PRODUCTIVITY OF OKRA (*Abelmoschus esculentus* (L.) Moench) AS INFLUENCED BY CROP COMBINATIONS

By
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THESIS

Submitted in partial fulfilment of the
requirement for the degree of

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DECLARATION

I hereby declare that the thesis entitled **"Productivity of okra (*Abelmoschus esculentus* (L.) Moench) as influenced by crop combinations"** 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, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that this thesis entitled **"Productivity of okra (*Abelmoschus esculentus* (L.) Moench) as influenced by crop combinations"** is a record of research work done independently by **Miss. Susan Anna John**, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship for her.

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Dedicated to my

Lord and Saviour

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Introduction

INTRODUCTION

Vegetables are considered to be an asset providing a good source of income to the growers and they form a vital part of the human diet. At present in India vegetables occupy 5.86 million hectare with a production of 87.5 million tons. As the country's population is increasing @ 1.8 per cent, our vegetable requirement by 2010 will be around 135 million tons. In Kerala also there is a wide gap between demand and supply of vegetables. The per capita consumption of vegetables in our state is only 125 grams per day as against the requirement of 285 grams. Even for this day to day requirement, we depend heavily on neighbouring states resulting in a substantial drain of money. It is estimated that about 7 lakh tonnes of vegetables are imported from neighbouring states to Kerala. With the increasing population, limited land and water resources, it is imperative to boost the farm productivity in the coming years. One important way to enhance vegetable production is by crop intensification in both time and space dimensions i.e., by intercropping.

Intercropping ensures maximum utilisation of sunlight and other resources, reduces soil erosion and weed growth thereby helps to maintain greater stability of yield. Farmers always strive for earning maximum net returns per unit area with minimum risk. Intercropping helps the farmer to exploit the full potential of the available limited land resources to the maximum extent possible. This system allows more crops to be harvested in the same period of time and permits more land occupancy by overlapping growth cycles.

In vegetable crops higher cropping intensities can be practiced to get high returns. Similarly vegetables being short duration crops fit in very well in most of the cropping systems as fillers or companion crops without competing much with the main crops for vital resources. The base crop selected should accommodate more intercrop and would make intercropping feasible and remunerative even in additive series.

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

1. To estimate the advantage of crop combinations in okra for maximising the productivity per unit area.
2. To develop a vegetable based cropping system for making efficient use of land and other resources in a sustainable way.
3. To assess the crop associative effects in resource utilization and overall economics of the whole system.

Review of Literature

REVIEW OF LITERATURE

An investigation was conducted to assess the suitability of raising intercrops with okra. Although in recent years researchers have started to evaluate the effect of intercropping on common vegetables there is still a dearth of information.

The relevant literature on the performance of vegetables in intercropping system, effect of intercropping on various growth and yield attributing factors, biological and economic efficiency are reviewed hereunder. Research information on other crops are also reviewed wherever pertinent literature is lacking.

2.1 Suitability of vegetables 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.

There are several reports to show that inclusion of legumes in the cropping system had indeed benefited the associated crop and improved the soil nitrogen status (Hall, 1974;Ruschel *et al.*, 1979 and Mandal *et al.*, 1987).

Wilson and Adenisan (1976) opined that an intercropping system of cassava with a sequence of three vegetables tomato, okra and french bean was more efficient than any of the crops grown alone.

Sayed (1979) opined that chilli could be very well intercropped with onion in red soils of Kovelpatti under irrigated condition. Shuo *et al.* (1980) reported the beneficial effect of intercropping *Brassica chinensis* with tomato.

According to Kale *et al.* (1981) radish and palak could be intercropped successfully in cabbage. An advantage of intercropping two species is likely to occur when individual components are of different morphological and growth habit (Dey and Singh, 1981). Shultz *et al.* (1982) found that polyculture of cucumber and tomato was beneficial over monoculture.

Rao *et al.* (1983) reported that vegetable legumes such as lablab bean, cowpea and cluster bean can form better component crop in intercropping system.

Kadali *et al.* (1988) reported that the interspaces of chilli could be best utilized for growing short duration vegetable like frenchbean.

Prabhakar *et al.* (1989) suggested that intercropping capsicum with beetroot was beneficial. Intercropping vegetables such as broccoli, chinese cabbage and radish with chilli was a promising production system (AVRDC, 1990)

Prabhakar and Shukla (1991) suggested that the intercropping system at all levels of fertilizer application was superior to sole crops indicating better utilization of fertilizer by the intercrops.

Leafy vegetables like coriander and fenugreek could be intercropped safely in maize crop (Jadhav *et al.,* 1992). Hernandez and Pino (1997) suggested that intercropping was better than monoculture and one of the best associations suggested was peanuts intercropped with pumpkin.

Intercropping of green gram in between two rows of groundnut performed well compared to groundnut alone (Gangwar and Gangwar, 2000)

2.2 Effect of intercropping on growth characters

Kondap *et al.* (1985) reported that sesamum branched more profusely when it was intercropped with black gram, green gram or pigenonpea in 1:1 proportion than when sown as a sole crop. Olasantan and Aina (1987) found that when okra + cowpea were planted in alternate rows the plant height and leaf area per plant of okra were increased. However, maximum plant height and leaf number per plant were recorded under sole crop of okra.

Ikeorgu (1990) opined that amaranthus performed better in mixtures than under sole cropping and that the plant height and root length were more in intercropped amaranthus compared to sole crop. Natarajan (1992) reported that plant height and number of branches in chilli were affected due to intercropping with okra, onion, coriander, green gram, black gram and cowpea.

When cowpea was intercropped with maize there was a significant increase in length of pods and peduncles and significant reduction in number of branches (Geethi *et al.*, 1993). Chilli + french bean intercropping system recorded higher leaf number, branches, dry matter production, fruit number, length, girth and volume of fruits compared to chilli + amaranthus and sole crop of chilli (Anitha, 1995).

According to Yali *et al.* (1996) intercropped cabbages had more rosette leaves, fewer head leaves, lower photosynthetic rate and dry matter accumulation compared to cabbage monoculture.

2.3 Effect of intercropping on yield and yield attributing characters

The study conducted by Meenakshy *et al.* (1974) revealed that none of the vegetables that were intercropped along with maize had any significant adverse effect on the maize yield.

Intercropping with okra significantly reduced the yield of improved cultivars of tomato, but the yield of a local variety was seen unaffected (Olasantan, 1985a). He reported that yield of okra when grown with tomato varieties was less than that of a sole crop and the combined yield of the two crops in mixtures was more than their pure crop yield.

Intercropping tomato or okra with cowpea was more productive than sole cropping (Olasantan, 1985b and Olasantan and Aina, 1987). Cowpea and onion gave higher yield than green gram, black gram and chilli in cotton based intercropping system (RRS, 1988).

Maity *et al.*(1995) reported that pointed gourd yield was highest when intercropped with spinach beet and lowest with tomatoes. Malhotra and Kumar (1995) opined that the potato tuber yield was decreased when intercropped with cabbages, turnips, chinese cabbages, lettuces or peas.

The best yields of *Capsicum annuum* was observed in the *C. annuim* +garlic cropping system followed by the *C. annuum* +onion cropping system (Mallangouda *et al.*, 1995). Intercropping potato with okra showed an increased tuber yield in hot conditions with an additional okra crop (Moreno *et al.*, 1995).

A study conducted by Amma and Ramadas (1991) to study the feasibility of growing amaranthus on growth and yield of okra proved that intercropping of okra with amaranthus recorded more fruit yield (10.36 t ha^{-1}) than pure crop of okra (9.66 t ha^{-1}).

Rahangdale *et al.* (1995) opined that growth and yield of cabbage were greater when grown as sole crop. While comparing the intercrops, they found that radish caused the greatest reductions in growth and yield because it had the most similar growth pattern to cabbage.

Sharma and Tiwari (1996) observed an increase in percentage fruit set, number and weight of fruits per plant and marketable yield in tomato when intercropped with maize.

Yield and yield components of okra reduced when intercropped with maize (Muoneka and Asiegbu, 1997). Higher (27 - 57%) yield of maize was produced in maize + cowpea intercropping system with a correspondingly lower number of stem borers (Skovgard and Pats, 1997).

Shahidhara *et al.* (1998) opined that the chilli monocrop produced the highest dry pod yield (441 kg ha^{-1}) followed by chilli + groundnut (359 kg chilli + 749 kg groundnut per ha). Ghosh *et al.* (1999) opined that groundnut pod yield per ha was highest when intercropped with fenugreek (2.82 t) and coriander (2.62 t) and lowest with radish (2.30 t) and spinach (2.07 t).

2.4 Effect of intercropping on biological efficiency

Francis *et al.* (1978) reported increased land utilization efficiency with intercropping system.

Significantly higher values of LER was noted in castor + legume combinations as compared to castor + sesamum (Prasad and Verma, 1986).

The biosuitability of chilli – amaranthus intercropping system studied by Anitha (1995) revealed a higher land equivalent ratio (2.74), land equivalent coefficient (1.52), area time equivalency ratio (1.61) and crop equivalent yield (10421 kg ha^{-1}) compared to chilli + french bean and chilli sole cropping system. Dry matter accumulation of maize and *Curcuma longa* were influenced significantly by intercropping system (Sivaraman and Palaniappan, 1995).

LER, LEC, ATER and aggressivity values revealed the biosuitability of ashgourd based cropping system (Balan, 1998). Indian mustard + linseed intercropping system recorded the highest LER (1.63) compared to other intercropping treatments (Narayan *et al.,* 1999).

Highest equivalent yield (2848 kg ha^{-1}), LER (1.33), RCC and aggressivity were recorded with wheat and grass pea in 3:1 row ratio (Rahman, 1999).

2.5 Effect of intercropping on economic efficiency

Meenakshy *et al.* (1974) reported that okra + maize combination has given the maximum additional return followed by cowpea + maize.

Intercropping of onion, lucerne, chilli and groundnut with cotton was found more remunerative than growing cotton alone (AICCIP, 1980). Several workers have reported that intercropping vegetables is profitable compared to sole cropping (Irulappan *et al.,* 1982 and Prabhakar and Srinivas, 1982).

Prabhakar and Shukla (1985) opined that okra could be profitably intercropped with radish and french bean.

By paired row planting of banana with cucumber and amaranthus as intercrop, income would be increased by 40 – 60 per cent compared to square system (KAU, 1986). Amma and Ramadas (1991) opined that intercropping of amaranthus with okra fetched an additional income and resulted in higher economic return of Rs. 9290/- per ha as against Rs. 5096/- per ha recorded by sole crop of okra.

Dixit and Misra (1991) observed that a net return of Rs. 7016/- per ha could be obtained when amaranthus was intercropped with sugarcane compared to the return of Rs. 4065/- per ha for sole crop of sugarcane. Singh (1991) reported that tomato – onion combination gave the highest net return of Rs. 44406/- and maximum profit (390 per cent) and generated an additional income of Rs. 13379/- compared with pure crop of tomato.

The economics of chilli + okra intercropping system revealed that okra was the best intercrop for chilli (Natarajan, 1992). According to Anitha (1995) chilli + amaranthus intercropping system gave a higher gross return (Rs. 156246/-), net return (Rs. 119926/-) and per day return (Rs. 1499/-) compared to their sole crops indicating the economic superiority of this system.

There was an increase of Rs. 3506.52/- and Rs. 227/- net return from okra+cowpea intercropping system over that of sole crop of okra and sole crop cowpea respectively according to Kalarani (1995).

Economic indices like gross return (Rs. 100005.56/-), net return (Rs. 54416.67/-) and per day return was higher for the combination of ashgourd +

cucumber + amaranthus. This was closely followed by ashgourd +cucumber+bush cowpea combination (Balan, 1998).

Growing radish, okra and cowpea as intercrops with mint improved the net economic returns over the sole crop of mint (Singh *et al.*, 1998). Punia *et al.* (1999) reported that the net returns were maximum from sole cropping of mustard(Rs. 16657/- per ha) which was on par with intercropping of mustard with chickpea in 1:5 ratio (Rs. 14021/- per ha).

Studies conducted by Verma *et al.* (1999) revealed that neither sole cropping of sorghum nor intercropping of sorghum with pigeon pea gave higher net return than sole cropping of pigeon pea. The highest benefit-cost ratio was also associated with sole cropping of pigeon pea.

2.6 Effect of intercropping on pest and disease incidence

Sharaiha *et al.* (1989) found that row intercropping reduced the incidence and severity of alternaria leaf spot on faba beans and rust on maize.

Pino *et al.* (1994) observed that the incidence of pest and diseases were lower in intercropped tomato plants than in those grown alone.

Hanna *et al.* (1996) suggested that intercropping cucumber with a nematode resistant tomato could be an effective cultural method to improve cucumber yields in soils that have root-knot nematode problem. Theunissen and Schelling (1996) observed that under sowing leeks with clover drastically reduced thrips infestations.

Intercropping coriander as a single line, double line or border crop with brinjal is an effective measure against *Leucinodes orbonalis* in reducing both infestation and amount of insecticide used by farmers (Khorsheduzzaman *et al.*, 1997).

Maurya *et al.* (1997) reported the lowest incidence of aphids in fennel when intercropped with garlic. Intercropping tomato with cowpea planted within the row significantly reduced bacterial wilt compared to the sole crop (Michel *et al.*, 1997).

Patil *et al.* (1997) observed greatest infestations of fruit borer in tomatoes when intercropped with snap beans and the lowest with radishes. The importance of intercropping as an approach to sustainable horticulture and as a means of pest and disease reduction was emphasised by Theunissen (1997).

Legutowska and Zawirska (1998) opined that the thrips were more abundant in monocropped leek and caused great damage than to intercropped leek plants.

Gupta *et al.* (1999) reported significantly lower infestations of *Leucinodes orbonalis* when three rows of nigella were planted as intercrop between rows of brinjal. Chinese chive plants significantly delayed and suppressed the occurrence of bacterial wilt of tomato (Jingquan and Yee, 1999).

2.7 Effect of intercropping on weed population

Several workers reported that more complete crop cover available in intercropping cause severe competition with weeds and reduce weed growth (Enyi, 1973 and Moody, 1978).

Potato as an intercrop in sugarcane reduced the weed growth and intensity (Nankare *et al.*, 1985). Amma and Ramadas (1991) reported that amaranthus when intercropped with okra reduced the weed population.

Naggar *et al.* (1996) opined that the fresh and dry weight of broadleaved and grass weeds were highest in the onion sole crop and lowest with intercropping in narrow ridges.

Effective weed suppression was obtained due to intercropping than in pure crops (Balan, 1998). Smother cropping with cowpea variety Kanakamony significantly reduced total weed count and weed drymatter production in okra (Sainudheen, 2000)

2.8 Effect of spacing and planting density

Closer spacing between and within the rows increased the yields of cowpea (Ezodinma, 1974). Subramanian *et al.* (1977) opined that a closer spacings of 60 ×15 cm (111000 plants ha^{-1}) recorded the highest yield in cowpea and was superior compared to other two spacings (60×20 cm and 60×25 cm).

Singh *et al.* (1978) reported that in pigeon pea, the net return was higher at a row spacing of 75 cm compared to 50 cm. According to Pandey and Singh (1979) medium spacing of 60 × 30 cm favourably influenced plant height of okra during late kharif.

Significant increase was noted in fresh and dry plant weight of okra with increase in spacing indicating a higher partitioning of assimilates towards vegetative growth under wider spacing (Gowda and Gowda, 1983).

Saharia (1988) noted an increased plant height in black gram when a closer spacing of 30 cm was given. But number of pods per plant was more in wider row spacing.

Prasad and Yadav (1990) observed significantly high grain and biological yield at an interrow spacing of 22.5 cm compared to closer spacings of 15 cm and a wider spacing of 30 cm in black gram. Thakuria and Saharia (1990) noted that the effect of plant density on plant height in summer green gram was non significant.

In frenchbean, net returns were significantly higher with 400000 plants per ha (30 cm row spacing) compared to 286000 plants per ha (45 cm row spacing) and 200000 plants per ha (60 cm row spacing) as reported by Dwivedi *et al.* (1994). Both the net return and return per rupee invested decreased markedly due to reduction in plant density in sesame (Ghosh and Patra, 1994).

