PRODUCTION POTENTIAL AND ECONOMICS OF SESAMUM - PULSE INTERCROPPING IN ONATTUKARA TRACT

By

BINDHU. J. S.

THESIS

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DECLARATION

I hereby declare that this thesis entitled **"Production potential and economics of sesamum - pulse intercropping in Onattukara tract"** 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.

Bindhu. J.S

Vellayani,
28-7-1999.

BINDHU. J. S.

CERTIFICATE

Certified that this thesis entitled **"Production potential and economics of sesamum - pulse intercropping in Onattukara tract"** is a record of research work done independently by **Mrs. Bindhu. J.S.** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

Vellayani,
28 · 7 · 1999.

Dr. V. MURALEEDHARAN NAIR
(Chairman, Advisory Committee)
Professor
Department of Agronomy,
Collge of Agriculture, Vellayani

Approved by

Chairman :

Dr. V. MURALEEDHARAN NAIR 23/11/99

Members :

1. Dr. G. RAGHAVAN PILLAI Raghavan Pillai 23/11/99

2. Prof. N. RAMACHANDRAN NAIR 23/11/99

3. Dr. (Mrs.) P. SARASWATHI Saraswathy 23/11/99

External Examiner : 23/11/99 (P. SUBRAMANIAN)

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Bindhu J.S

BINDHU J.S.

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INTRODUCTION

INTRODUCTION

Sesamum is a traditional oilseed crop of Kerala cultivated from time immemorial. It is a rich source of oil, protein and minerals. The oil is rich in vitamin E and is an excellent source of folic acid, which plays an important role in the prevention and cure of pernicious anemia.

The total area under sesamum in Kerala is 5204 ha and the total production is 1807 t (Farm Guide, 1999). The per hectare yield is reported to be low in our state which is 347 kg ha^{-1}, though it has an yield potential of 600-1000 kg ha^{-1} under rainfed and 1000-1200 kg ha^{-1} under irrigated conditions.

Sesamum is mainly grown in our state as a sole crop in the summer rice fallows of Onattukara tract spread over Kollam and Alappuzha districts. The soil in this area is sandy loam with low nutrient status. The crop grows in this tract utilizing the residual moisture available in rice fields. The establishment of the crop is often poor resulting in low productivity. It is very sensitive to heavy or scarce rains which often occurs during this period leading to instability in its production and economic returns. Under these adverse circumstances an intercropping system provides an insurance against failure of any one crop. Besides, in a normal season it increases the income of the farmer.

The problems of underfeeding and malnutrition of people are primarily due to inadequate supply of protein and edible oils. This has to be augmented from the existing oilseed and pulse crops by appropriately manipulating the production practices. Intercropping is one possible approach to raise the productivity per unit area per unit time, especially in the state where cultivable area is limited.

Pulses have certain unique features which together make them an indispensable component in sustainable agriculture. Pulse crops play an important role in the restoration and buildup 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.

Intercropping, apart from providing biological insurance against crop failure, facilitates better stability in yield and ensures higher total yield advantages and returns than sole cropping in the component crops. This can be attributed to the efficient utilization of resources such as moisture, nutrients and solar radiation especially under stress situations. By adjusting the planting geometry of crops, it is possible for maximising the productivity of intercropping system.

Experiments have shown that growing pulses like blackgram and greengram intercropped with sesamum is successful without any adverse effect on the latter crop. Suitable changes in the cropping system to accommodate both oilseeds and pulses will be a better proposition to bridge the gap between demand and supply of oilseeds and pulses in India, besides alleviating the problems of malnutrition.

Sesamum, being a soil exhausting crop, the inclusion of leguminous crops like blackgram and greengram may benefit the companion crop through current nitrogen transfer and to the succeeding rice crop through the residual effect. Hence selection of suitable crop combinations and adoption of proper planting geometry helps in increasing the crop productivity as well as economic returns from an intercropping system.

To increase and stabilize the productivity of sesamum, suitable intercropping systems have to be developed for Onattukara region. Thus considering the need for increased production of oilseeds and pulses, sesamum, blackgram and greengram will have better scope because of their suitability for this region. The present investigation was undertaken with the following objectives.

i) to find out the suitablility of raising pulses as an intercrop in sesamum

ii) to work out appropriate planting geometry in sesamum - pulse intercropping system

iii) to assess the economics of sesamum based intercropping system and

iv) to estimate the residual effect of the intercropping on succeeding crop of rice during *Virippu* season in Onattukara tract.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Horizontal expansion of plough - sown area to augment the food grain production is limited. The only alternative is to expand vertical growth by increasing the productivity per unit area per unit time. This necessitates development of feasible, location - specific intensive cropping system suitable for the agro-climatic condition.

Cultivation of intercrops is a part of intensive agriculture to obtain possible means of better income under rainfed condition. The productivity of pulses and oilseeds as sole crops is very low and often varies due to vagaries of weather. In view of the increased demand of edible oils and proteins there is a need to increase the production of oilseeds and pulses. In order to increase and stabilize the productivity of oilseed crops, suitable intercropping systems need to be evolved for problem areas like Onattukara region. Therefore the present study was undertaken to findout the production potential and economics of sesamum - pulse intercropping system in Onattukara tract. A brief review of the work done on intercropping of oilseeds and pulses is presented below.

2.1. Crop compatibility in intercropping system

The major objectives in intercropping are to produce an additional crop without affecting too much the yield of base crop, to obtain higher economic returns, to optimise the use of natural resources including light, water and nutrients (Donald, 1963) and to stabilize the yield of crop.

Pulses and oilseeds are energy rich crops which play an important role in human nutrition and animal feed; they occupy a key position in the diet of Indian masses as a majority of our population is vegetarian (Ramanarayan, 1973). Legumes have an important role in the intercropping system because of their potential to transfer the excreted nitrogen to the associated non legumes (Virtanen *et al.*, 1937; Ruschel *et al.*, 1979).

The crops selected for intercropping are normaly of different species, differing in their duration, canopy structure, rooting habits, water, nutrients and solar radiation requirements (Rao, 1986).

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).

Holker *et al.* (1991) opined that the success of an intercrop depends on the proper choice of genotypes to assure stable production in the semi-arid tropics. The genotypes suitable for sole cropping need not give better performance in intercropping. Sarkar and Pramanik (1992) reported that sesamum and mungbean due to their short duration, drought resistance, thermo and photo insensitive nature can be introduced in the summer rice fallows for maximum profit and stability in production.

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

Crop compatibility that depends on the selection of crops, constitutes an essential ingredient of successful intercropping system (Rajashekar *et al.*, 1997).

2.2. Effect of planting pattern on oilseed + pulse intercropping system

In rice fallows, intercropping is an important approach to achieve maximum profit and stability in production under limited resources, especially the soil moisture. Planting pattern of component crops plays an important role in maximising the productivity of intercropping system.

Mahapatra *et al.* (1990) studied the effect of row ratios in sesamum and pigeonpea intercropping. It was concluded that to obtain higher income than sole sesamum it was necessary to adopt intercropping with pigeonpea in uniform planting, particularly under late sown condition.

Dayal and Reddy (1991) conducted an experiment to find out the effect of intercropping of rainfed groundnut with annual oilseed crops under differnt planting pattern. The pooled data revealed that the planting pattern significantly affected the yield and yield components of groundnut. Paired-row planting gave significantly higher pod (23.4 per cent) and oil (22 per cent) yields than the normal planting, irrespective of variety and cropping system. The higher yield in paired row system is due to the wider intra row spacing than that of normal system of planting.

An intercropping of pigeonpea - groundnut at 100 per cent population of each was found most productive and efficient than their sole crops (Pareek and Turkhede, 1991). Ali (1992) studied the genotypic compatibility and spatial arrangements in chickpea and Indian mustard intercropping in north-east plains. The study revealed that intercropping of all the genotypes in 4:1 row ratio provided higher yield than sole crop of chickpea.

Planting pattern significantly affected the yield of component crops as well as gross monetary returns of the cropping system (Dayal *et al.*, 1992). Sachan and Uttam (1992) studied the effect of intercropping of mustard with gram under different planting systems on eroded soils. Here gram and mustard in 2:2 planting ratio gave the highest net return in comparison to other ratios of intercropping.

Uniform row planting of sunflower was conducive for better growth and yield of sunflower and soybean than paired row system

(Shivaramu and Shivashankar, 1992). Legha *et al.* (1993) reported that in pigeonpea - mungbean intercropping system, the best planting pattern with highest combined yield (pigeonpea equivalent) was 3:1 row combination. Tiwari *et al.* (1994) opined that sesamum + greengram in 1:1 row ratio was superior to other intercropping systems.

Sarkar and Pramanik (1992) reported the effect of planting pattern in sesamum + mungbean intercropping system. Results showed that sesamum + mungbean at their average row spacing of 37.5 cm in 2:2 row ratio of planting pattern was most productive with land equivalent ratio of 1.74 and benefit : cost ratio of 2.83.

Saraf (1992) conducted an agronomic evaluation of chickpea + safflower intercropping system under limited irrigation for sustained crop production. Results showed that planting pattern did not influence the grain yield of both the crops.

Singh (1995) opined that growing greengram as an intercrop with pigeonpea in normal planting at 60 cm in 2:1 row arrangement under recommended fertilization of both crops has the potential of giving maximum yields as well as monetary returns per unit area and time.

Nimje (1996) studied the effect of planting pattern and weed management in pigeonpea + soybean intercropping system. Pigeonpea + soybean in 1:3 ratio recorded the highest weed control efficiency as well as pigeonpea equivalent yield and net returns.

Sarkar *et al.* (1996) found that paired row planting gave higher pod yield of groundnut than normal planting, irrespective of the cropping system. The higher yield in this system resulted possibly due to improvement in drymatter production and yield attributes, owing to relatively more space available per plant compared with normal planting, where the pressure on population was greater due to reduced intra-row spacing.

2.3. Effect of intercropping on growth and yield attributes

Reddy and Chatterjee (1975) reported that the number of pods per plant was decreased significantly in mixed stand as compared to those in pure stand when soybean was grown in mixed stand. Rao and Willey (1980) opined that intercropping ensures adequate yield of one of the crops under aberrant weather situation. In intercropping situation, eventhough the yield of both the crops compared to yield of their sole crops is low, though the overall advantages over pure crop is higher (Willey *et al.*, 1981). Saraf and Chand (1981) reported that combined seed yield was increased by intercropping mungbean or urdbean in pigeonpea as compared with its monoculture.

Plant height of soybean, grown along with sesamum in any row proportion significantly increased as compared to that of pure stand (Sarmah *et al.*, 1984). Kondap *et al.* (1985) reported that sesamum branched more profusely when it was intercropped with blackgram, greengram or pigeonpea in 1:1 proportion than when sown as a sole crop. Asokaraj and Ramaiah (1987) found that leaf area index (LAI) of redgram was significantly influenced by intercropping treatments. Blackgram, greengram and cowpea as intercrops significantly increased the LAI of red gram (5.5 to 13.1 per cent) over sole redgram at all stages of crop growth.

Shinde *et al.* (1990) reported that intercropping of redgram and groundnut in 1:3 row proportion in summer, which gives an additional yield of redgram (5.3 $q \cdot ha^{-1}$) without affecting the pod and oil yield of summer groundnut. Though the individual component crops of the different intercropping systems were less productive than as sole crops, the component crops together produced more dry matter and economic yields per unit area (Venkateswarlu and Balasubramanian, 1990). In pigeonpea - groundnut intercropping, the pigeonpea equivalent yield with 100 per cent plant density of groundnut was significantly more than with the 50 per cent density (Pareek and Turkhede, 1991).

Reddy *et al.* (1991) found that in groundnut - pigeonpea intercropping system, LAI and dry matter production in the staggered groundnut was very low because of competition from pigeonpea for available resources which decreased the pod yield to a large extent. Ali (1992) reported that dry matter accumulation in chickpea under sole and intercropping systems was almost identical till 30 days after sowing and thereafter it declined in the intercropping system compared with sole crop. Deshpande *et al.* (1992) reported that growth components recorded significantly higher values in 1:1 planting ratio was due to less intra and inter row effect resulting in normal growth of plant parameters.

Highest yields of mustard, cowpea, soybean and blackgram were obtained from the sole crop of respective crops. Intercropping reduced the yields of both the crops obviously due to marked reduction in plant population and more competition (Kajarekar and Khanwilkar, 1992). When oilseed and pulse crops were intercropped with sunflower they reduced the LAI of sunflower which ranged from 6 to 18 per cent (Sarkar and Dhara, 1992).

Intercropping of groundnut with suitable intercrops brings stability in yield and improves total production (Mehta *et al.*, 1985; Simon *et al.*, 1992). Vyas and Rai (1992) reported that the dry matter production was significantly higher in mustard + chickpea (1:3) pattern than sole mustard and sole chickpea. Legha *et al.* (1993) opined that sole crop of summer mungbean produced significantly higher seed yield than intercropping system in which yield varied depending upon population and row spacing.

Behera *et al.* (1994) reported that the seed yield of sesamum was reduced significantly due to intercrops of greengram and blackgram in all combinations compared with sole crops except in 2:2 row ratio with blackgram.

Kumar *et al.* (1994) conducted intercropping studies in toria and revealed that the mean yield of toria was the highest in sole toria because of more plant population, higher dry matter accumulation per plant and reduced competition. Mandal *et al.* (1994) reported that safflower + chickpea at 2:1 planting ratio recorded the highest quantity of combined root dry weight as well as combined LAI.

The grain yield of pigeonpea and soybean components was significantly improved with intercropping as compared to their sole crop yields (Nimje, 1996). In groundnut - sunflower intercropping system, higher leaf area and dry matter production were found to be more in sole crops as compared to intercropped ones (Rajasekhar *et al.* , 1997). Groundnut intercropped with maize gave lower oil yield than sole groundnut owing to its appreciably lower pod yield in the intercropping system (Jana and Saren, 1998).

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

2.4. Economic efficiency of the intercropping system

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.

Giri *et al.* (1980) reported that pigeonpea intercropped with groundnut in 1:1 or 2:1 ratios was remunerative. Kachapur *et al.*

(1980) found that intercropping of groundnut and sunflower with niger is more profitable than the pure crop. Kunasekharan *et al.* (1980) opined that intercropping of blackgram with sorghum gave the highest net returns. They also reported that growing of pulses as sole crop was not remunerative.

The highest net returns were realised under the intercropping systems of groundnut + gingelly and groundnut + greengram than sole crops (Venkateswarlu *et al.*, 1980). The economics of mixed cropping of sesamum with pulses revealed that the net returns from crop mixture were higher irrespective of the pulse crop raised, compared to sole crop of sesamum (Bhaskaran, 1984). Sunflower - groundnut intercropping system is being adopted in the semi-arid regions, as it provides higher monetary returns (Sharma and Singh, 1987).

Singh and Jadav (1990) reported that intercropping of gram, lentil, peas and mustard in rainfed wheat gives higher monetary advantages as compared to pure stand of either of these crops. Intercropping of mustard with pea and urdbean increased the profit by Rs. 4500 and Rs. 1300 ha^{-1}, accounting for 127 per cent and 74 per cent increase respectively over the sole crop of mustard (Hedge and Pandey, 1992).

Higher gross returns in urdbean - pigeonpea intercropping system was reported by Rajput *et al.* (1989) and Goyal *et al.* (1991). Sarma and Kakati (1991) reported the compatibility of sesamum as an intercrop with maize, greengram and blackgram. The most profitable intercropping system was reported to be greengram + sesamum intercropping which gave a net return of Rs. 6586.14 ha^{-1} with a Benefit : Cost Ratio (BCR) of 3.35. In soybean - sesamum intercropping system, the net return and BCR was higher than sole cropping of both the crops (Singh, 1991).

Kushwaha (1992) observed that intercropping of groundnut with pigeonpea gave higher gross returns per hectare as compared to sole crop of groundnut. Rathore (1992) conducted experiments under dryland agriculture on intercropping systems and stated that the productivity in terms of base crop equivalent increased to the order of 7 to 26 q ha^{-1} thereby achieving additional monetary returns by 15 to 100 per cent.

Bhalerao *et al.* (1993) studied the effect of intercropping of sunflower with pigeonpea under rainfed condition. Highest total production, monetary returns and net income were obtained from 3:3 row proportion of intercropping system. Intercropping in 3:3 row proportion gave 21 and 55.3 per cent more net income than sole cropping of sunflower and pigeonpea respectively.

Kumar *et al.* (1994) conducted intercropping studies in toria. The mean net returns (Rs. 9689 ha^{-1}) were proved to be superior in intercropping over sole crop (Rs. 8005 ha^{-1}). Paikaray *et al.* (1994) reported that intercropping of soybean with niger (1:1) gave highest average gross return of Rs. 3996 ha^{-1} as compared to sole crop of niger, soybean and other treatments.

Thakuria and Saharia (1994) studied the production potential and economics of intercropping with sesamum and concluded that the highest net return and monetary advantage were obtained from sesamum + blackgram in 3:1 row ratio. It is a viable intercropping system for higher yield and monetary returns.

Jadhao *et al.* (1995) opined that in groundnut - sesamum intercropping system, sole groundnut and intercropping of groundnut + sesamum in 1:1 row proportion with 50 per cent of plant population of both crops were found profitable and economical.

Economic evaluation in terms of gross and net returns showed that the intercropping system of groundnut + soybean gave the highest gross returns as well as net returns than their solecrops (Kathmale *et al.*, 1995). Biological and economical sustainability of groundnut + pigeonpea association was reported by Rafey and Prasad (1995). Maximum and significantly more monetary returns were obtained from sorghum + pigeonpea intercropping than all other intercroppings and sole cropping (Ramteke *et al.*, 1995).

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

Sarma *et al.* (1995) conducted intercropping studies of greengram, blackgram and sesamum in pigeonpea under different seeding methods and concluded that the accommodation of one or two rows of blackgram and greengram provided better income than that of sesamum. Accommodation of one row of greengram was found most remunerative in terms of net returns and BCR.

Balusamy (1996) studied the economics of soybean pigeonpea intercropping and found that intercropping two rows of pigeonpea between paired rows of soybean recorded the highest net return of Rs. 14992 ha^{-1}. Hooda (1996) conducted experiments on intercropping of greengram and sesamum in pearl millet under different nitrogen fertilization. The sole greengram with 40 kg nitrogen per hectare were recorded more gross monetary returns and net return. Higher monetary returns were realized from sunflower + pigeonpea (2:1) intercropping compared to sole crop of sunflower (ICAR, 1997).

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

2.5. Biological efficiency of the intercropping systems

Francis *et al.* (1978) reported that land utilization efficiency increased with intercropping system. The land equivalent ratio (LER) is an indicator of efficient land utilization for intercropping systems (Jha and Chandra, 1982).

Prasad and Verma (1986) studied the effect of intercropping castor with greengram, blackgram, sesamum and sorghum on yield and net returns. Significantly higher values of LER, indicated efficient utilization of land by castor + legume combinations as compared to intercropping with sesamum.

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

Patil and Shinde (1992) conducted studies on intercropping of some *kharif* crops in sesamum. The study revealed that the values of LER were higher for sesamum + redgram in all row proportions than other intercropping systems of greengram, sunflower and sorghum crops. The sesamum + redgram (3:1) registered higher LER (1.45) followed by the same intercropping system in 2:1 ratio. The value of LER increased as the row proportion increased in intercropping of greengram and redgram.

In chickpea + safflower intercropping system, LER was higher in intercropping than under sole cropping system (Saraf, 1992). Sarkar and Pramanik (1992) studied the effect of planting pattern in sesamum + mungbean intercropping system. In all intercropping systems, LER excelled unity indicating greater biological efficiency of intercropping over sole cropping.

Singh and Singh (1992) studied the comparison of pigeonpea based intercropping system for dry lands of Vindhyan Red loam soils of eastern Uttar Pradesh. The LER of these intercropping treatments varied from 1.46 to 1.89 giving an yield advantages of 46 to 89 per cent over sole cropping. Partial LERs of individual crops in intercropping treatments decreased, but the combined yields increased giving higher total LERs. The combination of pigeonpea (100 per cent) + sesamum (75 per cent) was found to be superior to the other intercropping treatments giving a yield advantage of 89 per cent and net return of Rs. 2.80 per rupee invested. Similar results were reported by other workers (Dhoble *et al.*, 1990; Goyal *et al.*, 1991).

Tiwari *et al.* (1992) reported the effect of intercropping of mustard with gram and lentil. LER worked out from combined intercrop yields was always greater as compared to sole crop. The highest LER of 1.1 was recorded with 3:1 row ratio in gram and mustard which indicated better land utilization and biological efficiency in intercropping than in sole cropping system. The values of LER were higher for groundnut + sunflower in all row proportions than other intercropping systems of castor and sesamum (Guggari *et al.*, 1994). Experimentation on vertisols of Malwa plateau established that pigeonpea can be intercropped with soybean with very high yield advantage as judged by LER approaching 1.50 (Joshi *et al.*, 1994).

The LER value recorded in groundnut + soybean intercropping system in 6:2 row proportion was the highest (1.28) indicating on an average of 28 per cent biological advantage (Kathmale *et al.*, 1995).

There was sufficient increase in the LER due to intercropping of groundnut and sesamum in different row ratio, even the farmers practice of mixed seeding increased the LER over sole crops of groundnut as well as sesamum (Rathore and Gupta, 1995). In sorghum + groundnut intercropping system, LER was greater than unity, which clearly indicated the yield advantage of the system (Barik *et al.*, 1998). Saxena *et al.* (1998) reported that an introduction of 25 per cent pigeonpea in the maize or groundnut crop on a replacement basis beneficial in terms of higher LER values.

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

2.6 Effect of pulses on succeeding rice crop

Pulses constitute an important group of food grains next to cereals. Among the pulses cowpea, greengram and blackgram occupy major area in rice based cropping system. The productivity of pulses can be improved by proper crop management techniques in the system, which incidentally might also improve the nitrogen (N) economy of succeeding rice crop.

Sharma and Singh (1972) recorded higher yield of rice when rice was sown after pea and gram than after fallow. Misra and Misra (1975) indicated that greengram would benefit the following cereal crop in rotation and would increase the yield of the latter by 2-4 q ha^{-1}. Inclusion of legumes in the cropping systems improved the soil N status, thus reducing N application to the succeeding crop (Palaniappan *et al.*, 1976). Among five rice based multiple cropping patterns studied by Sasidhar and Sadanandan (1980), yields of the first crop of rice in rice-rice-cowpea cropping system were significantly higher than others.

The N need of a crop is reduced when the crop is preceded by legumes (Saxena and Yadav, 1975., Lal *et al.*, 1978., Faroda and Singh, 1983).

