was superior to all other treatments. The lowest competition ratio of rice was noticed when rice and greengram were grown in 2:1 row ratio. In the case of legumes, the highest value of competition ratio (4.265) was observed in greengram intercropped with rice in 2:1 ratio. The lowest value of competition ratio of legumes (1.173) was noticed when blackgram was intercropped with rice in 1:3 row ratio and was on par with all other treatments except when greengram was intercropped with rice in 1:2 row proportion.

4.3.5 Aggressivity

The mean values of aggressivity of main crop rice and intercrops blackgram, greengram and cowpea are presented in Table 31.

The aggressivity values were found to be positive in intercrops. A positive aggressivity value of 1.136 was recorded by greengram and a negative value of 1.136 was recorded by rice, when they were grown together in 2:1 row proportion. It was significantly superior to all other treatments. In rice + blackgram intercropping in 2:1 row proportion, blackgram recorded a positive value (0.198) and rice recorded a negative value (-0.198) and was inferior to all other treatments.

4.3.6 Relative Crowding Coefficient (RCC)

The mean values of RCC are shown in Table 31.

The RCC value of main crop rice (K_{ab}) was more than one in all intercropping systems except when intercropped with greengram. The RCC of intercrops (k_{ba}) were less than one in all crop combinations except when cowpea was intercropped with rice in 1:2 ratio. The RCC (K) which is the product of K_{ab} and K_{ba} was more than one in all

Table 31. Aggressivity and relative crowding coefficient (RCC) of rice and legumes

Treatments	Aggressivity		Relative crowding coefficient		
	Main crop (A_{ab})	Intercrop (A_{ba})	Main crop (K_{ab})	Intercrop (K_{ba})	K
T_5	-0.403	0.403	2.037	0.917	1.867
T_6	-1.136	1.136	0.301	0.985	0.296
T_7	-0.830	0.830	1.901	1.528	2.904
T_8	-0.198	0.198	3.660	0.447	1.636
T_9	-1.015	1.015	0.664	0.632	0.419
T_{10}	-0.841	0.841	2.758	0.783	2.159
$F_{5, 10}$	55.151**	55.151**	19.715**	67.899**	29.74**
SE	0.048	0.048	0.283	0.045	0.186
CD	0.153	0.153	0.893	0.142	0.586

** Significant at 1 % level

treatments except when rice was intercropped with greengram in 2:1 and 3:1 ratios. The highest value of K (2.904) was recorded by the intercrop combination of rice and cowpea in 2:1 ratio.

4.4 UPTAKE OF NUTRIENTS

4.4.1 Rice

The mean uptake of nutrient *viz.*, N, P and K by rice are presented in Table 32.

The N, P and K uptake by crop was significantly increased in the case of sole crop when compared to intercropped treatments. N uptake was maximum with sole crop (72.13 kg ha^{-1}) and minimum (46.79 kg ha^{-1}) with greengram intercropped in rice in 1:2 ratio.

The P uptake was significantly the highest with the sole crop (32.60 kg ha^{-1}). Rice intercropped with cowpea in 2:1 and 3:1 ratios, with blackgram in 2:1 and 3:1 ratios recorded 22.42, 25.38, 23.22 and 25.53 kg ha^{-1} P uptake respectively. The lowest P uptake (20.17 kg ha^{-1}) was observed in rice + greengram intercropping in 2:1 ratio.

The K uptake was also maximum (86.83 kg ha^{-1}) with sole crop and minimum (56.27 kg ha^{-1}) in the 2:1 row proportion of rice and greengram intercropping system.

4.4.2 Blackgram

The mean values of uptake of N, P and K are given in Table 33.

The uptake of nutrients was significantly influenced by the treatments. The sole crop recorded the highest uptake of N (66.16 kg ha^{-1}) and was significantly superior to the intercropping treatments. Among intercropping proportions, rice and greengram in 2:1 ratio recorded significantly the highest N uptake (25.02 kg ha^{-1}) compared to 3:1 proportion. The lowest N uptake (18.70 kg ha^{-1}) was recorded when rice and blackgram were grown in 3:1 ratio.

Table 32. Nutrient uptake by rice, kg ha^{-1}

Treatments	N	P	K
T_1	72.13	32.60	86.83
T_5	58.79	23.22	64.05
T_6	46.79	20.17	56.27
T_7	53.98	22.42	63.15
T_8	61.95	25.53	71.19
T_9	52.97	20.56	63.58
T_{10}	57.79	25.38	71.65
$F_{6, 11}$	138.21**	109.86**	381.62**
SE	0.679	0.403	0.500
CD	2.092	1.24	1.54

** Significant at 1 % level

Table 33. Nutrient uptake by blackgram, kg ha^{-1}

Treatments	N	P	K
T_2	66.16	9.64	37.28
T_5	25.02	3.85	11.90
T_8	18.70	2.78	8.49
$F_{2,4}$	50057.56**	3211.82**	1999.69**
SE	0.115	0.065	0.351
CD	0.452	0.255	1.380

** Significant at 1 % level

The highest uptake of P (9.64 kg ha^{-1}) was also recorded by the sole crop and it was superior to all other treatments. Rice and blackgram in 3 : 1 ratio recorded the lowest P uptake value of 2.78 kg ha^{-1}.

The K uptake was also maximum (37.28 kg ha^{-1}) with sole crop and minimum (8.49 kg ha^{-1}) in the 3 : 1 row proportion of rice and blackgram.

4.4.3 Greengram

The mean values of the data are given in Table 34.

The N, P and K uptake by greengram significantly increased in the case of sole crop. The N, P and K uptake by sole crop were 72.69, 10.55 and 35.32 kg ha^{-1} respectively. Greengram when intercropped with rice in 1 : 3 ratio recorded the lowest uptake of N (21.67 kg ha^{-1}), P (3.59 kg ha^{-1}) and K (9.32 kg ha^{-1}). It was significantly inferior to all other treatments.

4.4.4 Cowpea

The mean values of the data are given in Table 35.

The uptake of nutrients was significantly influenced by the treatments. The sole crop recorded the highest uptake of N (34.83 kg ha^{-1}), P (16.25 kg ha^{-1}) and K (24.15 kg ha^{-1}) and was significantly superior to the intercropping treatments. Among the intercropping systems, rice + cowpea in 3:1 ratio recorded the lowest uptake of N (9.13 kg ha^{-1}), P (5.11 kg ha^{-1}) and K (5.40 kg ha^{-1}).

4.5 SOIL ANALYSIS

4.5.1 Soil Nutrient Status Before the Experiment

The soil nutrient status before experiment is presented in Table 36.

The results revealed that there was no significant difference in the nutrient content in the various plots.

Table 34. Nutrient uptake by greengram, kg ha^{-1}

Treatments	N	P	K
T_3	72.69	10.55	35.32
T_6	28.14	4.60	10.65
T_9	21.67	3.59	7.98
$F_{2,4}$	24948.37**	866.907**	3698.22**
SE	0.175	0.127	0.247
CD	0.690	0.501	0.973

** Significant at 1 % level

Table 35. Nutrient uptake by cowpea, kg ha^{-1}

Treatments	N	P	K
T_4	34.83	16.25	24.15
T_7	13.11	6.30	6.77
T_{10}	9.13	5.11	5.40
$F_{2,4}$	1880.65**	1127.69**	12563.18**
SE	0.318	0.182	0.093
CD	1.252	0.715	0.366

** Significant at 1 % level

Table 36. Soil nutrient status before the experiment, kg ha^{-1}

Treatments	N	P	K
T_1	278.06	42.51	118.43
T_2	278.26	43.05	118.39
T_3	278.25	42.33	118.42
T_4	278.47	42.35	118.49
T_5	278.44	41.97	118.33
T_6	278.46	42.63	118.45
T_7	278.67	42.64	118.53
T_8	278.54	42.60	118.37
T_9	278.35	42.43	118.80
T_{10}	278.55	42.61	118.64
$F_{9,\ 18}$	4.00*	2.156^{NS}	1.777^{NS}
SE	0.117	0.189	0.102
CD	0.350	-	-

* Significant at 5 % level
NS-not significant

4.5.2 Soil nutrient status after the experiment

The soil nutrient status after the experiment is given in Table 37.

The soil nutrients (N, P and K) were found to be significantly influenced by the treatments.

The highest nitrogen content was found in plot of sole greengram (299.21 kg ha^{-1}). It was significantly superior to all other treatments. The nitrogen content of sole blackgram and cowpea were 296.17 kg ha^{-1} and 296.00 kg ha^{-1} respectively and were on par with each other. The lowest nitrogen content (250.64 kg ha^{-1}) was found in sole rice plot.

The highest P (44.81 kg ha^{-1}) content was observed in sole blackgram and was on par with sole greengram and sole cowpea. The sole rice treatment recorded the lowest P content (40.15 kg ha^{-1}) and was on par with rice intercropped with blackgram in 3:1 ratio.

The highest K content (123.42 kg ha^{-1}) was recorded in sole greengram which was on par with the sole cowpea. The sole rice plot recorded significantly the lowest content of K (112.76 kg ha^{-1}).

4.6 OBSERVATIONS ON PESTS AND DISEASES

4.6.1 Cowpea

4.6.1.1 Fusarium Wilt

The mean values of percentage of disease incidence are given in Table 38.

The treatments significantly influenced the disease incidence of fusarium wilt.

The percentage of disease incidence was the highest (39 %) with the sole cowpea and was statistically superior to all other treatments. The lowest percentage of disease incidence (14.33 %) occurred in cowpea when it was intercropped with rice in 1: 3 ratio and was on par with 1:2 ratio.

Table 37. Soil nutrient status after the experiment, kg ha^{-1}

Treatments	N	P	K
T_1	250.64	40.15	112.76
T_2	296.17	44.81	123.42
T_3	299.21	44.05	121.52
T_4	296.00	44.60	122.96
T_5	267.39	41.58	115.85
T_6	273.72	42.28	116.27
T_7	268.34	42.25	115.72
T_8	260.53	40.62	115.16
T_9	264.21	41.47	114.53
T_{10}	262.72	41.65	114.95
$F_{9,\ 18}$	695.490**	28.20**	71.642**
SE	0.649	0.305	0.451
CD	1.928	0.907	1.341

** Significant at 1 % level

4.7 ECONOMIC EFFICIENCY OF INTERCROPPING SYSTEM

4.7.1 Cost of Cultivation

The mean values of the data are given in Table 39.

Cowpea intercropped with rice in 1:2 ratio registered the maximum cost (Rs. 23574 ha^{-1}) for cultivation. It was followed by sole cowpea with Rs. 21767 ha^{-1}. The cost of cultivation of blackgram intercropped with rice in 1:2 and 1:3 ratios were Rs.19032 ha^{-1} and Rs. 18350 ha^{-1}. The lowest cost of cultivation (Rs.14133 ha^{-1}) was recorded by the greengram intercropped with rice in 1:2 ratio.

4.7.2 Gross Returns

The mean values of the data are given in Table 39.

Significant differences were observed for gross returns due to various treatments. The highest gross returns (Rs.34654 ha^{-1}) were obtained from the rice intercropped with cowpea in 2:1 ratio. The sole rice gave Rs.24884 ha^{-1} as gross returns. The lowest gross returns Rs.12851 ha^{-1} was obtained from the greengram intercropped with rice in 1:2 ratio.

4.7.3 Net Returns

The mean values of the data are presented in Table 39.

The data showed that the highest mean net returns of Rs.11080 ha^{-1} was obtained from cowpea intercropped with rice in 1:2 ratio. The net returns of Rs. 8925 ha^{-1} and Rs.8545 ha^{-1} were recorded by the sole cowpea and rice + cowpea intercropping in 3:1 ratio. Sole greengram and greengram intercropped with rice in 1:2 and 1:3 ratios recorded the loss of Rs.1619 ha^{-1}, Rs. 1282 ha^{-1} and Rs. 994 ha^{-1} respectively.

4.7.4 Benefit – Cost ratio

The results are presented in Table 39.

The highest BCR of 1.47 was obtained with the cowpea intercropped with rice in 1:2 ratio. Among the sole crops, the sole

Table 38. Fusarium wilt incidence in cowpea

Treatments	Disease incidence (%)
T_4	39.00
T_7	15.66
T_{10}	14.33
$F_{2, 4}$	216.49**
SE	0.9428
CD	3.70

** Significant at 1 % level

Table 39. Economics of crop production

Treatments	Cost of cultivation ($Rs.ha^{-1}$)	Gross returns ($Rs.ha^{-1}$)	Net returns ($Rs.ha^{-1}$)	Benefit-cost ratio
T_1	21088.50	24884.50	3796.00	1.18
T_2	15659.25	19887.25	4228.00	1.27
T_3	14718.50	13099.00	-1619.50	0.89
T_4	21767.80	30692.00	8925.80	1.41
T_5	19032.50	25883.00	6850.50	1.36
T_6	14133.25	12851.25	-1282.00	1.91
T_7	23574.50	34654.50	11080.00	1.47
T_8	18350.00	24589.00	6239.00	1.34
T_9	16574.75	15580.00	-994.75	0.94
T_{10}	21364.00	29909.75	8545.75	1.40

cowpea gave a BCR of 1.41. The blackgram intercropped with rice in 1:2 and 1:3 ratio gave a BCR of 1.36 and 1.34 respectively. The lowest BCR (0.89) was recorded by sole crop of greengram.