In summer black gram maximum number of pods and minimum number of primary branches per plant were produced at 30 cm row spacing compared to 22.5 cm and 15cm (Singh and Yadav, 1994).

A significant improvement in plant height and per plant branch number was seen in red gram by Padhi (1995) at a closer spacing of 30 cm compared to 45 cm. Moocia and Katcherian (1997) opined that in cherry tomato yield per unit area increased linearly with planting density while yield per plant decreased. They also reported that increasing plant density increased the number of trusses, flowers and fruits harvested, but decreased the average fruit weight.

An intrarow spacing of 10 cm increased root yield and reduced total shoot yield resulting in a higher root/shoot ratio in radish compared to 5 cm (Minami *et al.,* 1998). In chilli, the highest plant density treatment (60 ×30 cm) produced the highest yield ha^{-1} while the lowest plant density treatment (75×60 cm) produced the highest fresh and dry weight, number of branches and yield per plant (Revanappa *et al.,* 1998 and Pundir and Porwal, 1999).

The closest spacing of 30×30 cm induced earliness in tomato with respect to days to bud appearance, 50% flowering, breaking, first picking and last picking stages as compared to wider spacing of 60×60, 60×30 and 45×45 cm (Mehla *et al.*, 1999). But the plant growth was seen increased as the spacing became wider.

Naik and Singh (1999) obtained highest yield (126.4 and 85.3 q ha^{-1} during the first and second year respectively) from okra plants grown the closest spacing (90×15 cm).

Materials and Methods

MATERIALS AND METHODS

The present investigation was undertaken in two seasons to assess the feasibility of raising various intercrops with okra for maximising the productivity per unit area. The materials used and the methods adopted for the study are briefly described below.

3.1 Experimental site

The experiment was conducted in the Vegetable Research Farm of the Department of Olericulture, College of Horticulture, Thrissur. The research plot is located at 10°31′N latitude and 76°16′E longitude at an altitude of 22.5 m above mean sea level. The location enjoys a warm humid tropical climate.

3.2 Soil

The soil for the experimental site comes under the textural class of sandy clay loam and is acidic in reaction.

3.3 Season

The experiment was conducted in two seasons. First crop was planted on 21st of June and the second crop on 14th of October 2000.

3.4 Weather conditions during the cropping period

The meteorological parameters recorded are rainfall, maximum and minimum temperatures and relative humidity. The average weekly values are collected from the observatory attached to College of Horticulture and are presented in Appendix I.

3.5 Materials

3.5.1 Crop characters and source of seed materials

Crop	Variety	Duration (days)	Characters	Source
Okra	Arka Anamika	120	A less branched variety, having on an average100 cm height, short internodes producing medium green fruits after 5-6th node, resistant to yellow vein mosaic virus. Potential yield is about 11.5 t ha^{-1}	IIHR , Bangalore
Amaranthus	CO.1	50 – 60	Green coloured stem and leaves, reaches a height of 68.33 cm, resistant to Colletotrichum leaf spot, average yield is about 7.16 t ha^{-1}.	TNAU, Coimbatore
Cowpea	VS-389 (Bhagyalakshmi)	78	Bush type, early variety which flowers in 38 to 41 days, first harvest in 48 – 51 days .Pods are light green coloured, each weighing 7-13 g, average yield is about 6.48 t ha^{-1}.	Department of Olericulture, College of Horticulture, Thrissur
Cucumber *Cucumis melo* var. *conomon*	CS.26 (Mudicode)	79 – 88	Early maturing group with attractive golden yellow coloured fruit, first harvest in 55 – 60 days with 2.2 – 2.8 cm flesh thickness and 23.7 – 35 cm fruit length,average yield is about 29.3 t ha^{-1}.	Department of Olericulture, College of Horticulture, Thrissur

3.5.2 Manures and fertilizers

Good quality dry farmyard manure was used for the study. Urea (46%N), Mussoriephos (18% P_2O_5) and Muriate of Potash (60% K_2O) were used as sources of nitrogen, phosphorus and potassium respectively.

3.6 Methods

3.6.1 Design and layout

The field experiment was laid out in a randomised block design with three replications. The layout is given in Figure I.

3.6.2 Treatments

There were 11 treatments involving one base crop grown at two different spacings, three intercrops and their monocrops.

Base crop

Okra

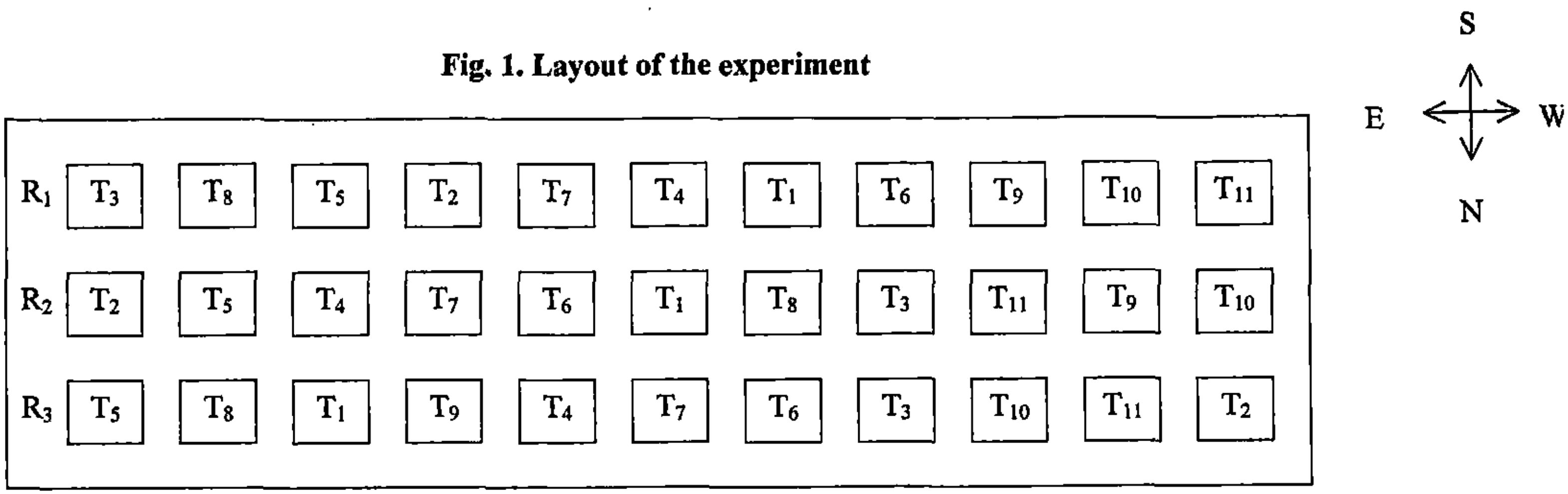
Intercrops (3)

1. Amaranthus (I_1)
2. Bush cowpea (I_2)
3. Cucumber (I_3)

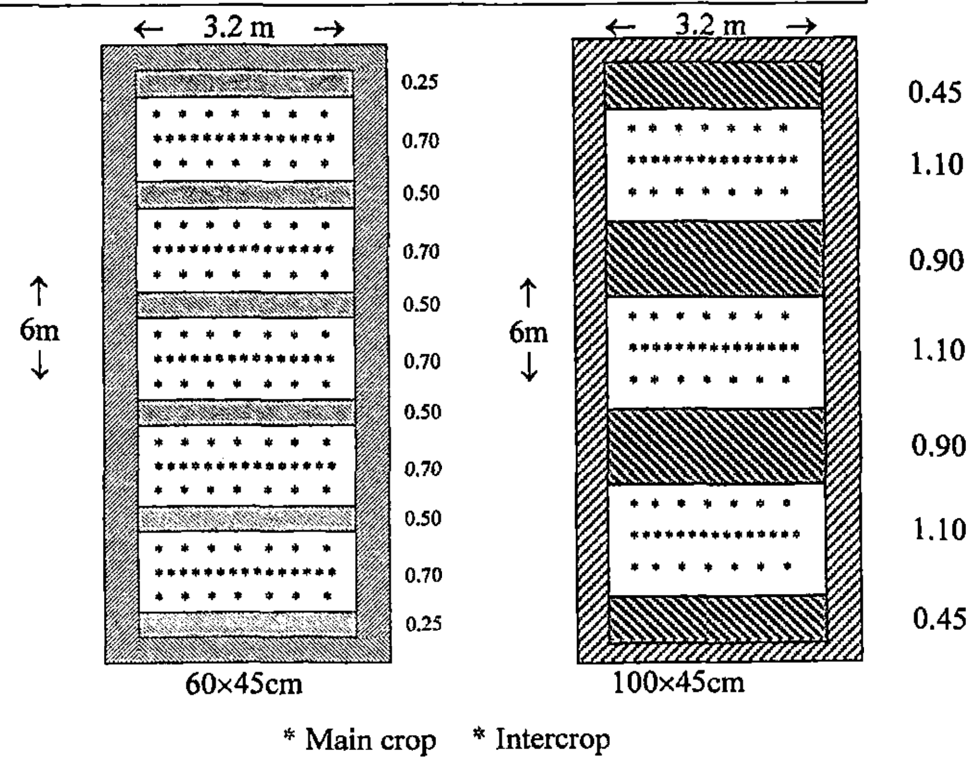
Spacing of base crop (2)

1. 60 × 45 cm (S_1)
2. 100 × 45 cm (S_2)

Fig. 1. Layout of the experiment



Design: Randomised block design
T_1 – Sole crop of okra at 60×45cm
T_2 – Sole crop of okra at 100×45cm
T_3 – Okra (60×45cm)+amaranthus
T_4 – Okra (100×45cm)+amaranthus
T_5 – Okra (60×45cm)+cowpea
T_6 – Okra (100×45cm)+cowpea
T_7 – Okra (60×45cm)+cucumber
T_8 – Okra (100×45cm)+cucumber
T_9 – Sole crop of amaranthus at 20 cm spacing
T_{10} – Sole crop of cowpea at 25×15 cm spacing
T_{11} – Sole crop of cucumber at 2×1.5 m spacing



3.6.3 Total treatment combinations

T_1 – Monocrop of okra at 60 × 45 cm spacing (S_1)

T_2 – Monocrop of okra at 100 × 45 cm spacing (S_2)

T_3 – Okra at 60 × 45 cm + amaranthus between rows at 20 cm spacing (S_1I_1)

T_4 – Okra at 100 × 45 cm + amaranthus between rows at 20 cm spacing (S_2I_1)

T_5 – Okra at 60 × 45 cm + cowpea between rows at 20 cm spacing (S_1I_2)

T_6 – Okra at 100 × 45 cm + cowpea between rows at 20 cm spacing (S_2I_2)

T_7 – Okra at 60 × 45 cm + cucumber between rows at 1 m spacing (S_1I_3)

T_8 – Okra at 100 × 45 cm + cucumber between rows at1 m spacing (S_2I_3)

T_9 – Sole crop of amaranthus at 20 cm spacing (I_1)

T_{10} – Sole crop of cowpea at 25 × 15 cm spacing (I_2)

T_{11} – Sole crop of cucumber at 2 × 1.5 m spacing (I_3)

Number of replications – 3

Number of plots/replication –11

Plot size – 19.2 m^2

3.7 Cultural operations

3.7.1 Land preparation

The experimental plot was dug once, stubbles were removed, clods were broken and levelled. The field was then laid out into three blocks, with 11 plots each. The plots were separated by channels of 30 cm width. The individual plots were thoroughly dug and levelled.

3.7.2 Sowing

All the crops were sown on the same date. Crop arrangement was followed according to the treatment schedule.

Okra seeds were dibbled at the spacing suggested for each treatment. Seeds of cowpea, amaranthus and cucumber were sown in the interspaces of okra raised at two different spacings (60 and 100 cm). Gap filling and thinning were done to secure a uniform stand of the crop.

3.7.3 Manures and fertilizer application

Manures and fertilizers were applied as per Package of Practices recommendation (KAU, 1996) for okra, bush cowpea, amaranthus and cucumber.

Fertilizer recommendation and schedule of fertilizer application are given below.

Crop	Recommendation (kg ha^{-1})			Schedule of application
	N	P_2O_5	K_2O	
Okra	50	8	25	1/2 N, full P and K as basal dose, remaining 1/2 N one month after sowing
Bush cowpea	20	30	10	1/2 N, full P and 1/2 K as basal, 1/2 N and 1/2 K 20 DAS
Amaranthus	50	50	50	N was applied at regular intervals as top dressing, 1/2 K and full P as basal and 1/2 K as top dressing 20 DAS
Cucumber	70	25	25	1/2 N, full P and K as basal dose, remaining 1/2 N in 2 equal splits at the time of vine growth and full bloom

3.7.4 After cultivation

Fertilizers were applied as per the Package of Practices recommendation. Crop was irrigated on alternate days when rainfall was inadequate. Weeding was done as and when required.

Plate 1. T_1 – Sole crop of okra at 60×45cm

Plate 2. T_2 – Sole crop of okra at 100×45cm

Plate 3. T_3 – Okra (60×45cm)+amaranthus

Plate 4. T_4 – Okra (100×45cm)+amaranthus

Plate 5. T_5 – Okra (60×45cm)+cowpea

Plate 6. T_6 – Okra (100×45cm)+cowpea

Plate 7. T_7 – Okra (60×45cm)+cucumber

Plate 8. T_8 – Okra (100×45cm)+cucumber

3.7.5 Plant protection

Necessary plant protection measures were taken when there was incidence of pests and diseases.

3.7.6 Harvesting

Harvesting was done when the fruits or leaves were ready..

3.8 Observations recorded

3.8.1 Okra

1. Plant height

The height was measured from the base to the terminal buds at final harvest.

2. Number of branches

Number of primary branches were counted at the final stage of the crop.

3. Number of internodes

The number of internodes were counted at the time of final harvest.

4. Internodal length

The length of internode between sixth and seventh node of five plants were taken at the final stage of the crop and the average was worked out and expressed in cm.

5. Canopy spread

Canopy spread of the standing plant was measured at final harvest and expressed in cm.

6. Root spread

The plants were uprooted carefully and the length of the longest lateral root on both sides of the taproot was measured at final harvest . Their average was found out and expressed in cm.

7. First flowering node

The node at which the first flower appeared was counted from the base.

8. Days to first flowering

Number of days taken for flowering from the date of sowing was noted.

9. Days to first harvest

Number of days taken for the first harvest from sowing was recorded.

10. Days of final harvest

Number of days taken for the final harvest from sowing was recorded.

11. Fruit length

The length of five fruits from the first and fourth harvests were measured from tip to the stalk end of the fruit. The average was worked out and expressed in cm.

12. Fruit girth

Measurement of this attribute was made by winding thread around the middle most length of the individual fruit. Measurements of five fruits from the first and fourth harvest were taken. The average was worked out and expressed in cm.

13. Single fruit weight

Weight of a single fruit was taken ten days after fruit set from each of the observation plant. The average was worked out and expressed in gram.

14. Fruit number per plant

The total number of fruits borne on the five observation plants were recorded and their mean was computed to get the fruit number per plant.

15. Fruit yield per plant

The total weight of the fruits harvested from the five observation plants were noted and their mean taken to get the fruit yield per plant and expressed in grams.

16. Fruit yield in t ha^{-1}

The weight of fruits from all the harvests were totalled up at the end of the cropping season and the yield in t ha^{-1} was worked out from the net plot yield.

17. Dry matter production at final harvest

The whole plant with leaves, stem and roots were oven dried at 70±5°C to constant weight. The final dry weight was noted and expressed in grams.

18. Occurrence of fruit and shoot borer

Percentage incidence of fruit and shoot borer was worked out at 70 DAS.

19. Occurrence of yellow vein mosaic

Percentage incidence of yellow vein mosaic was worked out at 70 DAS.

3.8.2 Amaranthus

1. Root spread

The plants were uprooted carefully and the length of the largest root on both sides of the taproot was measured at final harvest and their average was worked out and expressed in cm.

2. Number of cuttings.

Number of times of harvesting was recorded.

3. Days to first harvest

Number of days taken for the first harvest from sowing was counted.