With the overall view of maintaining soil fertility and economising fertilizer application, it was beneficial to include legume as component of intensive cropping systems (Palaniappan, 1985). Legumes, both as sole and as intercropping combinations with cereals have been advocated not only for yield augmentation but also for maintenance of soil health (Chatterjee and Bhattacharya, 1986). Grain and fodder legumes are included in the cropping system to cut down the N requirement and boost the yield of succeeding crops (Kushwaha and Ali, 1988). Jadhav (1989) pointed out that, inclusion of leguminous crop in the sequence leads to an improvement in soil nutrients and consequently results in increasing the yields of succeeding crops in the sequence.

Peoples and Herridge (1990) studied the estimates of N transfer to a companion non-legume which ranges between 25 and 155 kg N ha^{-1}. The amount of N fixed by the legume can range between 50 and 300 kg N ha^{-1}.

Srinivasan *et al.* (1991) studied the effect of summer legumes on the growth and productivity of the succeeding *kharif* maize. Summer pulses particularly cowpea, significantly increased the productivity of the succeeding *kharif* maize. Summer pulses contributed to an addition of 15 kg N ha^{-1} in the soil.

Legumes in association with paddy could enhance the total productivity as well as enrich the soil fertility under degraded fertility condition where particularly soybean and pigeonpea could be termed as promising ones (Banik and Bagchi, 1993).

Mahapatra and Sharma (1995) studied the effect of summer legumes on growth and yield of low land rice and its residual effect on succeeding wheat in rice-wheat system. Summer cropping of dhaincha for green manure and of cowpea for fodder had significant effect on growth, yield and N uptake in rice crop.

Kalarani (1995) reported that raising a summer crop resulted in a saving of 25 per cent N for the succeeding rice crop. Paliwal (1995) opined that the fertility of the soil is enriched by taking a pulse crop after the fields are exhausted in the *rabi* season.

Mathew *et al.* (1996) reported the influence of summer cropping and fallowing on fertilizer use efficiency and productivity of rice. The cropping systems studied are Rice-Rice-Fallow (RRF), Rice-Rice-Daincha (RRD), Rice-Rice-Sesamum (RRS), Rice-Rice-Cowpea (RRC). The highest yield was recorded by RRD followed by RRC and both were on par. This is due to addition of appreciable quantities of organic matter and fixation of N. The study revealed that chemical fertilizer application in rice can be reduced to 75 per cent when an ideal cropping sequence is followed.

From the above findings it is evident that inclusion of legumes in the cropping systems have several beneficial effects by improving the nitrogen status of the soil and reducing the N application and enhancing the yield of succeeding crops.

MATERIALS AND METHODS

MATERIALS AND METHODS

The present investigation was undertaken with the objective of studying the production potential and economics of sesamum - pulse intercropping in the summer rice fallows of Onattukara tract of Kerala. The study also aims at estimating the residual effect of the intercropping on succeeding crop of rice during *virippu* season. The field experiment was conducted during the period from February 1998 to August 1998 at Kayamkulam.

The details of materials used and methods adopted for the study are described below.

3.1 Materials

3.1.1 Experimental site

The experiment was conducted in the summer rice fallows of Rice Research Station, Kayamkulam under the Kerala Agricultural University. The experimental field is located at 9°80'N latitude and 76°20'E longitude at an altitude of 3.05 m above MSL.

3.1.2 Soil

The soil of the experimental site is loamy sand and acidic in nature. The soil belongs to the taxonomical order, Entisols. The physico-chemical properties of the soil are presented in Tables 1, 2a and 2b.

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

Sl. No.	Fractions	Content in soil	Methods used
A.	Mechanical composition		
1	Coarse sand (%)	56.50	International Pipette method (Piper, 1966)
2	Find sand (%)	16.10	
3	Silt (%)	20.35	
4	Clay (%)	5.80	
5	Textural class	loamy sand	

Table 2a. Physical constants of the soil of the experimental site

Sl. No.	Particulars	Depth of soil layer (0-30 cm)	Methods
B.	Physical constants		
1	Field capacity (%)	16.05	Core sampler method (Dasthane, 1967)
2	Permanent wilting point (%)	3.86	Pressure membrane apparatus (Richards, 1947)
3	Bulk density (kg m^{-3})	1.62	(Dakshinamurthy and Gupta, 1968)

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

Sl. No.	Parameter	Content	Rating	Methods used
C.	Chemical composition			
1	Available N (kg ha^{-1})	194.3	low	Alkaline permanganate method (Subbiah and Asija, 1956)
2	Available P_2O_5 (kg ha^{-1})	34.2	medium	Bray colorimetric method (Bray and Kurtz, 1945)
3	Exchangeable K_2O (kg ha^{-1})	43.2	low	Ammonium acetate method (Jackson, 1973)
4	Organic carbon (%)	0.45	low	Walkley and Black rapid titration method (Walkley and Black, 1934)
5	pH (dry soil)	5.40	acidic	1:2.5 soil solution ratio using pH meter with glass electrode (Jackson, 1973)

3.1.3 Cropping history of the field

The experimental area was under a bulk rice crop during the previous two seasons.

3.1.4 Season

The experiment was conducted during the summer season of February 1998 to May 1998 utilizing the residual soil moisture. After that, a bulk crop of rice was raised during the *virippu* season.

3.1.5 Weather conditions

The weekly averages of temperature, relative humidity, sunshine hours, rainfall and evaporation during the cropping period were collected from the observatory attached to CPCRI, Kayamkulam and the data are presented in Appendix I and illustrated graphically in Fig. 1a. The mean monthly meteorological data during the past ten years are graphically presented in Fig. 1b.

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

3.1.6 Crop characters and source of seed material

Sl. No.	Crop	Variety	Duration (days)	Characteristics	Source of seed materials
1	Sesamum	Kayamkulam-1	70-75	It is a pureline selection from Onattukara local. It is a branching type single poded, best suited to summer rice fallows of Onattukara tract	RRS, Kayamkulam
2	Blackgram	Syama	65-67	Medium statured plants with hairy pods, highly suited to the summer rice fallows of Onattukara	RRS, Kayamkulam
3	Greengram	Pusa 8973	65-70	Short statured, non lodging, high yielding and locally adapted to the summer rice fallows of Onattukara	RRS, Kayamkulam
4	Rice	Jyothi	110-125	Red, long, bold grain moderately tolerant to BPH and blast. Excessive shedding of grains at maturity	RRS, Kayamkulam

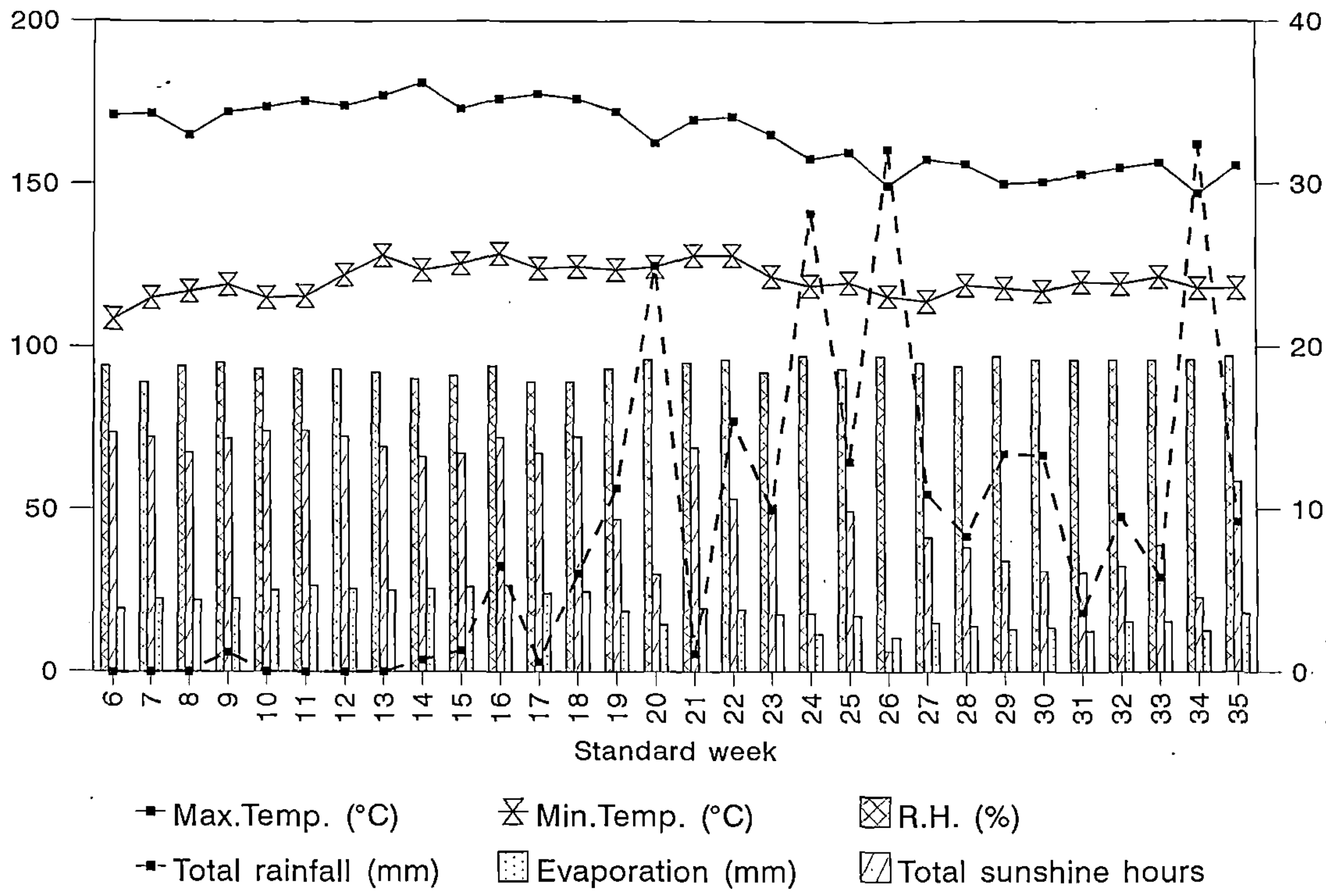

Fig. 1a. Weather data during the cropping period (February 1998 to August 1998)

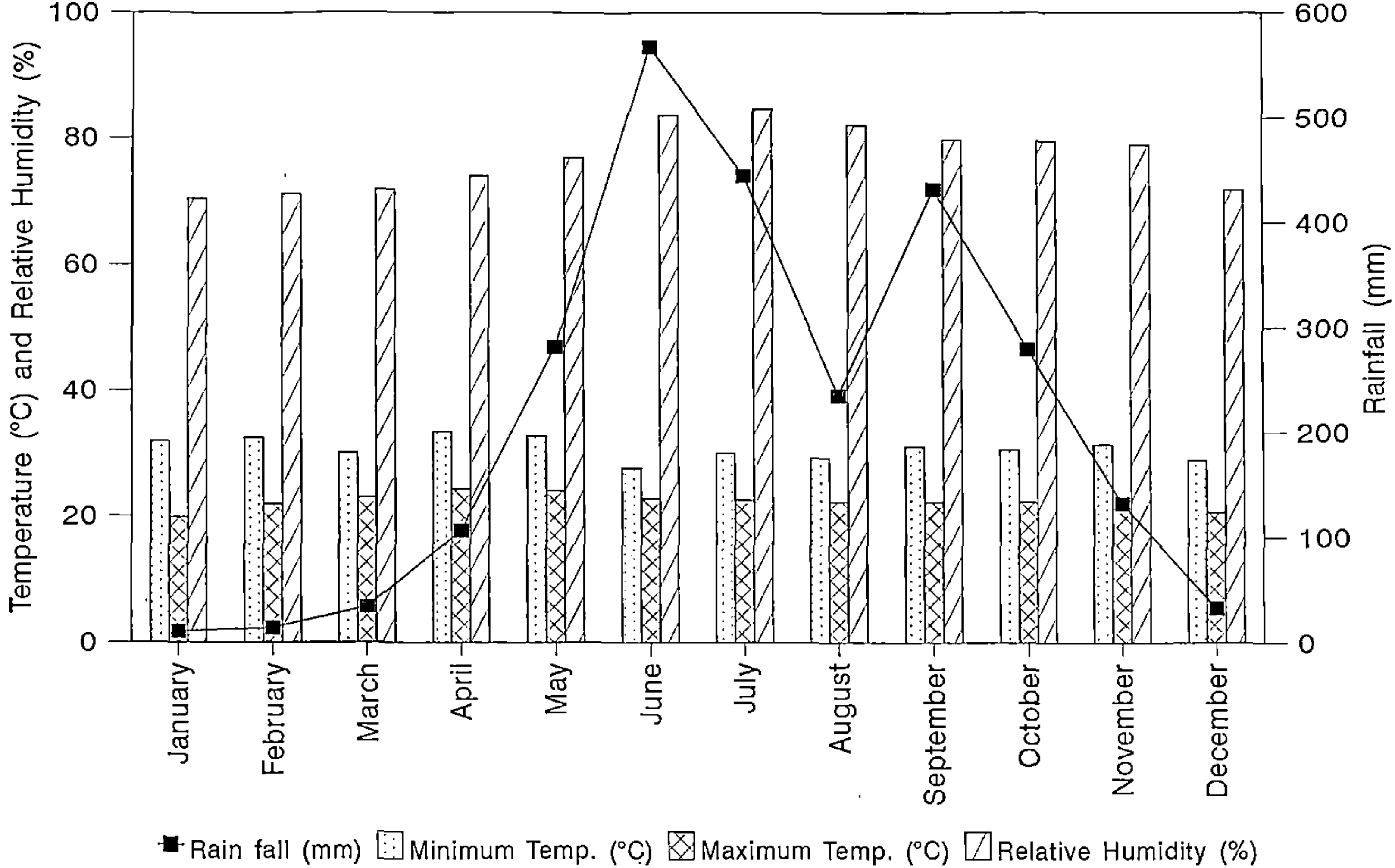

Fig. 1b. Mean monthly meteorological data during the past ten years (1987 to 1997)

3.1.7 Manures and fertilizers

Farm yard manure (0.4 per cent, 0.3 per cent, 0.2 per cent N, P_2O_5 and K_2O respectively) was used for the experiment. Urea (46 per cent N), Mussoriphos (20 per cent P_2O_5) and muriate of potash (60 per cent K_2O) were used as source of nitrogen (N), Phosphorus (P) and Potassium (K) respectively.

3.2 Methods

3.2.1 Design and layout

The experiment was laid out in randomised block design (Snedecor and Cochran, 1967). The experiment consisted of nine treatments with four replications. The layout plan of the experiment is given in figure 2. The details of the layout are given below

Number of treatments	=	9
Number of replications	=	4
Gross plot size	=	5 m x 4 m
Net plot size	=	4.5 m x 3.5 m
Spacing	=	30 cm x 15 cm
Total number of plots	=	36

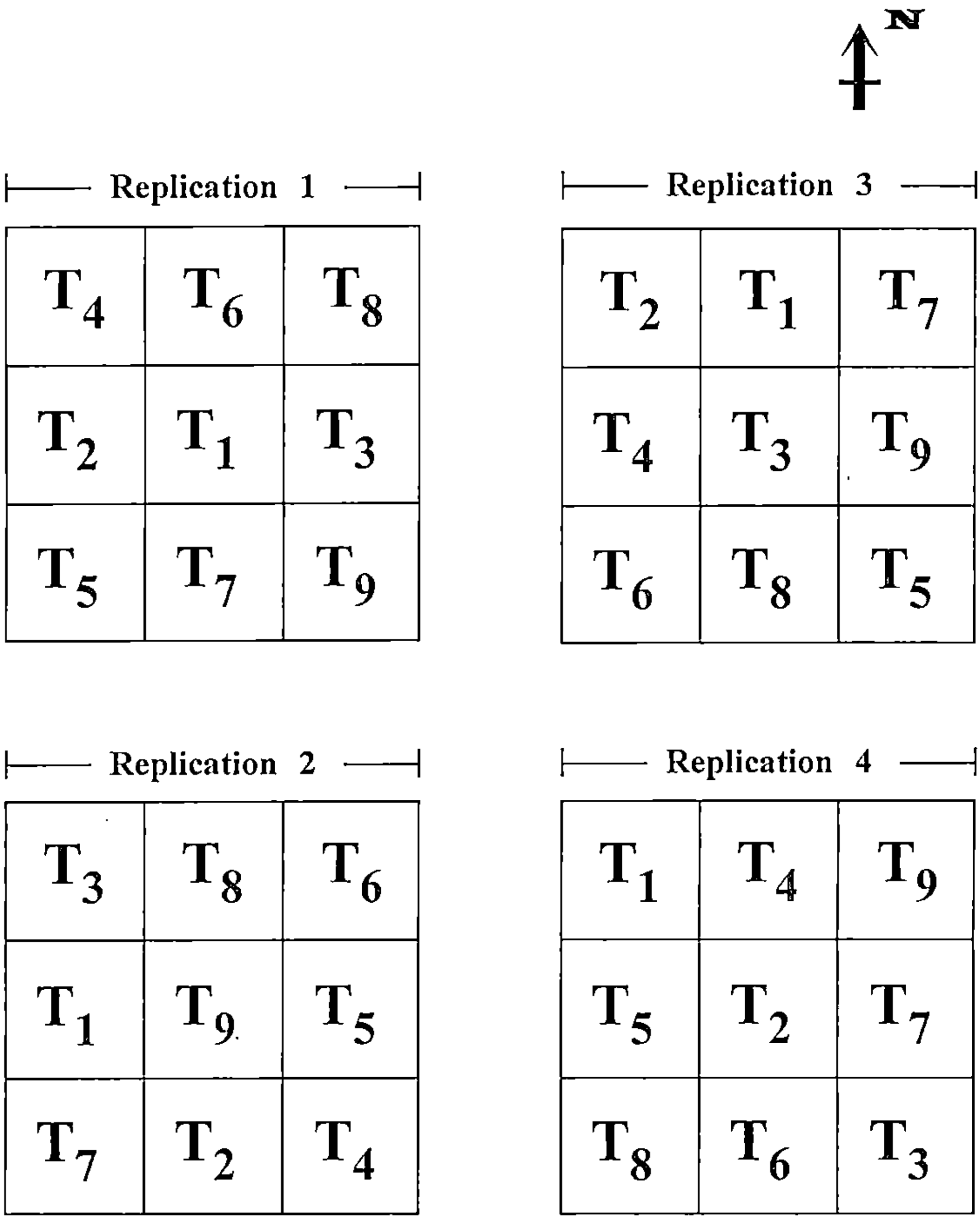

Fig. 2. Layout plan of the experimental site

3.2.2 Treatments

T_1 - Sesamum sole
T_2 - Blackgram sole
T_3 - Greengram sole
T_4 - Sesamum + Blackgram (1:1)
T_5 - Sesamum + Blackgram (2:1)
T_6 - Sesamum + Blackgram (3:1)
T_7 - Sesamum + Greengram (1:1)
T_8 - Sesamum + Greengram (2:1)
T_9 - Sesamum + Greengram (3:1)

A bulk crop of paddy was raised during the *virippu* season without disturbing the layout to study the residual effect of treatments on succeeding crop of the paddy. The final grain and straw yields of rice were estimated.

Field culture

3.2.3 Land preparation

The experimental area was ploughed with a 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 cowdung was applied as per the package of practice recommendation (KAU, 1996) and incorporated with the soil. The plots were separated by a distance of 60 cm and blocks by 100 cm.

3.2.4 Fertilizer application

Urea, Mussoriphos and Muriate of potash were applied as per the package of practices recommendations (KAU, 1996).

3.2.5 Seeds and sowing

Dry sowing of seeds along lines was done on 6th February, 1998. The seeds of sesamum at the rate of 5 kg ha^{-1} were mixed with four times its quantity of fine sand before sowing. After sowing, the seeds were covered with soil and planking done. Dry sowing of seeds of greengram and blackgram were also done on the same day. The seeds at the rate of 20 kg ha^{-1} for pure crop and 6 kg ha^{-1} for intercrop were used.

3.2.6 After cultivation

Thinning was done a fortnight after sowing, so as to maintain the spacing of 30 x 15 cm, between plants by working with 'Kochuthumpa' a special type of implement prevalent in Onattukara tract. The second interculture and weeding were done 25 days after sowing.

3.2.7 Plant protection

Ten per cent carbaryl was dusted to control the leaf and pod caterpillar during the flowering period of sesamum.

3.2.8 Harvesting

Sesamum was harvested on 27th April 1998 when the leaves and lower pods started turning yellow. Harvesting was done by pulling out the plants, cutting off the root portion and stacking the plants in shade in bundles for 3-4 days. Later, the bundles were spread in the sun and beaten with sticks to break the capsules and seeds were collected. Drying and threshing were repeated for four more days. Greengram and blackgram were harvested on 28th April 1998 when the leaves turned yellow. The pods were picked by hands and beaten with sticks to separate the seeds.

3.2.9 Bulk crop of paddy

A bulk crop of paddy was raised during succeeding *virippu* season retaining the same experimental lay out of the pervious crop. The seeds of paddy were broadcast at the rate of 100 kg ha^{-1} on 4th May 1998. No manuring was done to the crop. Two hand weedings were done on 20th and 40th days after sowing. Water management in the field was done by a local and popular device known as 'chakram'. Crop was harvested on 29th August, 1998. One row was left from each side of the plot and harvested separately. Grain and straw yields of each plot were recorded separately. The grain from each plot was dried, cleaned, winnowed, weighed and expressed in t ha^{-1}. Straw from each plot was dried under sun. The weight was recorded and expressed in t ha^{-1}.

3.3 Observations recorded

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

Sampling procedure

Observations on the growth characters like height, number of leaves per plant, number of branches per plant and number of pods per plant were taken from 10 plants from each plot at 30 Days After Sowing (DAS), 60 DAS and at harvest. After elimination of border plants, 10 plants were selected randomly as observational plants. At harvest, five out of ten observational plants were used for drymatter estimation and chemical analysis.

Parameters considered and methods followed are briefly described hereunder.

3.3.1 Growth characters

3.3.1.1 Height of the plant

The height of the plant was measured from the ground level to the growing tip of the observational plants and expressed in cm.

3.3.1.2 Number of leaves plant^{-1}

The number of fully opened leaves were counted from the observational plants and mean was worked out.

3.3.1.3 Number of branches plant^{-1}

The number of branches per plant was computed from the observational plants and mean was worked out.

3.3.1.4 Leaf Area Index (LAI)

Area of all leaves produced per plant was recorded by using LI-3100 Leaf Area meter and LAI was worked out using the formula suggested by William (1946).

$$LAI = \frac{\text{Leaf area}}{\text{Land area}}$$

Observation was recorded in five sample plants from each plot.