4.8 CORRELATION STUDIES

4.8.1 Rice

The mean values of simple correlation coefficient in rice are given in Table 40.

Results showed that many correlation coefficient values between yield and yield attributing characters like number of productive tillers $hill^{-1}$, length and weight of panicle, number of spikelets, number of filled grains $panicle^{-1}$, thousand grain weight, straw yield, harvest index, N, P and K uptake by rice were positive. Negative correlations to yield were observed for the characters like, days to 50 per cent flowering and chaff percentage.

Table 40. Values of simple correlation coefficients of rice

Sl. No.	Characters correlated	Correlation coefficient
1.	Yield vs Height at 30 DAS	0.7839**
2.	Yield vs Height at 60 DAS	0.7866**
3.	Yield vs Height at Harvest	0.9299**
4.	Yield vs Plant spread at harvest	0.8133**
5.	Yield vs Root spread at harvest	0.8924**
6.	Yield vs Tiller no/hill at 30 DAS	0.2694
7.	Yield vs Tiller no / hill at 60 DAS	0.2192
8.	Yield vs Tiller no/ hill at harvest	0.2506
9.	Yield vs Leaf area index at 60 DAS	0.6559**
10	Yield vs Drymatter production at harvest	0.9803**
11.	Yield vs Days to 50 per cent flowering	-0.3869
12.	Yield vs No. of productive tillers / hill	0.6989**
13.	Yield vs Length of panicle	0.8490**
14.	Yield vs Weight of panicle	0.8256**
15.	Yield vs No.of spikelets panicle^{-1}	0.5651**
16.	Yield vs No.of filled grains panicle^{-1}	0.7299**
17.	Yield vs Chaff percentage	-0.8378
18.	Yield vs 1000 grain weight	0.7780**
19.	Yield vs Straw yield	0.9565**
20.	Yield vs Harvest index	0.7215**
21.	Yield vs N uptake by plant	0.9364**
22.	Yield vs P uptake by plant	0.8912**
23.	Yield vs K uptake by plant	0.8839**

** significant at 1 % level

DISCUSSION

5. DISCUSSION

An investigation entitled "Competitive behaviour of different legumes grown as intercrop with direct seeded upland rice" was conducted at the Instructional Farm, College of Agriculture, Vellayani to find out an optimum row proportion of upland rice to legume combination, to assess the soil fertility improvement and to evolve an economically feasible legume intercropping system in upland rice. 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 different sections *viz.*,

5.1 Effect of intercropping of upland rice Vs sole cropping

5.2 Effect of intercropping of blackgram Vs sole cropping

5.3 Effect of intercropping of greengram Vs sole cropping

5.4 Effect of intercropping of cowpea Vs sole cropping

5.5 Evaluation of rice + legume intercropping system based on

- 5.5.1 Competitive behaviour of legumes
- 5.5.2 Biological efficiency
- 5.5.3 Economic efficiency

5.6 Soil nutrient status as influenced by intercropping

5.1 EFFECT OF INTERCROPPING OF UPLAND RICE VS SOLE CROPPING

5.1.1 Growth Characters

Different treatments of intercropping significantly influenced the growth characters of rice.

The results revealed that the sole cropping of rice recorded the highest height at all stages (Table 3). This was due to lesser competition between the rice plants in a monocropped situation. In intercropped conditions, legumes dominated the rice crop. Singh *et al.* (1996) also reported similar findings in rice + legume intercropping systems. In rice + greengram intercropping of 2:1 ratio recorded the lowest height among the treatments (Table 3). The dominance of the greengram on rice may be the reason for this lowest height. Similar reductions in the height of rice was noticed by Mandal *et al.* (1996) in his rice + ricebean intercropping studies.

In the case of plant and root spread it was significantly influenced by various treatments (Table 4). The plant spread of rice in all the treatments except greengram intercropped treatments were on par. This shows almost a similar development of rice crop produced under sole and intercropping systems. In the greengram intercropped treatments, greengram suppressed the rice growth due to its vigorous growth in rainy season. Rice + greengram in 2 : 1 ratio also recorded the lowest spread probably due to the same reason. Similar findings were reported by Mallick *et al.* (1992).

At all stages, number of tillers hill^{-1} was not significantly influenced by various treatments (Table 5). Sole rice produced the highest number of tillers 9.20, 10.20 and 10.10 at 30 DAS, 60 DAS and at harvest respectively. It was on par with all other treatments.

At 60 DAS, the leaf area index was significantly influenced by various treatments (Table 6).

In all intercropped treatments except greengram intercropped plots showed higher leaf area index than the sole crop. In intercropped situation, the higher leaf area index was achieved due to the shaded condition provided by intercropped treatments. Singh and Balyan (2000) and Maitra *et al.* (2001) also found that similar increase of LAI of cereals in cereal + legume intercropped conditions. In greengram intercropped plots, the general growth of rice was significantly reduced by the dominance of greengram.

In this experiment, the drymatter production of various treatments were found to be significant. The sole crop of rice produced the highest drymatter (7931 kg ha^{-1}) among the treatments (Table 6). It was significantly superior to all other treatments. Among the intercropping treatments in 2:1 ratio, rice + greengram intercropping recorded the lowest drymatter production. Similar results were also reported by Reddy *et al.* (1991). This was due to the poor performance of rice in association with greengram. Rice + blackgram, rice + cowpea and rice + greengram in 2:1 ratios produced 64, 65 and 30 per cent of the sole crop drymatter production respectively. In 3:1 proportion of intercroppings, rice + greengram intercropping recorded the lowest drymatter production. The difference in drymatter production among the sole, 2:1 row ratio and 3:1 row ratio was mainly due to the difference in population in the treatments. Quayyam and Maniruzzadin (1995) also found that decrease in drymatter production of rice in intercropped condition was due to less area occupied by rice.

In general, rice was significantly dominated by legumes particularly greengram, which suppressed the growth of rice in intercropped condition.

5.1.2 Yield and Yield Attributes

In all the treatments, it was observed that rice took an average of 67 to 68 days for completion of 50 per cent flowering.

The different treatmental effects significantly influenced the number of productive tillers hill^{-1}, length of panicle, weight of panicle, number of spikelets panicle^{-1}, number of filled grains panicle^{-1} and 1000 grain weight (Table 16 and 17).

In all the cases either rice + cowpea or rice + blackgram intercropping recorded the superior yield attributes. It was followed by sole rice and rice + greengram intercropping system.

In rice + cowpea or rice + blackgram intercropping systems, the improvement in yield attributes was occurred due to the complementary effects between rice and blackgram or cowpea. But in rice + greengram intercropping system, rice was suppressed by greengram. Pandita *et al.*

(2000) and Mandal *et al.* (2000) also reported similar findings in rice + legume intercropping.

The chaff percentage was highest in rice + greengram intercropping in 2:1 proportion (Table 17). In greengram intercropped condition, rice was severely affected by greengram and resulted in high chaff percentage. Similar results were also reported by Mandal *et al.* (2000).

Sole crop of rice gave significantly higher seed yield than when they were grown in intercropping system (Table 18 and Fig. 3). Among the treatments, rice + blackgram in 3:1 ratio recorded the highest yield. This might be attributed due to the improvement of yield components like number of spikelets panicle^{-1}, number of filled grains panicle^{-1}, low chaff percentage and thousand grain weight. Pandita *et al.* (2000) also reported an increase in thousand grain weight of maize when it was intercropped with legumes.

In intercropped situations, protein content of rice grain was significantly higher than sole rice. Excretion of amino acids from root nodules of legume might have increased the protein content of associated cereal.

Similar results were also reported by Singh and Balyan (2000).

In rice + blackgram and rice + cowpea intercropped treatments, there was an increase in rice yield above the expected level on the basis of land area. But in greengram intercropped treatments, there was reduction in rice yield below the expected level on the basis of land area. In 2:1 proportion, rice + greengram intercropping, 23 per cent of the sole rice yield was realised where as 66 per cent yield would be expected if intercrop competition was equal to monoculture competition. It indicates the competitive effect of greengram on rice. Sharma and Modgal (1984) also found that yield reduction on rice by shading of legumes in rice + legumes intercropping systems. In rice + blackgram intercropping systems in 2:1 and 3:1 ratios, the respective yields of rice were two per