4. Days to final harvest

Number of days taken for the final harvest from sowing was observed.

5. Yield per plant

The total weight of the leaves obtained from the five observation plants were noted and the mean taken to get the yield per plant and expressed as grams.

6. Yield in t ha^{-1}

The total weight of the leaves obtained from a plot was converted to yield per ha and expressed in t ha^{-1}

7. Incidence of leaf webber and leaf spot

Plants were inspected for the presence of leaf webber and leaf spot.

3.8.3 Cowpea

1. Plant height

The height was measured from the base to the terminal buds at final harvest.

2. Root spread

The plants were uprooted carefully and the length of the largest lateral root on both sides of the taproot was measured at final harvest and expressed in cm.

3. Canopy spread

Canopy spread of the standing plant was measured at final harvest and expressed in cm.

4. Days to first flowering

Number of days taken for flowering from the date of sowing was counted.

5. Days to first harvest

Number of days taken for the first harvest from sowing was recorded.

6. Days to final harvest

Number of days taken for the final harvest from sowing was recorded.

7. Number of pods per plant

The total number of pods borne on the five observation plants were recorded and their mean was computed as number of pods per plant.

8. Pod yield per plant

The total weight of the pods harvested from the five observation plants were noted and their mean taken to get the pod yield per plant.

9. Pod yield in t ha^{-1}

Total weight of the pods from all the harvests were totalled up at the end of cropping season and yield in t ha^{-1} was worked out from the net plot yield.

10. Dry matter production

The whole plant with leaves, stem and roots were oven dried at 70±5°C to constant weight. The final dry weight was noted and expressed in g.

11. Incidence of aphid

Number of plants attacked by aphid were counted at 70DAS and the percentage incidence was worked out.

3.8.4 Cucumber

1. Length of main vine (cm)

The plants were pulled out after the final harvest and length of the main vine was measured from the collar region to the tip of the main vine.

2. Number of primary branches per plant

The number of primary branches were counted at the final stage of the crop.

3. Number of female flowers per plot

Number of female flowers produced per plot was counted.

4. Percentage set

Percentage of female flowers that set fruits was worked out.

5. Days to first harvest.

Number of days taken for the first harvest from sowing was counted.

6. Days to final harvest.

Number of days taken for the final harvest from sowing was counted.

7. Circumference of fruits (cm)

This was measured by winding a thread around the middle of the fruit.

8. Average weight of fruits

Weight of the individual fruits were taken and the average was worked out.

9. Number of fruits

Total number of fruits obtained from the plot were noted.

10. Yield per plant.

Total weight of the fruits divided by the number of plants gave the yield per plant and expressed in grams.

11. Fruit yield in t ha^{-1}

Total weight of the fruits obtained were expressed in t ha^{-1}

12. Incidence of fruit fly and mosaic.

Number of fruits attacked by fruit fly were noted at 70 DAS and the percentage incidence was calculated. Plants were also observed for the incidence of mosaic.

3.9 Parameters for evaluation of cropping systems

3.9.1 Biological efficiency

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

The competition functions proposed to describe the competitive relationships in intercropping are given below.

1. Land equivalent ratio (LER).

LER was worked out from the data on the yield of main crop and intercrops in mixture and pure stands. It was worked out by using the formula suggested by Willey (1979).

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

Y_{ab} and Y_{ba} are the individual crop yield in intercropping and Y_{aa} and Y_{bb} are their yields as sole crop.

2. Land equivalent coefficient (LEC)

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

$$LEC = LA \times LB$$

$$LA = \text{LER of main crop}$$

$$LB = \text{LER of intercrop}$$

3. Area time equivalency ratio (ATER)

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

$$ATER = \frac{(Ry_a \times t_a) + (Ry_b \times t_b)}{T}$$

Ry = Relative yield of species 'a' or 'b' i.e., yield of intercrop/yield of main crop

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

T = duration (days) of the intercropping system.

4. Aggressivity

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

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

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

5. Relative Crowding Coefficient (RCC)

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

$$RCC = K_{ab} \times K_{ba}$$

$$K_{ab} = \frac{Y_{ab}}{Y_{aa} - Y_{ab}}$$

$$K_{ba} = \frac{Y_{ba}}{Y_{bb} - Y_{ba}}$$

K_{ab} and K_{ba} are the RCC for species 'a' and 'b' respectively. Y_{ab} and Y_{ba} are the individual crop yield in intercropping and Y_{aa} and Y_{bb} are their yields as sole crop.

6. Okra equivalent yield

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

$$\text{Okra equivalent yield (kg ha}^{-1}\text{)} = \frac{\text{Yield of intercrop}}{\text{Market price of okra}} \times \text{Market price of intercrop}$$

7. Total biomass production

The total weight of main crop and intercrop in a system along with their economic yield was calculated and expressed in kg per plot.

8. Fresh weight of weeds from interspace

The entire plot was weeded and the weight of weeds was taken 65 days after sowing and was expressed as kg/plot.

3.9.2 Economic suitability

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

The following economic indices were used to evaluate the system.

1. Gross return

This was calculated on the basis of price of the produce followed in Kerala Agricultural University and expressed as returns per hectare. The price was fixed as okra –Rs. 5/kg, cucumber –Rs. 5/kg, cowpea –Rs. 7/kg, amaranthus –Rs. 5/kg.

2. Net return

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

3. Per day return (PDR)

Per day return was calculated using the formula suggested by Palaniappan, 1988.

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

4. Benefit cost ratio (BCR)

   BCR was worked out as per the formula given below

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

5. Return per rupee invested on inputs

   a. Return per rupee invested on labour (RPL)

This was worked out using the formula

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

b. Return per rupee invested on fertilizers (RPF)

It gives an estimate of the production per unit cost spent as fertilizers for different treatments. It was calculated using the formula.

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

4.0 Soil analysis

Soil analysis was done before and after the raising of crops in both the seasons.

Chemical properties	Methods used	Reference
Organic carbon (%)	Walkley and Black Rapid Titration Method	Jackson (1958)
Available nitrogen (kg ha^{-1})	Alkaline permanganate method	Subbiah and Asija (1956)
Available potassium (kg ha^{-1})	Flame photometry, Neutral normal ammonium acetate extraction	Jackson (1958)

5.0 Statistical analysis

Data relating to different characters were analysed statistically by applying the technique of analysis of variance of randomised block design and the significance was tested by Duncans Multiple Range Test. Treatments having same alphabets as superscripts belong to same homogenous group. The data which showed wide variations were subjected to square root and logarithmic transformations to make the analysis valid (Gomez and Gomez, 1984). Performance of each intercrop in the cropping system was assessed by analysing the data on growth and yield parameters using Kruskal – Wallis one-way analysis of variance method (Siegel, 1956).

Results

RESULTS

The present investigation was conducted to study the productivity of okra as influenced by crop combinations. The experimental data collected were statistically analysed and the results are presented hereunder.

4.1 Growth and yield characters of okra

4.1.1 Plant height

Table 1 shows the effect of intercropping and spacing on the plant height of okra.

There was no significant difference in plant height of okra due to spacings, intercrops or their interactions. However, okra was tallest (121.27 cm) when grown as sole crop at lower spacing and shortest (64.67 cm) when intercropped with cowpea at lower spacing during the first season. During the second season okra was tallest (46.57 cm) when intercropped with amaranth at closer spacing and shortest (36.17 cm) when grown as sole crop at wider spacing.

4.1.2 Number of branches

The data on number of branches of okra is presented in Table 1.

Influence of spacing, intercrops and their interaction on number of branches of okra was not significant during both the seasons. Okra produced highest number of branches (0.70) when intercropped with cucumber at wider spacing in the first season and the lowest (0.20) when grown with cowpea at closer spacing. During the second season okra produced the maximum (0.80) number of branches when

Table 1. Effect of intercrops and spacing on plant height and number of branches of okra

Treatments	Plant height (cm)		Number of branches	
	I Season	II Season	I Season	II Season
T_1	121.27	43.47	0.40	0.50
T_2	110.88	36.17	0.30	0.10
T_3	115.87	46.57	0.50	0.80
T_4	106.33	42.39	0.60	0.30
T_5	64.67	43.93	0.20	0.70
T_6	113.70	44.30	0.30	0.30
T_7	101.90	44.60	0.30	0.60
T_8	112.27	42.78	0.70	0.40
Interaction	NS	NS	NS	NS

T_1 – Sole crop of okra at 60×45cm
T_2 – Sole crop of okra at 100×45cm
T_3 – Okra (60×45cm)+amaranthus
T_4 – Okra (100×45cm)+amaranthus
T_5 – Okra (60×45cm)+cowpea
T_6 – Okra (100×45cm)+cowpea
T_7 – Okra (60×45cm)+cucumber
T_8 – Okra (100×45cm)+cucumber
NS – Non significant

Table 2. Effect of intercrops and spacing on number of internodes and internodal length of okra

Treatments	Number of internodes		Internodal length (cm)	
	I Season	II Season	I Season	II Season
T_1	18.90	10.50	8.93	4.16
T_2	17.50	10.20	8.73	3.98
T_3	18.10	11.00	9.20	4.67
T_4	16.60	11.20	8.20	4.01
T_5	12.10	10.80	7.67	4.61
T_6	17.20	10.60	9.37	4.31
T_7	17.10	10.90	8.93	4.65
T_8	17.30	10.80	10.30	4.62
Interaction	NS	NS	NS	NS

T_1 – Sole crop of okra at 60×45cm
T_2 – Sole crop of okra at 100×45cm
T_3 – Okra (60×45cm)+amaranthus
T_4 – Okra (100×45cm)+amaranthus
T_5 – Okra (60×45cm)+cowpea
T_6 – Okra (100×45cm)+cowpea
T_7 – Okra (60×45cm)+cucumber
T_8 – Okra (100×45cm)+cucumber
NS – Non significant

intercropped with amaranth at lower spacing. Okra produced the least number of branches (0.30) when intercropped with amaranth or cowpea at wider spacing.

4.1.3 Number of internodes

The influence of intercropping and spacing on the number of internodes of okra is presented in Table 2.

Number of internodes was not affected either by intercrops, spacing or their interactions. The highest number of internodes (18.90) was noticed in the sole crop of okra at 60 × 45 cm spacing and the lowest (12.10) when intercropped with cowpea at closer spacing during the first season.

During the second season okra produced the maximum number of internodes (11.20) when intercropped with amaranth at wider spacing and minimum (10.20) when grown as sole crop at wider spacing.

4.1.4 Internodal length

Table 2 shows the effect of crop combinations and spacing on internodal length of okra.

Crop combinations and spacing did not significantly influence the internodal length during the two cropping seasons. However, internodal length in okra was maximum (10.30 cm) when intercropped with cucumber at wider spacing and minimum (7.67 cm) when cowpea was grown as intercrop at lower spacing during the first season. But in the second season internodal length was minimum (3.98 cm) for sole crop at wider spacing and maximum (4.67 cm) when intercropped with amaranth at lower spacing.

4.1.5 Canopy spread

Table 3 shows the effect of intercrops and spacing on canopy spread of okra .

The effect of intercrops, spacing and their interaction on canopy spread was found to be non significant. However, okra which was intercropped with cowpea at wider spacing recorded more canopy spread (31.56 cm) followed by the sole crop at lower spacing (30.90 cm) in the first season. During the second season okra intercropped with amaranth at lower spacing produced maximum canopy spread (31.0 cm) where as the lowest (17.9 cm) canopy spread was recorded by okra intercropped with cowpea at closer spacing.

4.1.6 Root spread

Table 3 shows the effect of intercrops and spacing on root spread of okra .

The root spread was not seen influenced by the spacing, intercrops and their interaction. In the first season okra with amaranth as intercrop at lower spacing produced the highest root spread (16.42cm). During the second season okra intercropped with cucumber at wider and closer spacing recorded the maximum and minimum root spread of 17.14 and 12.23 cm respectively.

4.1.7 First flowering node

The effect of intercrops and spacing on first flowering node of okra is given in Table 4.

Intercrops, spacing or their interaction did not significantly influence the first flowering node of okra.

Table 3. Effect of intercrops and spacing on the canopy spread and root spread of okra

Treatments	Canopy spread (cm)		Root spread (cm)	
	I Season	II Season	I Season	II Season
T_1	30.90	21.80	15.70	14.30
T_2	28.11	19.46	14.66	12.36
T_3	23.37	31.0	16.42	15.10
T_4	28.94	22.25	14.16	13.36
T_5	22.37	17.9	11.08	14.17
T_6	31.56	21.72	14.17	15.11
T_7	21.76	27.90	13.25	12.23
T_8	28.71	20.97	15.86	17.14
Interaction	NS	NS	NS	NS

T_1 – Sole crop of okra at 60×45cm T_2 – Sole crop of okra at 100×45cm
T_3 – Okra (60×45cm)+amaranthus T_4 – Okra (100×45cm)+amaranthus
T_5 – Okra (60×45cm)+cowpea T_6 – Okra (100×45cm)+cowpea
T_7 – Okra (60×45cm)+cucumber T_8 – Okra (100×45cm)+cucumber
NS – Non significant

Table 4. Effect of intercrops and spacing on days to first flowering and first flowering node of okra

Treatments	Days to first flowering		First flowering node	
	I Season	II Season	I Season	II Season
T_1	43.90	40.00	4.50	4.20
T_2	43.40	38.60	4.50	4.30
T_3	44.60	40.10	4.30	4.50
T_4	44.10	38.70	4.00	4.30
T_5	44.50	39.70	4.20	4.40
T_6	43.44	39.60	4.40	4.50
T_7	43.00	40.00	4.20	4.10
T_8	43.40	39.50	4.30	4.10
Interaction	NS	NS	NS	NS

T_1 – Sole crop of okra at 60×45cm T_2 – Sole crop of okra at 100×45cm
T_3 – Okra (60×45cm)+amaranthus T_4 – Okra (100×45cm)+amaranthus
T_5 – Okra (60×45cm)+cowpea T_6 – Okra (100×45cm)+cowpea
T_7 – Okra (60×45cm)+cucumber T_8 – Okra (100×45cm)+cucumber
NS – Non significant

Okra produced the first flower on the lowest node (4) when intercropped with amaranth at wider spacing during the first season. The first flowering node of okra was on 4.10 when intercropped with cucumber at both spacings during the second season.

4.1.8 Days to first flowering

The effect of intercrops and spacing on the days to first flowering of okra is presented in Table 4.

The intercrops, spacing and their interaction had no significant effect on days to first flowering. However, okra took the least number of days (43.0) to flower when intercropped with cucumber at S_1 during the first season. The sole crop of okra at wider spacing was the first to flower (38.60 days) during second season. Okra took a maximum of 44.60 and 40.10 days to first flowering when intercropped with amaranth at lower spacing during first and second season respectively.

4.1.9 Days to first harvest

The effect of intercrops and spacing on days to first harvest of okra is given in Table 5.

Intercrops, spacing and their interaction did not produce any significant influence on the days to first harvest. However, in the first season okra took 49.30 days when intercropped with cucumber and also as sole crop, both at wider spacing. Okra took 48.60 days when intercropped with amaranth at lower spacing. During the second season okra took 46.70 days when intercropped with cowpea at lower spacing and the sole crop at wider spacing took 45.30 days.

4.1.10 Days to final harvest

Intercrops, spacing and their interaction did not significantly influence the days to final harvest of okra (Table 5).

All the treatments took 80 and 72 days to final harvest during the first and second season respectively.

4.1.11 Fruit length

The effect of intercrops and spacing on fruit length of okra is given in Table 6.

The length of okra fruits were not significantly influenced by intercrops, spacing or their interaction. However, during the first season, okra produced the longest (13.17 cm) fruits when grown as sole crop at wider spacing and fruit length was minimum (10.40 cm) when intercropped with cowpea at closer spacing. During the second season, longest fruits (11.37 cm) were produced when intercropped with cowpea at wider spacing and smallest (8.80 cm) when intercropped with cucumber at wider spacing.

4.1.12 Fruit girth

The data on fruit girth of okra is presented in Table 6.

Fruit girth was not significantly influenced by spacing, intercrops and their interaction. Fruit girth of okra was maximum (5.49 cm) when grown as sole crop at wider spacing and minimum (4.92 cm) when intercropped with cowpea at wider spacing during first season.