3.3.1.5 Dry matter production

At the time of harvest, the observation plants were used for recording dry matter production. Five plants were uprooted from each plot carefully without damaging the roots. The plants were dried under shade and then oven dried at $80 \pm 5^{\circ}C$ till consecutive weights agreed. The dry weight of the plants were found out and expressed as kg ha^{-1}.

3.3.2 Yield and yield attributing characters

3.3.2.1 Days to 50 per cent flowering

Number of days taken by 50 per cent of plants for the emergence of flowers in each treatment were noted and recorded.

3.3.2.2 Number of pods plant^{-1}

The number of pods per plant was recorded at harvest from the sample plants.

3.3.2.3 1000 seed weight

From the produce obtained from the observational plants of sesamum, 1000 seeds were counted, oven dried and their weights recorded and expressed in grams.

3.3.2.4 100 seed weight

From the produce obtained from the observational plants of greengram and blackgram, 100 seeds were counted, oven dried and their weights recorded and expressed in grams.

3.3.2.5 Seed yield

The seed harvested from each net plot was dried, weighed and expressed as kg ha^{-1}.

3.3.2.6 Biological yield

This was estimated by adding the weight of seed and stover obtained from each plot and expressed in kg ha^{-1}.

3.3.2.7 Harvest Index (HI)

Harvest index was calculated by dividing the weight of seeds with the total weight of seeds and stover of each plot (Singh and Stoskopf, 1971).

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

3.3.2.8 Oil percentage

Sample lots of sesamum seeds were drawn from the seed obtained from each treatment plot and the oil content was estimated by cold percolation method (Kartha and Sethi, 1957).

3.3.2.9 Protein percentage

Nitrogen content in seeds of blackgram and greengram was analysed and percentage of protein in the seed was calculated by multiplying the percentage of nitrogen with the factor 6.25 (Simpson *et al.*, 1965).

3.4 Chemical analysis

3.4.1 Plant analysis

The plants of sesamum, greengram and blackgram at harvest were analysed for nitrogen, phosphorus and potassium. The samples were dried to constant weight in an electric hot air oven at 80$\pm$5^{o}C, ground into fine powder using wiley mill and used for chemical analysis.

3.4.1.1 Nutrient uptake studies

Total uptake of nitrogen, phosphorus and potassium at harvest was computed based on the content of these nutrients in plants and the total dry matter produced (Jackson, 1973).

3.4.2 Soil analysis

Soil analysis was done plot wise before and after the experiment. A representative soil sample of each plot was used for the initial and final determination of available nitrogen, available phosphorus and exchangeable potassium.

3.5 Parameters for evaluation of cropping system

3.5.1 Biosuitability

3.5.1.1 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.

3.5.1.2 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

3.5.1.3 Relative Crowding Coefficient (RCC)

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

$$k_{ab} = \frac{Y_{ab} \times Z_{ba}}{(Y_{aa} - Y_{ab})\, Z_{ab}} \qquad k_{ba} = \frac{Y_{ba} \times Z_{ab}}{(Y_{bb} - Y_{ba})\, Z_{ba}}$$

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

a - sesamum b - intercrop (Blackgram / greengram)

k_{ab} and k_{ba} are RCC for species a and b respectively

K - product of coefficient of species a and b respectively (kab x kba)

3.5.1.4 Aggressivity

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

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

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

a - sesamum   b - intercrop (Blackgram / greengram)

3.5.2 Economic efficiency

3.5.2.1 Cost of cultivation

It was calculated by adding the expenditure incurred on different items such as labour, seeds, fertilizer and other chemicals and expressed in Rs. ha^{-1}. The details regarding cost of various inputs and produce are given in Appendix II.

3.5.2.2 Gross return

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

3.5.2.3 Net return

This was calculated by subtracting the cost of cultivation from the gross return of different treatments.

3.5.2.4 Benefit - Cost Ratio (BCR)

BCR was worked out as per the formula given below

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

3.5.2.5 Net returns per rupee invested

$$\frac{\text{Gross income} - \text{cost of cultivation}}{\text{Cost of cultivation}}$$

3.5.2.6 Sesamum equivalent yield

This was calculated by converting the yield of intercrop into yield of base crop considering the market rates.

Sesamum Equivalent Yield (kg ha^{-1}) (SEY)

$$\text{SEY} = \frac{\text{Yield of intercrop (kg ha}^{-1}\text{)} \times \text{Market price of intercrop (Rs. kg}^{-1}\text{)}}{\text{Market price of sesamum (Rs. kg}^{-1}\text{)}}$$

3.5.2.7 Monetary advantage based on LER

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

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

3.5.3 Energy equivalents of cropping system

The various intercropping systems are evaluated in terms of energy values of the edible produces obtained from cropping systems. The energy values of the edible outputs under various cropping systems were worked out based on the calorific values given by Gopalan *et al.* (1991).

3.6 Statistical analysis

Data relating to each character was analysed by applying the Analysis of Variance technique (ANOVA) (Gomez and Gomez, 1984). Wherever the effects were found to be significant, critical differences were given for effecting comparison among the mean. Correlation studies were also carried out between yield and yield attributes.

RESULTS

RESULTS

An experiment to assess the production potential and economics of sesamum - pulse intercropping in Onattukara tract and to find out the residual effect of the intercropping on succeeding first crop of rice was conducted at the Rice Research Station, Kayamkulam. The field experiment was conducted during the period February 1998 to August 1998.

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, number of leaves, number of branches and leaf area index per plant at 30 DAS, 60 DAS and at harvest.

4.1.1. Sesamum

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.

Table 3. Height of sesamum (cm) at different days after sowing

Treatments	30 DAS	60 DAS	Harvest
T_1	19.61	87.78	99.48
T_4	16.29	81.68	93.13
T_5	16.40	81.18	94.60
T_6	17.36	86.28	95.98
T_7	17.90	80.78	93.75
T_8	16.69	84.55	92.00
T_9	16.03	88.95	93.25
$F_{6,18}$	1.982^{ns}	2.121^{ns}	1.016^{ns}
SE	0.891	2.287	2.468

ns - not significant

The different intercropping treatments did not significantly influence the height of plants when observed at 30 DAS, 60 DAS and at harvest. The height of the sole crop of sesamum was 19.61 cm at 30 DAS, 87.78 cm at 60 DAS and 99.48 cm at harvest. It was on par with intercropped sesamum.

4.1.1.2. Number of leaves per plant

The mean number of leaves per plant recorded at various growth stages are given in Table 4.

At 30 DAS, though the number of leaves produced by the sole crop was 14.48, it did not show any significant superiority over intercropping.

The maximum number of leaves was observed at 60 DAS. The number of leaves produced when sesamum and blackgram were intercropped in 3:1 ratio was 80.08 and it was on par with other treatments.

In general, lesser number of leaves were noticed at harvest. The number of leaves noticed in the intercropping treatment of sesamum and blackgram in 3:1 ratio was 69.83, and it was statistically similar to other treatments.

4.1.1.3. Number of branches per plant

The mean number of branches per plant are given in Table 5.

Table 4. Number of leaves of sesamum at different days after sowing

Treatments	30 DAS	60 DAS	Harvest
T_1	14.48	79.63	68.70
T_4	12.18	75.00	66.58
T_5	13.08	74.78	61.45
T_6	12.00	80.08	69.83
T_7	14.03	72.18	66.95
T_8	12.65	78.10	66.85
T_9	12.40	79.43	67.95
$F_{6,18}$	1.912^{ns}	1.236^{ns}	0.803^{ns}
SE	0.685	2.739	2.977

ns - not significant

Table 5. Number of branches of sesamum at different days after sowing

Treatments	60 DAS	Harvest
T_1	2.60	3.40
T_4	2.90	3.35
T_5	2.58	3.25
T_6	3.00	3.20
T_7	3.03	3.48
T_8	2.70	2.90
T_9	2.88	3.23
$F_{6,18}$	1.138^{ns}	1.082^{ns}
SE	0.174	0.179

ns - not significant

Branching initiated in sesamum one month after sowing but did not show any statistical significance among treatments. At 60 DAS, the number of branches produced varied from 2.58 in sesamum and blackgram in 2:1 ratio to 3.03 in sesamum and greengram in 1:1 ratio.

Branching increased considerably at harvest as compared to that at 60 DAS. All the treatments except sesamum and greengram grown in 2:1 ratio produced more than 3 branches. The number of branches recorded by sesamum and greengram in 2:1 ratio was 2.9.

4.1.1.4. Leaf Area Index (LAI)

The mean LAI are presented in Table 6.

The LAI was not influenced by the different intercropping treatments.

The highest LAI was obtained at 60 DAS and thereafter a gradual decline was noticed.

At 30 DAS, LAI of 0.72 was obtained with the sole crop of sesamum and it was on par with other treatments. At 60 DAS, and at harvest, the LAI recorded by the sole crop was 1.96 and 1.82 respectively. At harvest, the LAI recorded by sesamum when intercropped with blackgram and greengram in 1:1 ratio were 1.78, 1.83 and in 2:1 ratio were 1.79, 1.84 and in 3:1 ratio were 1.81, 1.83 respectively.

Table 6. Leaf area index of sesamum at different days after sowing

Treatments	30 DAS	60 DAS	Harvest
T_1	0.720	1.955	1.818
T_4	0.685	1.965	1.778
T_5	0.688	1.945	1.793
T_6	0.678	1.943	1.808
T_7	0.705	2.003	1.829
T_8	0.675	1.968	1.838
T_9	0.668	1.970	1.833
$F_{6,18}$	3.509^{ns}	0.843^{ns}	2.003^{ns}
SE	0.009	0.022	0.015

ns - not significant

4.1.2. Blackgram

4.1.2.1. Height of plants

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

The sole crop recorded the maximum height at all stages such as 30 DAS (13.14 cm), 60 DAS (29.53 cm) and at harvest (51.3 cm). It was significantly superior to other treatments at 30 DAS and at 60 DAS.

The plants showed lesser height when sesamum and blackgram were grown in 1:1 ratio at 30 DAS (9.99 cm), 3:1 at 60 DAS (25.43 cm) and 2:1 at harvest (44.13 cm) respectively.

4.1.2.2. Number of leaves per plant

The mean values of data are presented in Table 8.

The number of leaves produced by the sole crop was 9.8 at 30 DAS, 37.6 at 60 DAS and 36.65 at harvest. The treatments did not exhibit significant difference. The number of leaves produced when sesamum and blackgram in 1:1, 2:1 and 3:1 ratio at harvest were 30.58, 35.05 and 29.5 respectively.

Table 7. Height of Blackgram (cm) at different days after sowing

Treatments	30 DAS	60 DAS	Harvest
T_2	13.14	29.53	51.30
T_4	9.99	25.48	47.43
T_5	10.66	25.58	44.13
T_6	10.13	25.43	44.90
$F_{3,9}$	4.309*	5.875*	2.330^{ns}
SE	0.707	0.832	2.12
CD	2.26	2.66	—

* Significant at 5% level ns - not significant

Table 8. Number of leaves of Blackgram at different days after sowing

Treatments	30 DAS	60 DAS	Harvest
T_2	9.80	37.60	36.65
T_4	7.30	32.98	30.58
T_5	8.45	36.45	35.05
T_6	7.60	31.23	29.50
$F_{3,9}$	3.42^{ns}	2.02^{ns}	3.14^{ns}
SE	0.605	2.09	1.94

ns - not significant

4.1.2.3. Number of branches per plant

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

In blackgram, branching was initiated one month after sowing. At 60 DAS, the number of branches produced by the sole crop was 2. The number of branches were increased at the time of harvest. The number of branches produced by sesamum and blackgram grown in 2:1 ratio at harvest was 2.95 and it was on par with other treatments.

4.1.2.4. Leaf Area Index (LAI)

The mean LAI is presented in Table 10.

The sole crop of blackgram recorded the highest value throughout the growth period. Sole crop of blackgram recorded significantly higher LAI (0.77) at 30 DAS. At 60 DAS and at harvest, LAI was not significantly different with respect to the different treatments.

4.1.3. Greengram

4.1.3.1. Height of plant

The data on mean height of plant are given in Table 11.

At 30 DAS and 60 DAS, there was no significant difference in the average height of greengram plants when it was raised either as sole

Table 9. Number of branches of blackgram at different days after sowing

Treatments	60 DAS	Harvest
T_2	2.00	2.73
T_4	1.95	2.65
T_5	1.90	2.95
T_6	1.95	2.68
$F_{3,9}$	0.099^{ns}	2.50^{ns}
SE	0.13	0.277

ns - not significant

Table 10. Leaf area index of blackgram at different days after sowing

Treatments	30 DAS	60 DAS	Harvest
T_2	0.77	2.59	2.51
T_4	0.53	2.49	2.43
T_5	0.53	2.57	2.50
T_6	0.58	2.42	2.37
$F_{3,9}$	5.43^{*}	3.23^{ns}	2.61^{ns}
SE	0.044	0.044	0.039
CD	0.142	—	—

* Significant at 5% level ns - not significant

Table 11. Height of greengram (cm) at different days after sowing

Treatments	30 DAS	60 DAS	Harvest
T_3	10.11	33.15	45.98
T_7	10.29	27.48	42.80
T_8	10.45	28.15	43.28
T_9	10.03	29.35	40.05
$F_{3,9}$	0.119^{ns}	2.41^{ns}	4.31^{*}
SE	0.548	1.63	1.17
CD	—	—	3.74

* Significant at 5% level ns - not significant

crop or intercropped with sesamum at different proportions. But at harvest stage, significant increase in height was observed in sole crop (45.98 cm) when compared to intercropping treatment of sesamum and greengram in 3:1 ratio (40.05 cm).

4.1.3.2. Number of leaves per plant

The data on mean number of leaves per plant are given in Table 12.

Intercropping of sesamum and greengram in 1:1 ratio produced 7.48 leaves at 30 DAS and it was found on par with other treatments. At 60 DAS, the sole crop produced 34.38 leaves and was on par with other crop combinations in intercropping. At harvest also no significant difference was found between the treatments.

4.1.3.3. Number of branches per plant

The data on mean number of branches are given in Table 13.

Effect of various treatments on branching was not significant. The number of branches produced by sesamum and greengram in 2:1 proportion was 0.18 at 30 DAS and 1:1 proportion were 2.03 at 60 DAS and 2.75 at harvest respectively. They were on par with other treatments.

4.1.3.4. Leaf Area Index (LAI)

The data on mean LAI is presented in Table 14.

Table 12. Number of leaves of greengram at different days after sowing

Treatments	30 DAS	60 DAS	Harvest
T_3	7.48	34.38	28.03
T_7	7.80	29.93	28.77
T_8	7.78	29.30	26.80
T_9	7.43	30.85	28.78
$F_{3,9}$	0.186^{ns}	0.975^{ns}	0.653^{ns}
SE	0.455	2.30	1.15

ns - not significant

Table 13. Number of branches of greengram at different days after sowing

Treatments	30 DAS	60 DAS	Harvest
T_3	0.075	1.98	2.60
T_7	0.15	2.03	2.75
T_8	0.175	1.55	2.55
T_9	0.075	2.00	2.53
$F_{3,9}$	0.346^{ns}	1.73^{ns}	0.224^{ns}
SE	0.0875	0.172	0.213

ns - not significant

Table 14. Leaf area index of greengram at different days after sowing

Treatments	30 DAS	60 DAS	Harvest
T_3	0.63	2.68	2.51
T_7	0.64	2.60	2.46
T_8	0.65	2.58	2.50
T_9	0.63	2.63	2.48
$F_{3,9}$	0.192^{ns}	1.58^{ns}	0.944^{ns}
SE	0.024	0.034	0.025

ns - not significant

The LAI was not influenced by the different treatments. At 30 DAS, sesamum and greengram in 2:1 ratio recorded LAI of 0.65 and thereafter the sole crop of greengram registered the LAI of 2.68 at 60 DAS and 2.51 at harvest respectively. They were on par with other treatments.

4.2. Yield and yield attributing characters

4.2.1. Sesamum

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 15.

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 pods per plant

The mean number of pods produced by the plant are given in Table 15.

The number of pods produced by the sole crop was 30.25 and it was not statistically significant. The number of pods produced when sesamum was intercropped with blackgram and greengram in 1:1, 2:1 and 3:1 ratio were 28.18, 28.63, 29.78, 28.28, 29.9 and 28.7 respectively.

Table 15. Yield attributes of sesamum

Treatments	Days to 50% flowering	Number of pods per plant	1000 seed weight (g)	Oil content (%)
T_1	39.28	30.25	2.818	50.78
T_4	40.18	28.18	2.595	49.57
T_5	38.80	28.63	2.773	48.74
T_6	38.68	29.78	2.820	49.99
T_7	39.93	28.28	2.588	49.32
T_8	39.35	29.90	2.740	49.55
T_9	40.13	28.70	2.825	50.25
$F_{6,18}$	1.478^{ns}	1.397^{ns}	12.176^{**}	2.98^{ns}
SE	0.505	0.720	0.0298	0.384
CD	—	—	0.089	

** Significant at 1% level ns - not significant

4.2.1.3. 1000 seed weight

The mean 1000 seed weight are presented in Table 15.

The 1000 seed weight was found to be significantly influenced by the treatments. A 1000 seed weight of 2.83 g was recorded by sesamum, when it was intercropped with greengram in 3:1 ratio which was on par with the sole crop of sesamum, intercropped sesamum with blackgram in 2:1 and 3:1 ratio and with green gram in 2:1 ratio. But they were superior to the treatment combinations of sesamum and blackgram in 1:1 ratio and sesamum and greengram in 1:1 ratio, which were on par.

4.2.1.4. Seed yield

The effect of treatments on the seed yield are presented in Table 16.

The sole crop of sesamum recorded the maximum seed yield of 539 kg ha^{-1} and was significantly superior to all other treatments. In the case of sesamum + blackgram intercropping, the yield of sesamum was 406 kg ha^{-1} for 3:1 row ratio, 356 kg ha^{-1} for 2:1 ratio and 262 kg ha^{-1} for 1:1 ratio. The respective yields were 25, 34 and 51 per cent lesser than the sole crop yield.

The yield of sesamum when intercropped with greengram in the ratio of 3:1, 2:1 and 1:1 were 407, 363 and 262 kg ha^{-1} respectively.

Table 16. Seed yield, biological yield and harvest index of sesamum

Treatments	Seed yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest Index
T_1	539.53	2350.41	0.229
T_4	262.92	1287.76	0.204
T_5	356.21	1537.51	0.232
T_6	406.85	1740.37	0.235
T_7	262.76	1215.36	0.216
T_8	363.02	1522.98	0.239
T_9	407.72	1723.02	0.238
$F_{6,18}$	251.33**	494.79**	19.04**
SE	6.024	16.91	0.003
CD	17.898	50.24	0.009

** Significant at 1% level

The decrease in yield in 3:1, 2:1, 1:1 ratio were 24, 33 and 51 per cent over sole crop of sesamum. The seed yield of intercropping proportions of 3:1 were on par and higher than 2:1 and 1:1 proportions.

4.2.1.5. Biological yield

The results observed on biological yield are presented in Table 16.

Sole crop of sesamum recorded significantly higher biological yield as compared to intercropping treatments. The yields of sesamum when intercropped with blackgram in 1:1, 2:1 and 3:1 ratio were 1287, 1537 and 1740 kg ha^{-1} respectively. On the otherhand, when greengram was the intercrop, the yields were 1215, 1522 and 1723 kg ha^{-1} in 1:1, 2:1 and 3:1 ratio respectively. The minimum biological yield was recorded when sesamum and greengram were grown in 1:1 ratio.

The biological yield of sesamum in 3:1 proportions were on par and higher than 2:1 and 1:1 proportions. The yields of sesamum in 2:1 ratio were on par but superior to 1:1 ratio.

4.2.1.6. Harvest Index (HI)

The results on HI are presented in Table 16.

The highest HI of 0.239 was obtained when sesamum was grown with greengram in 2:1 ratio and it was found superior to sole sesamum and intercropped sesamum with blackgram and greengram in 1:1 ratio. This was on par with the intercropped sesamum and greengram in 3:1 ratio and sesamum and blackgram in 2:1 and 3:1 ratio. The least HI of 0.204 was recorded when it was intercropped with blackgram in 1:1 ratio.

4.2.1.7. Percentage Oil content

The mean values of percentage oil content are presented in Table 15.

No significant difference in oil content was observed with respect to the various treatments. The oil content of 50.78 per cent was obtained with the sole crop of sesamum. Among the intercropping treatments, the oil content of 50.25 per cent was recorded when sesamum and greengram were grown in 3:1 ratio and an oil content of 48.74 per cent was recorded when sesamum and blackgram were grown in 2:1 ratio.

4.2.2. Blackgram

4.2.2.1. Days to 50 per cent flowering

The data on mean values are given in Table 17.

The number of days taken for 50 per cent flowering by all the treatments was almost uniform (38 to 39 days).

Table 17. Yield attributes of blackgram

Treatments	Days to 50% flowering	Number of pods per plant	100 seed weight (g)	Protein (%)
T_2	38.15	27.30	4.485	22.18
T_4	38.85	24.55	4.512	21.90
T_5	38.73	24.53	4.508	21.73
T_6	38.60	24.70	4.513	21.82
$F_{3,9}$	0.903^{ns}	6.43^{*}	0.958^{ns}	0.397^{ns}
SE	0.321	0.535	0.013	0.298
CD	—	1.71	—	—

* Significant at 5% level ns - not significant

4.2.2.2. Number of pods per plant

The mean number of pods per plant is presented in Table 17.

The number of pods was significantly influenced by the treatments. The sole crop produced the maximum number of pods (27.3) and the lowest number (24.53) was noticed in the treatment combination of sesamum and blackgram in 2:1 ratio which was on par with sesamum and blackgram in 1:1 and 3:1 ratios.

4.2.2.3. 100 seed weight

The results on 100 seed weight are presented in Table 17.

100 seed weight did not show any variation among the treatments. The sole crop of blackgram recorded a 100 seed weight of 4.49 g which was on par with other treatments.

4.2.2.4. Seed yield

The results on seed yield are presented in Table 18.

The sole crop of blackgram recorded the highest seed yield (1401 kg ha^{-1}) was significantly superior to other intercropping treatments. Among the intercropping treatments, 1:1 row proportion gave significantly higher yield (763 kg ha^{-1}) than other intercropping treatments. It was 54

Table 18. Seed yield, biological yield and harvest index of blackgram

Treatments	Seed yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest Index
T_2	1401.25	3912.50	0.358
T_4	763.25	2140.00	0.357
T_5	462.25	1289.50	0.359
T_6	355.50	1005.50	0.354
$F_{3,9}$	1592.92**	867.32**	0.091^{ns}
SE	11.776	44.45	0.007
CD	37.67	142.19	—

** Significant at 1% level   ns - not significant

per cent of the sole crop yield. The yields of blackgram when sesamum and blackgram were grown in 2:1 and 3:1 ratio were 462 and 355 kg ha^{-1} respectively, which were 33 per cent and 25per cent of the sole crop yield.