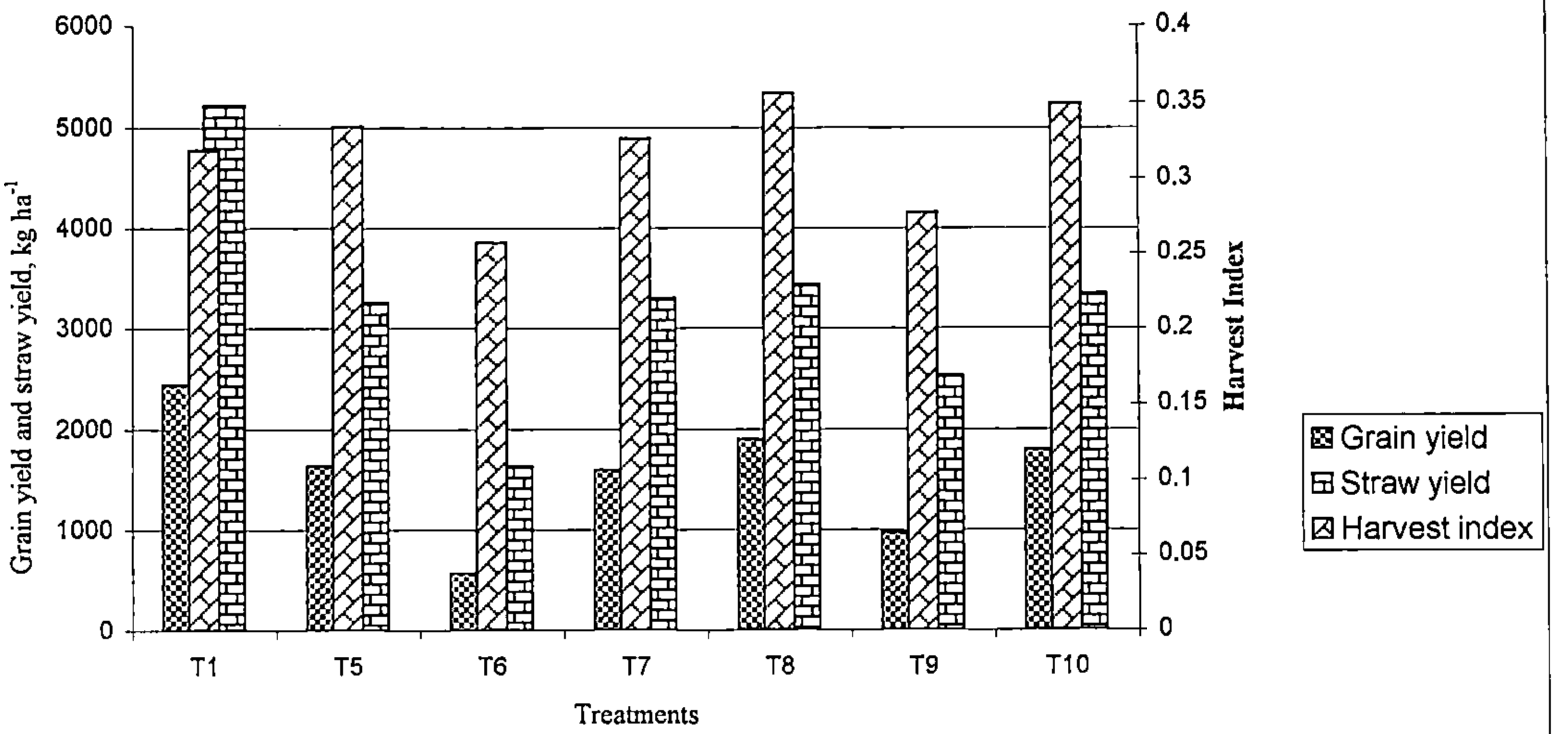

Fig. 3. Grain yield, Straw yield and harvest index of rice

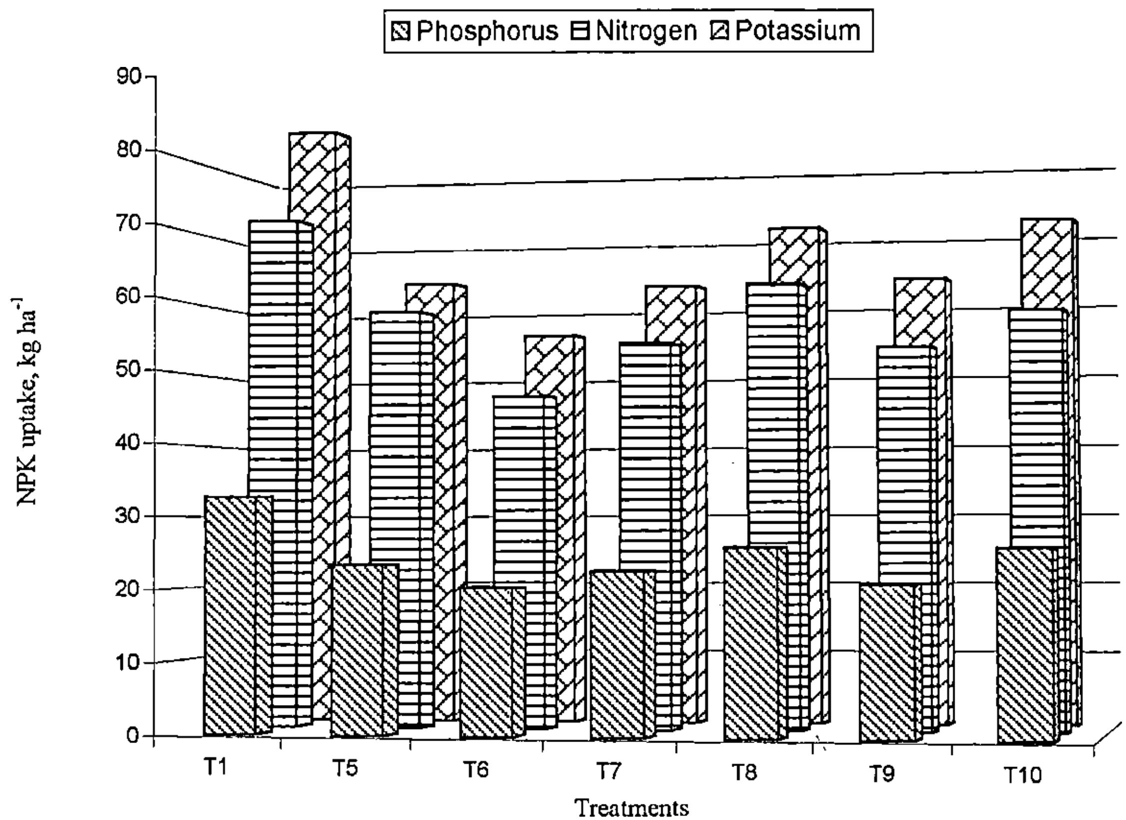

Fig. 4. Nutrient uptake by rice

cent and three per cent increased above the expected level on the basis of land area. This was due to the complementary effect of blackgram on rice. Similar results were also reported by Patra *et al.* (1986) and Mandal and Mahapatra (1990).

The sole crop of rice produced the highest straw yield among the treatments (Table 18 and Fig. 3) which was significantly superior to other treatments. Rice intercropped with blackgram in 2:1 proportion produced 62 per cent of the sole crop yield, with cowpea it produced 63 per cent and with greengram it produced only 31 per cent of the sole crop yield. The yields of rice when intercropped with blackgram, greengram and cowpea in 3:1 proportion were 65, 48 and 64 per cent respectively.

The increased nitrogen uptake was due to the increased drymatter production of the sole crop. As in the case of nitrogen, uptake of phosphorus and potassium were maximum under the sole crop situation (Fig. 4). Rice intercropped with blackgram, greengram and cowpea in 3:1 proportions showed higher values than 2:1 proportion in this respect. This might be due to higher plant population in 3:1 proportion as compared to 2:1 proportion.

The harvest index of rice was significantly influenced by the various treatments. Rice + legumes intercropping system recorded higher harvest index than sole rice (Table 18 and Fig. 3). Rice + greengram intercropping recorded the lowest harvest index. In intercropped situation, the availability of nutrients *viz.*, nitrogen and phosphorus to the rice was increased by legume intercropping, this might be the reason for the higher harvest index. In rice + greengram intercropping, the normal growth of rice was severely affected by greengram and which resulted in the poor harvest index. The results are in agreement with the findings of Mandal *et al.* (1990).

5.2 EFFECT OF INTERCROPPING OF BLACKGRAM VS SOLE CROPPING

5.2.1 Growth Characters

Plant height, plant and root spread, leaf area index, number of branches plant^{-1} were significantly influenced by the treatments.

At 30 DAS, blackgram intercropped with rice in 1:3 ratio gave the highest plant height (Table 7). The sole blackgram recorded the lowest. In sole blackgram, the intraspecies competition was more. But in intercropped situation they dominated rice by showing progressive growth.

At 60 DAS, the rice crop which is in its active growth stage managed to overcome the severe competition given by legumes and there was not significant influence.

At harvest, the sole crop showed lower height and it was due to more intraspecies competition (Table 7). But in intercropped situation they could dominate rice and the height was higher than sole blackgram. The result is in conformity with the findings of Verma and Warsi (1997).

In the case of plant spread, root spread, number of branches plant^{-1} and leaf area index were significantly influenced by the treatments (Table 8 and 9). In all cases, intercropped plants showed better performance than sole blackgram. Similar findings were reported by Asokaraj and Ramaiah (1987) and Shah *et al.* (1991). In rainy season, blackgram showed a vigourous growth. In intercropped situation, due to their dominance, they could able to utilise the component crop spacing and developed good canopy.

In intercropped situations, both the species have different root morphologies. Blackgram has tap root system and rice has adventious root system. In intercropped conditions, blackgram roots developed in deeper layers and spread more vigourously than sole crop. The result is in agreement with the findings of Ramamoorthy *et al.* (1997).

The sole crop recorded the highest drymatter production of 2412 kg ha^{-1} (Table 9). Drymatter production in intercropped blackgram with rice in 1:2 and 1:3 ratios were 44 and 29 per cent of the sole crop respectively. The difference in drymatter production was due to difference in plant population. In intercropped conditions, 33 per cent and 25 per cent plant population recorded 44 per cent and 29 per cent drymatter production of sole crop. This was due to the better performance of blackgram under intercropped situation than their sole crops.

The growth attributes of blackgram was significantly influenced by the intercropping treatments. In intercropped situation blackgram performed better than sole crop, because of their dominance over rice.

5.2.2 Yield and Yield Attributes

The number of days taken for 50 per cent flowering in blackgram ranges from 38 to 39 days (Table 19). There was no significant difference between treatments in the case of number of pods $plant^{-1}$.

The length and weight of pod also had not been significantly influenced by the treatments (Table 19). The hundred grain weight for intercropped blackgram with rice in 1:3 ratio was 4.83 g which was on par with other treatments. The differences in yield attributes of blackgram *viz.*, days to 50 per cent flowering, number of pods $plant^{-1}$, 100 grain weight were not significant due to treatments thereby indicating almost similar individual plant development of blackgram in sole and intercropping system.

The number of filled grains pod^{-1} for intercropped blackgram with rice 1:2 ratio was 8.43 and was on par with intercropped blackgram with rice in 1:3 ratio. In sole blackgram it was 7.45 (Table 20). It may be due to the fact that legume could dominate cereal and performed well by utilizing the nutrients, which were applied to rice. These results are in conformity with the findings of Mandal *et al.* (2000).

The sole crop of blackgram produced significantly higher seed yield than intercropping systems (Table 21). The yield varied due to difference in population. The mean reduction in yield of blackgram noticed was 53 and 69 per cent of the sole crop yield in 2 :1 and 3:1 ratios respectively. Similar reduction in the yield of blackgram were also reported by Legha *et al.* (1993) and Sarkar *et al.* (1996).

The sole crop recorded the highest stover yield also and was significantly superior to other treatments (Fig. 5). The mean reduction in stover yield when compared to sole crop yield were 58 and 73 per cent in treatments of 2:1 and 3:1 row proportions respectively(Table 21).

The nutrient uptake was significantly higher in sole crop when compared to intercropping treatments (Table 33 and Fig. 6). Among the treatments, rice + blackgram in 2:1 ratio recorded higher uptake value than 3:1 ratio. This might be due to the difference in plant population between treatments and the consequent drymatter accumulation.

The harvest index of various treatments did not exhibit any significant difference (Fig. 5). The sole crop recorded a harvest index of 0.279 and the harvest index of intercropped blackgram ranged from 0.279 to 0.306 (Table 21). The highest harvest index is an indicator of better partitioning of photosynthesis.

The protein content of seeds was significantly influenced by the various treatments (Table 20). In intercropped conditions, the nitrogen transfer from legumes to rice may reduce the protein content of legumes. Sole blackgram has the highest protein content and intercropped blackgram showed lower protein content because nitrogen is the basic component of aminoacids and proteins. Similar reports were also observed by Eaglesham *et al.* (1982) and Herridge (1982).