Table 5. Effect of intercrops and spacing on the days to first and final harvest of okra

Treatments	Days to first harvest		Days to final harvest	
	I Season	II Season	I Season	II Season
T_1	49.00	45.70	80.00	72.00
T_2	49.30	45.30	80.00	72.00
T_3	48.60	46.00	80.00	72.00
T_4	49.40	45.70	80.00	72.00
T_5	48.70	46.70	80.00	72.00
T_6	48.70	45.70	80.00	72.00
T_7	48.70	45.70	80.00	72.00
T_8	49.30	45.70	80.00	72.00
Interaction	NS	NS	NS	NS

T_1 – Sole crop of okra at 60×45cm
T_2 – Sole crop of okra at 100×45cm
T_3 – Okra (60×45cm)+amaranthus
T_4 – Okra (100×45cm)+amaranthus
T_5 – Okra (60×45cm)+cowpea
T_6 – Okra (100×45cm)+cowpea
T_7 – Okra (60×45cm)+cucumber
T_8 – Okra (100×45cm)+cucumber
NS – Non significant

Table 6. Effect of intercrops and spacing on fruit length, fruit girth and single fruit weight of okra

Treatments	Fruit length (cm)		Fruit girth (cm)		Single fruit weight (g)	
	I Season	II Season	I Season	II Season	I Season	II Season
T_1	11.07	10.16	5.4	3.79	13.41	7.90
T_2	13.17	9.95	5.49	3.75	15.34	8.71
T_3	11.11	8.91	5.13	3.93	14.95	10.44
T_4	11.86	10.06	5.35	4.24	13.55	12.09
T_5	10.40	9.31	4.93	4.20	10.46	7.13
T_6	10.44	11.37	4.92	4.29	13.68	8.72
T_7	11.55	9.27	5.13	4.12	12.80	12.30
T_8	11.76	8.80	5.44	4.15	14.42	9.87
Interaction	NS	NS	NS	NS	NS	NS

T_1 – Sole crop of okra at 60×45cm
T_2 – Sole crop of okra at 100×45cm
T_3 – Okra (60×45cm)+amaranthus
T_4 – Okra (100×45cm)+amaranthus
T_5 – Okra (60×45cm)+cowpea
T_6 – Okra (100×45cm)+cowpea
T_7 – Okra (60×45cm)+cucumber
T_8 – Okra (100×45cm)+cucumber
NS – Non significant

It was reverse in the second season. When intercropped with cowpea at wider spacing okra produced maximum (4.29 cm) fruit girth and minimum (3.75 cm) when grown as sole crop at wider spacing.

4.1.13 Single fruit weight

Table 6 shows the effect of intercrops and spacing on the single fruit weight of okra.

The single fruit weight was not significantly influenced by the intercrops, spacing or their interaction. However, in the first season sole crop of okra at wider spacing recorded the highest (15.34 g) single fruit weight. During the second season single fruit weight was maximum (12.30 g) when intercropped with cucumber at lower spacing. Single fruit weight was lowest when intercropped with cowpea at lower spacing producing 10.46 and 7.13 g during first and second season respectively.

4.1.14 Fruit number per plant

The effect of intercrops and spacing on fruit number per plant of okra is given in Table 7.

The fruit number per plant in okra was significantly influenced by the intercrops, spacing and their interactions only in the second season. During first season sole crop of okra at wider spacing recorded the maximum number of fruit per plant (7.50) followed by the sole crop at 60×45 cm (7.10). The lowest fruit number per plant (3.60) was recorded when intercropped with cowpea at lower spacing.

During the second season, fruit number per plant in okra was maximum (8.92 and 8.83) when intercropped with cowpea at both spacings. The least (2.43) fruit

Table 7. Effect of intercrops and spacing on fruit number and fruit yield per plant of okra

Treatments	Fruit number per plant		Fruit yield per plant (g)	
	I Season	II Season	I Season	II Season
T_1	7.10	*2.02[b] (3.60)	*9.73[a] (97.44)	*5.36[c] (28.47)
T_2	7.50	*2.13[b] (4.10)	*10.66[a] (115.72)	*5.97[bc] (35.63)
T_3	5.80	*2.29[b] (4.93)	*9.09[a] (83.61)	*6.87[abc] (48.15)
T_4	6.30	*2.24[b] (4.57)	*9.84[a] (96.59)	*7.26[abc] (52.43)
T_5	3.60	*3.04[a] (8.83)	*6.21[b] (38.44)	*7.86[ab] (62.13)
T_6	5.40	*3.05[a] (8.92)	*8.41[ab] (71.05)	*8.78[a] (77.42)
T_7	7.00	*1.69[b] (2.43)	*9.47[a] (90.48)	*5.29[c] (28.24)
T_8	7.10	*2.12[b] (4.10)	*10.12[a] (103.42)	*6.27[bc] (39.97)
Interaction	NS	S	S	S

T_1 – Sole crop of okra at 60×45cm
T_2 – Sole crop of okra at 100×45cm
T_3 – Okra (60×45cm)+amaranthus
T_4 – Okra (100×45cm)+amaranthus
T_5 – Okra (60×45cm)+cowpea
T_6 – Okra (100×45cm)+cowpea
T_7 – Okra (60×45cm)+cucumber
T_8 – Okra (100×45cm)+cucumber
NS – Non significant

S – Significant

* $\sqrt{x+\frac{1}{2}}$ transformation

Values in parenthesis are the original values
Treatments having same alphabets as superscripts belong to same homogenous group

number per plant was recorded when intercropped with cucumber at lower spacing which was on par with all other treatments (S_1, S_2, S_1I_1, S_2I_1, and S_2I_3).

4.1.15 Fruit yield per plant

The effect of intercrops and spacing on fruit yield per plant of okra is presented in Table 7.

Okra fruit yield per plant was significantly influenced by spacing, intercrops and their interactions during both the seasons.

During first season, fruit yield per plant was maximum in okra (115.72 g) when grown as sole crop at wider spacing. This was on par with okra grown as S_1, S_1I_1, S_2I_1, S_1I_3, S_2I_3 and S_2I_2. During the second season per plant fruit yield in okra was maximum (77.42 g) when grown with cowpea at wider spacing. This was on par with okra intercropped with cowpea at lower spacing (62.13 g) and those intercropped with amaranth at lower and wider spacing (48.15 and 52.43 g). Okra produced lowest fruit yield per plant when grown as sole crop (28.47g) and when intercropped with cucumber (28.24 g) both at lower spacing.

4.1.16 Fruit yield in t ha^{-1}

Table 8 shows the effect of intercrops and spacing on fruit yield of okra.

Intercrops, spacing and their interactions were significantly influenced the fruit yield of okra during both the seasons. During the first season the yield was highest for sole crop at lower spacing (7.10 t ha^{-1}), which was on par with all other treatments except those intercropped with cowpea at lower and wider spacing.

Table 8. Effect of intercrops and spacing on yield per ha and dry matter production of okra

Treatments	Yield (t ha^{-1})		Dry matter production at final harvest (g plant^{-1})	
	I Season	II Season	I Season	II Season
T_1	7.10^{a}	2.07^{bc}	*5.87 (34.30)	24.17
T_2	5.06^{ab}	1.56^{c}	*6.08 (37.45)	21.44
T_3	6.10^{a}	3.51^{ab}	*5.74 (32.90)	25.67
T_4	4.23^{ab}	2.29^{bc}	*5.16 (26.21)	26.00
T_5	3.15^{b}	4.53^{a}	*3.66 (12.90)	22.33
T_6	3.11^{b}	3.39^{abc}	*5.71 (32.55)	22.63
T_7	6.60^{a}	2.06^{bc}	*5.36 (28.50)	24.57
T_8	4.52^{ab}	1.75^{bc}	*5.63 (31.95)	22.42
Interaction	S	S	NS	NS

T_1 – Sole crop of okra at 60×45cm T_2 – Sole crop of okra at 100×45cm
T_3 – Okra (60×45cm)+amaranthus T_4 – Okra (100×45cm)+amaranthus
T_5 – Okra (60×45cm)+cowpea T_6 – Okra (100×45cm)+cowpea
T_7 – Okra (60×45cm)+cucumber T_8 – Okra (100×45cm)+cucumber

S – Significant * $\sqrt{x+\frac{1}{2}}$ transformation

Values in parenthesis are the original values
Treatments having same alphabets as superscripts belong to same homogenous group

In the second season, okra recorded the maximum (4.53 t ha^{-1}) fruit yield when intercropped with cowpea, followed by those intercropped with amaranth (3.51 t ha^{-1}) both at lower spacing.

Okra fruit yield per ha was comparatively higher at lower spacing (S_1) irrespective of season and intercrops.

4.1.17 Dry matter production at final harvest

The data on the dry matter production of okra at final harvest is presented in Table 8.

Dry matter production of okra was not significantly influenced by the intercrops, spacing and their interaction during both the seasons.

The dry matter production was maximum in the sole crop during the first season. Sole crop at wider spacing produced the highest dry matter (37.45 g $plant^{-1}$) followed by those at closer spacing (34.30 g $plant^{-1}$).

In the second season okra that was intercropped with amaranth at wider spacing recorded the maximum dry matter (26.00 g $plant^{-1}$). Sole crop at wider spacing recorded the lowest dry matter production (21.44 g $plant^{-1}$) during this season.

4.1.18 Occurrence of fruit and shoot borer

The effect of intercrops and spacing on the occurrence of fruit and shoot borer of okra is presented in Table 9.

Table 9. Effect of intercrops and spacing on the occurrence of fruit and shoot borer and yellow vein mosaic of okra

Treatments	Occurrence of fruit and shoot borer (%)		Occurrence of yellow vein mosaic (%)	
	I Season	II Season	I Season	II Season
T_1	*3.33 (4.50)	82.43	**3.33 (10.77)	0.00
T_2	*5.46 (2.43)	84.69	**5.46 (29.53)	0.00
T_3	*2.75 (1.90)	69.55	**2.75 (7.75)	0.00
T_4	*3.41 (1.45)	80.98	**3.41 (11.50)	0.00
T_5	*3.32 (1.33)	73.13	**3.2 (10.63)	0.00
T_6	*3.71 (2.73)	72.8	**3.71 (14.63)	0.00
T_7	*3.97 (1.53)	81.4	**3.97 (16.03)	0.00
T_8	*4.08 (4.82)	70.15	**4.08 (17.67)	0.00
Interaction	NS	NS	NS	NS

T_1 – Sole crop of okra at 60×45cm T_2 – Sole crop of okra at 100×45cm
T_3 – Okra (60×45cm)+amaranthus T_4 – Okra (100×45cm)+amaranthus
T_5 – Okra (60×45cm)+cowpea T_6 – Okra (100×45cm)+cowpea
T_7 – Okra (60×45cm)+cucumber T_8 – Okra (100×45cm)+cucumber

* $\sqrt{x+10}$ transformation ** $\sqrt{x+\frac{1}{2}}$ transformation

NS – Non significant
Values in parenthesis are the original values

There was no significant difference among the treatments in the occurrence of okra fruit and shoot borer. However during the first season maximum incidence (4.82%) was noticed for okra when intercropped with cucumber at wider spacing and minimum when intercropped with cowpea (1.33%) at lower spacing .

During the second season sole crop of okra at wider spacing recorded the maximum incidence (84.69%) followed by sole crop at lower spacing (82.43%). Percentage incidence was minimum for okra intercropped with amaranthus at lower spacing (69.55%). Fruit and shoot borer incidence was very high during the second season.

4.1.19 Occurrence of yellow vein mosaic

The data on the occurrence of yellow vein mosaic is presented in Table 9.

Intercrops, spacing or their interaction had any significant influence on the occurrence of yellow vein mosaic in okra. Occurrence of yellow vein mosaic was maximum in sole crop of okra at wider spacing (29.53%) during the first season. Lowest occurrence (7.75%) was observed in okra which was intercropped with amaranth at lower spacing. During the second season there was no incidence of okra yellow vein mosaic.

4.2 Growth and yield characters of amaranth

4.2.1 Root spread

The effect of intercropping and spacing on root spread of amaranth is given in Table 10.

Table 10. Effect of intercropping and spacing on root spread and number of cuttings of amaranthus

	Root spread (cm)		Number of cuttings	
	I Season	II Season	I Season	II Season
T_3	14.6	16.73	6.30	6.0
T_4	11.67	17.68	5.70	6.0
T_9	13.73	19.5	6.30	6.0
Interaction	NS	NS	NS	NS

T_3 – Okra (60×45cm)+amaranthus T_4 - Okra (100×45cm)+amaranthus
T_9 –Sole crop of amaranthus at 20 cm spacing
NS –Non significant

Table 11. Effect of intercropping and spacing on days to first harvest, days to final harvest, yield per plant and yield per ha of amaranthus

Treatments	Days to first harvest		Days to final harvest		Yield per plant (g)		Yield (t ha^{-1})	
	I Season	II Season	I Season	II Season	I Season	II Season	I Season	II Season
T_3	43.00	41.00	83.00	78.00	38.91	38.7	1.52	1.51
T_4	43.00	41.00	83.00	78.00	43.16	56.12	1.01	1.32
T_9	43.00	41.00	83.00	78.00	55.25	73.87	4.32	5.77
Interaction	NS	NS	NS	NS	NS	S	NS	S

T_3 – Okra (60×45cm)+amaranthus T_4 – Okra (100×45cm)+amaranthus
T_9 – Sole crop of amaranthus at 20 cm spacing S –Significant
NS – Non significant

Root spread of amaranth was not affected by intercropping, spacing and their interaction. However amaranth at lower spacing recorded the maximum root spread of 14.6 cm during the first season and the sole crop recorded the maximum root spread of 19.5 cm during the second season.

4.2.2 Number of cuttings

The data on number of cuttings of amaranth is presented in Table 10.

The number of cuttings in amaranth did not differ significantly due to spacing and intercropping. During the first season the number of cuttings obtained was maximum (6.30) for sole crop and for amaranth grown as intercrop at lower spacing. The number of cuttings obtained was same (6) for all the treatments during the second season.

4.2.3 Days to first harvest

Intercropping and spacing did not significantly influence the days to first harvest (Table 11).

The days taken to first harvest was 43 and 41 during the first and second season respectively for all the treatments.

4.2.4 Days to final harvest

Intercropping and spacing did not significantly influence the days to final harvest (Table 11).

For all the treatments the days taken to final harvest were 83 and 78 during first and second season respectively.

4.2.5 Yield per plant

The effect of intercropping and spacing on the yield per plant of amaranth is given in Table 11.

Yield per plant of amaranth was significantly influenced by spacing and intercropping only in the second season. During both the seasons, highest per plant yield of amaranth was recorded in sole cropping. Sole crops recorded 55.25 and 73.87 g during the first and second season respectively. When intercrops were compared, yield per plant was superior at wider spacing compared to those at closer spacing.

4.2.6 Yield in t ha^{-1}

The data on the yield of amaranth in t ha^{-1} is presented in Table 11.

The effect of intercropping and spacing on yield of amaranth was found to be significant only in the second season. Yield was higher for sole crop producing 4.32 and 5.77 t ha^{-1} during the first and second season respectively. Amaranth grown as intercrop at wider spacing recorded the least yield (1.01 and 1.32 t ha^{-1} during first and second season respectively).

4.2.7 Incidence of leaf webber and leaf spot

No incidence of leaf webber and leaf spot was noticed in amaranth in any of the treatments.

4.3 Growth and yield characters of cowpea

4.3.1 Plant height

The effect of intercropping and spacing on plant height of cowpea is presented in Table 12.

Intercropping and spacing failed to exert any significant influence on the plant height of cowpea during the first season. Sole crop of cowpea recorded a higher mean plant height of 56.89 and 52.33cm during the first and second season compared to intercropped ones. However, significant interactions were recorded among all the treatments in the second season.

4.3.2 Root spread

The effect of intercropping and spacing on root spread of cowpea is presented in Table 12.

Influence of intercropping and spacing on root spread was found to be nonsignificant. However during the first season the root spread was minimum (10.86 cm) for sole crop where as it was maximum in sole crop (13.33 cm) during the second season. Similarly cowpea as intercrop at wider spacing produced maximum root spread (12.06 cm) during first season and minimum (10.81 cm) during the second season.