4.2.2.5. Biological yield

The results are presented in Table 18.

The sole crop of blackgram recorded significantly higher biological yield (3912 kg ha^{-1}) as compared to intercropping treatments. The lowest yield (1005.5 kg ha^{-1}) was recorded when it was intercropped with sesamum in 1:3 ratio, which was 26 per cent of the sole crop yield. It was significantly inferior to all other treatments. The yield of blackgram and sesamum in 1:1 and 1:2 ratio were 2140 and 1289 kg ha^{-1} respectively.

4.2.2.6. Harvest Index (HI)

The results are given in Table 18.

The treatment effects were not significant. The sole crop recorded a HI of 0.358. The HI of 0.359 was recorded by sesamum and blackgram in 2:1 ratio, 0.357 in 1:1 ratio and 0.354 in 3:1 ratio respectively.

4.2.2.7. Protein percentage

The mean values of the protein content of seeds in percentage are given in Table 17.

The sole crop of blackgram recorded the protein content of 22.18 per cent and it remained unaltered when it was intercropped with sesamum at different ratios.

The protein contents of blackgram when it was intercropped with sesamum in 1:1, 1:2 and 1:3 ratio were 21.9, 21.7 and 21.8 respectively, that is almost about 22 per cent.

4.2.3. Greengram

4.2.3.1. Days to 50 per cent flowering

The mean number of days to 50 per cent flowering are given in Table 19.

Greengram when intercropped with sesamum in 1:1 ratio took 38 days to 50 per cent flowering and it was on par with other treatments.

4.2.3.2. Number of pods per plant

The mean number of pods per plant are given in Table 19.

Table 19. Yield attributes of greengram

Treatments	Days to 50% flowering	Number of pods per plant	100 seed weight (g)	Protein (%)
T_3	37.93	25.15	4.178	22.65
T_7	38.28	24.90	4.083	21.80
T_8	37.55	24.80	4.100	22.10
T_9	37.73	23.75	4.113	22.00
$F_{3,9}$	0.335^{ns}	3.613^{ns}	2.207^{ns}	2.565^{ns}
SE	0.536	0.325	0.028	0.227

ns - not significant

In greengram, the mean number of pods remained unaffected by the treatments. The number of pods produced by the sole crop was 25.15. The intercropped greengram with sesamum in 1:1, 1:2 and 1:3 ratios produced the number of pods *viz.*, 24.9, 24.8 and 23.75 respectively.

4.2.3.3. 100 seed weight

The results are given in Table 19.

The sole crop of greengram recorded a 100 seed weight of 4.18 g which was on par with other treatments.

4.2.3.4. Seed yield

The results on seed yield are given in Table 20.

The sole crop of greengram produced the highest seed yield of 1200 kg ha^{-1} and it was found to be significantly superior to other treatments. The yields of greengram when sesamum and greengram were grown in 1:1, 2:1 and 3:1 ratio were 633, 435 and 327 kg ha^{-1} respectively. The mean reduction in yield of greengram was 47, 64 and 73 per cent of the sole crop yield due to intercropping of sesamum and greengram in 1:1, 2:1 and 3:1 ratio respectively.

4.2.3.5. Biological yield

The mean biological yield of the data are given in Table 20.

The sole crop of greengram recorded the highest yield of 3529

Table 20. Seed yield, biological yield and harvest index of greengram

Treatments	Seed yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest Index
T_3	1200.00	3529.00	0.339
T_7	633.75	1791.50	0.354
T_8	435.50	1302.56	0.334
T_9	327.25	951.00	0.344
$F_{3,9}$	247.37^{**}	309.45^{**}	2.818^{ns}
SE	247.05	65.004	0.004
CD	79.03	207.95	—

** Significant at 1% level   ns - not significant

kg ha^{-1} and was found to be significantly superior to other treatments. The yield of greengram, when sesamum and greengram were intercropped in 1:1, 2:1 and 3:1 ratio were 1791, 1302 and 951 kg ha^{-1} respectively. The mean reduction in yield when compared to sole crop yield were 49, 64 and 74 per cent in 1:1, 2:1 and 3:1 row proportions.

4.2.3.6. Harvest Index (HI)

The mean values of HI are given in Table 20.

The treatments did not exhibit significant differences. The value of HI ranges from 0.334 to 0.354. The sole crop of greengram recorded a HI of 0.339.

4.2.3.7. Protein percentage

The percentage content of protein in greengram with respect to various treatments are presented in Table 19.

The intercropping treatments did not significantly influence the protein content of seeds. The sole crop recorded a protein content of 22.65 per cent and it was on par with other intercropping treatments.

4.3.1. Uptake of nutrients

4.3.1.1. Sesamum

The mean uptake of nutrients *viz.*, N, P and K by sesamum are presented in Table 21.

Table 21. Nutrient uptake by sesamum

Treatments	Nitrogen (kg ha^{-1})	Phosphorus (kg ha^{-1})	Potassium (kg ha^{-1})
T_1	45.89	6.42	23.13
T_4	25.12	3.53	12.94
T_5	30.14	4.22	15.43
T_6	34.37	4.83	17.49
T_7	24.19	3.34	12.23
T_8	29.96	4.23	15.29
T_9	33.81	4.78	17.33
$F_{6,18}$	291.28**	565.04**	247.87**
SE	0.426	0.043	0.230
CD	1.260	0.128	0.684

** Significant at 1% level

The N, P and K uptake by crop significantly increased in the case of sole crop when compared to intercropped treatments. N uptake was maximum with the sole crop (45.89 kg ha^{-1}) and minimum with intercropping of sesamum and blackgram in 1:1 ratio (25.12 kg ha^{-1}) and sesamum and greengram in 1:1 ratio (24.19 kg ha^{-1}) which were on par. The nutrient uptake by sesamum in intercropping treatment of 3:1 proportions were on par but higher than in 2:1 proportions, which inturn were also on par.

The P uptake was high with the sole crop (6.42 kg ha^{-1}) and low with sesamum and greengram in 1:1 ratio (3.34 kg ha^{-1}). No significant difference in P uptake was observed between sesamum and blackgram in 3:1 ratio and sesamum with greengram in 3:1 ratio and also between the same crop combinations in 2:1 ratio. However, the 3:1 ratio recorded a higher uptake value than 1:1 and 2:1 proportions.

The K uptake was also high with the sole crop (23.13 kg ha^{-1}) and low with sesamum and greengram in 1:1 ratio (12.23 kg ha^{-1}). The results were similar to that of P uptake.

4.3.1.2. Blackgram

The mean values of uptake of N, P and K were given in Table 22.

The uptake of nutrients was significantly influenced by the treatments. The sole crop recorded the highest uptake of N (82.16 kg ha^{-1}) and was significantly superior to the intercropping treatments.

Table 22. Nutrient uptake (kg ha^{-1}) by blackgram

Treatments	Nitrogen (kg ha^{-1})	Phosphorus (kg ha^{-1})	Potassium (kg ha^{-1})
T_2	82.16	10.76	38.56
T_4	44.69	5.83	20.76
T_5	27.15	3.45	12.58
T_6	21.17	2.75	9.85
$F_{3,9}$	723.341**	979.35**	634.14**
SE	1.021	0.116	0.514
CD	3.267	0.370	1.644

** Significant at 1% level

Among intercropping proportions, sesamum and blackgram in 1:1 ratio recorded an uptake value of N (44.69 kg ha^{-1}) and was significantly superior to 2:1 and 3:1 proportions. The lowest N uptake was recorded (21.17 kg ha^{-1}) when sesamum and blackgram were grown in 3:1 ratio.

The highest uptake of P (10.76 kg ha^{-1}) was also recorded by the sole crop and was superior to other treatments. Sesamum and blackgram in 3:1 ratio recorded the lowest uptake value of 2.75 kg ha^{-1}.

The K uptake was also maximum (38.56 kg ha^{-1}) with sole crop and minimum (9.85 kg ha^{-1}) in the 3:1 proportion of sesamum and blackgram.

4.3.1.3. Greengram

The mean values of the data are given in Table 23.

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 73.47, 9.61 and 34.83 kg ha^{-1} respectively. Greengram when intercropped with sesamum in 1:3 ratio recorded the lowest uptake of N (19.9 kg ha^{-1}), P (2.6 kg ha^{-1}) and K (9.32 kg ha^{-1}) respectively. It was significantly inferior to other treatments.

Table 23. Nutrient uptake (kg ha^{-1}) by greengram

Treatments	Nitrogen (kg ha^{-1})	Phosphorus (kg ha^{-1})	Potassium (kg ha^{-1})
T_3	73.47	9.61	34.83
T_7	37.49	4.83	16.32
T_8	27.29	3.59	12.78
T_9	19.90	2.60	9.32
$F_{3,9}$	371.002**	236.37**	166.046**
SE	1.232	0.202	0.883
CD	3.943	0.646	2.82

** Significant at 1% level

4.4. Soil analysis

4.4.1. Soil nutrient status before the experiment

The soil samples collected from the individual plots were analysed for available nitrogen, available phosphorus and exchangeable potassium.

The mean values of the nutrient contents of soil before the experiment are presented in Table 24.

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

4.4.2. Soil nutrient status after the experiment

The soil nutrient status after the experiment are given in Table 25.

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

The highest nitrogen content was found in the plot of sole greengram (206.58 kg ha^{-1}) which was on par with sole crop of blackgram. The treatments of sesamum and blackgram in 1:1, 2:1 ratios and sesamum + greengram in 1:1, 2:1 and 3:1 row proportions were on par. The plot of sole sesamum recorded the lowest N content (193.03 kg ha^{-1}).

Table 24. Soil nutrient status before the experiment (kg ha^{-1})

Treatments	Nitrogen (kg ha^{-1})	Phosphorus (kg ha^{-1})	Potassium (kg ha^{-1})
T_1	194.5	34.32	42.94
T_2	193.4	33.77	42.70
T_3	194.9	32.97	43.33
T_4	194.5	33.69	42.95
T_5	194.1	34.14	43.49
T_6	193.2	33.24	42.57
T_7	194.3	32.77	42.63
T_8	194.4	33.42	43.23
T_9	193.1	33.38	42.94
$F_{8,24}$	2.26^{ns}	1.86^{ns}	0.441^{ns}
SE	0.664	0.264	0.425

ns - not significant

Table 25. Soil nutrient status after the experiment (kg ha^{-1})

Treatments	Nitrogen (kg ha^{-1})	Phosphorus (kg ha^{-1})	Potassium (kg ha^{-1})
T_1	193.03	35.68	41.17
T_2	205.45	37.98	43.59
T_3	206.58	38.33	44.20
T_4	198.35	37.93	41.32
T_5	197.20	37.30	40.45
T_6	195.73	38.18	39.06
T_7	197.23	38.73	39.85
T_8	198.03	38.08	40.03
T_9	197.10	36.98	39.48
$F_{8,24}$	29.17**	3.30*	15.64**
SE	0.818	0.505	0.453
CD	2.39	1.47	1.323

* Significant at 5% level

** Significant at 1% level

The highest P content (38.73 kg ha^{-1}) was observed in intercropped plots of sesamum and greengram in 1:1 ratio, which was on par with all other treatments except sole crop of sesamum and sesamum intercropped with greengram in 3:1 ratio.

The highest K content (44.2 kg ha^{-1}) was recorded in the plots of sole crop of greengram which was on par with sole blackgram. The plots of intercropped sesamum and greengram in 1:1 ratio which was on par with the same crop combination in 2:1 and 3:1 row ratio recorded a significantly lower content of K (39.06 kg ha^{-1}).

4.5. Biological efficiency of intercropping system

4.5.1. Land Equivalent Ratio (LER)

The mean values of LER are presented in Table 26(a).

The LER of the intercropping system was not significantly influenced by the treatments. In all intercropping systems, LER excelled unity indicating greater biological efficiency of intercropping over sole cropping. Sesamum and greengram intercropped in 2:1 row arrangement gave the LER value (1.04) followed by sesamum and blackgram in 1:1 ratio and sesamum + greengram in 3:1 row arrangement (1.03). They were on par with other treatments.

Table 26a. Biological efficiency of the intercropping systems

Treatment	LER	LEC
T_1	1.00	0.25
T_2	1.00	0.25
T_3	1.00	0.25
T_4	1.03	0.27
T_5	1.00	0.22
T_6	1.01	0.20
T_7	1.02	0.26
T_8	1.04	0.24
T_9	1.03	0.21
$F_{8,24}$	1.38^{ns}	9.38^{**}
SE	0.014	0.008
CD	—	0.023

** Significant at 1% level   ns - not significant

4.5.2. Land Equivalent Coefficient (LEC)

The results on LEC are presented in Table 26(a).

The values of LEC differ significantly by the treatments. The maximum value of LEC (0.27) was noticed when sesamum and blackgram were grown in 1:1 row ratio and it was on par with the sole crops of sesamum, blackgram, greengram and sesamum + greengram in 1:1 ratio. The minimum value of LEC (0.2) was obtained when sesamum and blackgram were grown in 3:1 ratio which was on par with the same crop combinations in 2:1 ratio and sesamum + greengram in 3:1 ratio.

4.5.3. Aggressivity

The mean values of aggressivity of main crop sesamum and intercrops, blackgram and greengram are presented in Table 26(b).

The aggressivity values were found to be positive in intercrops. A positive aggressivity value of 0.12 was recorded by blackgram and a negative value of 0.12 was recorded by sesamum, when they were grown together in 1:1 row proportion. They were on par with other treatments.

4.5.4. Relative Crowding Coefficient (RCC)

The mean values of RCC are shown in Table 26(b).

The RCC of main crop sesamum (kab) was more than one when

Table 26b. Biological efficiency of the intercropping system

Treatments	Aggressivity		Relative crowding coefficient		
	Main crop (Aab)	Intercrop (Aba)	Main crop kab	Intercrop kba	K
T_4	-0.120	0.120	0.958	1.195	1.143
T_5	-0.023	0.023	0.968	1.003	0.975
T_6	-0.015	0.015	1.040	1.025	1.070
T_7	-0.090	0.090	0.958	1.143	1.098
T_8	-0.103	0.103	1.020	1.173	1.193
T_9	-0.085	0.085	1.070	1.138	1.218
$F_{5,15}$	1.34^{ns}	1.34^{ns}	1.43^{ns}	1.94^{ns}	1.38^{ns}
SE	0.037	0.037	0.038	0.057	0.075

ns - not significant

intercropped with blackgram in 3:1 ratio and greengram in 2:1 and 3:1 ratios. The RCC of intercrops (kba) were more than one in all crop combinations. The RCC (K), which is the product of kab and kba was more than one in all treatments except when sesamum was intercropped with blackgram in 2:1 row proportion. The highest value of K (1.218) which was recorded by the intercrop combination of sesamum and greengram in 3:1 ratio was on par with other treatments.

4.6. Bio-economic efficiency of intercropping system

4.6.1. Sesamum equivalent

The mean values of the data are given in Table 27(a).

The sesamum equivalent yield showed significant difference among the treatments. The sole crop of blackgram recorded the highest equivalent yield (1006 kg ha^{-1}) and was superior to other treatments.

Among the intercropping combinations, sesamum + blackgram in 1:1 ratio recorded the highest equivalent yield (812 kg ha^{-1}) and found superior to other intercropping treatments. However, the sesamum equivalent yield (539 kg ha^{-1}) recorded by sesamum alone was statistically inferior to sole crop of greengram and blackgram and also intercrop of sesamum + blackgram and sesamum + greengram.

Table 27. Bio-economic efficiency of the intercropping system

a. Sesamum equivalent

Treatments	Sesamum equivalent (kg ha^{-1})
T_1	539.53
T_2	1006.90
T_3	720.00
T_4	812.46
T_5	689.03
T_6	662.81
T_7	643.01
T_8	624.32
T_9	604.07
$F_{8,24}$	126.22**
SE	12.3
CD	35.89

** Significant at 1% level

b. Monetary advantage based on LER

Treatments	Monetary advantage (Rs. ha^{-1})
T_4	1219.63
T_5	-171.42
T_6	293.46
T_7	529.31
T_8	1191.27
T_9	916.08
$F_{5,15}$	1.27^{ns}
SE	486.73

ns - not significant

4.6.2. Monetary advantage based on LER

The results on monetary advantage are presented in Table 27(b).

The monetary advantage based on LER was found to be statistically not significant. A monetary advantage of Rs. 1219 ha^{-1} was obtained from the intercropping of sesamum and blackgram in 1:1 row ratios, and a loss of Rs. 171 ha^{-1} was obtained when sesamum and blackgram were grown in 2:1 row arrangement.

4.7. Economic efficiency of intercropping system

4.7.1. Gross returns

The mean values of the data are given in Table 28.

Significant differences were observed for gross returns due to various treatments. Maximum and significantly more gross returns (Rs. 50445 ha^{-1}) were obtained from sole crop of blackgram. In intercropping systems, the highest gross returns (Rs. 40623 ha^{-1}) was seen in sesamum + blackgram in 1:1 row proportion followed by sesamum + blackgram in 2:1 row proportion (Rs. 34451 ha^{-1}) and sesamum + blackgram in 3:1 row proportion (Rs. 33140 ha^{-1}). The least gross returns (Rs. 26976 ha^{-1}) was obtained from the sole crop of sesamum and was significantly inferior to other treatments.

Table 28. Economics of crop production

Treatments	Gross returns (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	Benefit-cost ratio	Net return per rupee invested
T_1	26976.50	4976.50	1.23	0.23
T_2	50445.00	25445.00	2.02	1.02
T_3	36000.00	11000.00	1.44	0.44
T_4	40623.00	17123.00	1.73	0.73
T_5	34451.25	11451.25	1.50	0.50
T_6	33140.50	10390.50	1.46	0.46
T_7	32150.38	8650.38	1.37	0.37
T_8	31215.75	8215.75	1.36	0.36
T_9	30203.38	7453.38	1.33	0.33
$F_{8,24}$	128.78**	102.15**	89.65**	89.67**
SE	611.11	611.15	0.026	0.026
CD	1783.81	1783.92	0.075	0.075

** Significant at 1% level

4.7.2. Net returns

The mean values of the data are presented in Table 28.

The data showed that the highest mean net returns of Rs. 25445 ha^{-1} was received from the sole crop of blackgram and it was found significantly superior to other treatments. Intercropping of sesamum with blackgram in 1:1 row arrangement recorded maximum and significantly more net returns (Rs. 17123 ha^{-1}) than sole crop of sesamum (Rs. 4976 ha^{-1}) and other intercropping treatments.

4.7.3. Benefit : Cost Ratio (BCR)

The results of BCR were presented in Table 28.

The BCR differed significantly in different treatments. The highest ratio of 2.02 was obtained with the sole crop of blackgram and it was found superior to other treatments. The most profitable intercropping treatment was sesamum + blackgram in 1:1 ratio which gave a BCR of 1.73 which was significantly superior to other intercropping treatments. The BCR was greater than one in all treatments. The lowest BCR (1.23) was recorded by the sole crop of sesamum.

4.7.4. Net returns per rupee invested

The mean values of the data are presented in Table 28.

The net returns per rupee invested was significantly influenced by the treatments and was maximum with the sole crop of blackgram (1.02). Sesamum and blackgram in 1:1 ratio gave the highest value of 0.73 among the intercropping treatments. The lowest value (23 paise) was obtained with the sole crop of sesamum which was significantly inferior to all other treatments.

4.8. Energy equivalents of cropping system

The mean energy values of edible produces obtained from different intercropping systems are presented in Table 29.

The results revealed that the energy values differed significantly in different treatments. The sole crop of blackgram produced the maximum energy (20421 MJ ha^{-1}) and was superior to other treatments. When the intercropping systems are considered, sesamum + blackgram in 1:1 ratio produced an energy of 17340 ha^{-1}, was superior to other intercropping treatments. It was on par with sole greengram. Sesamum + greengram in 1:1 ratio was on par with sesamum + blackgram in 2:1 ratio and found superior to sole sesamum, sesamum + blackgram in 3:1 ratio sesamum + greengram in 2:1 and 3:1 ratios.

Sesamum + blackgram in 3:1 ratio was statistically similar to sesamum + greengram in 2:1 and 3:1 ratios and superior to sole sesamum. The least quantum of energy (12757 MJ ha^{-1}) was produced by the sole crop of sesamum.

Table 29. Energy values of edible produces (MJ ha^{-1}) from different intercropping systems

Treatments	Energy value
T1	12757.73
T2	20421.82
T3	17539.2
T4	17340.61
T5	15159.66
T6	14830.28
T7	15476.06
T8	14949.12
T9	14423.88
$F_{8,24}$	60.50**
SE	287.59
CD	839.46

** Significant at 1 per cent level

4.9. Grain and straw yield of succeeding rice crop

The mean yield of grain and straw are given in Table 30.

The treatment differences did not show any significant influence on the yield of succeeding crop of rice. Among the treatments the yield of grain (1.23 t ha^{-1}) and straw (2.19 t ha^{-1}) were obtained when the preceding crop combination was sesamum and blackgram in 2:1 row proportion. In addition to this, the sole crops of blackgram and greengram and sesamum + greengram in 2:1 ratio, also revealed their superiority in producing more than one tonne of grain and two tonnes of straw. When the field was utilised for raising monocrop of sesamum during the preceding summer season the grain and straw yields of first crop of rice were 0.9 and 1.79 t ha^{-1}.

4.10. Correlation studies in sesamum

The mean values of simple correlation coefficient in sesamum are given in Table 31.

Results showed that all correlation coefficient values between yield and yield attributing characters like number of pods per plant, oil content of seed, 1000 seed weight, biological yield, Harvest Index, N, P and K uptake by plant were significantly correlated to the yield of sesamum. Negative correlations for yield were observed for the characters like number of branches at 60 DAS, leaf area index at 60 DAS and days to 50 per cent flowering.