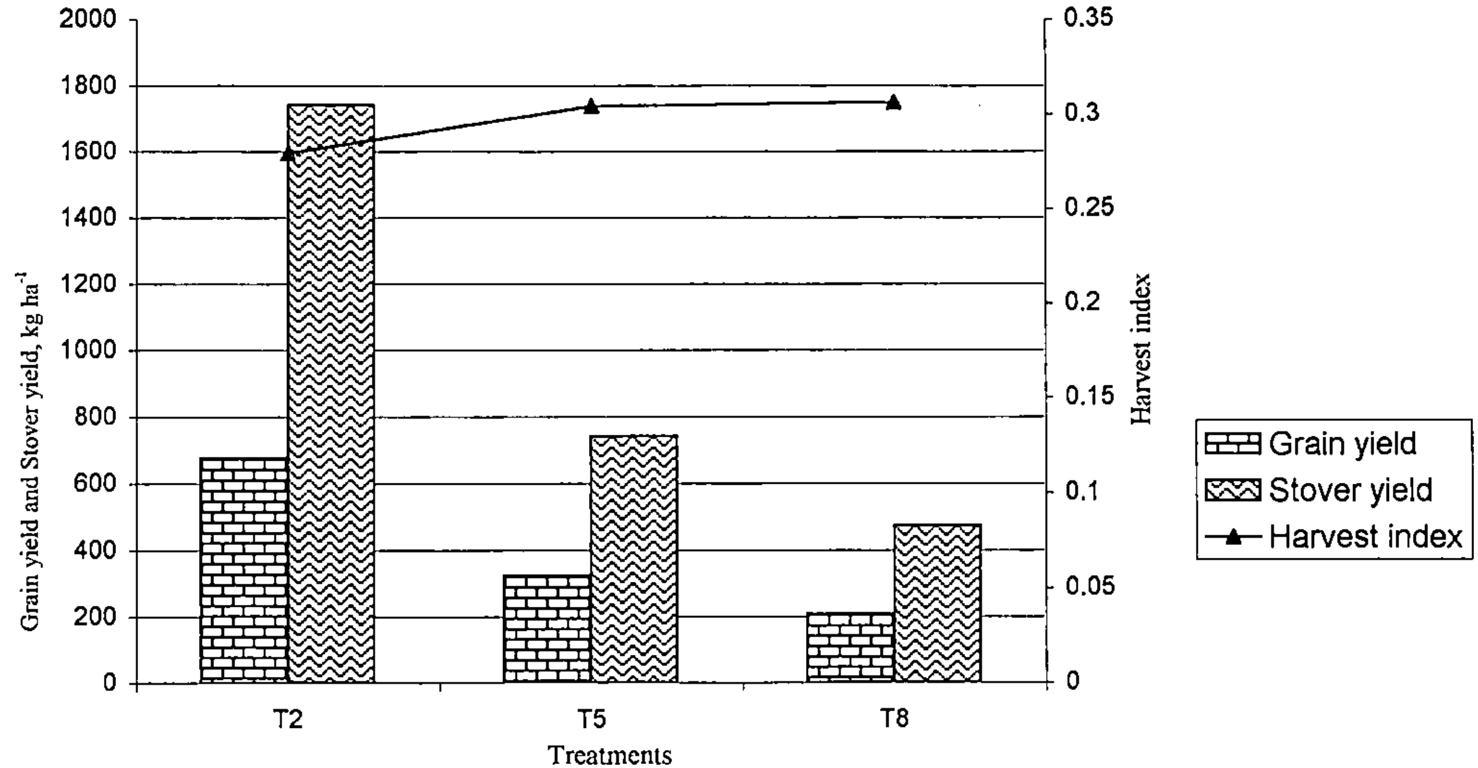

Fig. 5. Grain yield, stover yield and harvest index of blackgram

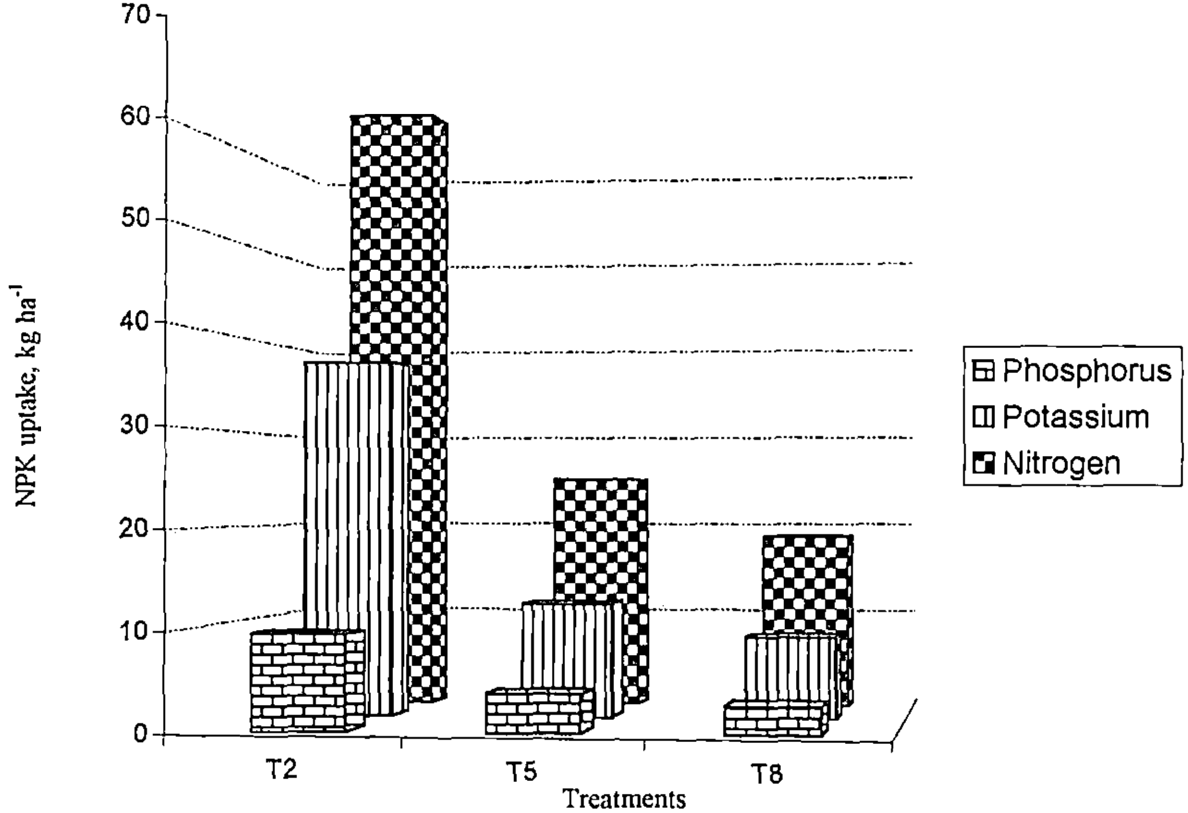

Fig. 6. Nutrient uptake by blackgram

5.3 EFFECT OF INTERCROPPING OF GREENGRAM VS SOLE CROP

5.3.1 Growth Characters

Intercropping treatments significantly influenced the plant height of greengram at all stages. The height of intercropped greengram was always higher than sole crop (Table 10). This was probably due to the effect of intraspecies competition in sole greengram. In intercropped systems, greengram dominated rice crop and showed better performance. The results are in conformity with the findings of Reddy *et al.* (1991).

Plant spread and number of branches were significantly influenced by the treatments (Table 11 and 12).

Root spread of intercropped plants were superior to sole crop (Table 11). This was due to the absence of competition between rice and legume in deeper root layers. Similar results were reported by Mallick *et al.* (1992).

Leaf area index was not significantly influenced by the treatments. The leaf area index of sole crop was on par with the intercropped greengram (Table 12). Similar results were also reported by Reddy *et al.* (1991).

The sole crop of greengram recorded the highest drymatter production and was significantly superior to other treatments (Table 12). The mean reduction in drymatter production when compared to sole crop yield were 54 per cent and 64 per cent in treatments of 2:1 and 3:1 row proportions respectively.

The difference in drymatter production of sole greengram and intercropped greengram was mainly due to difference in population. These results are in conformity with the findings of Legha *et al.* (1993) and Sarkar *et al.* (1996).

5.3.2 Yield and yield attributes

On an average, it took about 44 days for attaining 50 per cent flowering in all treatments (Table 22).

Number of pods $plant^{-1}$, weight of pod, number of filled grains pod^{-1} and hundred grain weight were not significantly influenced by various treatments (Table 22). The difference in yield attributes of greengram *viz.*, days to 50 per cent flowering, 100 grain weight and number of filled grains pod^{-1} (Table 23) were not significant due to treatments.

Length of pod was significantly influenced by the treatments. Both intercropped treatment proportions were on par and superior to sole crop.

The sole crop recorded the highest seed yield (442 kg ha^{-1}) which was superior to all other treatments (Table 24). Among the treatments, 2:1 row proportion gave significantly higher yield than other intercropping treatments. Rice and greengram in 3:1 ratio gave 38 per cent of the sole crop yield (Fig. 7). The sole crop of greengram produced significantly higher stover yield of 1479 kg ha^{-1} (Table 24). Rice and greengram when grown in 3:1 ratio produced only 35 per cent of the sole crop yield. It was significantly inferior to all other treatments. But the yield of greengram in 2:1 ratio with rice was 45 per cent of the sole crop yield (Fig. 7). Similar reduction in the yield of greengram in the intercropping systems were also reported by Legha *et al.* (1993) and Sarkar *et al.* (1996).

The nutrient uptake was significantly higher in sole crop when compared to intercropping treatments (Table 34). Among the treatments, rice + greengram in 2:1 ratio recorded the highest uptake value and 3:1 ratio recorded the lowest (Fig. 8). This might be due to the difference in plant population between treatments and the consequent drymatter accumulation.

The harvest index recorded by the sole crop of greengram was on par with intercropped greengram (Table 24 and Fig. 7).

The protein content in seeds was significantly influenced by the treatments (Table 23). The sole greengram has higher protein content

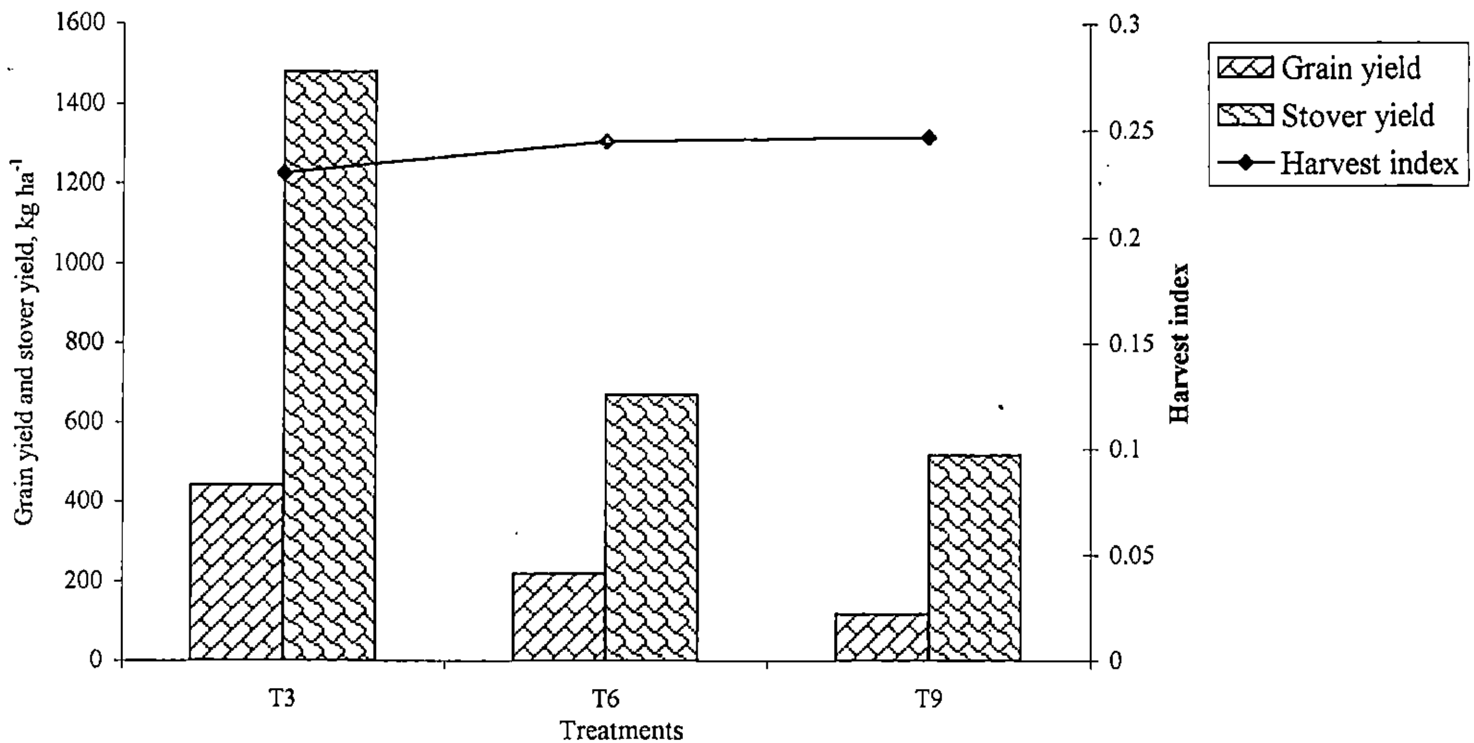

Fig. 7. Grain yield, Stover yield and harvest index of greengram

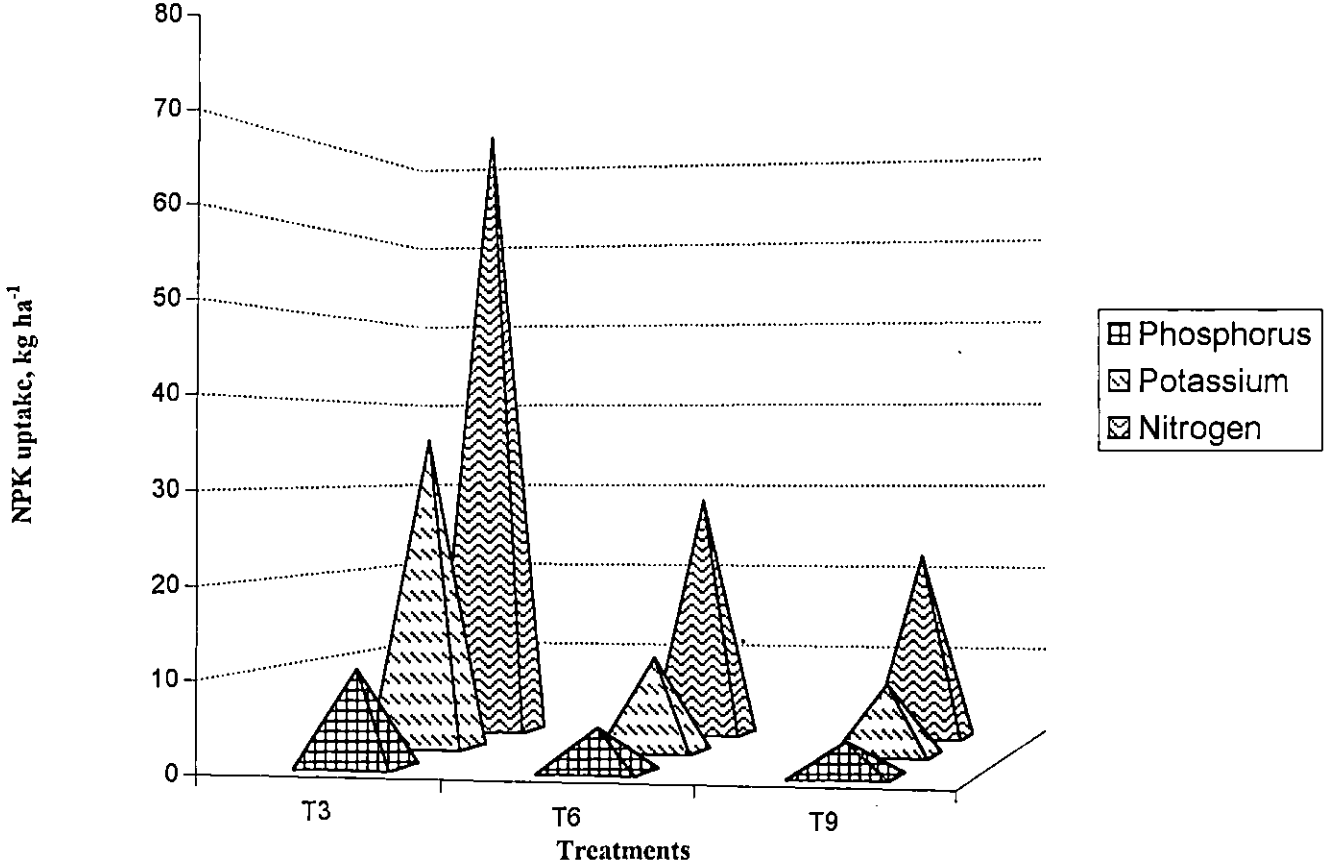

Fig. 8. Nutrient uptake by greengram

than intercropped greengram. In intercropped condition, the nitrogen might have been transferred from legume root nodules to associated cereal. Due to the nitrogen transfer, protein content was reduced. The results are in conformity with the findings of Eaglesham *et al.* (1982) and Herridge (1982).

5.4 EFFECT OF INTERCROPPING OF COWPEA VS SOLE CROPPING

5.4.1 Growth Characters

Different treatments of intercropping significantly influenced the growth characters of cowpea.

At all stages the height of intercropped cowpea with rice was significantly superior to sole cowpea (Table 13). Among the intercropped cowpea treatments, cowpea + rice in 1:3 ratio gave the highest height. The results are in conformity with the findings of Verma and Warsi (1997).

In the case of number of branches at harvest and leaf area index, the intercropped cowpea treatments showed superiority over sole crop (Table 15). In sole crop, closer spacing of 20 x 15 cm resulted in highest intraspecies competition. But in the intercropped treatments, legumes dominated the cereal components by the vigourous growth in rainy season. Hence the performance of intercropped cowpea was better than sole cowpea. Similar results were also reported by Verma and Warsi (1997).