4.3.3 Canopy spread

The data on canopy spread of cowpea is given in Table12.

Intercropping or spacing did not significantly influence the canopy spread of cowpea at final harvest. However, cowpea grown as intercrop at wider spacing

Table 12. Effect of intercropping and spacing on plant height, root spread and canopy spread of cowpea

Treatments	Plant height (cm)		Root spread (cm)		Canopy spread (cm)	
	I Season	II Season	I Season	II Season	I Season	II Season
T_5	52.43	42.88	11.33	10.93	39.47	23.62
T_6	56.55	41.50	12.06	10.81	41.44	25.10
T_{10}	56.89	52.33	10.86	13.33	34.67	24.67
Interaction	NS	S	NS	NS	NS	NS

T_5 – Okra (60×45cm)+cowpea T_6 – Okra (100×45cm)+cowpea
T_{10}– Sole crop of cowpea at 25 × 15 cm spacing NS –Non significant
S -Significant

Table 13. Effect of intercropping and spacing on days to first flowering, first and final harvest of cowpea

Treatments	Days to first flowering		Days to first harvest		Days to final harvest	
	I Season	II Season	I Season	II Season	I Season	II Season
T_5	41.20	41.00	48.00	44.33	80.00	78.0
T_6	41.00	40.70	48.00	44.67	80.00	77.0
T_{10}	41.10	40.70	48.00	44.33	80.00	78.0
Interaction	NS	NS	NS	NS	NS	NS

T_5 – Okra (60×45cm)+cowpea T_6 – Okra (100×45cm)+cowpea
T_{10}- Sole crop of cowpea at 25 × 15 cm spacing NS –Non significant

recorded a maximum canopy spread of 41.44 and 25.10cm in the first and second season respectively.

4.3.4 Days to first flowering

Table 13 shows the effect of intercropping and spacing on days to first flowering of cowpea.

Days to first flowering did not show any significant difference due to intercrops and spacing. Compared to sole crop, cowpea grown as intercrop at closer spacing was the last to flower with 41.2 and 41.0 days in the first and second season respectively.

4.3.5 Days to first harvest

Table 13 shows the data on days to first harvest of okra.

There was no significant difference in the days to first harvest. During the first season the days to first harvest was 48.0 irrespective of the treatments where as in the second season, cowpea as intercrop at wider spacing took 44.70 days to first harvest.

4.3.6 Days to final harvest

Table 13 shows the data on days to final harvest of okra.

The days to final harvest of cowpea was 80.0 for all the treatments during the first season. But in the second season cowpea grown as intercrop at wider spacing was the earliest with 77 days and other treatments took 78 days to final harvest.

4.3.7 Number of pods per plant

Table 14 shows the influence of intercropping and spacing on pod number per plant of cowpea.

Intercropping and spacing significantly influenced the pod number per plant during both the season. Cowpea grown as intercrop at wider spacing recorded the maximum pod number per plant producing 18.70 and 23.60 during the first and second season respectively. Sole crop recorded the least pod number per plant (8.20 and 14.30 during the two seasons).

4.3.8 Pod yield per plant

The data regarding pod yield per plant of cowpea is given on Table 14.

Pod yield per plant showed significant difference due to intercropping and spacing. Cowpea grown as intercrop at wider spacing recorded maximum fruit yield of 91.45and 117.12 g per plant during the first and second season respectively. Sole crop produced the least pod yield per plant during both the seasons (44.53 and 71.53 g per plant).

4.3.9 Pod yield in t ha^{-1}

The effect of intercropping and spacing on yield of cowpea is given in Table 14.

Yield of cowpea showed significant difference due to intercropping and spacing only during the second season. Sole crop cowpea recorded superior marketable yield of 10.44 and 16.77 t ha^{-1} during the first and second season

Table 14. Effect of intercropping and spacing on number of pods per plant, pod yield per plant and pod yield per ha of cowpea

Treatments	Number of pods per plant		Pod yield per plant (g)		Yield (t ha^{-1})	
	I Season	II Season	I Season	II Season	I Season	II Season
T_5	14.40	16.20	72.28	79.60	5.65	6.22
T_6	18.70	23.60	91.45	117.12	4.29	5.49
T_{10}	8.20	14.30	44.53	71.53	10.44	16.77
Interaction	S	S	S	S	NS	S

T_5 – Okra (60×45cm)+cowpea T_6 – Okra (100×45cm)+cowpea
T_{10} – Sole crop of cowpea at 25 × 15 cm spacing NS – Non significant
S – Significant

Table 15. Effect of intercropping and spacing on the dry matter production of cowpea at final harvest

Treatments	Dry matter production at final harvest	
	I Season	II Season
T_5	24.0	25.93
T_6	25.56	26.04
T_{10}	21.82	27.17
Interaction	NS	NS

T_5 – Okra (60x45cm)+cowpea T_6 – Okra (100×45cm)+cowpea
T_{10}–Sole crop of cowpea at 25 × 15 cm spacing
NS –Non significant

respectively, where as the least yield was recorded by cowpea grown as intercrop at wider spacing during the two seasons.

4.3.10 Dry matter production at final harvest

Table 15 shows the effect of spacing and intercropping on dry matter production of cowpea at final harvest.

Dry matter production of cowpea was not significantly influenced due to intercropping and spacing. Cowpea as intercrop at wider spacing recorded the maximum dry matter production (25.56 g per plant) during the first season where as in the second season sole crop produced the maximum dry matter of 27.17 g per plant.

4.3.11 Incidence of aphid

The data regarding the incidence of aphid is presented in Table 16.

Aphid incidence was significantly influenced due to intercropping and spacing. Sole crop recorded the highest aphid incidence of 75.40% and 79.43% during the first and second season respectively. Cowpea grown as intercrop at closer spacing showed the least incidence of 63.15 and 63.07% during the first and second season respectively.

4.4 Growth and yield characters of cucumber

4.4.1 Length of main vine

The effect of intercropping and spacing on the length of main vine of cucumber is given in Table 17.

Table 16. Effect of intercropping and spacing on the incidence of aphid at 70 DAS in cowpea

Treatments	Incidence of aphid (%) at 70 DAS	
	I Season	II Season
T_5	63.15	63.07
T_6	69.72	69.37
T_{10}	75.40	79.43
Interaction	S	S

T_5 – Okra (60×45cm)+cowpea T_6 – Okra (100×45cm)+cowpea
T_{10} – Sole crop of cowpea at 25 × 15 cm spacing S – Significant

Table 17. Effect of intercropping and spacing on length of main vine and number of primary branches of cucumber

Treatments	Length of main vine (cm)		Number of primary branches	
	I Season	II Season	I Season	II Season
T_7	193.33	161.57	4.10	2.60
T_8	201.10	125.55	4.50	2.90
T_{11}	222.78	191.90	4.40	3.20
Interaction	NS	NS	NS	NS

T_7 – Okra (60x45cm)+cucumber T_8 – Okra (100x45cm)+cucumber
T_{11} – Sole crop of cucumber at 2 × 1.5 m spacing
NS – Non significant

Intercropping or spacing had no significant effect on the main vine length of cucumber. During the first season sole crop of cucumber recorded the maximum vine length of 222.78 cm which was followed by the combination of cucumber and okra at 100 × 45 cm spacing. In the second season also the sole crop of cucumber recorded superior vine length of 191.90 cm.

4.4.2 Number of primary branches per plant

The data on number of primary branches per plant is presented in Table 17.

Intercropping and spacing did not significantly influence the number of primary branches of cucumber. In the first season cucumber as intercrop at wider spacing recorded the highest value of 4.50 where as in the second season sole crop recorded the highest mean of 3.20. During both the seasons, cucumber as intercrop at lower spacing produced the lowest (4.10 and 2.60) number of primary branches.

4.4.3 Number of female flowers

The effect of intercropping and spacing on number of female flowers in cucumber is given in Table 18.

Number of female flowers were not influenced by intercropping or spacing. However, cucumber when grown as intercrop at lower spacing produced highest number of female flowers per plot (32.90 and 34.00 during the first and second season respectively). Sole crop of cucumber produced the lowest number of female flowers per plot (22.10 and 21.60) during both the seasons.

Table 18. Effect of intercropping and spacing on number of female flowers per plot, percentage fruit set, days to first harvest and days to final harvest of cucumber

Treatments	Number of female flowers per plot		Percentage fruit set		Days to first harvest		Days to final harvest	
	I Season	II Season	I Season	II Season	I Season	II Season	I Season	II Season
T_7	32.90	34.00	71.99	80.20	61.00	56.00	75.00	74.00
T_8	32.10	30.60	63.53	70.59	61.00	56.00	75.00	74.00
T_{11}	22.10	21.60	69.31	77.01	61.00	56.00	75.00	74.00
Interaction	NS	NS	NS	NS	NS	NS	NS	NS

T_7 – Okra (60×45cm)+cucumber T_8 – Okra (100×45cm)+cucumber
T_{11}– Sole crop of cucumber at 2 × 1.5 m spacing NS – Non significant

Table 19. Effect of intercropping and spacing on number of fruits per plot, average weight of fruits and circumference of fruits in cucumber

Treatments	Circumference of fruits (cm)		Average weight of fruits (kg)		Number of fruits per plot	
	I Season	II Season	I Season	II Season	I Season	II Season
T_7	22.37	25.43	0.37	0.66	22.00	23.00
T_8	25.17	23.83	0.56	0.91	18.30	17.30
T_{11}	26.96	27.47	0.97	1.25	12.60	13.00
Interaction	NS	NS	S	NS	NS	S

T_7 – Okra (60×45cm)+cucumber T_8 – Okra (100×45cm)+cucumber
T_{11}– Sole crop of cucumber at 2 × 1.5 m spacing NS – Non significant
S – Significant

4.4.4 Percentage fruit set

Table 18 shows the data on percentage fruit set of cucumber

There was no significant variation in per cent fruit set due to intercropping and spacing. During the first and second season cucumber as intercrop at lower spacing recorded a maximum mean fruit set of 71.99 and 80.20 per cent respectively. Lowest percentage set was recorded (63.53 and 70.59) during both the seasons when it was intercropped in okra at wider spacing.

4.4.5 Days to first harvest

Days to first harvest in cucumber was not affected by intercropping or spacing (Table 18).

All the treatments took 61 and 56 days to first harvest during the first and second season respectively irrespective of intercropping and spacing.

4.4.6 Days to final harvest

Intercropping and spacing did not influence the days to final harvest (Table 18).

Irrespective of intercropping and spacing all the plants took 75 and 74 days to final harvest during the first and second season respectively.

4.4.7 Circumference of fruits

Table 19 shows the data on circumference of cucumber fruits.

Intercropping and spacing had no significant influence on the circumference of fruits in both the seasons. However, sole crop of cucumber produced fruits with maximum circumference (26.96 and 27.47 cm) during both the seasons.

4.4.8 Average weight of fruits

The effect of intercropping and spacing on average weight of cucumber fruits is given in Table 19.

Intercropping and spacing exerted a significant influence on average fruit weight during the first season only. Sole crop of cucumber recorded highest (0.97 kg and 1.25 kg) and cucumber as intercrop at closer spacing recorded the lowest (0.37 and 0.66 kg fruit weight during the first and second season respectively).

4.4.9 Number of fruits per plot

The data on number of fruits per plot in cucumber is presented in Table 19.

Number of fruits per plot were significantly influenced by intercropping and spacing only in the second season. However, in the first season cucumber grown as intercrop at closer spacing recorded the highest number of fruits per plot (22.0) while sole crop produced the lowest (12.60) number of fruits. During the second season also cucumber as intercrop at closer spacing produced the highest number of fruits (23.0) and sole crop the lowest (13.0).

4.4.10 Yield per plant

The yield per plant of cucumber is presented in Table 20.

Table 20. Effect of intercropping and spacing on fruit yield per ha and per plant of cucumber

Treatments	Yield per plant (g)		Fruit yield (t ha^{-1})	
	I Season	II Season	I Season	II Season
T_7	262.40	645.54	4.10	7.74
T_8	544.30	865.00	5.10	8.10
T_{11}	766.70	1014.58	6.39	8.45
Interaction	S	NS	NS	NS

T_7 – Okra (60×45cm)+cucumber T_8 – Okra (100×45cm)+cucumber
T_{11}– Sole crop of cucumber at 2 × 1.5 m spacing NS –Non significant,
S – Significant

Table 21. Effect of intercropping and spacing on incidence of fruit fly in cucumber

Treatments	Incidence of fruit fly (%)	
	I Season	II Season
T_7	7.07	15.57
T_8	10.12	19.25
T_{11}	17.31	21.67
Interaction	S	S

T_7 – Okra (60×45cm)+cucumber T_8 – Okra (100×45cm)+cucumber
T_{11}- Sole crop of cucumber at 2 × 1.5 m spacing
S –Significant

The yield per plant of cucumber showed significant difference only in the first season. However sole crop recorded the maximum per plant yield of 766.07 and 1014.58 g whereas cucumber as intercrop at lower spacing recorded the minimum yield per plant of 262.40 and 645.54 g during the first and second season respectively.

4.4.11 Yield in t ha^{-1}

The effect of intercropping and spacing on yield of cucumber in t ha^{-1} is given in Table 20.

The influence of intercropping and spacing on the yield of cucumber was found to be nonsignificant. Pure crop of cucumber recorded the highest yield of 6.39 and 8.45 t ha^{-1} during the first and second season respectively. Lowest (4.10 and 7.74 t ha^{-1}) yield was produced by cucumber grown as intercrop at lower spacing during the two seasons.

4.4.12 Incidence of fruit fly and mosaic

Table 21 shows the percentage incidence of fruit fly in cucumber.

There was significant difference in the fruit fly incidence due to intercropping and spacing during both the seasons. Sole crop of cucumber recorded the highest incidence of 17.31% and 21.67% in the first and second season respectively. Cucumber grown as intercrop at closer spacing recorded a lower incidence compared to those grown at wider spacing during both the seasons. No incidence of mosaic was noticed in cucumber during both the seasons.

4.5 Biological efficiency of intercropping system

4.5.1 Land equivalent ratio (LER)

The data on LER were statistically analysed and the mean values are presented in Table 22.

Intercrops, spacing and their interaction significantly influenced the total LER only in the first season. The combination of okra and cucumber gave the highest LER value of 1.85 which was on par with S_1I_3 and S_1I_1. Okra + cowpea at lower spacing gave the lowest value of 1.05 during the first season. During the second season okra + cowpea at wider spacing recorded the highest value (2.69) followed by S_1I_2. Okra + amaranth combinations recorded the lowest values of 1.77 and 1.91 at wider and closer spacing respectively.

4.5.2 Land equivalent coefficient (LEC)

The data on LEC is presented in Table 22.

As in the case of LER, LEC was significantly influenced by intercrops, spacing and their interaction only in the first season. In the first and second season okra with cucumber combination at S_2 gave the highest value of 0.88 and 1.13. The lowest LEC value of 0.22 and 0.35 was recorded by okra + amaranth combination at S_2 during the first and second year respectively.

4.5.3 Area time equivalency ratio (ATER)

Data on ATER values are presented in Table 22.