Table 30. Grain and straw yield (t ha^{-1}) of succeeding rice crop

Treatment	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
T_1	0.90	1.79
T_2	1.15	2.01
T_3	1.16	2.05
T_4	1.00	1.88
T_5	1.23	2.19
T_6	0.94	1.93
T_7	0.91	1.83
T_8	1.11	2.04
T_9	1.00	1.95
$F_{8,24}$	2.22^{ns}	1.00^{ns}
SE	0.081	0.124

ns - not significant

Table 31. Values of simple correlation coefficient

Sl. No.	Characters correlated	Correlation coefficient
1	Yield Vs Plant height at 30 DAS	0.3573
2	Yield Vs Plant height at 60 DAS	0.4479*
3	Yield Vs Plant height at harvest	0.2706
4	Yield Vs Number of leaves at 30 DAS	0.1460
5	Yield Vs Number of leaves at 60 DAS	0.3102
6	Yield Vs Number of leaves at harvest	0.1471
7	Yield Vs Number of branches at 60 DAS	-0.1873
8	Yield Vs Number of branches at harvest	0.0056
9	Yield Vs Leaf area index at 30 DAS	0.2038
10	Yield Vs Leaf area index at 60 DAS	-0.2330
11	Yield Vs Leaf area index at harvest	0.1789
12	Yield Vs Days to 50% flowering	-0.2465
13	Yield Vs Number of pods per plant	0.4028*
14	Yield Vs Oil content of seed	0.4919**
15	Yield Vs 1000 seed weight	0.7369**
16	Yield Vs Biological yield	0.9839**
17	Yield Vs Harvest Index	0.5842**
18	Yield Vs N uptake by plant	0.9799**
19	Yield Vs P uptake by plant	0.9878**
20	Yield Vs K uptake by plant	0.9861**

** Significant at 1% level

* Significant at 5% level

DISCUSSION

DISCUSSION

An investigation entitled "Production potential and economics of sesamum - pulse intercropping in Onattukara tract" was conducted at the Rice Research Station, Kayamkulam to assess the suitability of raising blackgram and greengram as intercrops in sesamum at different row proportions and to assess the influence of summer rice fallow cropping on succeeding rice crop. 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.*,

- ❑ Effect of intercropping of sesamum Vs. sole cropping
- ❑ Effect of intercropping of blackgram Vs. sole cropping
- ❑ Effect of intercropping of greengram Vs. sole cropping
- ❑ Evaluation of sesamum - pulse intercropping system for their biological efficiency and economic suitability
- ❑ Soil nutrient status as influenced by intercropping
- ❑ Effect of summer cropping on succeeding crop of rice

5.1. Effect of intercropping of sesamum Vs sole cropping

5.1.1. Growth characters

In general, the different treatments of intercropping did not significantly influence the growth characters of sesamum.

The results revealed that the sole crop of sesamum surpassed the intercrop in plant height but there were no significant difference between intercrops in reducing the height of intercropped sesamum (Table 3). At all growth stages, the sole crop of sesamum showed more plant height as compared to intercropped sesamum. This may be due to lesser competition between the plants in a monocropping situation. Similar results were reported by Kondap *et al.* (1985).

In the early stages of growth, the sole crop of sesamum produced more number of leaves than the intercropped sesamum. But at 60 DAS and at harvest, more number of leaves were noticed in a sesamum - blackgram intercropping (3:1) situation (Table 4).

In all treatments, leaf area index (LAI) of sesamum showed a definite pattern at various growth stages. The sole crop of sesamum recorded higher LAI at 30 DAS (Table 6). LAI increased progressively in all treatments up to 60 DAS and thereafter declined. It is clear from the results that higher LAI was recorded due to good vegetative growth and favourable soil moisture conditions. Similar results were also reported by Reddy *et al.* (1991) in groundnut - pigeonpea system. At 60

DAS and at harvest the higher LAI was noticed when sesamum was intercropped with greengram in 1:1 and 2:1 ratio respectively.

Branching initiated in sesamum one month after sowing. Sesamum showed profuse branching tendency when it was intercropped with greengram in 1:1 ratio than when sown as a sole crop (Table 5). At harvest, more than three branches were observed in all treatments except when sesamum and greengram were intercropped in 2:1 ratio.

In the present study sesamum did not show any significant superiority in growth characters, when it was raised either as sole crop or as intercrop with greengram and blackgram. Sesamum in general, having an erect growing habit was least affected by shade when put under intercropping systems with different planting ratios. This was in conformity with the findings of Deshpande *et al.* (1992). Thus the results indicated that sesamum can be successfully intercropped with greengram and blackgram without much competition.

5.1.2. Yield and yield attributes

In all treatments, it was observed that sesamum took on an average 38 to 40 days for completing 50 per cent flowering. The sole crop of sesamum produced more number of pods per plant (Table 15). The 1000 seed weight was found to be significantly influenced by intercropping treatments (Table 15). The 1000 seed weight of sesamum grown as sole crop, intercropped sesamum with greengram in 2:1 and 3:1 ratios, intercropped sesamum with blackgram in 2:1 and 3:1 proportions were on par and significantly superior to sesamum + greengram grown in 1:1 ratio and also sesamum + blackgram in 1:1 ratio. Plant competition due to higher population observed in treatments when sesamum and greengram and sesamum and blackgram were grown in 1:1 proportion can be attributed as the reason for this response.

Sole crop of sesamum gave significantly higher seed yield than when they were grown in intercropping system (Table 16). This might be attributed to improvement of yield components like more number of capsules per plant and higher 1000 grain weight, in sole crop over intercrop. The result is in conformity with the findings of Desai and Goyal (1980) and Samui *et al.* (1993).

In all intercropped treatments, there was reduction in sesamum yield below the expected level on the basis of planted area. In 1:1 proportion of intercropping sesamum and blackgram, 49 per cent of the sole sesamum yield was realized where as 50 per cent yield would be expected if intercrop competition was equal to monoculture competition. This indicates the competitive effect of blackgram on sesamum. Similar results were also reported by Kondap *et al.* (1985). In sesamum + blackgram intercropping system in 2:1 and 3:1 ratios, the respective yields of sesamum were 34 and 25 per cent lesser than the sole crop yield. Similarly, when sesamum and greengram were intercropped in 1:1, 2:1

and 3:1 proportions, the decrease in sesamum yield were 51, 33 and 24 per cent over sole crop of sesamum. The seed yield of sesamum in different treatments are graphically illustrated in Fig. 3.

Drymatter accumulation in plant is an indicator of the physiological efficiency of plant resulting in higher seed yield. Hence seed yielding ability of sesamum under different cropping systems depend upon the total drymatter accumulation.

In this experiment, the biological yield of various treatments were found to be statistically significant (Fig. 3.). The sole crop of sesamum produced the highest biological yield among the treatments (Table 16) which was significantly superior to other treatments. Sesamum intercropped with blackgram in 1:1 proportion produced 55 per cent of the sole crop yield and with greengram it produced only 52 per cent. The yields of sesamum when intercropped with greengram and blackgram in 2:1 proportions were almost 65 per cent of the sole crop yield. The yields of sesamum when intercropped with blackgram and greengram in 3:1 proportions were 74 per cent and 73 per cent of the sole crop yield respectively.

The increased nitrogen uptake noticed was due to the increased drymatter production of the sole crop. As in the case of nitrogen, uptake of phosphorous and potassium were maximum under the sole crop situation (Fig. 4). Sesamum intercropped with blackgram and greengram

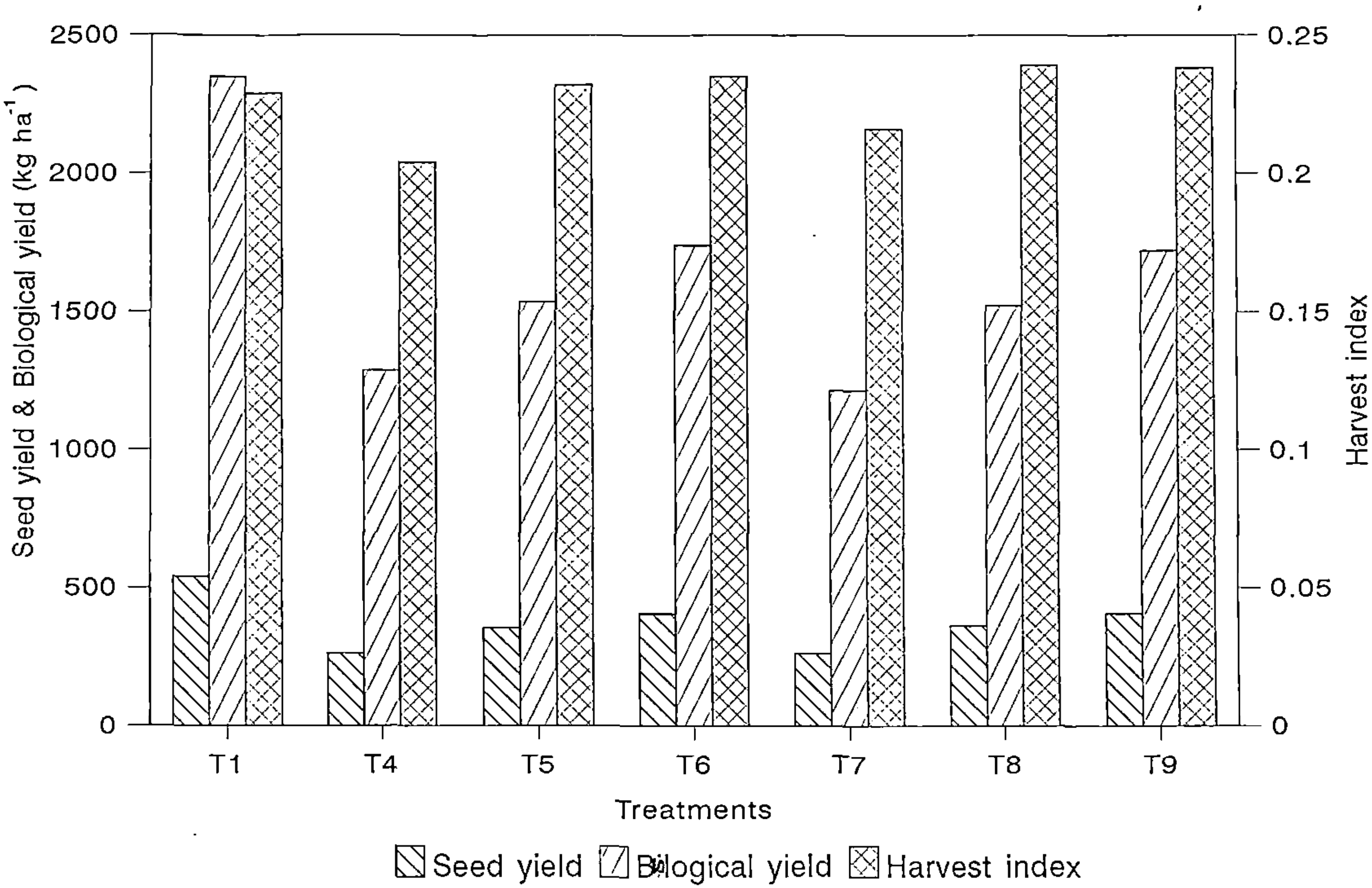

Fig. 3. Seed yield, biological yield (kg ha^{-1}) and harvest index of sesamum

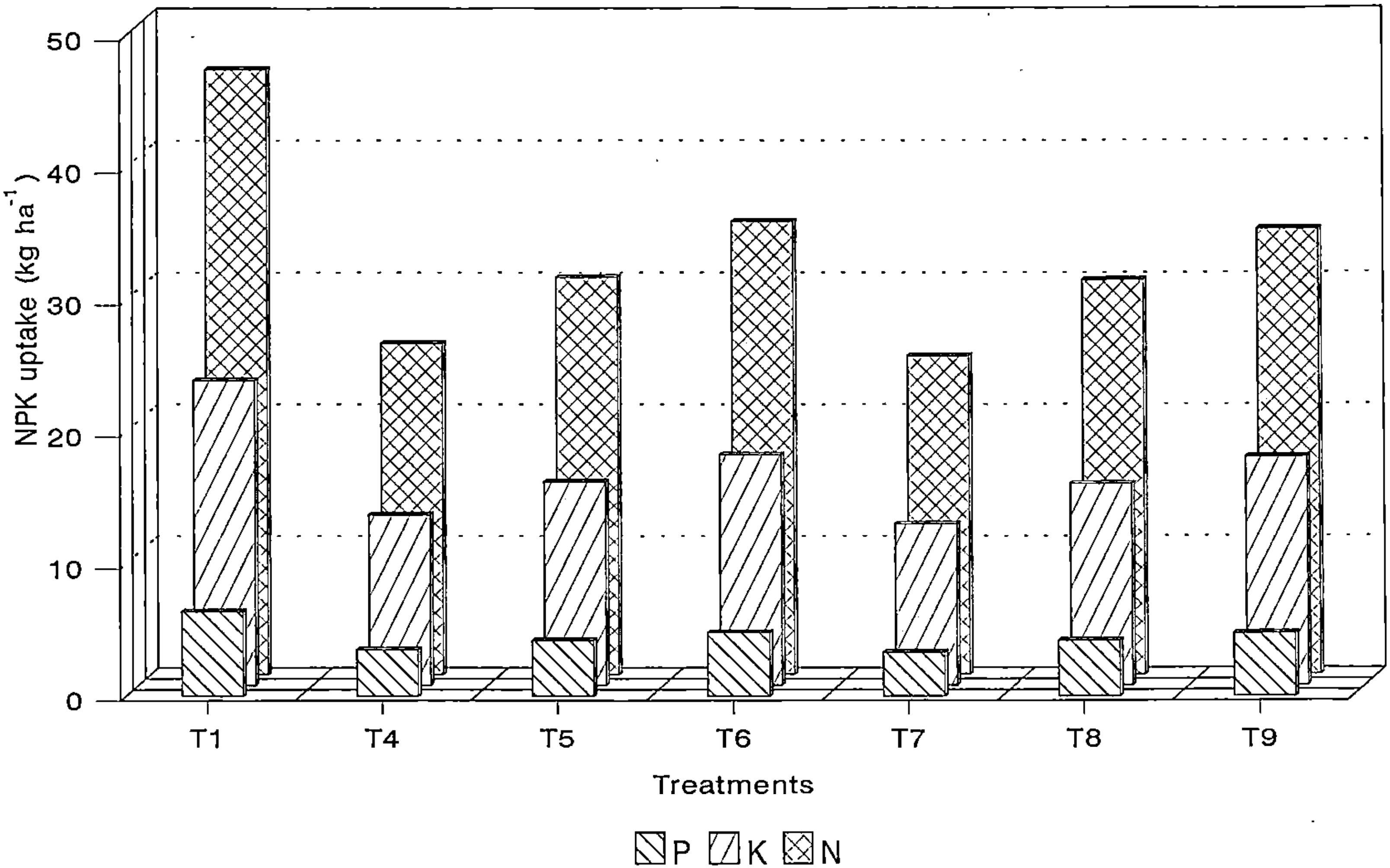

Fig. 4. Nutrient uptake (kg ha^{-1}) by sesamum

in 3:1 proportions showed higher values than 1:1 and 2:1 proportions in this respect which may be due to higher plant population in 3:1 proportion as compared to 2:1 and 1:1 proportions.

Among the different treatments, sesamum intercropped with greengram in 2:1 ratio showed the highest harvest index. This indicates a better partitioning of photosynthates (Table 16; Fig. 3). This was on par with sesamum and greengram in 3:1 ratio and sesamum and blackgram in 2:1 and 3:1 ratios. They were superior to the treatments of sole sesamum, intercropped sesamum with greengram and blackgram in 1:1 ratio. The lowest harvest index (0.204) was recorded when sesamum and blackgram were grown in 1:1 ratio and it was significantly inferior to all other treatments.

The oil percentage of seeds of sesamum (Table 15) was not influenced by growing them as sole crop or as intercrop, irrespective of the planting pattern. Similar findings were reported earlier by Dayal and Reddy (1991) in groundnut and Simon *et al.* (1992) in sunflower.

5.2. Effect of intercropping of blackgram Vs sole cropping

5.2.1. Growth characters

Blackgram, when grown as sole crop recorded the maximum height at all stages of crop growth (Table 7). It was significantly superior to intercropped blackgram at 30 DAS and at 60 DAS. When blackgram was grown as an intercrop with sesamum at different ratios it did not show any superiority and they were on par. The number of leaves produced by the sole crop was on par with the intercropped blackgram at all stages of crop growth (Table 8).

In blackgram, branching was initiated one month after sowing. At 60 DAS, the sole crop produced two branches and it was on par with the intercropped blackgram. The number of branches were increased at the time of harvest. Bishnoi *et al.* (1987) also reported similar results in pigeonpea based intercropping systems.

The results on leaf area index showed that the sole crop of blackgram recorded the highest LAI throughout the growth period. Sole crop recorded significantly higher LAI at 30 DAS (Table 10). But at 60 DAS and at harvest, LAI recorded by the sole crop was on par with other treatments. The result is in conformity with the findings of Reddy *et al.* (1991) in groundnut-pigeonpea intercropping system.

5.2.2. Yield and yield attributes

Among the yield attributes, the number of pods per plant alone showed significant treatment difference (Table 17). On an average it took about 38 to 40 days for attaining 50 per cent flowering in all treatments. The maximum number of pods was produced by the sole crop which was significantly superior to intercropped blackgram. But the 100 seed weight recorded by various treatments were on par (Table 17).

It could be seen from the data that sole crop of blackgram gave higher seed yield per hectare (Table 18) than when grown as intercrop. This can be attributed to the improved yield attributes like more number of pods per plant and limited disturbance of habitat owing to absence of interspecific competition.

The sole crop recorded the highest seed yield (1401 kg ha^{-1}) which was superior to all other treatments. Among the intercropping treatments, 1:1 row proportion gave significantly higher yield than other intercropping treatments. It was 54 per cent of the sole crop yield. Sesamum and blackgram in 2:1 and 3:1 ratios gave 33 and 25 per cent of the sole crop yield. It is graphically presented in Fig. 5.. The sole crop of blackgram produced significantly higher biological yield (3912 kg ha^{-1}). Sesamum and blackgram when grown in 3:1 ratio produced only 26 per cent of the sole crop yield. It was significantly inferior to all other treatments. But the yield of blackgram in 1:1 and 2:1 ratio with sesamum were 55 and 33 per cent of the sole crop yield (Fig. 5).

The nutrient uptake was significantly higher in sole crop when compared to intercropping treatments (Table 22). Among the intercropping treatments, sesamum + greengram in 1:1 ratio recorded the highest uptake value and 3:1 ratio recorded the lowest (Fig. 6). This

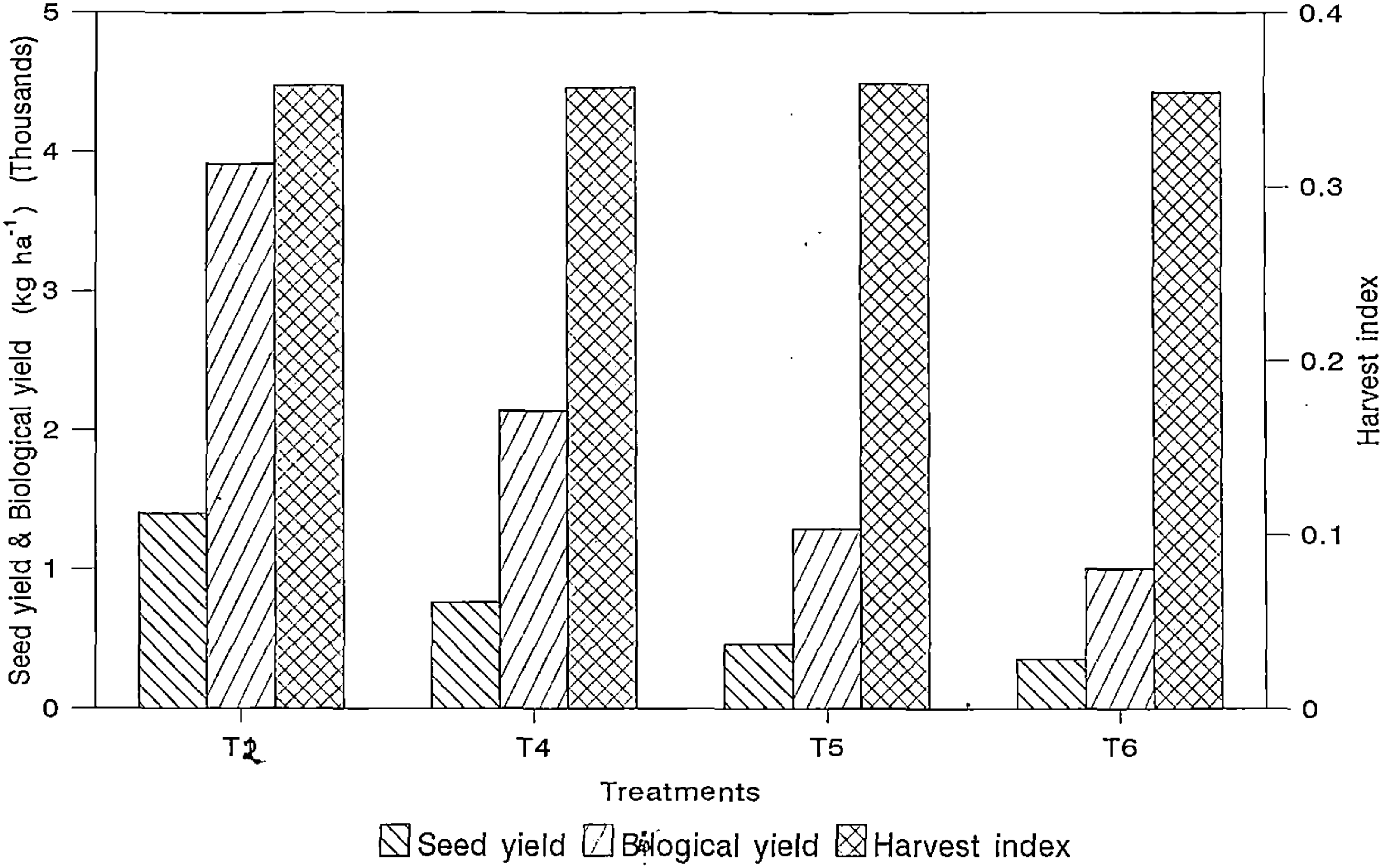

Fig. 5. Seed yield, biological yield (kg ha^{-1}) and harvest index of blackgram

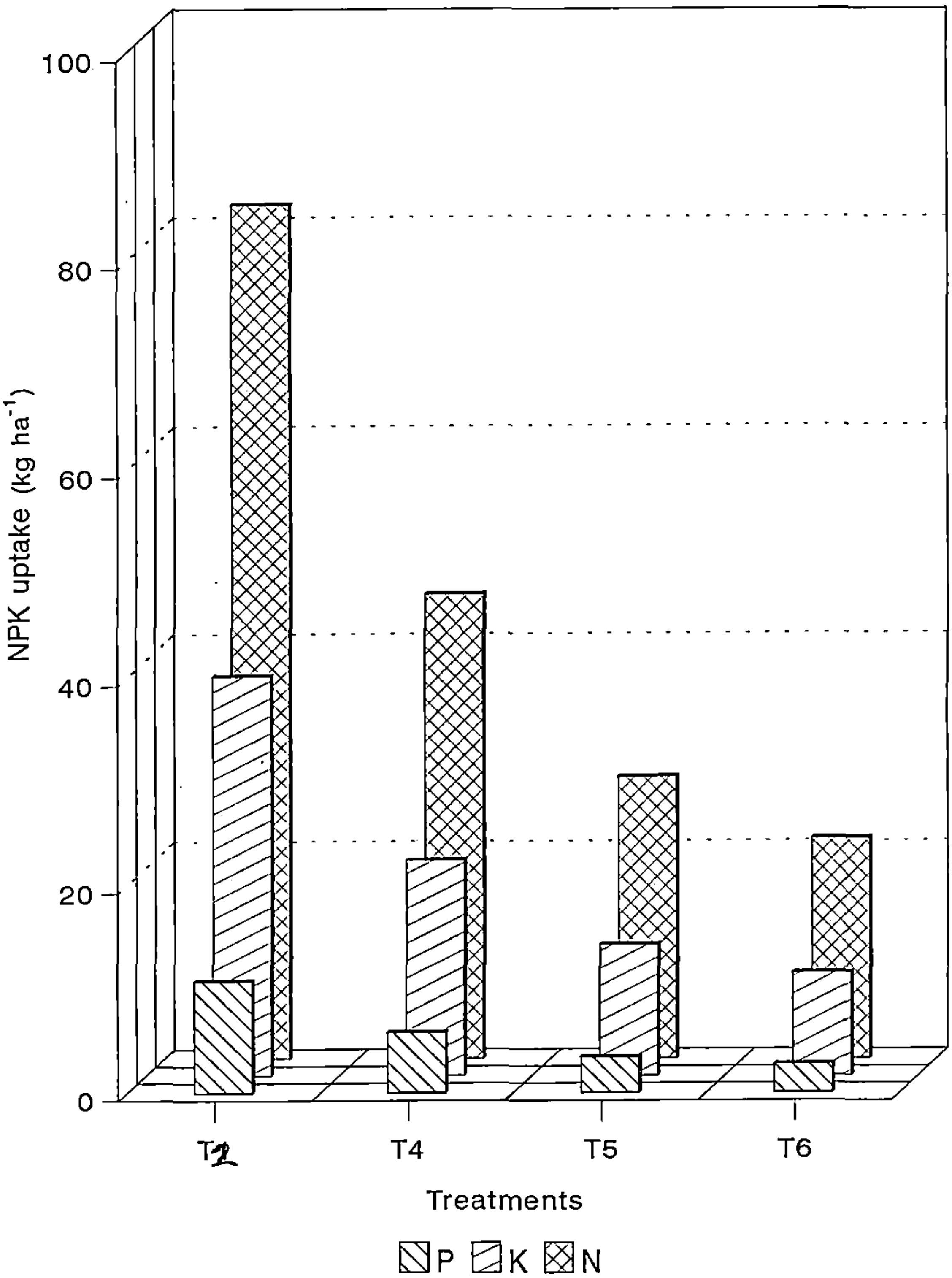

Fig. 6. Nutrient uptake (kg ha^{-1}) by blackgram

might be due to the difference in plant population between treatments and the consequent dry matter accumulation.