Treatments significantly influenced the plant and root spread. Rice + cowpea intercropping system in 3:1 ratio recorded the highest plant and root spread followed by rice + cowpea intercropping in 2:1 ratio (Table 14). In intercropped situation the cereals have the root density mainly in the top layers, where as legumes have tap roots at deeper layers. In sole cowpea, there may be stiff competition for nutrients in deeper layers. The results are in agreement with the findings of Mallick *et al.* (1992).

The sole crop recorded the highest drymatter production of 2004 kg ha^{-1}, which was superior to all other treatments (Table 15). Among the intercropping treatments, 2:1 row proportion resulted in 58 per cent of the sole crop yield, which was significantly higher than other treatment. Rice and cowpea in 3:1 ratio gave 42 per cent of the sole crop yield. The variation in drymatter production might be due to the difference in plant population between treatments.

The fusarium wilt incidence was significantly influenced by various treatments. The sole cowpea was severely affected with 39 per cent disease incidence. The rice + cowpea in 3:1 ratio recorded the disease incidence of 14 per cent which was on par with rice + cowpea in 2:1 ratio (Table 38). In an intercrop situation, there is greater distance from one host plant to another, which helps to reduce disease incidence. This finding is similar to the finding of Altieri and Liebman (1986).

Thus it can be concluded that the species diversity of natural ecosystems and thus the dispersion of individual host species apparently restrict the spread of plant pathogens. The more the intercrop system resembles the diversity of the natural (resistant or tolerant) ecosystem, the more success there will be in avoiding destructive levels of plant diseases.

5.4.2 Yield and Yield Attributes

The number of days taken for 50 per cent flowering in cowpea ranges from 39 to 40 days (Table 25). As regard to the length of pod and weight of pod, there were no significant differences between the treatments.

The number of pods $plant^{-1}$ was significantly influenced by the treatments (Table 25). The highest number of pods $plant^{-1}$ was recorded in cowpea intercropped with rice in 1:2 ratio.

The number of filled grains pod^{-1} and the hundred grain weight were not significantly influenced by the treatments (Table 26). The differences in yield attributes of cowpea *viz.*, the days to 50 per cent flowering, length of pod, weight of pod, 100 grain weight were not significantly influenced by the treatments thereby indicating similar plant developments of cowpea in sole and intercropping system.

The sole crop of cowpea produced significantly higher vegetable yield than intercropping systems (Table 27 and Fig. 9) in which yield varied due to difference in population. There were 33 and 25 per cent population in treatments of 2:1 and 3:1 row proportions respectively and the mean reduction in yield of cowpea noticed were 40 per cent and 56 per cent of the sole crop yield respectively. Similar results in intercropping systems were also reported by Quayyam and Maniruzzadin (1995).

The sole crop recorded the highest stover yield and was significantly superior to other intercropping treatments (Fig. 9). The mean reduction in biological yield when compared to sole crop yield were 45 per cent and 59 per cent in treatments of 2:1 and 3:1 row proportions respectively (Table 27).

The sole crop of cowpea recorded the highest uptake of N, P and K (Fig. 10). Cowpea when intercropped with rice in 1:3 ratio recorded the lowest uptake of nutrients (Table 35). Among the treatments, rice + cowpea in 2:1 ratio recorded the maximum NPK uptake due to more drymatter production.

The harvest index of various treatments did not exhibit any significant difference (Fig. 9). The sole crop recorded a harvest index of 0.268 and harvest index recorded by cowpea intercropped with rice in 2:1and 3:1 ratios were 0.287 and 0.286 respectively (Table 27). The higher harvest index is an indicator of better partitioning of photosynthates.

The protein content in seeds was significantly influenced by the treatments. The lower protein content of cowpea in intercropped condition was because of nitrogen transfer to the cereal component. The

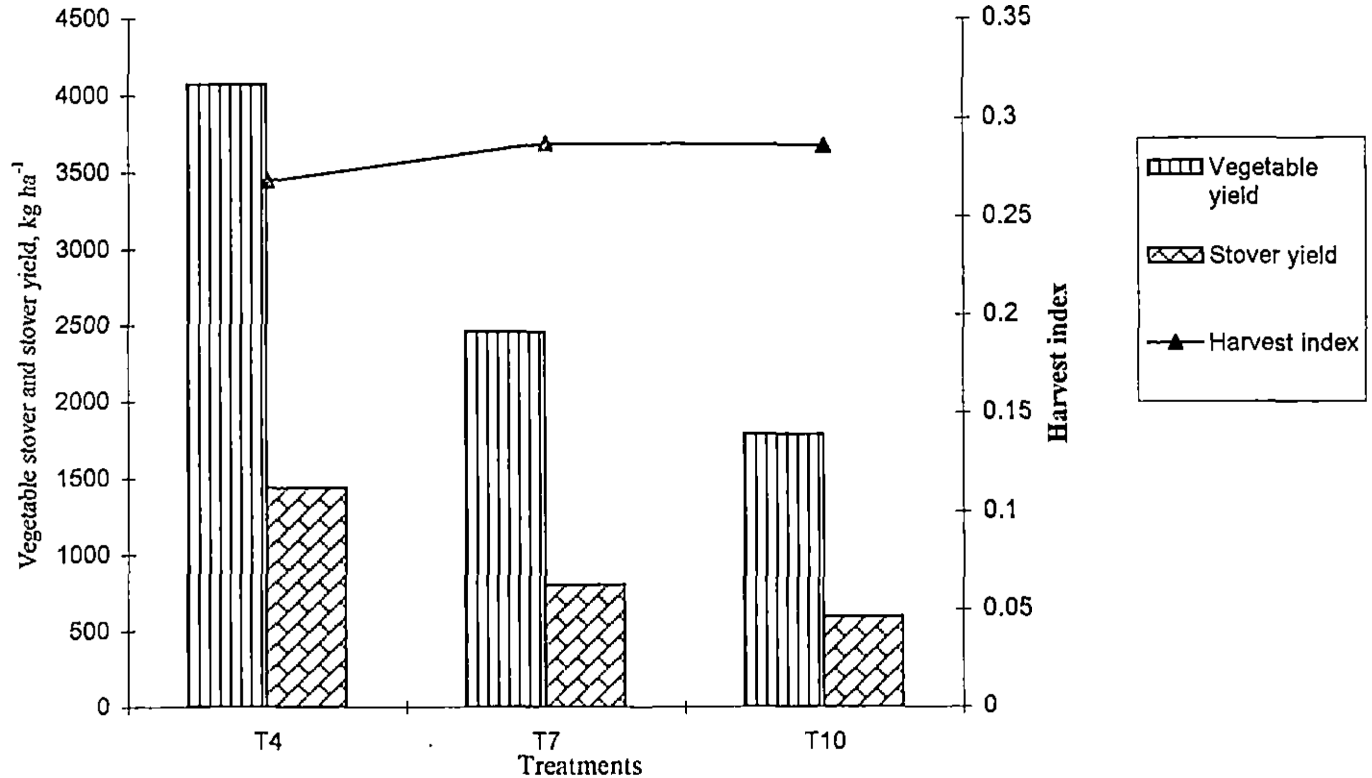

Fig. 9. Vegetable yield, stover yield and harvest index of cowpea

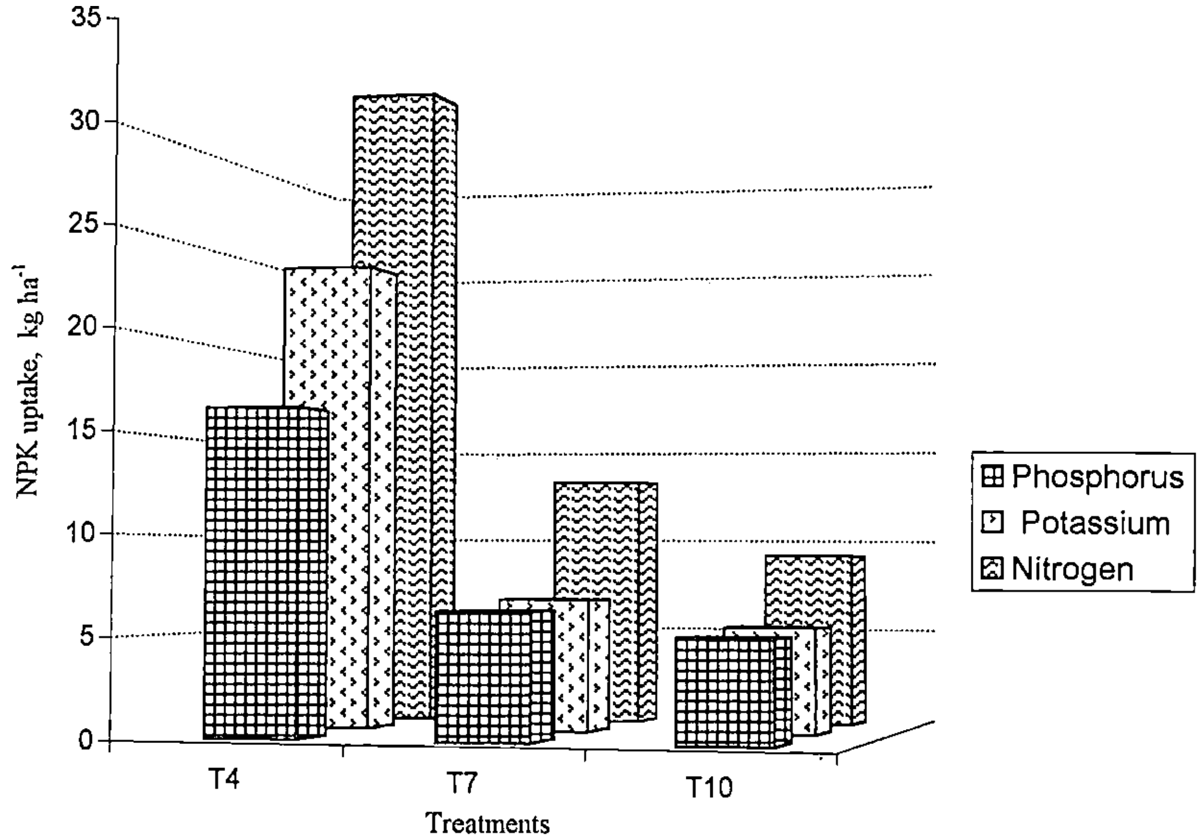

Fig. 10. Nutrient uptake by cowpea

results are in agreement with the findings of Eaglesham *et al.* (1982) and Herridge (1982).

5.5 EVALUATION OF RICE + LEGUME INTERCROPPING SYSTEM BASED ON THE COMPETITIVE BEHAVIOUR OF LEGUMES, BIOLOGICAL EFFICIENCY AND ECONOMIC SUITABILITY.

To achieve higher productivity from intercropping, the component crops are to be evaluated and selected for better compatability. Therefore, a basic knowledge of techniques of evaluation of competitive relation of component crops and their yield advantages in the intercropping situation would be helpful in future for selecting suitable intercropping system for any specific agro-ecological situation.

5.5.1 Competitive Behaviour of Legumes in Rice + Legume Intercropping System

For any intercropping system, evaluation of the competitive relations of component crops and their yield advantages in intercropping situation provides a useful basis to describe different competitive situations (Sheelavantar, 1990). The various parameters used for evaluating competitive behaviour of component crops in this experiment are discussed below.

5.5.1.1 Relative Crowding Coefficient

This was proposed by de Wit (1960). It assumes that mixture treatments form a replacement series. Each species has its own coefficient (K), which gives a measure of whether that species has produced better yield than expected.

To determine if there is an yield advantage of mixing, the product of the coefficients is formed, which is designated as K. If the value of $K>1$ there is yield advantage, if $K=1$ there is no difference and if $K<1$ there is a yield disadvantage (Sankaran and Mudaliar, 1997).

In the experiment the main crop rice has its coefficient value greater than one in all treatments except intercropping of greengram with rice (Table 31). That means all rice + legumes intercropping systems except rice + greengram intercropping performed better than expected. This is because of complementarity and compatibility between rice and blackgram or cowpea. But in rice + greengram intercropping due to the suppressing ability of greengram, the rice yield was reduced.

The product of RCC (K) was greater than one in all treatments except in rice + greengram intercropping, indicating a definite yield advantage due to intercropping (Fig. 12). The highest advantage was noticed in the intercropping system of rice and cowpea in 2:1 row proportion. Similar results were also reported by Sand and Thakuria (1993), Ahmed and Prasad (1996) and Mandal *et al.* (1997).

5.5.1.2 Aggressivity

For assessing the competition between component crops in intercropping, calculation of aggressivity was proposed by Mc Gilchrist (1965). In mixed stand, it was assumed that the mixture formed a replacement series. It gives a simple measure of how much the relative yield increase in species 'a' is greater than that for species 'b'. An aggressivity value of zero indicates that the component species are equally competitive. For any other situation, both species will have the same numerical value but the sign of dominant species will be positive and that of the dominated species will be negative (Willey, 1979).