Table 22. Effect of intercropping and spacing on land equivalent ratio, land equivalent coefficient and area time equivalency ratio in okra based cropping system

Treatments	Land equivalent ratio		Land equivalent coefficient		Area time equivalency ratio	
	I Season	II Season	I Season	II Season	I Season	II Season
T_3	1.45[ab]	1.91	*0.93 (0.38)[b]	*0.97 (0.45)	1.41[ab]	1.79
T_4	1.12[b]	1.77	*0.85 (0.22)[b]	*0.92 (0.35)	1.09[b]	1.65
T_5	1.05[b]	2.62	*0.88 (0.27)[b]	*1.17 (0.89)	1.05[b]	2.45
T_6	1.08[b]	2.69	*0.88 (0.28)[b]	*1.13 (0.78)	1.08[b]	2.53
T_7	1.71[a]	2.01	*1.07 (0.65)[ab]	*1.21 (1.01)	1.67[a]	1.98
T_8	1.85[a]	2.24	*1.15 (0.88)[a]	*1.27 (1.13)	1.80[a]	2.21
Interaction	S	NS	S	NS	S	NS

T_3 – Okra (60×45cm)+amaranthus
T_4 – Okra (100×45cm)+amaranthus
T_5 – Okra (60×45cm)+cowpea
T_6 – Okra (100×45cm)+cowpea
T_7 – Okra (60×45cm)+cucumber
T_8 – Okra (100×45cm)+cucumber
NS – Non significant
S – Significant

* $\sqrt{x+\frac{1}{2}}$ transformation

Values in parenthesis are the original values

Treatments having same alphabets as superscripts belong to same homogenous group

ATER was significantly influenced by intercrops, spacing and their interaction only in the first season. Highest ATER value was recorded by okra + cucumber combination at wider spacing (1.80) which was on par with S_1I_3 (1.67) and S_1I_1(1.41) in the first season. The lowest value (1.05) was for okra + cowpea combination at closer spacing which was on par with S_2I_2, S_2I_1 and S_1I_1. During the second season highest ATER value was recorded with S_2I_2 (2.53) followed by S_1 I_2 (2.45) and the lowest with S_2 I_1 (1.65).

4.5.4 Aggressivity

The data on aggressivity values were statistically analysed and is presented in Table 23.

The aggressivity values were significantly influenced by the intercrops and spacing during both the seasons. Okra + cucumber at wider spacing recorded the highest aggressivity values of 3.14 and 3.95 during the first and second season respectively. This was on par with okra + cucumber at closer spacing during both the seasons. In the first season lowest value was recorded with okra + amaranth at wider spacing (-0.73) where as okra +cowpea at wider spacing recorded the lowest value (-4.24) in the second season.

4.5.5 Relative crowding coefficient (RCC)

The data on relative crowding coefficient is presented in Table 23.

RCC was not significantly influenced by the intercrops, spacing and their interaction. Negative RCC values were observed for okra + amaranth at wider spacing (-0.33) and okra + cucumber at closer spacing (-13.27) in the first season. Also the treatments S_1I_1, S_1I_2 and S_2I_2 recorded a value greater than one. In the

Table 23. Effect of intercropping and spacing on aggressivity and relative crowding coefficient in okra based cropping system

Treatments	Aggressivity		Relative crowding coefficient	
	I Season	II Season	I Season	II Season
T_3	*2.08[b] (-0.0.61)	**2.86[b] (-1.79)	***1.744 (6.07)	***1.69 (-1.17)
T_4	*2.07[b] (-0.73)	**2.88[b] (-1.73)	***1.70 (-0.33)	***1.69 (-1.54)
T_5	*2.22[b] (-0.04)	**2.46[bc] (-3.92)	***1.72 (2.02)	***1.69 (-1.39)
T_6	*2.10[b] (-0.58)	**2.36[c] (-4.24)	***1.72 (2.33)	***1.69 (-1.16)
T_7	*2.69[a] (2.30)	**3.71[a] (3.76)	***1.46 (-13.27)	***1.62 (11.66)
T_8	*2.85[a] (3.14)	**3.73[a] (3.95)	***1.69 (0.32)	***1.54 (-14.37)
Interaction	S	S	NS	NS

T_3 – Okra (60×45cm)+amaranthus

T_4 – Okra (100×45cm)+amaranthus

T_5 – Okra (60×45cm)+cowpea

T_6 – Okra (100×45cm)+cowpea

T_7 – Okra (60×45cm)+cucumber

T_8 – Okra (100×45cm)+cucumber

NS – Non significant

S – Significant

$*\sqrt{x+5}$ transformation

$**\sqrt{x+10}$ transformation

$***\log(x+50)$ transformation

Values in parenthesis are the original values

Treatments having same alphabets as superscripts belong to same homogenous group

second season all combinations except okra + cucumber at closer spacing recorded a negative value.

4.5.6 Okra equivalent yield

The data on okra equivalent yield were statistically analysed and is presented in Table 24.

Okra equivalent yield was significantly influenced by intercrops, spacing and their interaction during both the seasons. Among the different treatments okra in combination with cowpea at lower spacing gave the maximum okra equivalent yield (7906.55 and 8708.63 kg ha^{-1} in the first and second season respectively). In the first season S_1I_2 was on par with S_2I_2 while in the second season S_1I_2 on par with S_1I_3, S_2I_3 and S_2I_2. During the two seasons the lowest okra equivalent yield was recorded by okra +amaranth at S_2 (1012.15 and 1314.23 kg ha^{-1}).

4.5.7 Total biomass production.

The data on the total biomass production is given in Table 25.

The biomass production was highest in the okra + cowpea intercropping system at lower spacing (50.55 and 51.84 kg per plot during the first and second season respectively). In the first season this was on par with okra + cowpea at wider spacing, okra + cucumber at lower spacing and okra + amaranth at lower spacing. The lowest total biomass was recorded by sole crop at wider spacing in the second season (6.14 kg per plot).

Table 24. Effect of intercropping and spacing on okra equivalent yield

Treatments	Okra equivalent yield (kg ha^{-1})	
	I Season	II Season
T_3	1520.82^{c}	1512.15^{b}
T_4	1012.15^{c}	1314.23^{b}
T_5	7906.55^{a}	8708.63^{a}
T_6	6006.77^{ab}	7682.94^{a}
T_7	4100.67^{b}	7739.54^{a}
T_8	5102.40^{b}	8104.12^{a}
Interaction	S	S

T_3 – Okra (60×45cm)+amaranthusT_4 – Okra (100×45cm)+amaranthus
T_5 – Okra (60×45cm)+cowpea T_6 – Okra (100×45cm)+cowpea
T_7 – Okra (60×45cm)+cucumber T_8 – Okra (100×45cm)+cucumber
S – Significant
Treatments having same alphabets as superscripts belong to same homogenous group

Table 25. Effect of intercropping and spacing on total biomass production and fresh weight of weeds from interspace in okra based intercropping system

Treatments	Total biomass production (kg per plot)		Fresh weight of weeds from interspace (kg $plot^{-1}$)	
	I Season	II Season	I Season	II Season
T_1	25.89^{cd}	11.11^{e}	2.50^{b}	2.25^{b}
T_2	20.10^{d}	6.14^{f}	3.43^{a}	2.94^{a}
T_3	36.40^{abc}	21.39^{d}	1.08^{cd}	1.05^{cd}
T_4	20.03^{d}	12.71^{e}	1.23^{c}	1.25^{c}
T_5	50.55^{a}	51.84^{a}	0.64^{d}	0.80^{ef}
T_6	43.62^{ab}	44.22^{b}	0.88^{cd}	0.99^{de}
T_7	38.69^{abc}	32.51^{c}	0.65^{d}	0.73^{f}
T_8	30.63^{bcd}	24.09^{d}	0.87^{cd}	1.08^{cd}
Interaction	S	S	S	S

T_1 – Sole crop of okra at 60×45cm T_2 – Sole crop of okra at 100×45cm
T_3 – Okra (60×45cm)+amaranthus T_4 – Okra (100×45cm)+amaranthus
T_5 – Okra (60×45cm)+cowpea T_6 – Okra (100×45cm)+cowpea
T_7 – Okra (60×45cm)+cucumber T_8 – Okra (100×45cm)+cucumber
S –Significant
Treatments having same alphabets as superscripts belong to same homogenous group

4.5.8 Fresh weight of weeds from interspace

The data on fresh weight of weeds obtained form interspace is presented in Table 25.

The fresh weight of weeds from interspace was significantly influenced by the intercrops and spacing.

Weed weight was maximum (3.43 kg per plot and 2.94 kg per plot) in sole crop plots at wider spacing during both the seasons. Weeds of sole crop at lower spacing followed this. Okra plants intercropped with cowpea and cucumber both at lower spacing recorded the least weed weight during the first and second season respectively.

4.6 Economic Suitability

4.6.1 Gross return

The data on gross return was statistically analysed and is presented in Table 26.

Gross return was significantly influenced by intercrops, spacing and their interaction in both the seasons. Okra + cowpea combination at S_1 gave the highest gross return of Rs. 55305.20/- and Rs. 66198.31/- per ha in first and second season respectively. Significantly lowest gross return was obtained by sole crop of okra at 100 × 45 cm spacing (Rs. 25312.33/- and Rs. 7786.41/- during first and second season respectively). In the first season S_1I_2 was on par with S_1I_3.

4.6.2 Net return

Table 26 shows the effect of intercropping, spacing and their interaction on net return.

Table 26. Effect of intercropping and spacing on gross return and net return in okra based intercropping system

Treatments	Gross return (Rs.)		Net return (Rs.)	
	I Season	II Season	I Season	II Season
T_1	36187.27[d]	10373.20[de]	17390.52	-8465.22[e]
T_2	25312.33[e]	7786.41[e]	11708.23	-6041.63[e]
T_3	38095.24[d]	25110.93[c]	14314.113	538.16[c]
T_4	26187.33[e]	18045.02[cd]	9359.31	784.71[c]
T_5	55305.20[a]	66198.31[a]	33456.39	43328.67[a]
T_6	45563.95[c]	55341.66[b]	30006.75	27788.74[ab]
T_7	53485.77[ab]	48987.53[b]	27465.10	22289.78[b]
T_8	48135.11[bc]	49312.18[b]	29687.31	30468.55[ab]
Interaction	S	S	NS	S

T_1 – Sole crop of okra at 60×45cm T_2 – Sole crop of okra at 100×45cm
T_3 – Okra (60×45cm)+amaranthus T_4 – Okra (100×45cm)+amaranthus
T_5 – Okra (60×45cm)+cowpea T_6 – Okra (100×45cm)+cowpea
T_7 – Okra (60×45cm)+cucumber T_8 – Okra (100×45cm)+cucumber
NS – Non significant   S –Significant
Treatments having same alphabets as superscripts belong to same homogenous group

Intercrops and spacing had significant influence on the net return only in the second season.

As in the case of gross return higher net return was obtained from okra + cowpea combination at lower spacing (Rs. 33456.39/- and Rs. 43328.67/- per ha during first and second season respectively). Okra + amaranth at wider spacing recorded the least net return (Rs. 9359.31/-) in the first season whereas in the second season sole crop of okra at lower spacing gave the least net return which was statistically on par with S_2, S_1I_1 and S_2I_1.

4.6.3 Per day return

Table 27 shows the data on per day return.

The per day return was significantly influenced by intercrops, spacing and their interaction only in the second season.

The treatment combinations with cowpea gave the highest per day return in both seasons. In the first season okra + cowpea at closer spacing recorded the maximum per day return of Rs. 418.21/- followed by okra + cowpea at S_2 (Rs. 375.08/-). Okra + amaranth at wider spacing gave the least per day return of Rs. 112.77/- during first season. During second season okra + cowpea at closer spacing gave the maximum per day return of Rs. 555.50/- which was on par with the same combination at S_2 (Rs. 509.29/-). Sole crop of okra gave the lowest per day return during the second season.

Table 27. Effect of intercropping and spacing on per day return and benefit cost ratio in okra based intercropping system

Treatments	Per day return (Rs.)		Benefit cost ratio (Rs.)	
	I Season	II Season	I Season	II Season
T_1	*1.88 (217.38)	-108.53[d]	1.92	0.55[c]
T_2	*2.01 (146.35)	-77.46[d]	1.86	0.56[c]
T_3	*2.03 (172.46)	6.90[d]	1.59	1.02[c]
T_4	*2.04 (112.77)	10.06[d]	1.56	1.05[c]
T_5	*2.60 (418.21)	555.50[a]	2.53	2.89[ab]
T_6	*2.57 (375.08)	509.29[ab]	2.93	3.43[a]
T_7	*2.49 (343.31)	301.21[c]	2.06	1.84[bc]
T_8	*2.56 (371.09)	405.55[bc]	2.61	2.62[ab]
Interaction	NS	S	NS	S

T_1 – Sole crop of okra at 60×45cm
T_2 – Sole crop of okra at 100×45cm
T_3 – Okra (60×45cm)+amaranthus
T_4 – Okra (100×45cm)+amaranthus
T_5 – Okra (60×45cm)+cowpea
T_6 – Okra (100×45cm)+cowpea
T_7 – Okra (60×45cm)+cucumber
T_8 – Okra (100×45cm)+cucumber
NS – Non significant
S – Significant
Treatments having same alphabets as superscripts belong to same homogenous group
Values in parenthesis are the original values

4.6.4 Benefit cost ratio

The data on the benefit cost ratio is presented in Table 27.

In the first season intercrops and spacing had no significant influence on the BC ratio. However okra + cowpea at lower spacing recorded the highest BC ratio (2.53) and the lowest was for the combination of okra and amaranth at closer spacing (1.56) during the first season. In the second season intercrops exert a significant influence on BC ratio. The okra + cowpea combination at wider spacing (3.43) gave the highest value which was statistically on par with S_1I_2 and S_2I_3. Sole crop treatments of okra recorded the lowest BC ratios during the second season.

4.6.5 Return per rupee invested on fertilizer (RPF)

Table 28 shows the data on return per rupee invested on fertilizer.

RPF was influenced by the intercrops and spacing only in the second season. The highest return per rupee invested on fertilizer was obtained for okra + cowpea combination at wider spacing (7.25 and 9.17 in the first and second season respectively) followed by okra + cowpea at lower spacing during both the seasons. Okra + amaranth at wider spacing recorded the least return (Rs. 2.84/-) in the first season where as sole crop at lower and wider spacing recorded the least return per rupee invested on fertilizer in the second season.

4.6.6 Return per rupee invested on labour (RPL)

The data on return per rupee invested on labour were statistically analysed and is given in Table 28.

Table 28. Effect of intercropping and spacing on return per rupee invested on fertilizer and rertum per rupee invested on labour

Treatments	RPF (Rs.)		RPL (Rs.)	
	I Season	II Season	I Season	II Season
T_1	*2.10 (4.27)	-0.59^{e}	3.23^{ab}	-0.083^{e}
T_2	*1.95 (3.49)	-0.29^{e}	3.12^{ab}	-0.05^{e}
T_3	*1.92 (3.37)	1.09^{d}	2.21^{b}	1.04^{d}
T_4	*1.82 (2.84)	1.15^{d}	2.14^{b}	1.09^{d}
T_5	*2.73 (7.05)	8.83^{a}	4.63^{ab}	5.23^{b}
T_6	*2.78 (7.25)	9.17^{a}	5.62^{a}	6.55^{a}
T_7	*2.05 (3.79)	3.92^{c}	3.73^{ab}	3.08^{c}
T_8	*2.35 (5.06)	5.17^{b}	5.02^{a}	4.91^{b}
Interaction	NS	S	S	S

T_1 – Sole crop of okra at 60×45cm
T_2 – Sole crop of okra at 100×45cm
T_3 – Okra (60×45cm)+amaranthus
T_4 – Okra (100×45cm)+amaranthus
T_5 – Okra (60×45cm)+cowpea
T_6 – Okra (100×45cm)+cowpea
T_7 – Okra (60×45cm)+cucumber
T_8 – Okra (100×45cm)+cucumber
NS – Non significant
S – Significant

* $\sqrt{x+\frac{1}{2}}$ transformation

Treatments having same alphabets as superscripts belong to same homogenous group
Values in parenthesis are the original values

Intercrops and spacing exerted a significant influence on the return per rupee invested on labour. Okra with cowpea at wider spacing recorded the highest value of Rs. 5.62/- and Rs. 6.55/- in the first and second season respectively. During the first season okra + amaranth at wider spacing recorded the lowest return (Rs. 2.14/-) while sole crop treatments recorded the least return of –0.083 and –0.05 in the second season.

5.0 Soil nutrient status

Table 29 shows the data on soil nutrient status.

Intercropping and spacing significantly influenced the soil nutrient status. Before the first season, content of organic carbon was 0.35 %. The content was maximum (0.67%) in the combination of okra+cowpea at 100×45cm and lowest (0.32%) for the sole crop at closer spacing, after the first season. After the second season also okra+cowpea at wider spacing recorded the maximum (0.60) percentage of organic carbon. The lowest value (0.25%) was for the okra+amaranthus combination at 60×45cm.