The harvest index recorded by the sole crop of blackgram (Table 18, Fig. 5) was on par with intercropped blackgram.

The protein per cent in seeds did not differ significantly between blackgram in sole crop situation and intercropped situation.

4.3. Effect of intercropping greengram Vs sole cropping

4.3.1. Growth characters

Intercropping treatments significantly influenced the plant height of greengram at harvest (Table 11). Sole crop of greengram recorded the highest plant height whereas height was lower in sesamum + greengram in 3:1 ratio. Hegde and Saraf (1982) and Legha *et al.* (1993) also reported similar findings.

The number of leaves produced by the plant did not show any significant variation between the treatments. The number of leaves produced by the sole crop was 7.48 at 30 DAS, 34.38 at 60 DAS and 28.03 at harvest respectively. It was on par with the intercropped greengram.

The number of branches produced by the plant also showed no significant variation. The number of branches produced by the sole crop (Table 13) was on par with the intercropped greengram.

The increase in the leaf area index of greengram showed a definite pattern during its growth, which did not differ in the different systems of planting.

From the above results, it is clear that association of sesamum had lesser adverse effect on legumes and legumes can be grown in a compatible manner without much competition.

4.3.2. Yield and yield attributes

The number of days taken for 50 per cent flowering in greengram ranges from 37 to 38 days. As regards to the number of pods per plant, there was no significant differences between treatments.

The 100 seed weight for sole crop was 4.178 g which was on par with other treatments. The differences in yield attributes of greengram *viz.*, days to 50 per cent flowering, number of pods per plant, 100 seed weight were not significant due to treatments thereby indicating similar individual plant developments of greengram in sole and intercropping system.

The sole crop of summer greengram produced significantly higher seed yield than intercropping systems (Table 20) in which yield varied due to difference in population. With 50, 33 and 25 per cent population in treatments of 1:1, 2:1 and 3:1 row proportions, the mean reduction in yield of greengram noticed was 47, 64 and 73 per cent of the sole crop yield. 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 seed yield of various treatments are graphically presented in Fig. 7.

The sole crop recorded the highest biological yield also and was significantly superior to other intercropping treatments (Fig. 7). The mean reduction in biological yield when compared to sole crop yield were 49, 64 and 74 per cent in treatments of 1:1, 2:1 and 3:1 row proportions (Table 20).

The sole crop of greengram recorded the highest uptake of N, P and K (Fig. 8). Greengram when intercropped with sesamum in 1:3 ratio recorded the lowest uptake of nutrients (Table 23). Among the intercropping treatments, sesamum + greengram in 1:1 ratio recorded the maximum uptake values due to more dry matter production when compared to other ratios.

The harvest index of various treatments did not exhibit any significant difference (Fig. 7). The sole crop recorded a harvest index of 0.339 and harvest index recorded by intercropped greengram ranges from 0.334 to 0,354. The highest harvest index is an indicator of better partitioning of photosynthates.

The protein content in seeds for all the treatments were identical which was about 22 per cent.

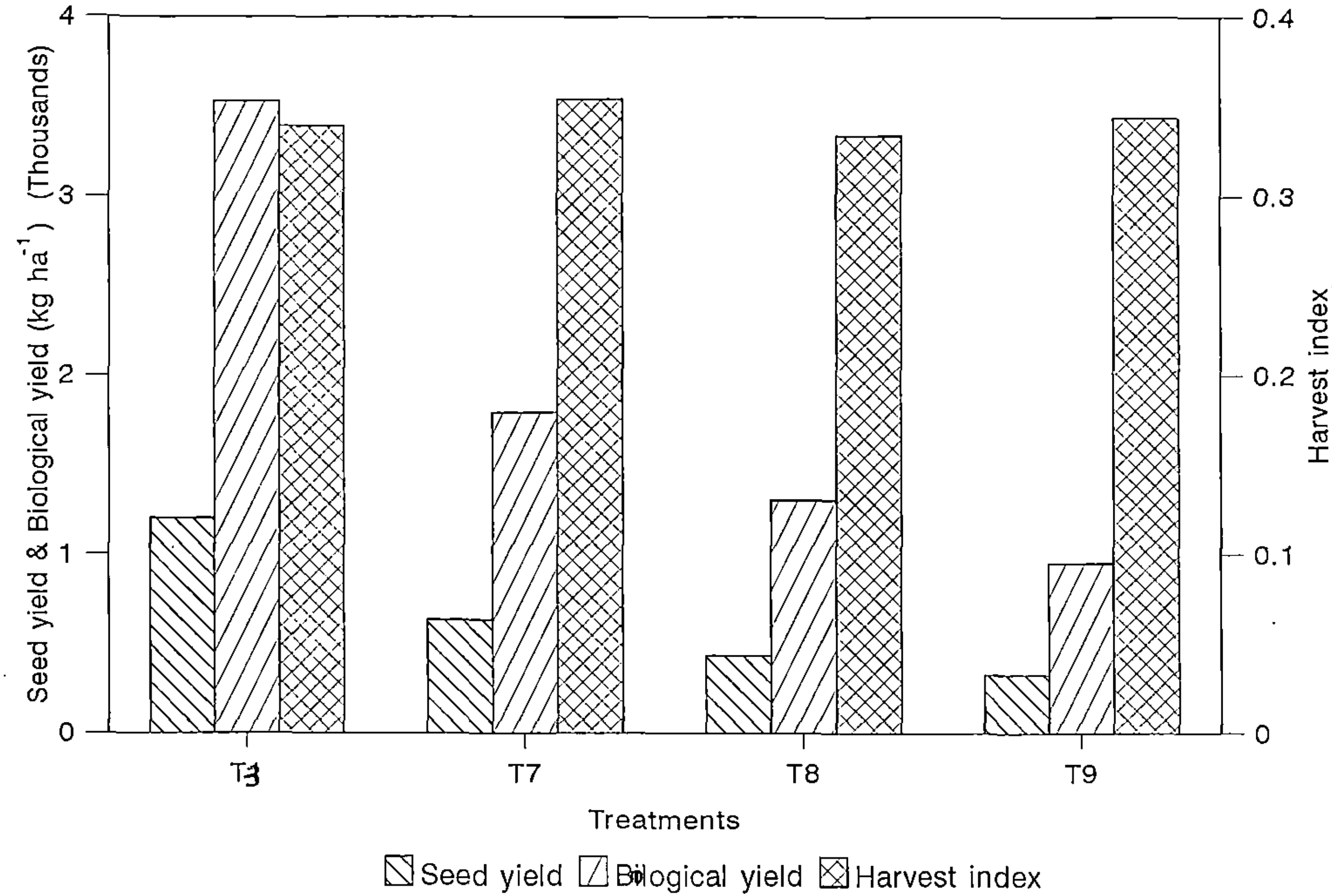

Fig. 7. Seed yield, biological yield (kg ha^{-1}) and harvest index of greengram

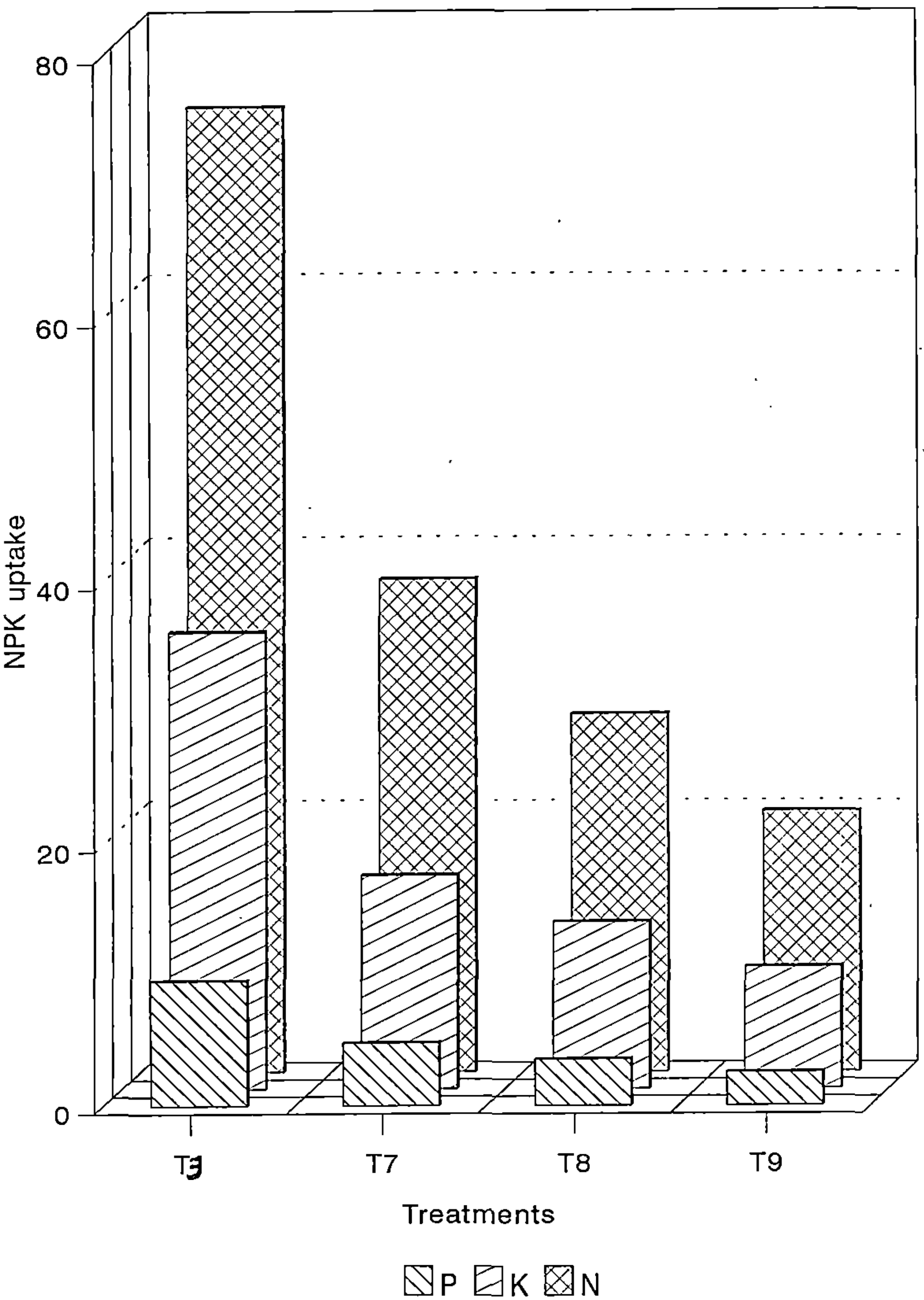

Fig. 8. Nutrient uptake (kg ha^{-1}) by greengram

5.4. Evaluation of sesamum-pulse intercropping system for their 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 intercropping situation would be helpful in future for selecting suitable intercropping system for any specific agro-ecological situation.

5.4.1. Biological efficiency of sesamum - pulse 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 bio-efficiency parameters used for evaluating the competitive relation between component crops in this experiment are discussed below.

5.4.1.1. Land equivalent ratio (LER)

LER is the relative land area under sole crops that is required to produce an yield 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 system except sesamum and blackgram in 2:1 ratio, LER excelled unity indicating greater biological efficiency of intercropping over sole cropping (Fig. 9). Sesamum when intercropped with greengram in 2:1 ratio gave the highest LER (1.04) closely followed by sesamum and blackgram in 1:1 ratio and sesamum and greengram in 3:1 ratio (Table 26). Thus these intercropping treatments indicated that on a unit land area basis they have recorded 4 and 3 per cent yield advantages respectively. The results clearly showed that growing greengram and blackgram as intercrop with sesamum has the potential of giving maximum yields per unit area and time. Thus LER establishes the advantages of intercropping system which was well literated by De (1980), Rafey *et al.* (1986), Samui and Roy (1990), Samui *et al.* (1993) and Kathmale *et al.* (1995).

5.4.1.2. Land equivalent coefficient (LEC)

The total LER was approximating to the LER of the dominant species and failed to show the competitive effects. In this context, the use of LEC in 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 give atleast 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).

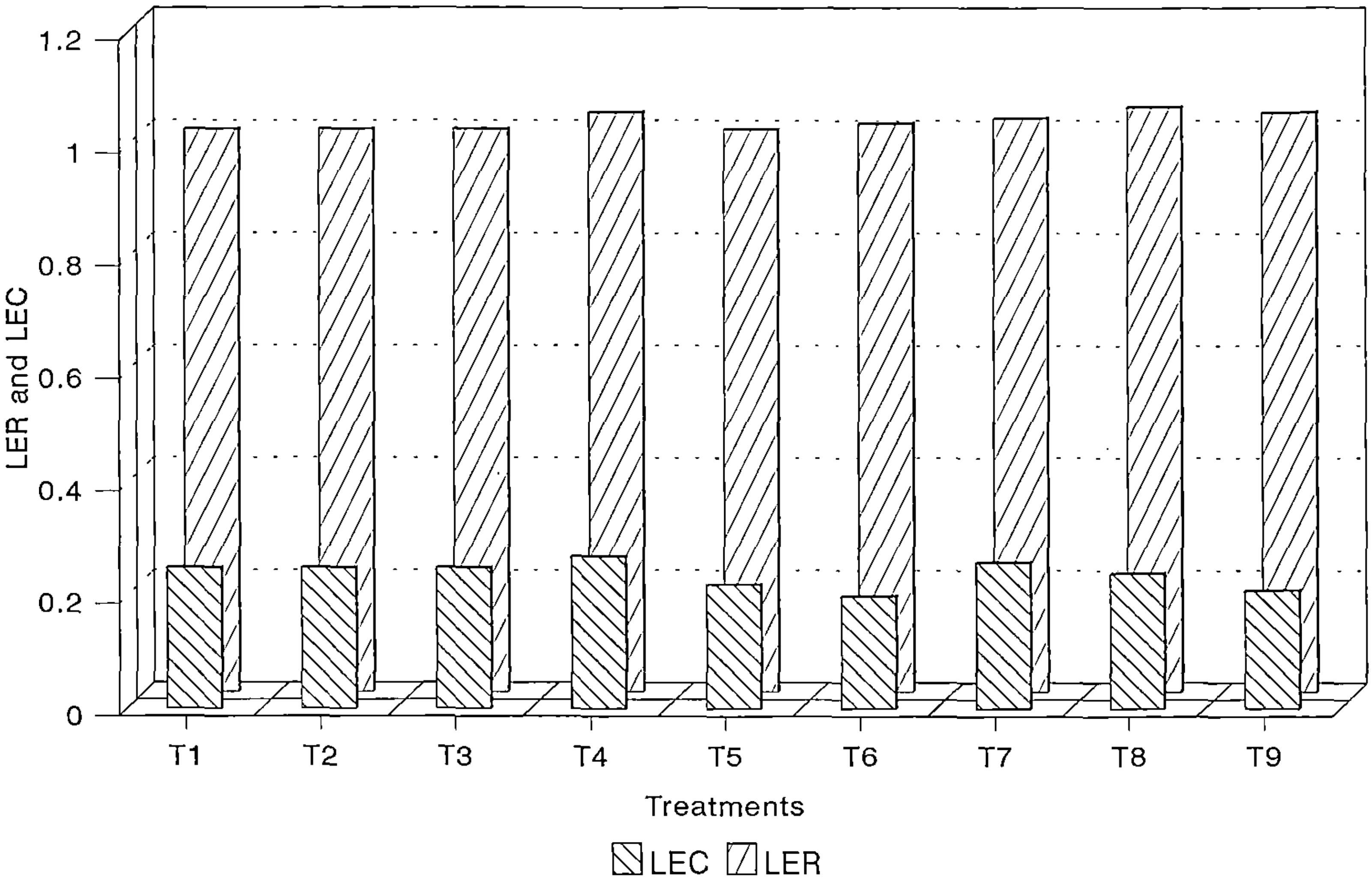

Fig. 9. Biological efficiency of sesamum - pulse intercropping system

The results on LEC (Table 26a) showed that LEC was more than 0.25 in sesamum and blackgram in 1:1 ratio and sesamum + greengram in 1:1 row proportion and they were statistically on par. In all other intercropping situations LEC was less than 0.25 which indicated that due to competition between the component crops the yield would be less than the expected yield. The maximum reduction of yield was noticed when sesamum and blackgram were grown in 3:1 ratio, which recorded an LEC of 0.20 (Fig. 9).

5.4.1.3. 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. Here the species were not equally competitive. 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 the dominant species will be positive and that of the dominated will be negative (Willey, 1979). Here the species were not equally competitive.

The aggressivity values (Table 26b) were found to be positive in pulses and negative in sesamum. The maximum value of aggressivity

(0.12) was recorded by blackgram when it was intercropped with sesamum in 1:1 ratio. In this investigation the intercrops blackgram and greengram were the dominant ones and sesamum was found to be the dominated one *in intercropping situation (Fig. 10).*

Less aggressivity of sesamum when it was intercropped with pulses was reported earlier by Sarkar and Pramanik (1992).

5.4.1.4. Relative crowding coefficient (RCC)

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 more, or less, yield than expected. If a species has a coefficient less than, equal to, or greater than one it means it has produced less yield, the same yield or more yield.

To determine if there is an yield advantage of mixing, the product of the coefficients is formed, which is designated as K. If K is equal to one there is no difference and if K is greater than one there is yield advantage and less than one, there is a yield disadvantage (Sankaran and Mudaliar, 1997).

Here, the intercrops blackgram and greengram has its coefficient greater than one in all treatments (Table 26b, Fig. 10). Greengram and

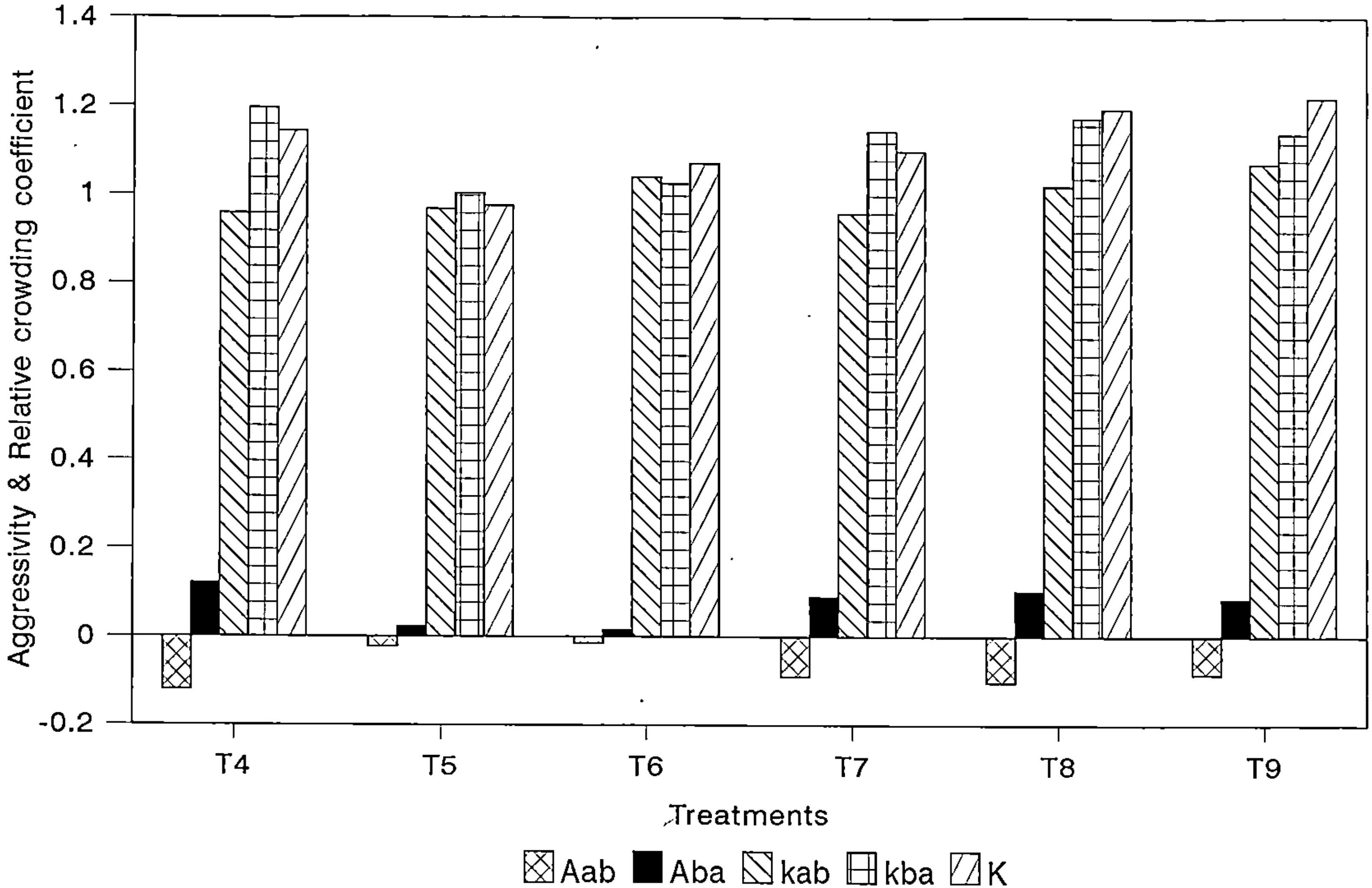

Fig. 10. Biological efficiency of sesamum - pulse intercropping system

blackgram are the dominant components except in a situation when sesamum + blackgram are grown in 3:1 ratio where sesamum had higher RCC than blackgram. The RCC of main crop sesamum was greater than one when it was intercropped with blackgram in 3:1 ratio and with greengram in 2:1 and 3:1 ratios, respectively. The product of RCC (K) was greater than one except in sesamum + blackgram in 2:1 row arrangement, indicating a definite yield advantage due to intercropping (Fig. 10). The highest advantage was noticed in the intercropping system of sesamum and greengram grown in 2:1 row proportion.