The aggressivity values were found to be positive in legumes and negative in rice. The maximum values of aggressivity (1.136) was recorded by greengram when it was intercropped with rice in 1:2 ratio (Table 31 and Fig. 12). In this investigation the intercrops blackgram, greengram and cowpea were the dominant ones and rice was found to be dominated by legumes in intercropping situation.

Under intercropped situation the performance of cowpea and blackgram were superior to their sole crops. So in mixtures they gave higher yield than expected. Rice also gave more yield than expected but, the increase in yield of rice is lesser than that of legume in mixtures. Sand and Thakuria (1993) also concluded that in rice + legume intercropping systems, rice gave more yield than expected.

5.5.1.3 Competition Ratio (CR)

This was proposed by Willey and Rao (1981). The CR is simply the ratio of the individual LERs of the two component crops, with correction for the proportions in which the crops were initially sown. It gives the exact degree of competition by indicating the number of times one crop is more competitive than the other. The CR values of the two crops will in fact be the reciprocals of each other. This helps to identify the plant characters, which determine competitive ability. CR provides a way of defining relations between competitive ability and different plant characters. It can be suggested that the CR term may in some combinations, help to identify the balance of competition between the component crops that is most likely to give maximum yield advantage.

The data on competition ratio (Table 30) showed that the legume components were more competitive in all intercropping systems. The highest numerical value of greengram (4.265) in rice + greengram in 2:1 ratio indicated that it had the abilities to produce four times more yield than expected and four times more competitive compared to other legumes. The greengram showed a much vigorous growth which helped greengram to compete rice with more effectively. These findings are also in line with the findings of Abbas *et al.* (1995).

5.5.2 Biological Efficiency of Rice + Legume Intercropping System

Evaluation of intercropping systems in economic terms is considered inappropriate due to seasonal price fluctuations of inputs and the lack of cash economy in most areas where intercropping is practised

(Beets, 1982). The various parameters used for evaluating biological efficiency in this experiment are discussed below.

5.5.2.1 Land Equivalent Ratio (LER)

LER is considered to be the most appropriate general function to determine the efficiency of cereal + legume intercropping systems. LER is 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 greater than one denotes advantage and less than one represents disadvantage.

In all intercropping systems except greengram intercropping system LER excelled unity indicating greater biological efficiency of intercropping over sole cropping. Cowpea when intercropped with rice in 1:2 ratio gave the highest LER (1.24) followed by blackgram intercropped with rice in 1:2 ratio (Table 29 and Fig. 11). Thus these intercropping treatments indicated that on a unit land area basis they have recorded 13 to 24 per cent yield advantages respectively. The results clearly showed that growing cowpea and blackgram with rice in 1:2 ratio gave maximum yield per unit area and time. The intercropping of cowpea and blackgram with rice has the potential of increasing yield. This was due to the development of complementary effects between rice and cowpea or blackgram. The greengram intercropping with rice recorded the LER of less than unity. The vigorous growth of greengram in rainy season affected the performance of rice by suppressing rice growth. Thus the greengram + rice intercropping proved to be disadvantageous. The LER establishes the advantage of intercropping system which was literated by Rao and Willey (1980), Mandal and Mahapatra (1990), Ramamoorthy *et al.* (1994), Barik *et al.* (1998) and Pandita *et al.* (2000).

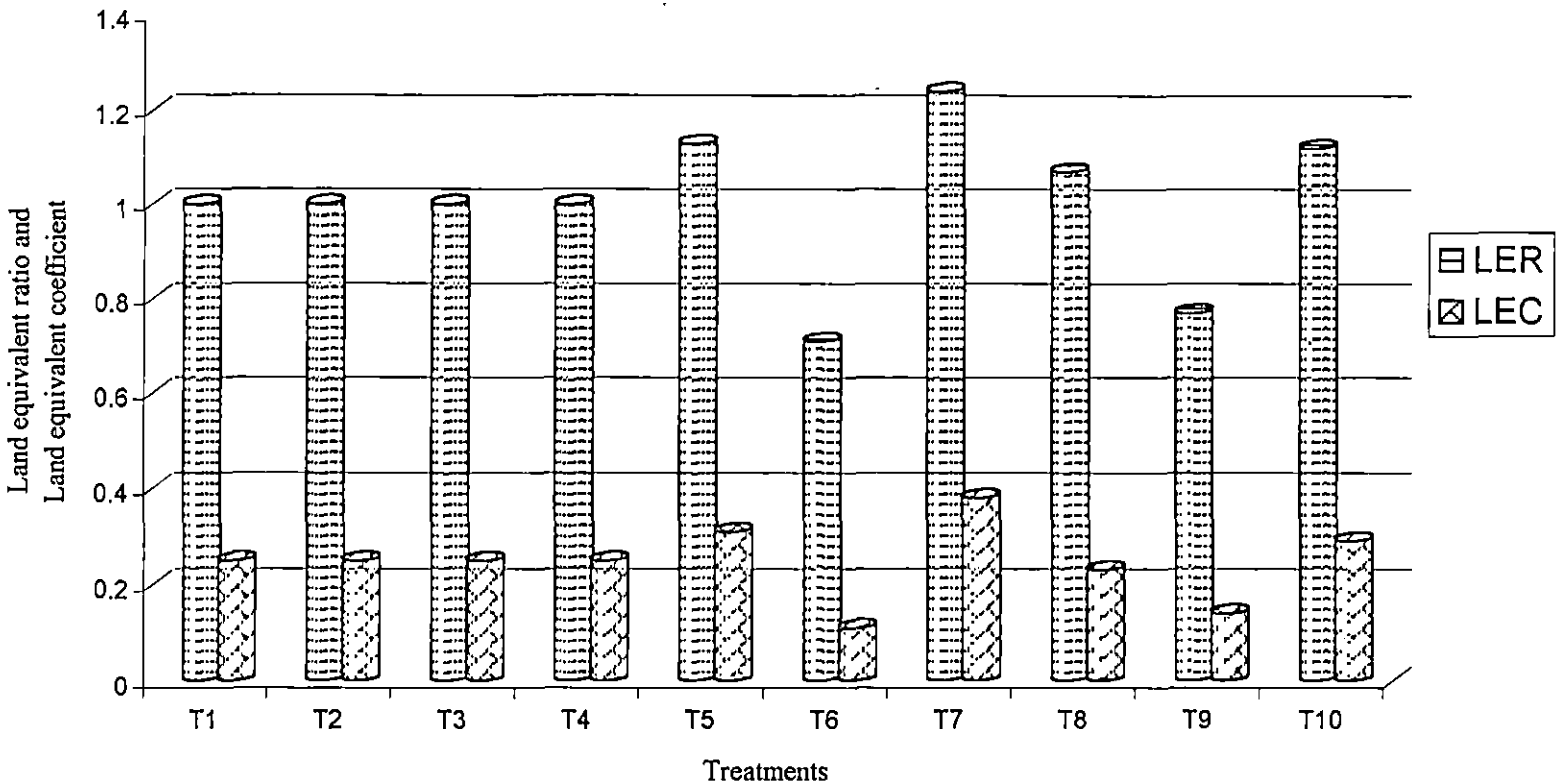

Fig. 11. Land equivalent ratio and land equivalent coefficient of rice+legume intercropping systems

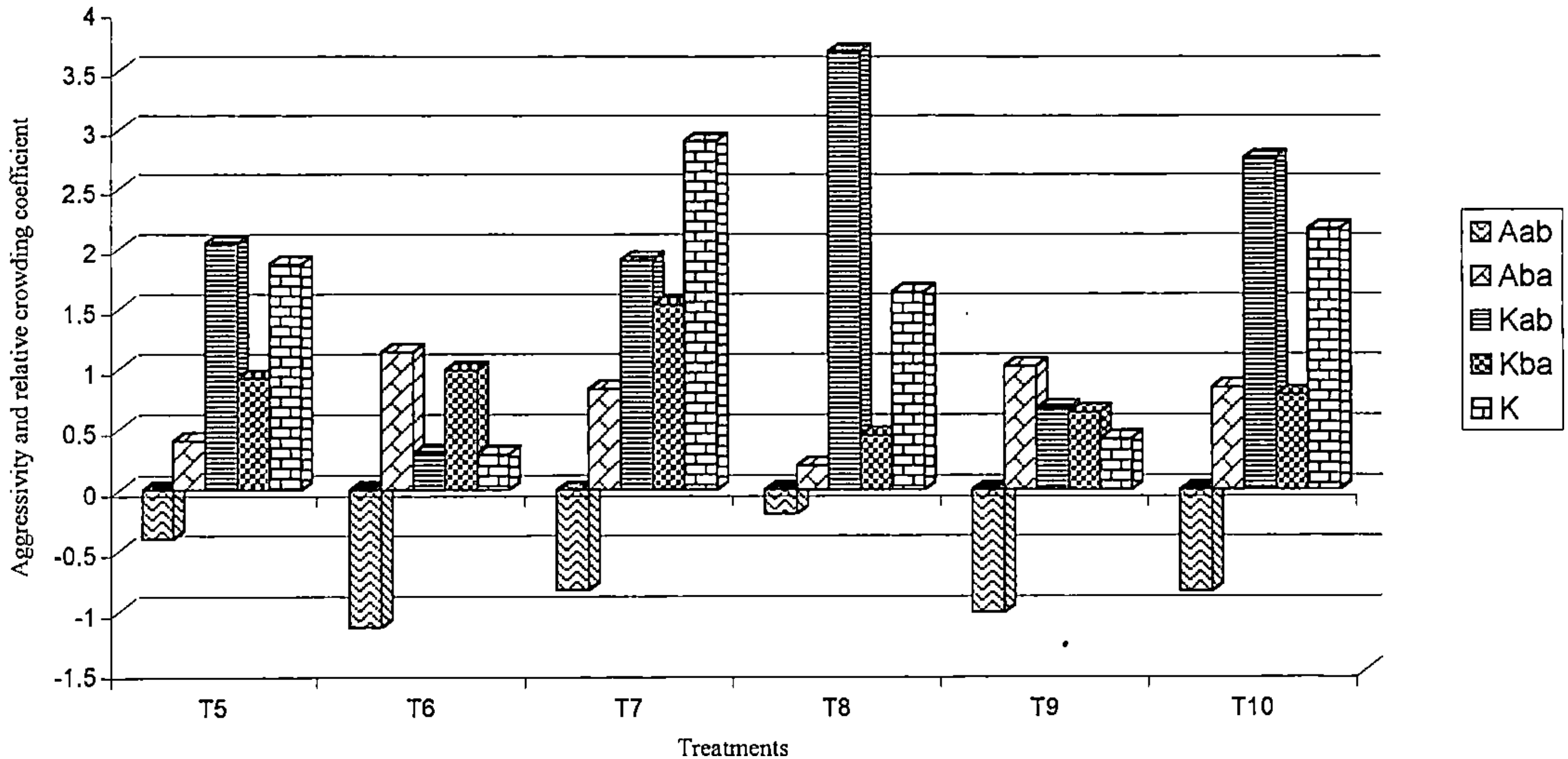

Fig. 12. Aggressivity and relative crowding coefficient of rice and legumes in intercropping systems

5.5.2.2 Land Equivalent Coefficient

The total LER was approximately to the LER of the dominant species and failed to show the competitive effects. In this context, the use of LEC is advantageous. It considers the LERs of the individual crop being the product of LER of component crops in the intercropping system. For any intercropping system (involving 2 crops) to be advantageous, the LEC must be above 0.25 indicating that each component crop in the system should given at least 50 per cent of their sole crop yield or the yield of either of the component should be more than expected (Adetiloye *et al.*, 1983).

The results on LEC (Table 29) that LEC was more than 0.25 in rice + cowpea in 2:1 and 3:1 ratios and rice + blackgram in 2:1 ratio. Intercropping rice and cowpea in both 2:1 and 3:1 ratios and rice and blackgram in 2:1 ratio reduced the yield of component crops than expected because of the competition between the component crops.

In all other intercropping situations LEC was less than 0.25, which indicated that due to competition between the component crops the yield was less than the expected. The maximum reduction in yield was noticed when rice and greengram were grown in 2:1 ratio, which recorded a LEC of 0.11 (Fig. 11).

Similar results were also reported by Sarkar *et al.* (1996).

5.5.2.3 Rice Equivalent Yield

In intercropping, it is very difficult to compare the economics of produce with different nature. Hence equivalent yield is calculated by converting the intercrop yield into base crop yield by considering the market rates of both the crops. However, the total productivity was given in terms of rice equivalent yield (Table 28) after converting intercrop yield in to rice based on market prices.

Rice equivalent yield from all intercropping system were significantly more than sole rice yield, except when rice was intercropped with greengram. Highest equivalent yield (4384 kg ha^{-1}) was obtained from the sole crop of cowpea. Intercropping of rice with cowpea in 2:1 proportion recorded significantly more rice equivalent (4244 kg ha^{-1}) than sole rice and all other intercropping treatments. These two treatments respectively showed 79 per cent and 74 per cent increased rice equivalent yield than sole rice yield. In rice + greengram intercropping (2.1) and rice + greengram intercropping (3:1) showed 39 per cent and 31 per cent decreased rice equivalent yield than sole rice yield. Thus the results clearly indicated the superiority of intercropping except rice intercropping with greengram over sole cropping of rice. These results are inline with the findings of Sarma and Kakati (1991), Sarkar and Pramanik (1992) and Quayyam and Maniruzzadin (1995).