The content of available nitrogen before the first season was 784 kg ha^{-1}. The content was significantly higher in okra+cowpea at 60×45cm (1500.8 and 1344.0 kg ha^{-1} after the first and second season respectively)

Available K content before the first season was 110 kg ha^{-1}. After the first season, the content was significantly higher (200 kg ha^{-1}) in the sole crop at lower spacing. Okra+cucumber combination at 100×45cm recorded the highest K content (255 kg ha^{-1}) after the second season.

Table 29. Effect of intercropping and spacing on soil nutrient status

Treatments	Organic carbon (%)		Available Nitrogen (kg ha^{-1})		Available Potassium (kg ha^{-1})	
	After Season I	After Season II	After Season I	After Season II	After Season I	After Season II
T_1	0.32^g	0.28^e	716.8^g	627.2^e	200^a	180^f
T_2	0.42^e	0.46^c	940.8^e	1030.4^c	135^f	175^g
T_3	0.39^f	0.35^d	873.6^f	784.0^d	175^c	195^e
T_4	0.53^d	0.25^f	1187.2^d	560.0^f	110^h	180^f
T_5	0.60^b	0.56^b	1344.0^b	1254.4^b	160^d	200^d
T_6	0.67^a	0.60^a	1500.8^a	1344.0^a	130^g	225^c
T_7	0.53^d	0.35^d	1187.2^d	784.0^d	140^e	240^b
T_8	0.56^c	0.28^e	1254.4^c	627.2^e	190^b	255^a
Interaction	S	S	S	S	S	S

T_1 – Sole crop of okra at 60×45cm
T_2 – Sole crop of okra at 100×45cm
T_3 – Okra (60×45cm)+amaranthus
T_4 – Okra (100×45cm)+amaranthus
T_5 – Okra (60×45cm)+cowpea
T_6 – Okra (100×45cm)+cowpea
T_7 – Okra (60×45cm)+cucumber
T_8 – Okra (100×45cm)+cucumber
S – Significant

Discussion

DISCUSSION

Vegetables being short duration crops are well suited for intercropping. The intercropping system enables the farmer to earn maximum returns per unit area.

The present investigation entitled "Productivity of okra as influenced by crop combinations" was conducted at the Vegetable Research Farm of the Department of Olericulture, College of Horticulture, Vellanikkara, to assess the suitability of raising intercrops along with okra. The study also aims at evaluating the biological efficiency and economic feasibility of okra based cropping system.

The data on various growth and yield characters and biological and economic indices were analysed statistically and the results are discussed in this chapter.

5.1 Performance of okra in intercropping system

The experiment was conducted to evaluate the productivity of okra when it was grown along with intercrops like amaranthus, bush cowpea and cucumber.

The study revealed that the intercrops had significant influence on the yield of okra. Okra plants when grown as sole crop were taller than the plants in intercropping treatments during the first season (Table 1). Okra intercropped with cowpea recorded the minimum plant height. Cowpea having a rapid initial growth might have interfered with okra in resource utilisation. The influence of intercrops in suppressing the growth of main crop was reported earlier by Soundararajan and Palaniappan (1979) in red gram, Sheela (1981) in tapioca + cowpea intercropping system, Olasantan (1992) and Kalarani (1995) in okra+cowpea intercropping system. During the second season okra plants were smaller when grown as sole crop and taller when grown along with cowpea. In general, plant height of okra was less in the second season when compared to the first season. This can be attributed to the seasonal influence and the severe incidence of fruit and shoot borer during the second season. Randhawa (1967) found that higher temperature and longer days prevailed during the kharif season caused okra plants to grow taller.

Number of internodes, internodal length and number of branches of okra were not significantly affected by intercropping or spacing. However, sole crop at lower spacing recorded the maximum number of internodes in the first season and in the second season those intercropped with amaranthus gave the highest value (Table 2). Internodal length in okra was maximum when intercropped with cucumber at wider spacing in the first season and when intercropped with amaranth at closer spacing in the second season. Okra produced highest number of branches when intercropped with cucumber in the first season and when intercropped with amaranthus at lower spacing in the second season when crops were raised as sole crop or intercrops they took more or less the same days for first flowering, first and final harvest.

Fruit size indicated by single fruit weight, fruit length and girth were found to be non-significant in both sole crop and intercrops (Table 6). However, these parameters were on a higher side for the sole crop at wider spacing during the first season. Lack of competition for space and nutrients in sole crop system might have contributed to the production of bigger fruits in sole crop plants. This was in line with the findings of Balan (1998) in ashgourd based cropping system.

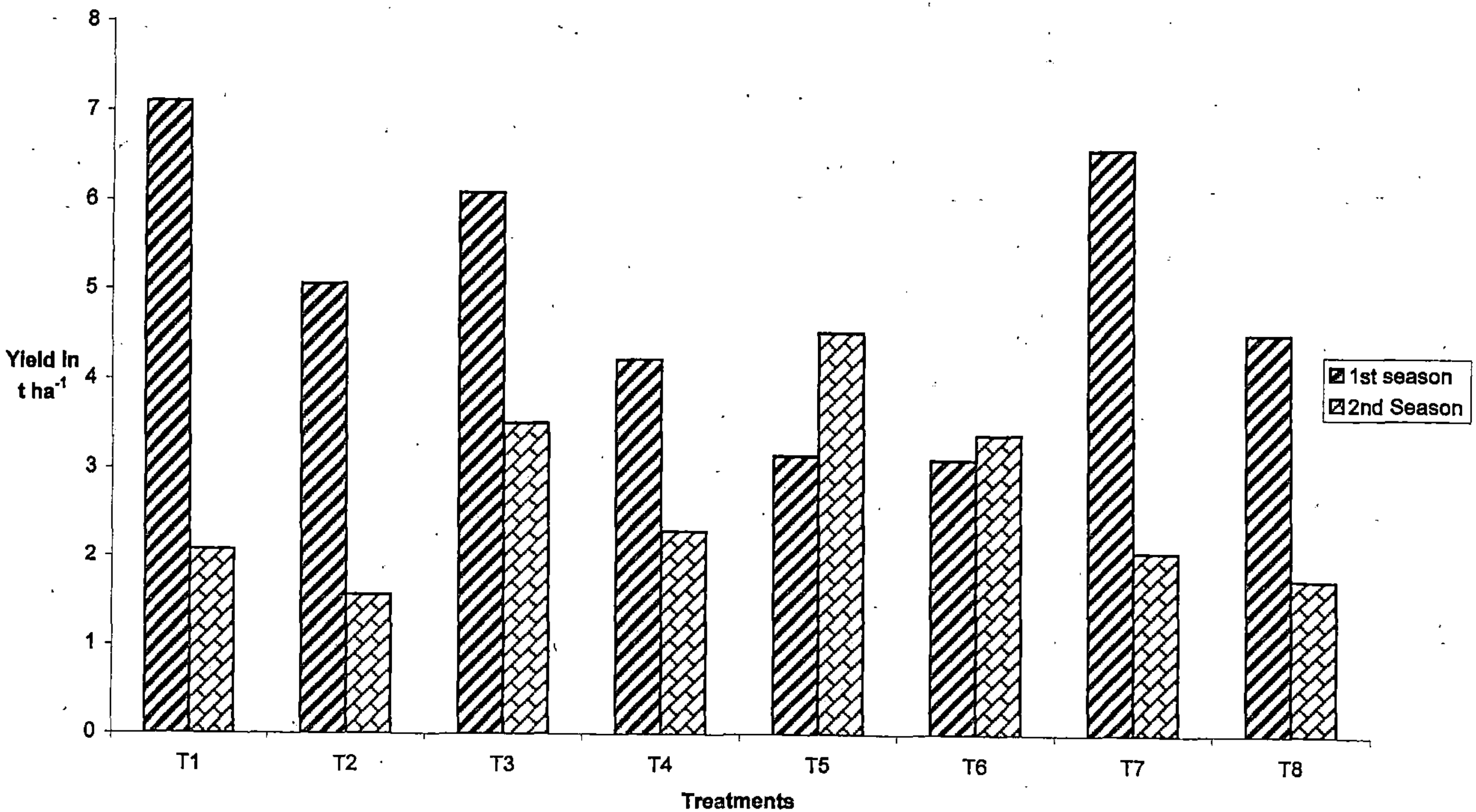
Number of fruits and fruit yield per plant were found to be higher in sole crop than intercropped treatments in the first season (Table 7). During the second season these characters were significantly higher in okra intercropped with cowpea. The higher the plant height, plant produces more number of nodes, thereby more flowers and fruits.The fruit yield of okra per hectare was significantly higher in the pure crop during the first season (Table 8). The yield contributing characters such as number of fruits per plant and fruit yield per plant were more for sole crop and resulted in higher fruit yield per ha (Fig.2).The results of first season were in accordance with the findings of Olasantan (1991) in okra/tomato + cowpea intercropping system and Kalarani (1995) in okra+cowpea intercropping system where maximum number of fruits were recorded by sole crop of vegetables. There are many reports to show the superiority of sole cropping over intercropping. Kadali *et al.* (1988) found that yield of chilli was maximum under sole cropping. Similar reports were made by Sheela (1981), Singh (1991), Natarajan (1992) and Balan (1998) in different vegetable based cropping systems.

During the second season, okra intercropped with cowpea at lower spacing recorded the maximum yield per ha. This may be due to the residual effect of cowpea grown in the first season. Olasantan (1998) reported an increased yield of okra after sole crop of cowpea or the maize+cowpea intercropping system.

In intercropping system yield advantage occur when growth pattern of component crops differ in time to make their major demands on resources. But in this investigation, the main crop and intercrops had more or less the same duration.

Fruit yield per plant was significantly higher in wider spaced okra when compared to the closely spaced plants, while the fruit yield per ha was significantly higher in okra plants spaced at 60×45 cm than at 100 × 45 cm. Kamalanathan *et al.* (1970) reported that in okra, yield per ha was higher in closest spacing where as number and weight of fruits per plant decreased with decrease in spacing. Rukmani (1990), Maya *et al.* (1997), Yilmaz (1999) and Pundir and Porwal (1999) also found similar effects in different crops.

Fig. 2. Effect of intercropping and spacing on yield per ha of okra



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

1. Where intercropping must give full yield of main crop and some yield of second crop.
2. Where the combined intercrop yield must exceed the higher sole crop yield.
3. Where the combined intercrop yield must exceed a combined sole crop yield.

From the results of this study, it could be seen that in the first season, okra intercropped with amaranthus and cucumber satisfied the second criterion. In the second season all the combinations except those intercropped with cucumber at closer spacing satisfied the first criterion. The second criterion was satisfied by okra + amaranthus, and okra + cowpea at lower spacing and okra + cucumber at both spacings. Thus the present study revealed that intercropping in okra is scientifically adviseable.

The dry matter production of sole crop okra was higher than intercropped plants at final harvest in the first season (Table 8). This might be due to higher plant height with lesser competition. Similar reduction in dry matter production due to intercropping was reported by Sheela (1981) in tapioca+cowpea/groundnut, Sunitha (1990) in maize+cowpea and Kalarani (1995) in okra+cowpea intercropping system.

5.2 Performance of intercrops in okra based intercropping system

5.2.1 Amaranthus

The influence of intercropping and spacing on the number of cuttings, root spread, days to first and final harvest of amaranthus was nonsignificant, while yield per plant and marketable yield per ha were found to be significant only in the second season. This was higher in sole crops compared to intercrops (Table 11).

When the performance of amaranthus at different spacings were compared, yield per plant was superior at wider spacing (100 × 45 cm) compared to those at closer spacing (60 cm × 45 cm) where the plants got more opportunities to express their potential since competition for moisture ,nutrients and light was less while yield per ha was higher at closer spacing. Per plant performance was better when individual plant receives more spacing. Revanappa *et al.* (1998) reported that in chilli highest yield per ha was produced at 60 × 30 cm while yield per plant was higher at 75 × 60 cm.The crop was completely free from leafspot disease since the variety selected was CO.1.

5.2.2 Cowpea

Various growth and yield characters of cowpea were significantly influenced by intercropping and spacing. Plant height showed significant difference only in the second season (Table 12). Sole crop of cowpea recorded a higher mean plant height of 56.89 and 52.33 cm during the first and second season respectively. This was in accordance with the findings of Natarajan (1992) in chilli. Reduced plant height in intercropping might be due to the competition between the crops.

Yield per ha, number of pods per plant and pod yield per plant were significantly influenced by intercropping and spacing (Table 14). Yield per ha of cowpea was superior in sole cropping compared to intercropping. The yield reduction due to intercropping was reported by Ofori and Stern (1986) in cowpea, Malhotra and Kumar (1995) in potato and Rahangdale *et al.* (1995) in cabbage.

Pod yield per plant and number of pods per plant were higher in cowpea grown as intercrop at wider spacing of 100 × 45 cm than when grown as intercrop at 60 × 45 cm and sole crop.This might be due to the better utilisation of resources.

Cowpea grown as intercrop at 100 × 45 cm spacing recorded a maximum fruit yield of 91.45 and 117.12 g per plant during the first and second season respectively.

Root spread, canopy spread and dry matter production at final harvest was found to be non-significant . Cowpea as intercrop at 100 × 45 cm spacing produced maximum root spread and dry matter during first season and maximum canopy spread during both the seasons. This might be due to the better partitioning of assimilates towards vegetative growth under wider spacing. Similar report was made by Gowda and Gowda (1983) in okra.

Sole crop recorded maximum incidence of aphid while intercropping reduced the incidence (Table 16). Legutowska and Zawirska (1998) reported that thrips were more abundant in monocropped leek than in intercropped plants.

5.2.3 Cucumber

The results showed that the number of female flowers, percentage fruit set, length of vine and number of primary branches were not significantly influenced by intercropping or spacing. Pure crop of cucumber recorded the maximum vine length (Table 17). The lower values when intercropped may be due to the competition of main crop and cucumber for nutrients and space.

The number of fruits per plot in cucumber was found to be significantly affected by intercropping and spacing (Table 19). Cucumber grown as intercrop at lower spacing recorded the highest number of fruits per plot. This might due to the greater number of flowers and highest percentage of fruit set during both the seasons.

Fruit size indicated by average fruit weight was greater in the sole crop of cucumber during both the seasons (Table 19). These results are in accordance with the findings of Olasantan (1991) in okra + cowpea intercropping where maximum fruit weight of vegetables were recorded under sole cropping.

Sole crop of cucumber produced fruits with maximum circumference (26.96 and 27.47 cm during the first and second season respectively). The lack of competition for space and nutrients might have contributed to the bigger sized fruits in sole cropped plots. Geethakumari (1989) found that in maize + cowpea intercropping system sole crop arrangement of maize produced longer cobs than the intercropped ones.

The fruit yield per hectare was significantly higher in the pure crop of cucumber. Sole crop recorded a mean yield of 6.39 t ha^{-1} in the second season . The yield per plant was also higher in pure crop of cucumber (Table 20). Cucumber grown as intercrop at 60 × 45 cm recorded lowest yield per plant compared to those at 100 × 45 cm.

Fruit fly incidence was maximum in sole crop (Table 21). Pino *et al.* (1994) observed higher incidence of pests in pure crop than in intercropped tomato plants. Cucumber grown as intercrop at closer spacing (60 × 45 cm) recorded lower incidence compared to those grown at wider spacing (100 × 45 cm).

5.3 Biological efficiency of intercropping system

Biological efficiency parameters are used for evaluating the competitive relation between component crops in intercropping.

5.3.1 Land equivalents ratio (LER)

According to Willey (1979) the most generally used index for expressing the yield advantage is LER, defined as the relative land area occupied by sole crops to produce the same yield as in intercropping. If the LER is unity there is neither gain nor loss by intercropping. Value less than unity denotes disadvantage and a value more than unity represents advantage in intercropping.