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

5.4.1.5. Sesamum equivalent

More than one species are involved in intercropping. Hence it is difficult to compare the produce of different crops with different nature and hence efforts have been made to convert the yield of component crops into equivalent of the crop yield. Here the total productivity was given in terms of sesamum equivalent (Table 27) after converting intercrop yield into sesamum based on market prices. Sesamum equivalent yields from all intercropping system were significantly more than sole sesamum yield. Highest equivalent yield (1006 kg ha^{-1}) was obtained from the sole crop of blackgram. Intercropping of sesamum with blackgram in 1:1 proportion recorded significantly more sesamum equivalent (812 kg ha^{-1}) than sole sesamum and other intercropping treatments. These two

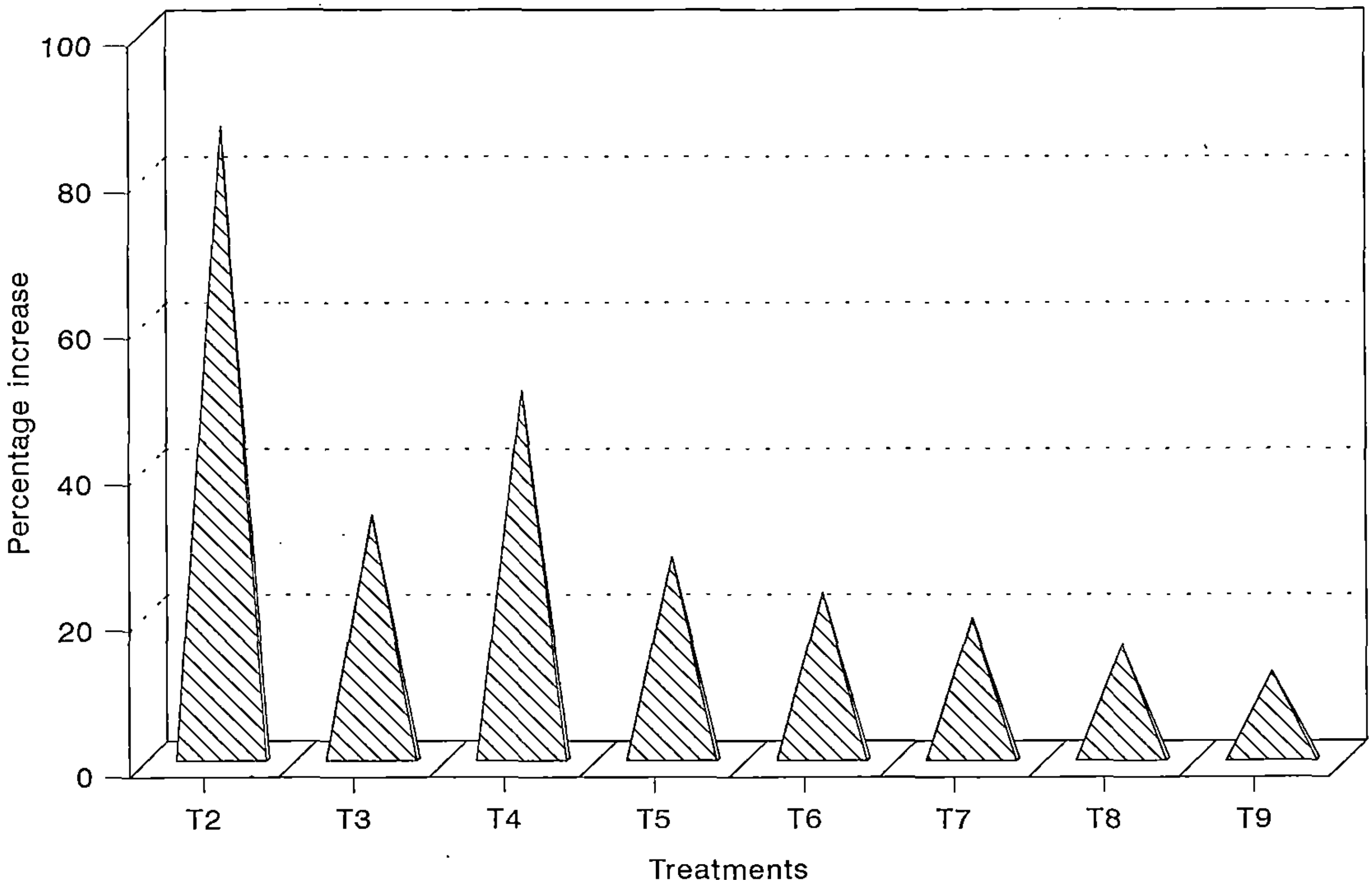

Fig. 11. The percentage of increase in sesamum equivalent yield over the sole crop of sesamum

treatments showed 87 per cent and 51 per cent increased sesamum equivalent yield than sole sesamum yield. Thus the results clearly indicated the superiority of intercropping over sole cropping of sesamum. The percentage of increase in yield over sole cropping are illustrated graphically in Fig. 11. These results agreed with the findings of Sarma and Kakati (1991), Sarkar and Pramanik (1992).

In sunflower + pulse intercropping system, high sunflower equivalent in intercropping was also reported by Sarkar and Dhara (1992), Kawada and Khanvilkar (1987) and Umarani *et al.* (1987).

5.4.2. Economic suitability of sesamum-pulse intercropping system

Intercropping system seems to be more stable than the existing monocropping system. But if any system is to be recommended to the farmer it should be economically viable. Sometimes it is necessary to identify a stable system from among different useful intercropping systems that the farmers can adopt to get stable yield. Hence the produce of the component crops in intercropping system are converted in terms of returns to farmers and is compared to assess the economic suitability. Thus the economic feasibility was tested using various efficiency parameters like gross returns, net returns, benefit cost ratio, net returns per rupee invested and monetary advantage based on LER.

The economics of the intercropping system are presented in (Table 28) and illustrated graphically in Fig. 12. The results revealed

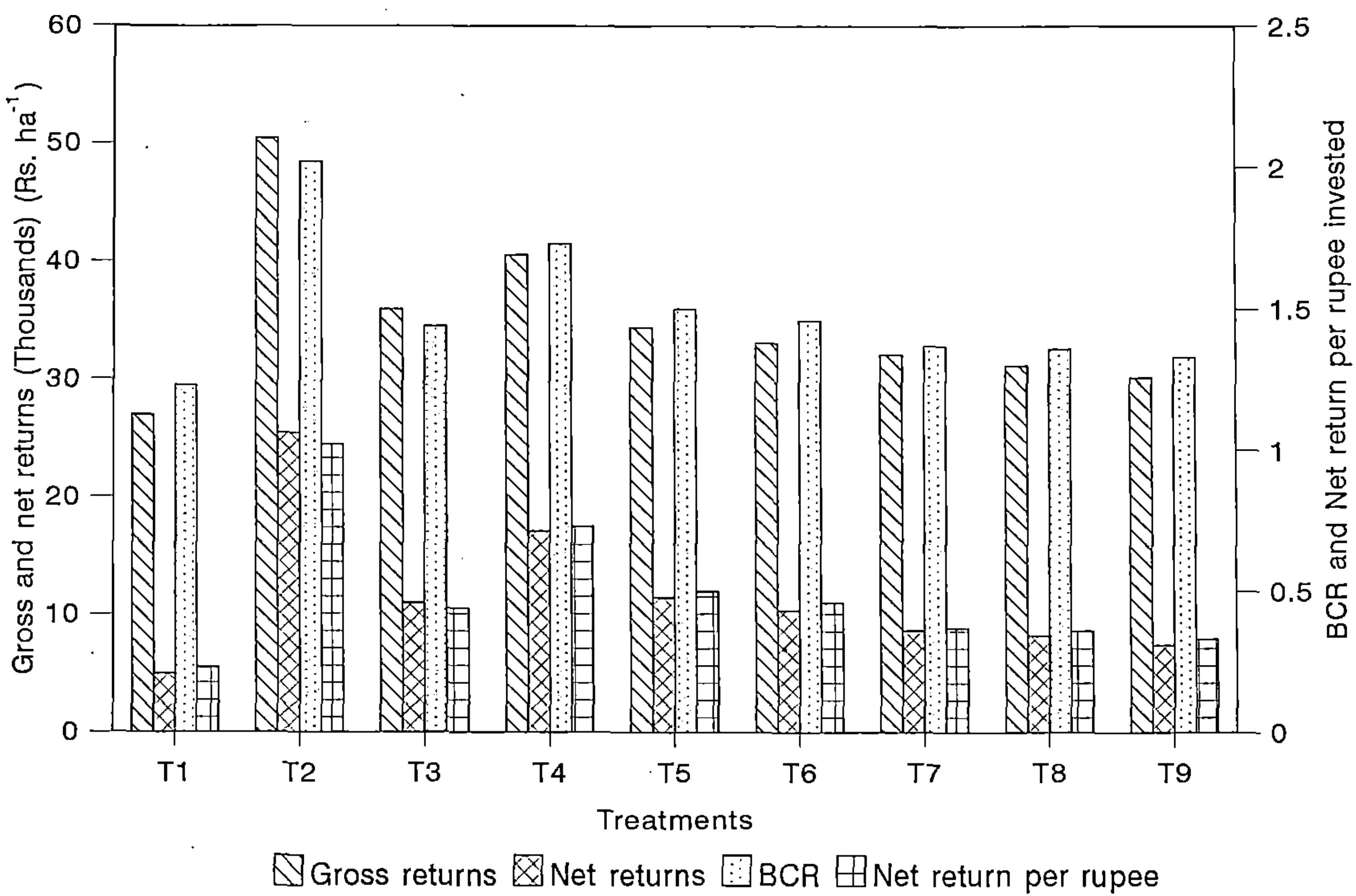

Fig. 12. Economic efficiency of sesamum - pulse intercropping system

that the economics of the intercropping system was significantly influenced by the treatments. The monetary returns were higher irrespective of the pulse crop raised compared to sole crop of sesamum.

The highest gross returns (Rs. 26976 ha^{-1}) were realised from the sole crop of blackgram which was almost twice the returns of sesamum sole crop. This was mainly due to the higher yield of the blackgram, eventhough the market price of the produce is lower than that of sesamum.

Among the intercropping system, sesamum-blackgram system was found more economically feasible than sesamum-greengram system. This is due to higher yield and greater market price of blackgram as compared to greengram. It is also revealed that the planting geometry of 1:1 proportion is economically more feasible than 2:1 and 3:1 row arrangements. The 1:1 proportion of sesamum and blackgram combination was better than the other intercrop patterns and would be recommended where an intercrop is desired. Sesamum and blackgram combination in 1:1 proportion gave an extra net return of Rs. 12146 ha^{-1} than growing sesamum alone, indicating the superiority of this combination when the choice is between sesamum sole crop and an intercrop.

The superiority of 1:1 arrangement in intercropping situation, have also been reported by several earlier workers like Giri *et al.* (1980), Bhaskaran (1984), Samui and Roy (1990), Deshpande *et al.* (1992), Paradkar and Sharma (1992) and Jadhao *et al.* (1995).

Intercropping sesamum and blackgram in 1:1 proportion gave 50 per cent and 65 per cent more returns than in 2:1 and 3:1 combinations respectively. Similarly in sesamum - greengram system 1:1 ratio gave five per cent and 16 per cent more net returns than 2:1 and 3:1 ratio system, respectively.

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 (Table 28; Fig. 12) excelled unity and the maximum value of 2.02 was recorded by the sole crop of blackgram. This is due to higher yield achieved with lower cost of cultivation. Among intercropping systems, sesamum + blackgram in 1:1 ratio recorded the highest value (1.73) followed by the same crop combination in 2:1 ratio. The high BCR of sesamum - blackgram intercropping system revealed its superiority over sesamum - greengram system and sole crop of sesamum and greengram. The higher monetary returns by intercropping of sesamum with pulses have also been reported by Kondap *et al.* (1985) Sarma and Kakati (1991), Singh (1991), Sarkar and Pramanik (1992) and Thakuria and Saharia (1994).

The net returns per rupee invested follow the same trend of BCR. The maximum value of net returns per rupee invested was obtained with the sole crop of blackgram (Table 28, Fig. 12). Among intercropping systems, sesamum and blackgram in 1:1 ratio gave the maximum value of 73 paise per rupee invested.

The monetary advantage based on LER obtained in intercropping system (Table 27(b), Fig. 13) indicated a definite gain from all intercropping systems except intercropping of sesamum and blackgram in 2:1 proportion. The maximum monetary advantage of Rs. 1219 ha^{-1} was obtained when sesamum and blackgram were grown in 1:1 proportion which was followed by sesamum and greengram in 2:1 proportion (Rs. 1191 ha^{-1}). Higher monetary advantage was due to higher values of the produce of combined intercrops. The lower monetary advantage in other intercropping system may be attributed to the lower value of the product of combined intercrops. The yield reduction in either of the crop species in intercropping might be due to competition and or lesser number of plant population of one species when grown in conjunction with another species due to incompatabilities.

The results of the study revealed that a system of intercropping sesamum with blackgram in 1:1 ratio and sesamum with greengram in 2:1 ratio appeared to be economically viable practice for the rice fallows of Onattukara region. The higher monetary advantage is indicative of a better cropping system. Similar results due to intercropping have also been reported by Singh and Yadav (1990) and Rathore and Gupta (1995).

In conclusion, sesamum combinations with blackgram or greengram gave higher net returns and BCR than sole sesamum. Raising

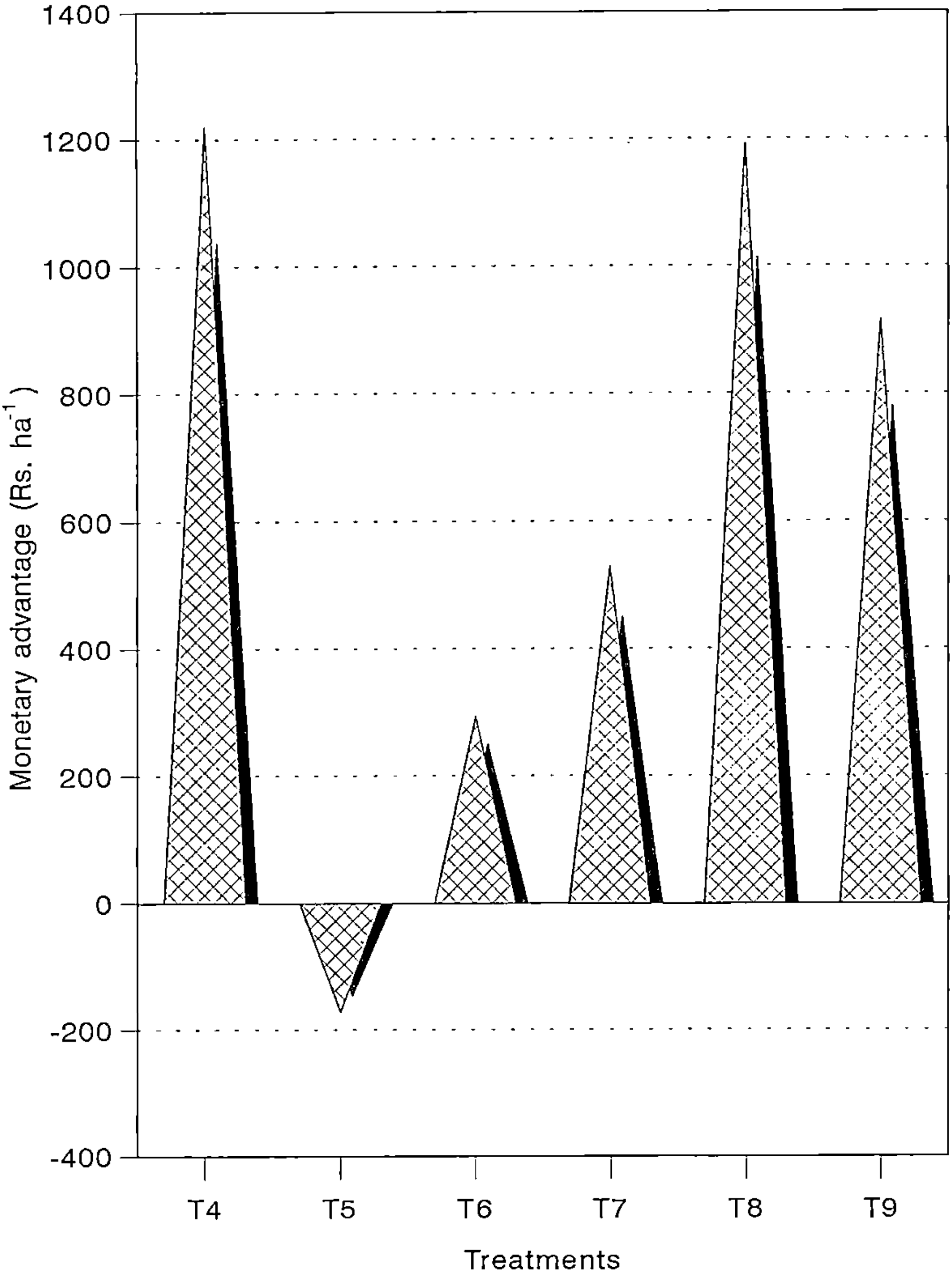

Fig. 13. Monetary advantage based on LER of the intercropping system (Rs. ha^{-1})

a sole crop of blackgram in the rice fallow of Onattukara tract appears to be more profitable. Under circumstances where an intercrop is desired for yield stability, to reduce risk or for yield diversity, raising sesamum and blackgram in 1:1 proportion can be recommended as an economically viable practice for the rice fallows of Onattukara region during the summer season.

5.4.3. Energy equivalents of intercropping system

The results on mean energy values showed that the highest energy values were obtained from the sole crop of blackgram due to the highest seed yield (Table 29). Among the intercropping systems, sesamum and blackgram grown in 1:1 row arrangement gave the highest energy values in intercropping system next to sole blackgram. It was on par with sole greengram also. Sesamum + blackgram grown in 2:1 ratio was statistically similar to sesamum + greengram in 1:1 ratio. Sesamum + blackgram in 3:1 ratio was on par with sesamum + greengram in 2:1 and 3:1 ratios and superior to sole sesamum. The least quantum of energy was obtained from the sole crop of sesamum (Fig. 14). This may be due to lower seed yield of sesamum eventhough the calorific value of sesamum seeds were high.

5.5. Soil nutrient status as influenced by intercropping

The soil nutrient status (available nitrogen, available phosphorus and exchangeable potassium) of the experimental site before the

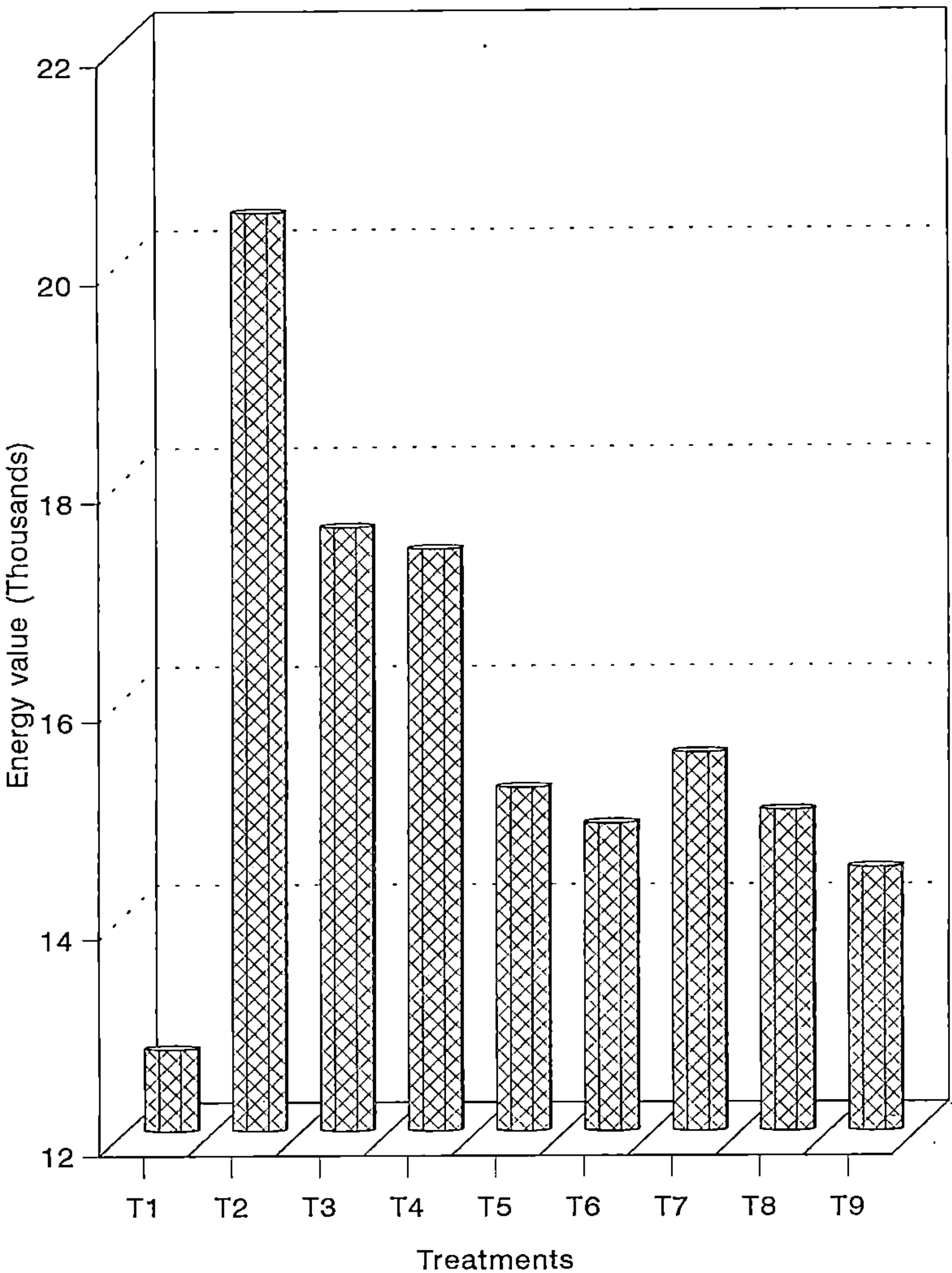

Fig. 14. Energy equivalents of sesamum - pulse intercropping system (MJ ha^{-1})

experiment are presented graphically in Fig. 15. 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 experimental field (Table 24).