5.5.3 Economic Suitability

Intercropping system seems to be more stable than sole rice system except in greengram + intercropped system. But if any system is to be recommended it should be economically viable. It is necessary to identify a stable system from among different useful intercropping systems that the farmers can adopt to get a stable yield. Hence the produce of the component crops in intercropping systems are converted in terms of returns to farmers and is compared to assess the economic suitability. Thus the economic suitability was tested using various efficiency parameters like gross returns, cost of cultivation, net returns and benefit cost ratio.

The economics of the intercropping system are presented in (Table 39) and illustrated graphically in Fig. 13. The results revealed that sole greengram and rice + greengram intercropping system is not profitable. The economics of the intercropping system was significantly influenced by the treatments. The monetary returns were higher from sole blackgram and cowpea except greengram compared to sole rice.

Among the treatments, the highest cost of cultivation was incurred into the rice + cowpea intercropped in 2:1 ratio followed by sole cowpea (Table 39 and Fig. 13). Generally, labour requirement of vegetable cowpea was higher than other legumes because vegetable cowpea was harvested eleven times. But in other legumes there were only two pickings. Sole rice and sole cowpea registered more or less similar cost of cultivation. In the case of greengram, the cost of cultivation was the least among all the sole legumes.

The difference in cost of cultivation of sole blackgram and sole greengram was due to less labour requirement because, the greengram showed quicker and earlier vigorous growth which efficiently suppressed weed growths and needed no weeding.

Among all the treatments, rice + cowpea in 2:1 ratio gave the highest gross returns (Rs.34654 ha^{-1}) followed by the sole cowpea (Rs.30692 ha^{-1}). Similar results were also reported by Ramamoorthy *et al.* (1994) and Singh and Singh (2001). This was mainly due to the higher yield of cowpea even though the market price of cowpea is equal to rice. Sole greengram gave the lowest gross returns of Rs.13099 ha^{-1}. In all greengram intercropped plots they gave lower gross returns compared to other treatments because, the greengram gave poor performance in terms of seed yield with higher vegetative growth till its harvest and intercropped situations, greengram suppressed the rice yield.

Rice + cowpea in 2:1 ratio gave the highest net returns of Rs.11080 ha^{-1} (Table 39 and Fig. 13). This is almost thrice the net return of rice. These results are in agreement with the findings of Kunasekharan (1980), Ramamoorthy (1994) and Pandita *et al.* (2000). Among the sole crops, the sole cowpea performed better than other treatments by giving a net return of Rs.8925 ha^{-1}.

It was also revealed that the intercropping in 2:1 proportion is economically more feasible than 3:1 row arrangements. The 2:1 proportion of rice and cowpea combination was better than the other

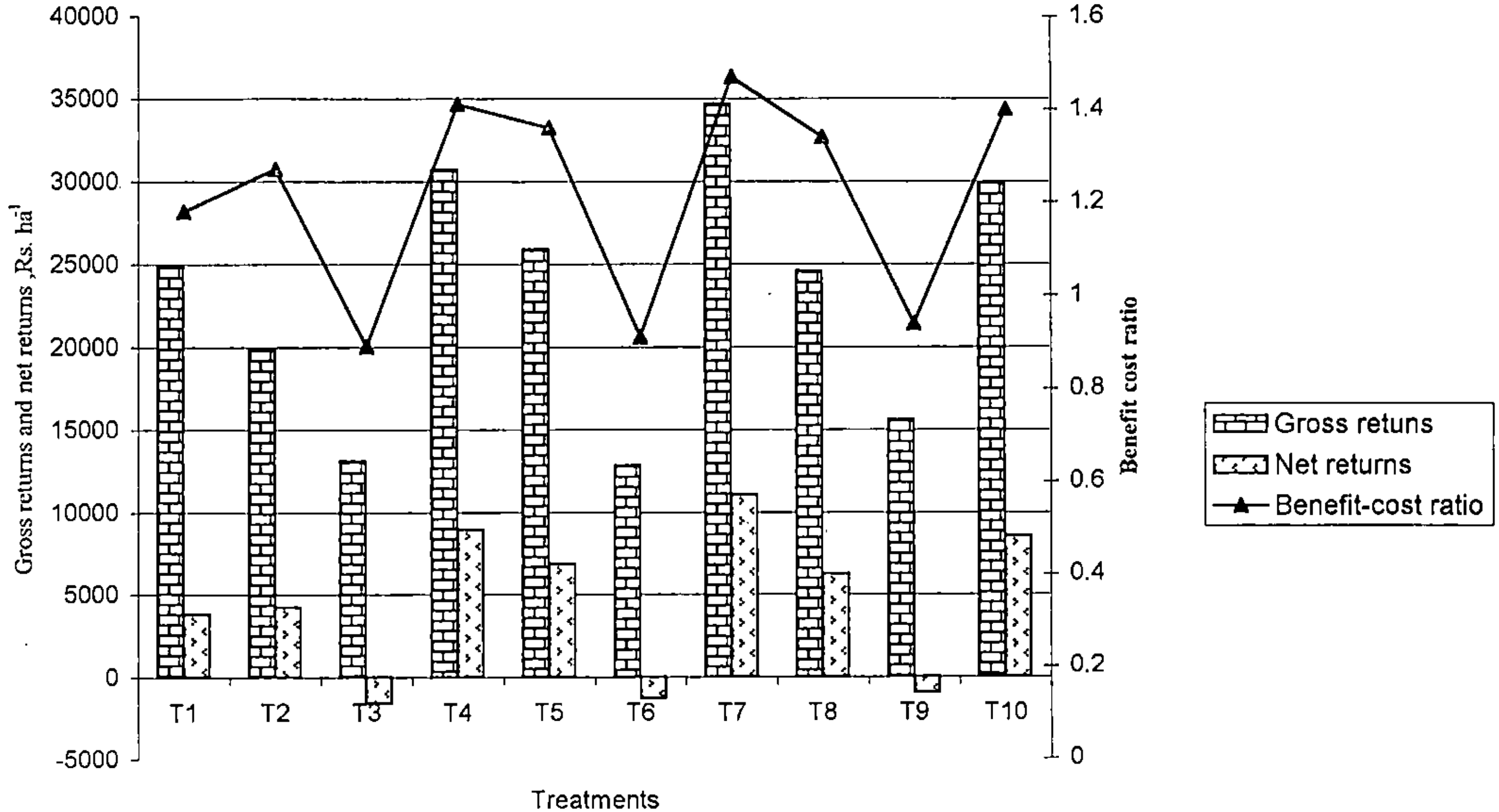

Fig. 13. Economic efficiency of intercropping systems

intercropping treatments and would be recommended where an intercrop is desired. The rice and cowpea combination in 2:1 proportion gave an extra net return of Rs.7284 ha^{-1} than growing rice alone, indicating the superiority of this combination when the choice is between rice sole crop and an intercrop.

The superiority of 2:1 arrangement in intercropping situation than 3:1 have also been reported by several earlier workers like Bhaskaran (1984), Samui and Roy (1990), Deshpande *et al.* (1992) and Paradkar and Sharma (1992).

Intercropping rice and cowpea in 2:1 proportion gave 29 per cent more net returns than 3:1 combinations respectively. Similarly in rice + blackgram intercropping system in 2:1 ratio gave 9 per cent more net returns than 3:1 ratio.

Intercropping of rice with greengram is profitable because the greengram variety (CO2) was not compatible with the rice due to its progressive growth which suppressed the performance of rice.

Benefit-Cost Ratio (BCR) of an intercropping system provides an estimate of the benefit the farmer derives for the expenditure incurred in adopting a particular intercropping system.

In all treatments, BCR excelled unity (Table 39 and Fig. 13) except sole and intercropped greengram systems and the maximum value of 1.47 was recorded by the rice + cowpea intercropping system in 2:1 ratio. This was due to higher yield achieved by cowpea and the development of complementary effects between rice and cowpea. Similar results due to intercropping have also been reported by Quayyam and Maniruzzadin (1995) and Pandita *et al.* (2000). Rice intercropping with cowpea or blackgram is economically advantageous one. Sole cowpea also recorded a high BCR of 1.41, which indicates that the sole cowpea cultivation also can be practised.

The rice + greengram intercropping system gave a BCR of less than unity which means rice + greengram intercropping is not economically viable.

The results of the study revealed that a rice + cowpea intercropping system in 2:1 ratio appeared to be economically viable. The higher monetary advantage is an indicator of a better cropping system. Similar results have also been reported by Singh and Yadav (1990) and Rathore and Gupta (1995).

In conclusion, rice in combination with blackgram or cowpea gave higher net returns and BCR than sole rice. Raising a sole crop of cowpea also appears to be a profitable one. Under the circumstances, where an intercrop is desired for yield stability, to reduce risk or to get yield diversity, raising rice and cowpea in 2:1 proportion can be recommended as an economically viable practice.

5.6 SOIL NUTRIENT STATUS AS INFLUENCED BY INTERCROPPING

The soil nutrient status (available nitrogen, available phosphorus and available potassium) of the experimental site before the experiment are presented graphically in Fig. 14. The results on the nutrient status before the experiment indicated that there was not much variation in the fertility status of the soil of the experiment field (Table 36).

The soil test data after the experiment indicated a significant positive buildup of nitrogen and phosphorus in all sole legume plots. The reason for buildup of nitrogen in these plots is that the legumes have the potential for self sufficiency for N, the nutrient most limiting to productivity, by symbiotically fixing atmospheric N. In fixing atmospheric N, legumes contribute to the N content of soil either as sole crops, or as intercrops.

The 'N' content has been significantly influenced by the sole treatments. Among the sole legume plots, sole greengram recorded the highest amount of N content of 299.21 kg ha^{-1} which means an increase of 21 kg ha^{-1} (Table 37 and Fig. 14). These results are in line with the findings of Mandal *et al.* (1987). Other legumes *viz.*, sole blackgram and sole cowpea recorded an approximate increase in N content of 18 kg ha^{-1}. Greengram variety used in this experiment showed an indeterminate growth in rainy season and it fixed more N than cowpea and blackgram. These results shows that legumes of indeterminate growth are more efficient, in terms of N fixation than the determinate types.

Sole rice recorded the lowest amount of N content after the experiment. This was due to the absence of N_2 fixing system in rice.

Among the intercropping systems, rice + legumes intercropped plots in 2:1 ratio recorded higher amount of N than 3:1 ratio plots. The quantity of N fixed by the legume component in cereal legume intercropping depends on the species, morphology, density of legume in the mixture, the type of management and the competitive abilities of the component crops. Among the intercropping systems in 2:1 ratio, the N content was higher in the greengram intercropped plots. The greengram showed vigourous growth when it was not much shaded by rice, but the other legumes were much shaded by rice which reduces the N fixation potential of companion legume.

In case of available P content, among the sole crops all legume plots showed an increase in available P content but in sole rice, there was a decrease in P content.

In all the sole legume plots, the increase in P availability was upto 2 kg ha^{-1}. In sole rice there was a decrease of 1.5 kg ha^{-1}. This may be because of the ability of legumes to extract insoluble forms of soil phosphorus. The fact that the legumes have considerably greater capacity than other crops to use the less readily available sources of phosphate open the possibility of making them convert some of these phosphates into a more easily available form by growing them. The

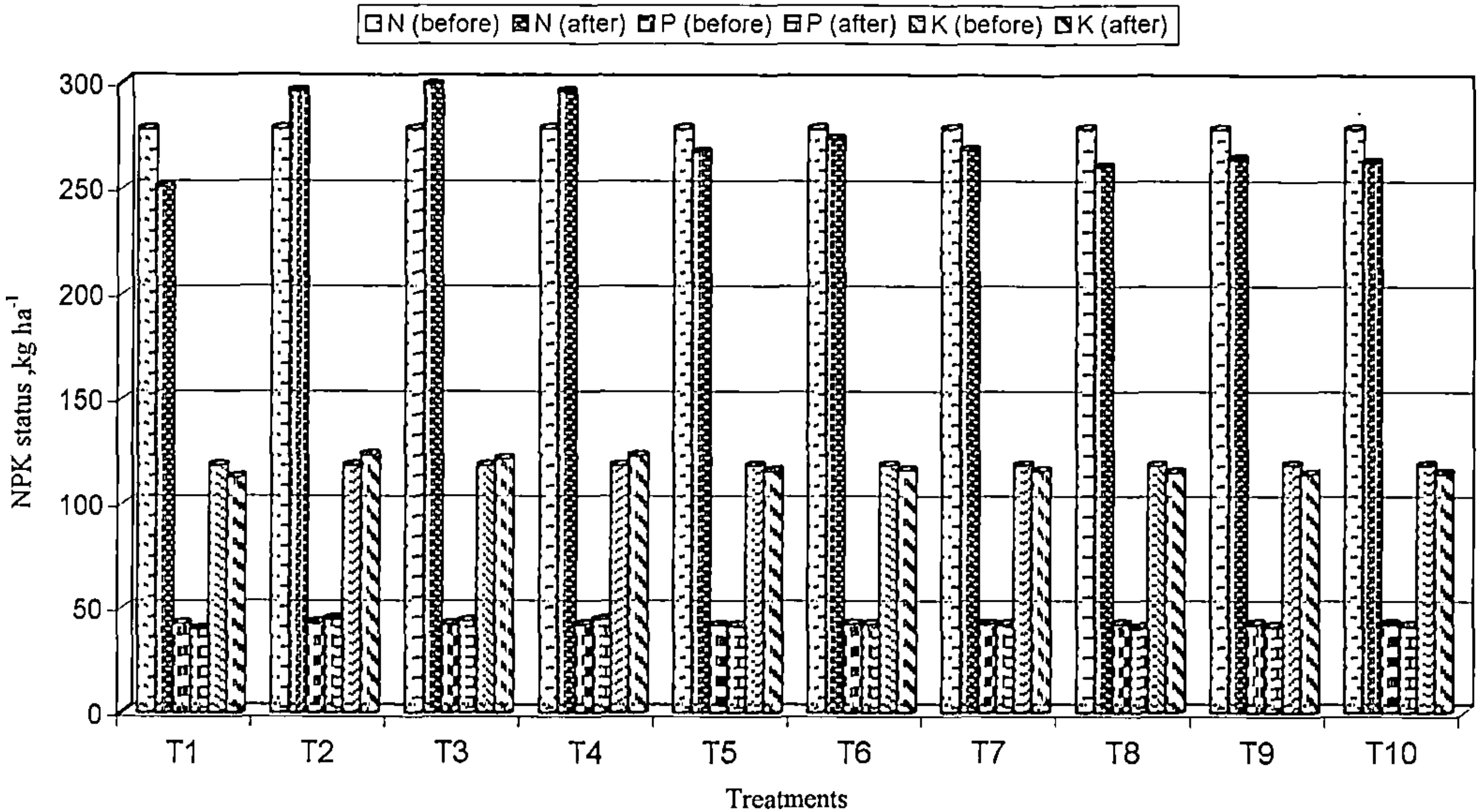

Fig 14. Soil nutrient status before and after the experiment

results are in agreement with the findings of Sharma and Singh (1970) and Patra *et al.* (1990).

In response to phosphorus deficiency some plant species are capable of modifying the chemistry of their rhizospheres by exuding acids, iron chelators, reducing agents or enzymes. Legumes can reduce the rhizosphere pH more effectively than cereal and this may increase the concentration of phosphate in the rhizosphere several fold by increasing the desorption of phosphate from the solid phase (Marschner *et al.*, 1987).

All legume included treatments showed an improvement in P availability and in intercropping situation, the increased P availability has been utilized by companion cereal rice crop.

The available K status of soil was also significantly influenced by the treatments (Table 37). The K content of soil of all treatments except sole legumes was decreased after the experiment (Fig. 14). This may be due to the fact that the total K uptake of the system exceeded the total addition.

After the final harvest, bhusa of legumes was incorporated into the soil. This was the reason for the nutrient improvement in legumes included plots. These results are in agreement with the findings of Sharma and Choubey (1991) in maize + legume intercropping system.

SUMMARY

6. SUMMARY

An experiment was undertaken during the kharif season of 2001 at the Instructional Farm, College of Agriculture, Vellayani, Thiruvananthapuram to find out an optimum row proportion of upland rice to legume combination, to assess the soil fertility improvement and to evolve an economically feasible legume intercropping system in upland rice. The field experiment was conducted during the period from June 2001 to October 2001.

The experiment was laid out in a randomised block design with ten treatments and three replications. The treatments were sole cropping of rice, blackgram, greengram and cowpea and intercropping of rice with blackgram, greengram and cowpea in 2:1 and 3:1 ratios. The results of the study are summarised below.

In rice, plant height was significantly influenced by treatments. Sole rice recorded the highest height among the treatments at all stages. Plant and root spread and leaf area index were also significantly influenced by the treatments. In all the cases, rice + greengram intercropping systems recorded lower values. Number of tillers was not significantly influenced by treatments.

Among the yield attributes, days to 50 per cent flowering was not influenced by treatments.

Intercropping rice with cowpea in 3:1 ratio recorded the highest number of productive tillers hill^{-1}, weight of panicle, number of filled grains panicle^{-1} and 1000-grain weight. Rice + cowpea intercropping in 2:1 ratio gave higher values of length of panicle and number of spikelets panicle^{-1}. The lowest chaff percentage was recorded with rice + blackgram intercropping in 2:1 ratio.

In all yield-attributing characters, rice and greengram intercropping systems recorded lower values.

The sole crop of rice gave significantly higher seed (2436 kg ha^{-1}) and straw yield (5218 kg ha^{-1}) than when it was grown in intercropping system.

The total dry matter production of rice was maximum (7931 kg ha^{-1}) with the sole crop. The total N, P and K uptake were also maximum with the sole crop.

The harvest index was significantly influenced by the treatments. The highest harvest index of 0.356 was obtained when rice was intercropped with cowpea in 3:1 ratio.

In blackgram, the growth characters like plant height, plant and root spread, number of branches and leaf area index were significantly influenced by intercropping treatments. The intercropped blackgram with rice in 1:3 ratio recorded the highest value of plant height, root spread and in the case of plant spread, number of branches $plant^{-1}$ and leaf area index were on par with intercropped blackgram with rice in 1:2 ratio.

Among the yield attributes, the number of filled grains pod^{-1} and protein content of seeds showed significant treatment differences. The sole crop recorded the highest protein content of grains and intercropped blackgram with rice recorded higher number of filled grains pod^{-1} than sole blackgram.

The sole crop recorded the highest seed yield (675 kg ha^{-1}) which was significantly superior to other treatments. The yield of blackgram in 2:1 and 3:1 ratios were 47 and 30 per cent of the sole crop yield respectively.

The stover yield and nutrient uptake were significantly higher in the sole crop as compared to intercropping treatments.

The harvest index was not influenced by treatments.

In greengram plant height, plant and root spread, number of branches $plant^{-1}$, leaf area index were significantly influenced by the treatments. In all the cases, intercropped greengram with rice in 1:3

ratio recorded the highest values whereas the values of all growth character values were lesser in sole greengram.

Among the yield attributes, days to 50 per cent flowering, number of pods plant^{-1}, weight of pod, number of filled grains pod^{-1} and hundred grain weight were not significantly influenced by the treatments. The protein content and length of pod were significantly influenced by the treatments. The protein content was highest in the sole greengram and lowest in intercropped greengram with rice in 1:3 ratio. In the case of pod length, intercropped greengram had the highest value and sole crop had the lowest value.

The sole crop of greengram produced significantly higher seed yield (442 kg ha^{-1}) than the intercropping system in which yield varied due to difference in population. In 2:1 and 3:1 ratios, the yields were 49 and 38 per cent of the sole crop yield respectively.

The highest biological yield and nutrient uptake were also recorded by the sole crop.

In cowpea, the growth characters like the plant height, plant and root spread, number of branches plant^{-1} and leaf area index were significantly influenced by treatments. The intercropped cowpea showed superiority to sole cowpea in all the growth characters.

The dry matter production was significantly higher in the sole crop as compared to intercropping treatments.

Among the yield attributes, days to 50 per cent flowering, length of pod, weight of pod, number of filled grains pod^{-1} and hundred grain weight were not significantly influenced by treatments.

Number of pods plant^{-1} and protein content were significantly influenced by treatments. Among the treatments, intercropped cowpea showed higher number of pods plant^{-1} and sole cowpea recorded the highest protein content.

The sole crop recorded the highest vegetable yield (4071 kg ha^{-1}) which was significantly superior to other treatments. The yield of cowpea in 2:1 and 3:1 ratios were 60 and 43 per cent of the sole crop yield respectively.

The biological yield and nutrient uptake were significantly higher in the sole crop as compared to intercropping treatments

The harvest index was not influenced by treatments.

The value of LER was the highest when rice and cowpea were grown in 2:1 ratio. The maximum value of LEC (0.38) was noticed when rice and cowpea were grown in 2:1 ratio. The aggressivity values were positive for intercrops in all the treatments. The RCC was more than one in all the treatments except when rice was intercropped with greengram. Among the intercropping treatments, greengram intercropped with rice in 1:2 ratio recorded the highest value of competition ratio (4.265).

The sole crop of cowpea recorded the highest rice equivalent yield (4384 kg ha^{-1}). Among the intercropping combinations rice-cowpea in 2:1 ratio recorded the highest rice equivalent yield (4244 kg ha^{-1}).

The monetary returns was the highest in rice + cowpea intercropping in 2:1 ratio. It was found that the cultivation of greengram either as sole crop or intercrop was not profitable. The BCR also followed the same trend.

After the experiment, the soil nutrient status was significantly influenced by treatments. In general, a positive build up of soil N, P and K were noticed in all legume included plots.

Thus in kharif season, instead of growing sole crop of upland rice, rice intercropped with cowpea in 2:1 proportion can be recommended as an economically viable, biologically suitable and sustainable intercropping system.

In this study, three leguminous crops were tried as intercrops along with rice. In future, the compatibility of these crops with other cereals which are suitable for the specific agroclimatic regions can also be studied.

Further research can be done on the following lines.

1. The pathways of N losses from cereal + legume intercrop systems to maximize the utilization of N fertilization and reduced wastage of an expensive input.
2. The application of low rates of N fertilizer early in order to encourage nitrogen fixation of the intercrop legume, together with later application of N during the peak vegetative stage of the cereal, in order to minimize competition for N.
3. The effects of applied N on N_2 fixation of the intercrop legume.

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*Originals not seen

COMPETITIVE BEHAVIOUR OF DIFFERENT LEGUMES GROWN AS INTERCROP WITH DIRECT SEEDED UPLAND RICE

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Abstract of the
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ABSTRACT

A field experiment entitled "Competitive bahaviour of different legumes grown as intercrop with direct seeded upland rice" was conducted at the Instructional Farm, College of Agriculture, Vellayani from June 2001 to October 2001. The study aims to find out an optimum row proportion of upland rice to legume combination, to assess the soil fertility improvement and to evolve an economically feasible legume intercropping system in upland rice.

The experiment was laid out in randomised block design with ten treatments in three replications. The weather condition during the cropping period was congenial for crop growth. The treatments were sole crops of upland rice, blackgram, greengram and cowpea, intercropping of upland rice with blackgram, greengram and cowpea in 2 : 1 and 3 : 1 ratios.

The results of the study indicated that the legumes performed well under intercropped condition than under sole crop situation by dominating the cereal component rice.

The association of legumes excepting greengram had complementary effect on rice and it was proved that blackgram or cowpea can be grown in a compatible manner with rice.

The sole crops produced significantly higher seed yield than the intercropping systems, in which yield varied due to differences in population. The sole crops recorded the maximum nutrient uptake over the intercropping treatments.

The competitive behaviour of the components and the bio-economic suitability of the intercropping systems were studied. Higher LER, LEC, RCC and rice equivalent yield were obtained in rice + cowpea in 2:1 ratio. The highest competition ratio and the highest aggressivity values were obtained in rice + greengram in 2:1 ratio.

The results on monetary returns were higher in intercropping systems except greengram intercropping compared to sole crop of rice. The highest gross returns, net returns and benefit cost ratio were realised from the rice + cowpea intercropping system in 2:1 ratio. Among the sole crops, cowpea gave higher monetary returns and benefit - cost ratio. The maximum net returns (Rs. 11080 ha^{-1}) was obtained when rice and cowpea were grown in 2:1 proportion. Greengram intercropping with rice was not profitable.

In general, the soil nutrient status indicated a significant positive buildup of nitrogen, phosphorus and potassium in all legume included plots where legumes were incorporated into the soil after the final harvest.

Thus, raising cowpea or blackgram as an intercrop in upland rice appears to be more profitable. Under the circumstances, where an intercrop is desired for yield stability, to reduce risk or to get yield diversity, raising cowpea and rice in 1:2 proportion can be recommended as an economically viable and biologically sustainable practice.

APPENDIX

APPENDIX – I

Weather parameters during the experimental period
(June – October 2001)

Standard weeks	Relative humidity, %	Maximum temperature, ^0C	Minimum temperature, ^0C	Evaporation, mm	Rainfall, cm
22	80.20	29.5	21.7	3.6	3.82
23	85.65	28.6	20.1	2.5	3.10
24	87.80	28.7	20.9	2.1	7.12
25	82.40	30.0	21.9	3.3	4.69
26	82.45	29.7	20.9	3.4	3.68
27	87.10	28.4	20.1	2.7	10.2
28	81.25	29.5	19.9	2.3	16.97
29	77.90	29.9	20.7	3.1	0
30	82.70	29.3	20.2	3.1	2.24
31	83.95	27.6	19.3	2.8	6.31
32	84.20	30.3	21.2	3.8	0
33	85.80	32.0	21.0	3.6	1.42
34	83.35	29.7	21.1	3.2	10.66
35	84.90	29.9	23.7	3.3	0.52
36	84.00	31.0	23.8	4.9	0
37	75.08	31.9	24.5	5.1	0
38	86.80	29.5	23.6	3.0	29.40
39	90.50	28.2	23.1	2.3	26.42
40	81.80	29.9	24.4	3.9	1.58
41	81.95	30.0	23.7	4.2	6.38
42	86.40	29.5	24.0	2.7	8.16
43	82.15	30.2	23.8	2.7	9.57