The soil test data after the experiment indicated a significant positive buildup of nitrogen and phosphorus in all plots except in plots of sole crop of sesamum where a slight reduction in the soil nitrogen status was observed. But in case of potassium, the exchangeable potassium was slightly reduced after the experiment. The nutrient status after the experiment is graphically illustrated in Fig. 15.

The results of the experiment showed that there was a gain in nitrogen in which legume crop were included and maximum gain was noticed in the plots with the treatment of sole crop of blackgram and greengram. All intercropping combinations except sesamum + blackgram in 3:1 ratio were statistically on par. The plot of sole crop of sesamum recorded the lowest nitrogen content (193 kg ha^{-1}). The favourable effect of legumes in cropping systems have been reported by Sasidhar (1978), Dwivedi (1981) and Prasad *et al.* (1998).

The available phosphorus content of the soil also had been significantly increased after the experimentation. The maximum gain was observed in the intercropped plot of sesamum and greengram in 1:1 ratio (38.73 kg ha^{-1}). The plot of sole sesamum recorded the lowest value of P (35.68 kg ha^{-1}). Sharma and Singh (1970) also reported that

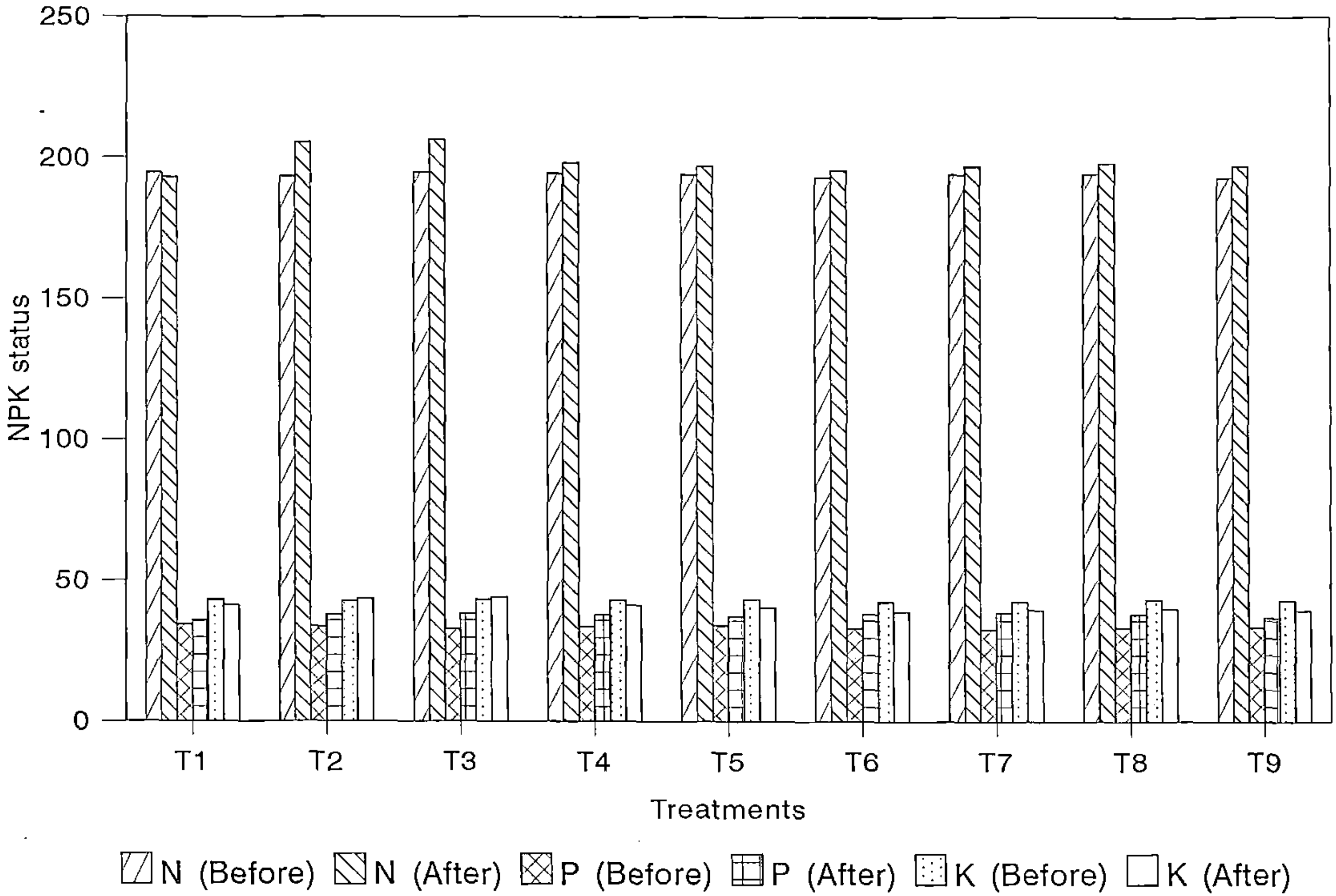

Fig. 15. Soil nutrient status before and after the experiment (kg ha^{-1})

the available P content of the soil increased with crop sequences including legumes.

The exchangeable potassium status of the soil was also significantly influenced by the treatments. In general, the K content of soil was found to be decreased after the experiment. The decrease was maximum in the intercropped plot of sesamum and greengram in 3:1 ratio (39.48 kg ha^{-1}). This may be due to the fact that the total potassium uptake of the systems exceeded the total addition. Further, the soil of the experimental site was sandy loam in texture which might have contributed to the leaching loss of potassium. The results are in agreement with the findings of Sharma and Choubey (1991) in maize + legume intercropping system and Kalarani (1995) in bhindi + cowpea intercropping system.

5.7. Effect of cropping in summer rice fallows on succeeding first crop of rice

A major advantage of using legumes as component crops in an intercropping system was that they can bring about an increase in nitrogen content of soil and this nitrogen in turn may be available to crops grown either in the same season or in succeeding season (Mandal *et al.*, 1991).

In this experiment, rice fallows were cultivated by growing sesamum and pulses as summer crops. A bulk crop of rice was raised during the succeeding *viruppu* season, to assess the residual fertility.

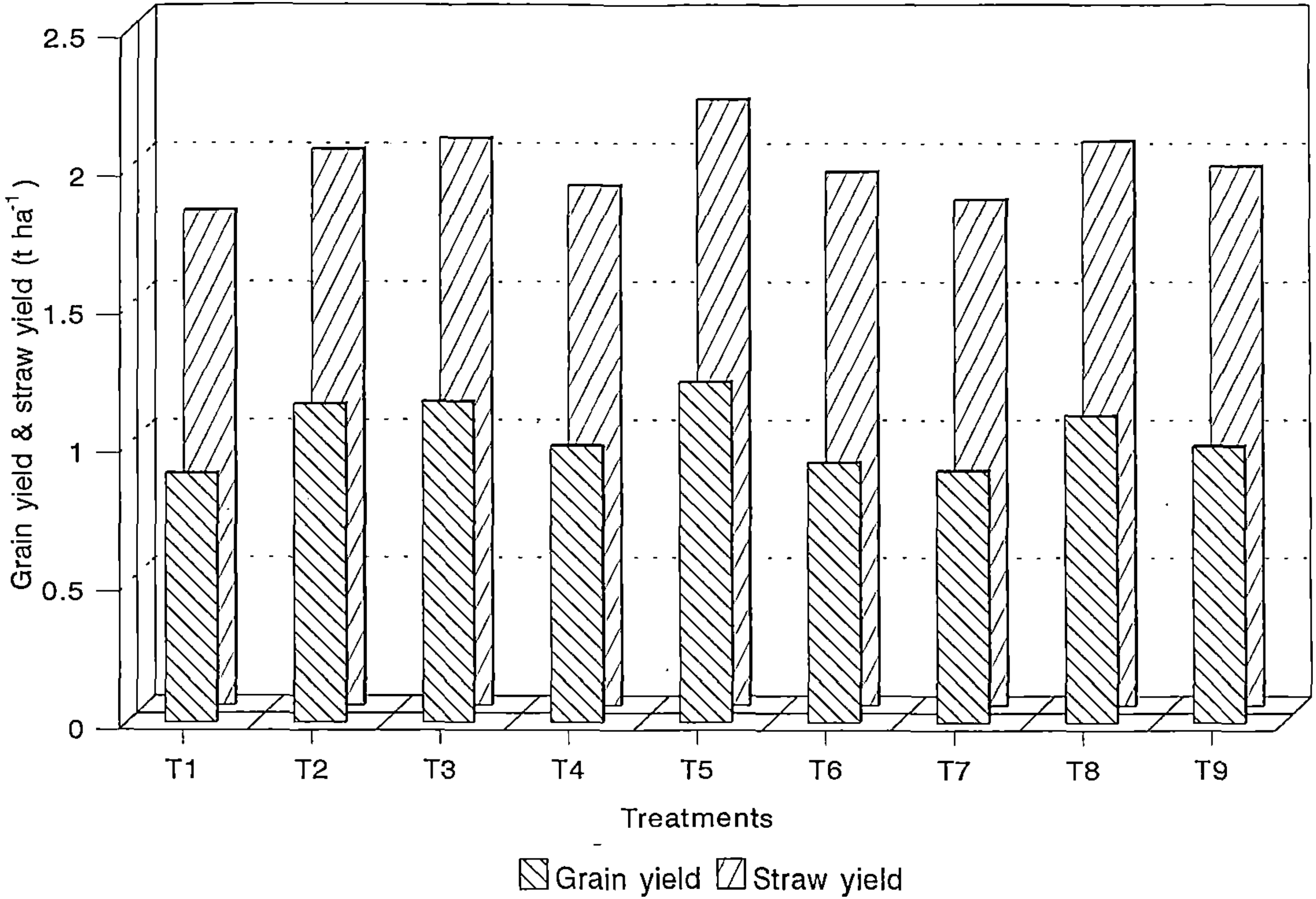

Fig. 16. Grain and straw yield of succeeding rice crop (t ha^{-1})

In this experiment the sole and intercropped blackgram and greengram proved more efficient in increasing the grain yield of paddy compared to sole crop of sesamum. The highest grain and straw yields were obtained from plots when the preceding crop combination was sesamum and blackgram in 2:1 row arrangement (Table 30). The results indicated that legume association with sesamum could increase the total productivity in addition to enrichment of soil fertility. The grain and straw yields obtained are graphically illustrated in Fig. 16.

Similar beneficial effects of legumes on succeeding crops were reported by earlier workers such as Ofori and Stern (1987), Srinivasan *et al.* (1991), Banik and Bagchi (1993) and Mahapatra and Sharma (1995).

SUMMARY

SUMMARY

An experiment was undertaken during the third crop season in the rice fallows of Rice Research Station, Kayamkulam to study the production potential and economics of sesamum-pulse intercropping in the summer rice fallows of Onattukara tract of Kerala and also the residual effect of the intercropping on succeeding crop of rice during *Virippu* season. The field experiment was conducted during the period from February 1998 to August 1998.

The experiment was laid out in a randomised block design with four replication and nine treatments. The treatments were sole cropping of sesamum, blackgram and greengram and intercropping of sesamum with blackgram and greengram in 1:1, 2:1 and 3:1 ratios. The results of the study are summarised below.

Sesamum did not show any significant superiority in growth characters like plant height, number of leaves, number of branches and leaf area index per plant, when it was raised either as sole crop or as an intercrop with greengram and blackgram.

The yield attributes like number of days to 50 per cent flowering, number of pods per plant, oil content in seeds were not influenced by

intercropping. But the 1000 seed weight was significantly superior in sole sesamum, sesamum intercropped with blackgram and greengram in 2:1 and 3:1 ratios as compared to other treatments. The sole crop of sesamum gave significantly higher seed yield (539 kg ha^{-1}) than when it was grown in intercropping system.

The total dry matter production of sesamum was maximum (2350 kg ha^{-1}) with the sole crop. The total uptake of N, P and K was also maximum with the sole crop.

The Harvest Index was significantly influenced by treatments. The highest harvest index of 0.239 was obtained when sesamum was intercropped with greengram in 2:1 ratio.

In blackgram, the growth characters like plant height and LAI were significantly influenced by intercropping treatments. The sole crop of blackgram recorded the highest value throughout the growth period.

Among the yield attributes, the number of pods per plant alone showed significant treatment differences. The sole crop recorded the maximum number of pods per plant.

In yield, the sole crop recorded the highest seed yield (1401 kg ha^{-1}) which was significantly superior to other treatments. The yield of blackgram in 1:1, 2:1 and 3:1 ratios were 54, 33 and 25 per cent of the sole crop yield respectively.

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

The Harvest Index was not influenced by treatments.

In greengram, among the growth characters, plant height alone was significantly influenced by the treatments. The sole crop recorded the highest plant height where as the height was lesser in sesamum + greengram grown in 1:1 ratio.

The yield attributes of greengram were not influenced by intercropping.

The sole crop of greengram produced significantly higher seed yield (1200 kg ha^{-1}) than the intercropping system in which yield varied due to difference in population. In 1:1, 2:1 and 3:1 ratios, the yields were 53, 36 and 27 per cent of the sole crop yield respectively.

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

The values of LER were the highest when sesamum and greengram were grown in 2:1 ratio. The maximum value of LEC (0.27) was noticed when sesamum and blackgram were grown in 1:1 ratio. The aggressivity values were positive for intercrops in all treatments. The RCC was more than one in all treatments except when sesamum was intercropped with blackgram in 2:1 ratio.

The sole crop of blackgram recorded the highest sesamum equivalent yield (1006 kg ha^{-1}). Among the intercropping combinations, sesamum + blackgram in 1:1 ratio recorded the highest equivalent yield (812 kg ha^{-1}). The monetary advantage based on LER was maximum when sesamum was intercropped with blackgram in 1:1 ratio (Rs. 1219 ha^{-1}).

The monetary returns was the highest in sole blackgram and the lowest in sole crop of sesamum. Among intercropping combinations, sesamum + blackgram in 1:1 ratio recorded the highest value. The BCR and net returns per rupee invested followed the same trend.

The highest energy values were obtained from the sole crop of blackgram followed by sesamum + blackgram in 1:1 ratio.

After the experiment, the soil nutrient status was significantly influenced by treatments. In general, a positive buildup of soil N and P were noticed in all plots. But the exchangeable K was slightly decreased after the experiment.

The yield of succeeding crop of rice was not influenced by the preceding crops.

Thus in summer rice fallows, instead of growing sole crop of sesamum, intercropping of sesamum with blackgram in 1:1 proportion can be recommended as an economically viable, biological suitable and a sustainable intercropping system.

In this study, only two crops were tried as intercrops along with sesamum. In future the compatibility of other crops which are suitable for the region can also be studied under sesamum based intercropping system.

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* Original not seen

APPENDICES

Appendix I

Weather data during the cropping period (February 1998 - August 1998)

Sl. No.	Standard week	Date	Mean Max. Temp. (ºC)	Mean Min. Temp. (ºC)	R.H. (am)	R.H. (noon)	Total rainfall (mm)	Sunshine hours (Total)	Sunshine hours (Daily average)	Evaporation (mm)
1	6	5-11 Feb	34.2	21.7	94	51	0	73.5	10.5	3.9
2	7	12-18	34.3	23	89	53	0	72.2	10.3	4.5
3	8	19-25	33	23.4	94	60	0	67.4	9.6	4.4
4	9	26-4 Mar	34.4	23.8	95	57	6	71.6	10.2	4.5
5	10	5-11	34.7	23	93	55	0	73.8	10.5	5
6	11	12-18	35.1	23.1	93	52	0	74.2	10.6	5.3
7	12	19-25	34.8	24.4	93	61	0	72.3	10.3	5.1
8	13	26-1 Apr	135.4	25.6	92	66	0	69.2	9.9	5
9	14	2-8	36.2	24.7	90	56	3.6	66.1	9.4	5.1
10	15	9-15	34.6	25.1	91	57	6.5	67	9.6	5.2
11	16	16-22	35.2	25.7	94	61	32.5	72	10.3	5.3
12	17	23-29	35.5	24.8	89	59	3	67.1	9.6	4.8
13	18	30-6 May	35.2	24.9	89	61	30.1	72.1	10.4	4.9
14	19	9-13	34.4	24.7	93	68	56.3	46.7	6.7	3.7
15	20	14-20	32.5	24.9	96	74	124.8	29.9	4.3	2.9
16	21	21-27	33.9	25.6	95	70	5.5	68.9	9.8	3.9
17	22	28-3 Jun	34.1	25.6	96	70	77.1	53.2	7.6	3.8
18	23	4-10	33	24.3	92	72	49.8	51.4	7.3	3.5
19	24	11-17	31.5	23.7	97	78	140.8	17.8	2.5	2.3
20	25	18-24	31.9	23.9	93	72	64.3	49.2	7	3.4
21	26	25-1 Jul	29.9	23.1	97	84	160.7	6.3	0.9	2.1
22	27	2-8	31.5	22.8	95	65	54.6	41.3	5.9	3
23	28	9-15	31.2	23.8	94	76	41.6	38.3	5.5	2.8
24	29	16-22	30	23.6	97	77	67	34	4.9	2.6
25	30	23-29	30.1	23.4	96	77	66.5	30.9	4.4	2.7
26	31	30-5 Aug	30.6	24	96	76	18.2	30.5	4.4	2.5
27	32	6-12	31	23.9	96	72	47.8	32.5	4.6	3.1
28	33	13-19	31.3	24.3	96	71	29.1	38.9	5.6	3.1
29	34	20-26	29.4	23.6	96	78	262.1	22.7	3.2	2.5
30	35	27-2 Sept	31.1	23.6	97	68	46.1	58.4	8.3	3.6

Source : Central Plantation Crops Research Institute, Kayamkulam

Appendix II

Basic data used for calculating the cost of cultivation (Rs. ha^{-1}) are furnished below

A. Cost of labour

1.	Man labourer	-	Rs. 130 day^{-1}
2.	Women labourer	-	Rs. 130 day^{-1}

B. Cost of manures and fertilizers

1.	FYM	-	Rs. 360 t^{-1}
2.	Urea	-	Rs. 4 kg^{-1}
3.	Mussoriephos	-	Rs. 3 kg^{-1}
4.	Muriate of potash	-	Rs. 4 kg^{-1}

C. Cost of seeds

1.	Sesamum	-	Rs. 50 kg^{-1}
2.	Blackgram	-	Rs. 30 kg^{-1}
3.	Greengram	-	Rs. 37 kg^{-1}

D. Cost of economic produce

1.	Sesamum grains	-	Rs. 50 kg^{-1}
2.	Blackgram seeds	-	Rs. 36 kg^{1-}
3.	Greengram seeds	-	Rs. 30 kg^{-1}

PRODUCTION POTENTIAL AND ECONOMICS OF SESAMUM - PULSE INTERCROPPING IN ONATTUKARA TRACT

By

BINDHU. J. S.

ABSTRACT OF THE THESIS
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ABSTRACT

An experiment entitled "Production potential and economics of sesamum-pulse intercropping in Onattukara tract" was conducted in the summer rice fallows of Rice Research Station, Kayamkulam from February 1998 to August 1998. The study also aims at estimating the residual effect of the intercropping on succeeding crop of rice during *virippu* season.

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

The results indicated that sesamum in general, having a tall growing habit was least affected by shade when put under intercropping systems with pulses under different planting ratios. The association of sesamum had lesser adverse effect on legumes and it was proved that legumes can be grown in a compatible manner with sesamum.

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 values due to more drymatter production as compared to intercropping treatments.

The bio-economic suitability of the intercropping systems were studied. Higher LER, LEC, RCC, Aggressivity and sesamum equivalent were obtained in sesamum + blackgram in 1:1 ratio and sesamum + greengram in 2:1 ratios.

The results on monetary returns were higher in intercropping systems irrespective of the pulse crops raised, compared to sole crop of sesamum. The highest gross returns, net returns per rupee invested and benefit cost ratio were realised from the sole crop of blackgram. Among intercropping systems, sesamum + blackgram in 1:1 ratio gave higher monetary returns and benefit cost ratio. The maximum monetary advantage based on LER (Rs. 1219 ha^{-1}) was obtained when sesamum and blackgram were grown in 1:1 proportion.

The results on energy equivalents were also higher for sole crop of blackgram and sesamum + blackgram in 1:1 ratio.

In general, the soil nutrient status indicated a significant positive buildup of nitrogen and phosphorus. But in case of potassium, the exchangeable potassium was slightly reduced after the experiment. The yield of succeeding rice crop was not significantly influenced by the preceding crops combinations.

Thus raising a sole crop of blackgram in the rice fallows of Onattukara tract appears to be more profitable. Under the circumstances, where an intercrop is desired for yield stability, to reduce risk or for yield diversity, raising sesamum and blackgram in 1:1 proportion can be recommended as an economically viable and biologically sustainable practice for the rice fallows of Onattukara region during the summer season.