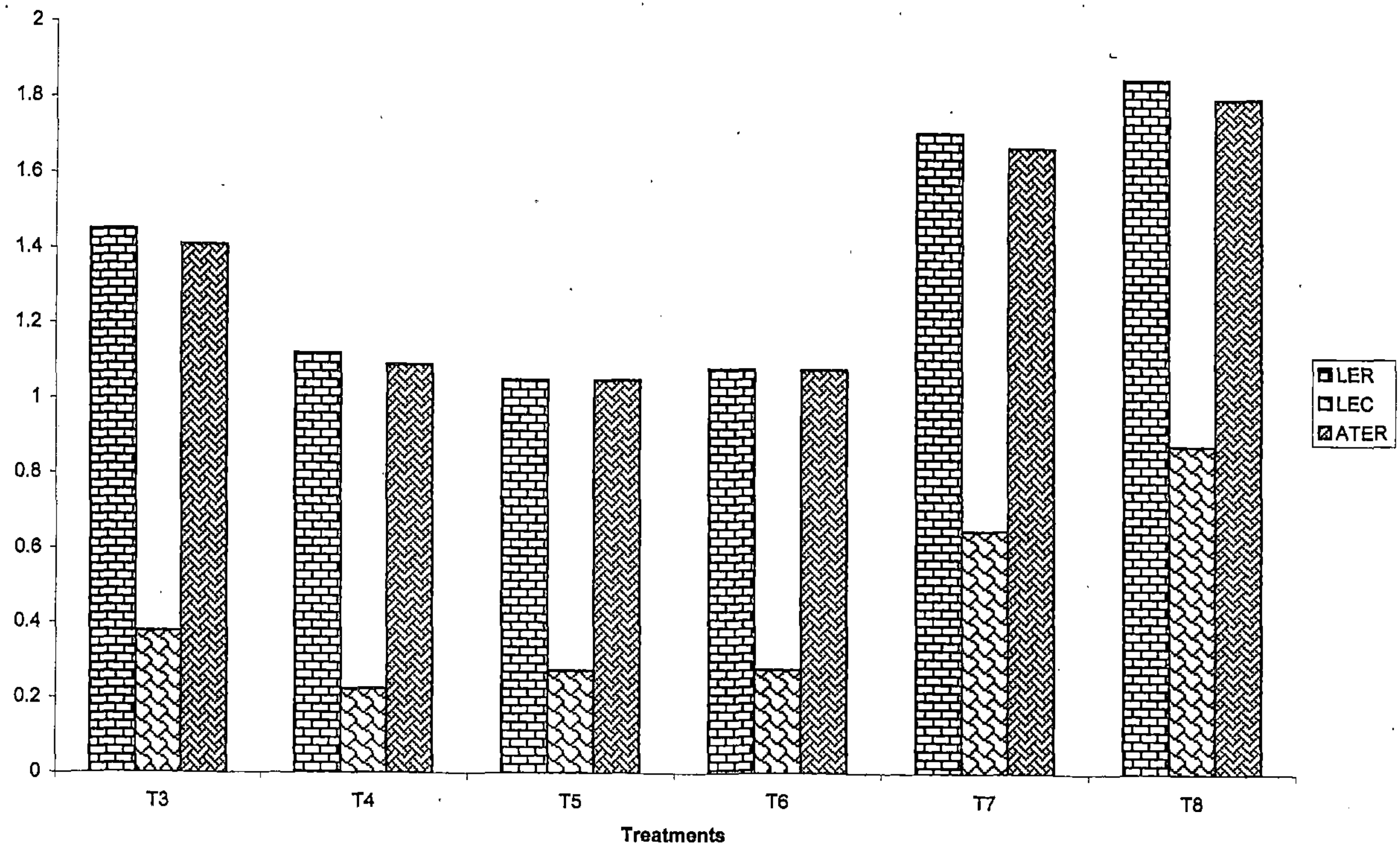
In all the treatment combinations LER was found to be more than unity indicating an advantage in land use by intercropping in okra. During the first season okra intercropped with cucumber at wider spacing gave the highest LER value (1.85) which was on par with okra + cucumber and okra + amaranthus at lower spacing (Table 22). The LER value of 1.85 indicate that 85% more land would be required as sole crops to produce the same yield as intercropping i.e., it was 85% more efficient than sole crops (Fig.3). During the second season okra + cowpea at 100 × 45 cm spacing recorded the highest value (2.69).

The results were in accordance with the findings of Ramachander *et al.* (1989) and Sur and Das (1992) in pigeon pea + maize intercropping, Balasubramanian *et al.* (1994) in cotton + black gram intercropping and Punia *et al.* (1999) in mustard + chickpea intercropping system. In all these findings the LER values suggest that intercropping system is more efficient in utilizing resources than sole cropping , resulting in higher productivity per unit space.

5.3.2 Land equivalent coefficient (LEC)

LEC has been found to be very effective in deciding the mixture yield. According to Willey (1979) one criterion for assessing the yield advantage of cropping system is to realise full yield from the base crop and to get some extra

Fig. 3. Effect of intercropping and spacing on LER, LEC and ATER (I Season)



yield from the component crops. In this study 100 per cent of the pure crop population was maintained in all the crops. Any intercropping system involving two crops, to become beneficial should have an LEC of more than 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 components should be more than expected. In this study all treatments recorded LEC of more than 0.25 except okra + amaranth at wider spacing in the first season. This again confirmed the suitability of intercropping in okra based cropping system (Fig.3).

5.3.3 Area time equivalency ratio (ATER)

In the evaluation of LER, the time the field was dedicated to production was not considered. But ATER as proposed by Hiebsch and McCollum (1987) considers the land occupancy period of the crops also. In this study crops selected had almost the same duration. When components are of similar growth durations, ATER values are similar to LER (Ofori and Stern, 1987). In this study also, the system which has higher ATER values produced higher LER values. In the first season okra intercropped with cucumber at both spacings recorded the highest values (Table 21). During the second season okra intercropped with cowpea recorded the highest value (Fig.3).

5.3.4 Aggressivity

Aggressivity is a parameter that helps to asses the competitive nature of the component crops. 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 negative. The greater the numerical value the bigger is the difference in competitive abilities.

Negative aggressivity values were obtained for all the treatments except those intercropped with cucumber (Fig.4). This clearly pointed out that cowpea and amaranthus were dominant over okra while cucumber was dominated. This may be due to the difference in the growth habit of cucumber. Rana *et al.* (1999) reported the dominant nature of linseed in the potato-linseed intercropping system.

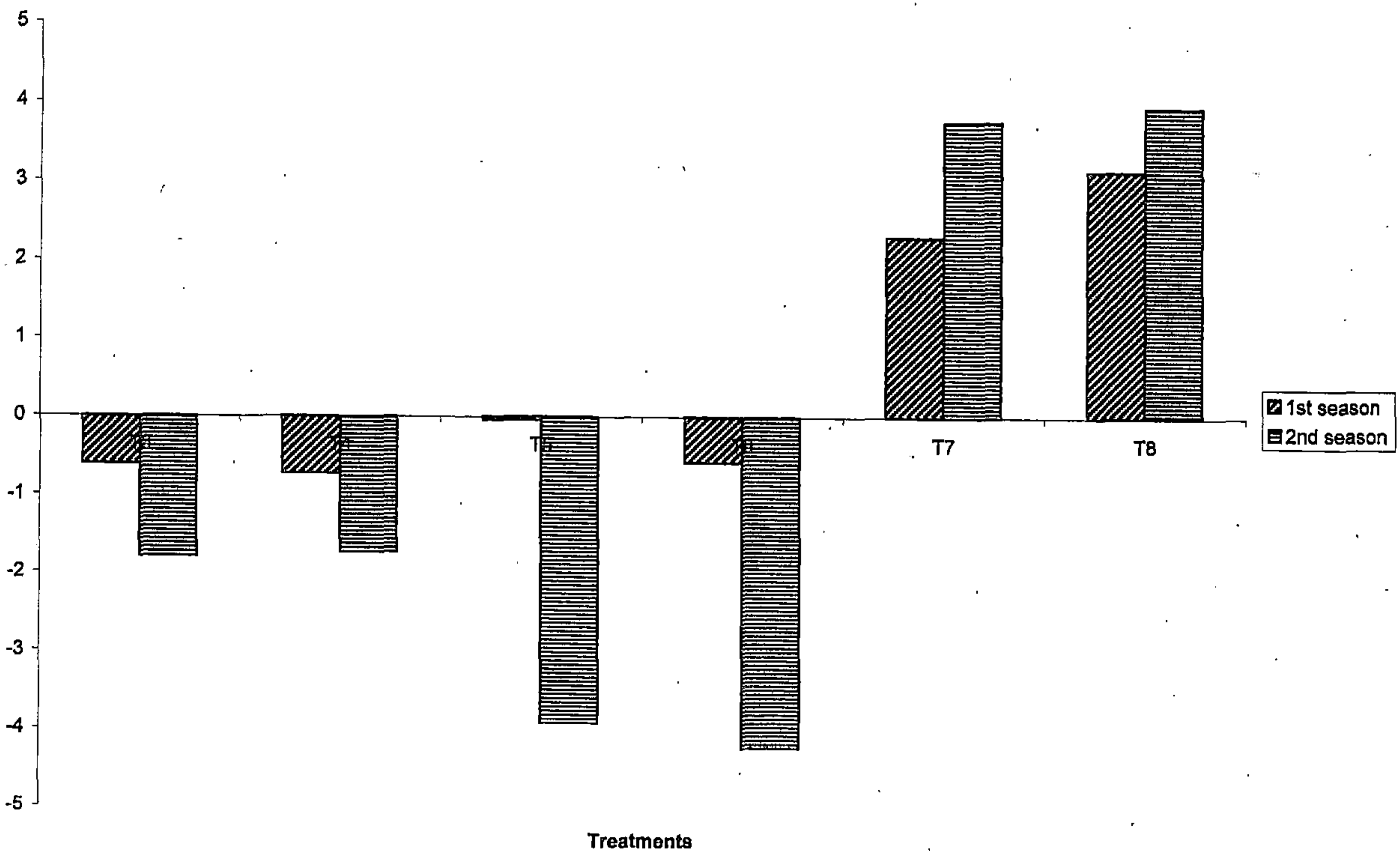
5.3.5 Relative crowding coefficient (RCC)

RCC is used to determine the yield advantage due to mixing. If a component has a coefficient less than, equal to or greater than one, it means it has produced less yield, the same yield or more yield than expected, respectively. In the first season, RCC was found to be less than one for treatments okra + cowpea at wider spacing and okra + cucumber at lower spacing (Table 23). But in the second season, RCC value of more than one in the treatment okra+cucumber indicated that there was no yield reduction due to intercropping. But in all other treatments the values were negative indicating that all the crops failed to express its full potential.

5.3.6 Okra equivalent yield

In an intercropping system since more than one species is involved it is difficult to compare the produce of different nature. Hence equivalent yield was calculated by converting the intercrop yield into base crop yield by considering the market rates of both the crops. Okra equivalent yield was highest for okra intercropped with cowpea at lower spacing (Table 24). This is attributed to the maximum utilization of renewable and non-renewable resources of production and higher economic value of cowpea. Balan (1998) reported higher ashgourd equivalent yield in an ashgourd based intercropping system compared to sole crop of ashgourd.

Fig. 4. Effect of intercropping and spacing on aggresivity values (I and II Season)



5.3.7 Total biomass production

Total biomass production was highest when intercropped with cowpea at lower spacing during both the seasons. Intercropped plots gave higher biomass than sole cropped ones (Fig. 5).

5.8.3 Fresh weight of weeds from interspace

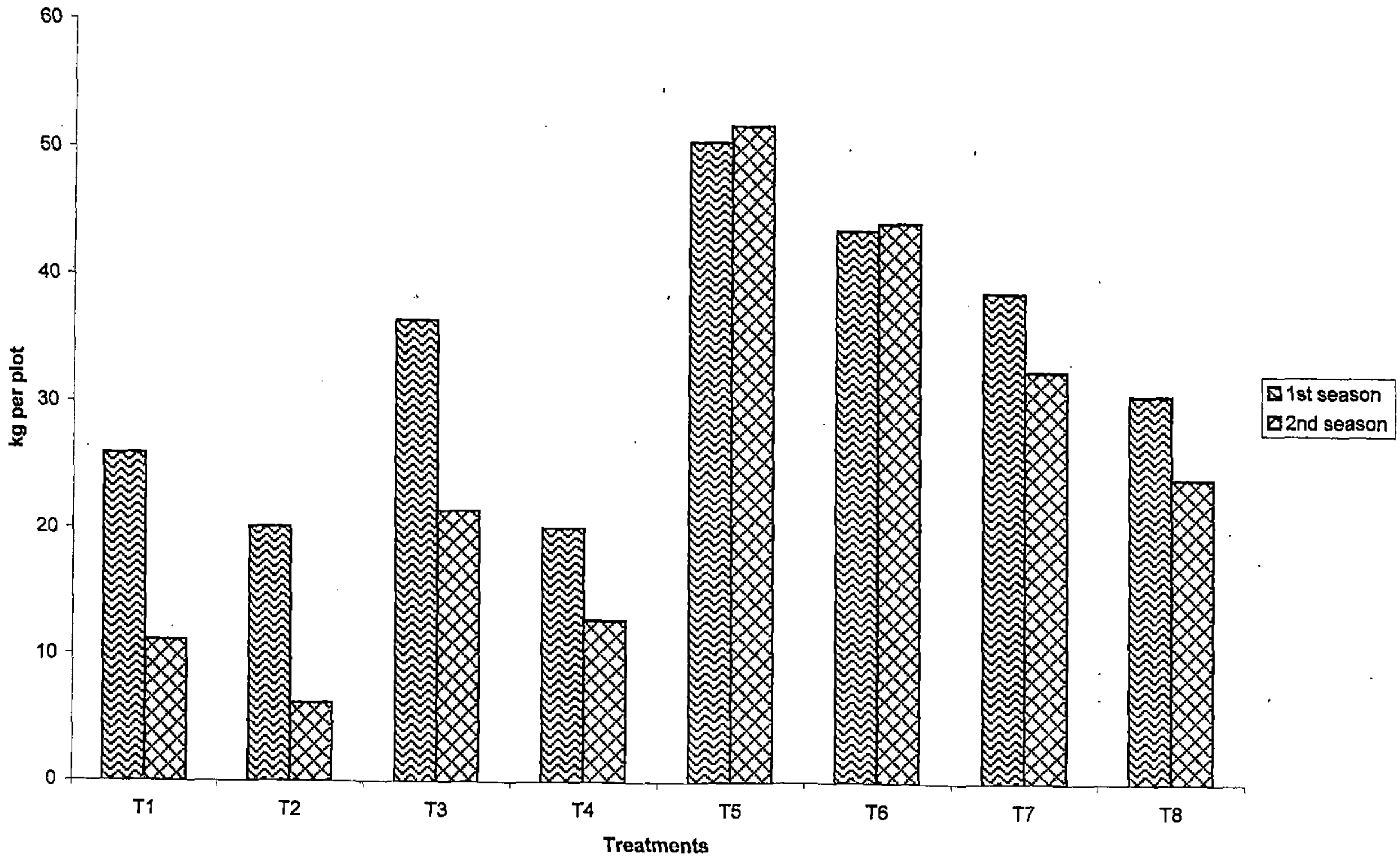
Weed infestation was considerably less in intercropping system compared to sole crop. Effective weed control was obtained for the treatment including okra + cowpea and okra + cucumber at 60 × 45 cm spacing (Table 25). The fast growing intercrops help to cover the vacant interspace rapidly and keep weeds under check. Smother cropping with cowpea resulted in satisfactory control of all types of weeds in okra (Sainudheen, 2000). Amma and Ramadas (1991) and Balan (1998) reported reduced weed infestation in the intercropped plots.

5.4 Economic suitability

Any system, to be recommended to the farmer should be economically viable. Hence the produce of different crops are converted in terms of monetary returns and is compared to assess the economic suitability. Economic feasibility was tested using various efficiency parameters like gross return, net return, benefit cost ratio, per day return and return per rupee invested on labour and fertilizer.

The results revealed that economics of the intercropping system was significantly influenced by spacing, intercrops and their interaction. The gross return, net return, and per day return were highest for the system including okra + cowpea at 60 × 45 cm spacing (Tables 26 & 27). The reduction in the yield of okra was compensated by the additional yield from intercrops. The least gross return was

Fig. 5. Effect of intercropping and spacing on total biomass production (I and II season)



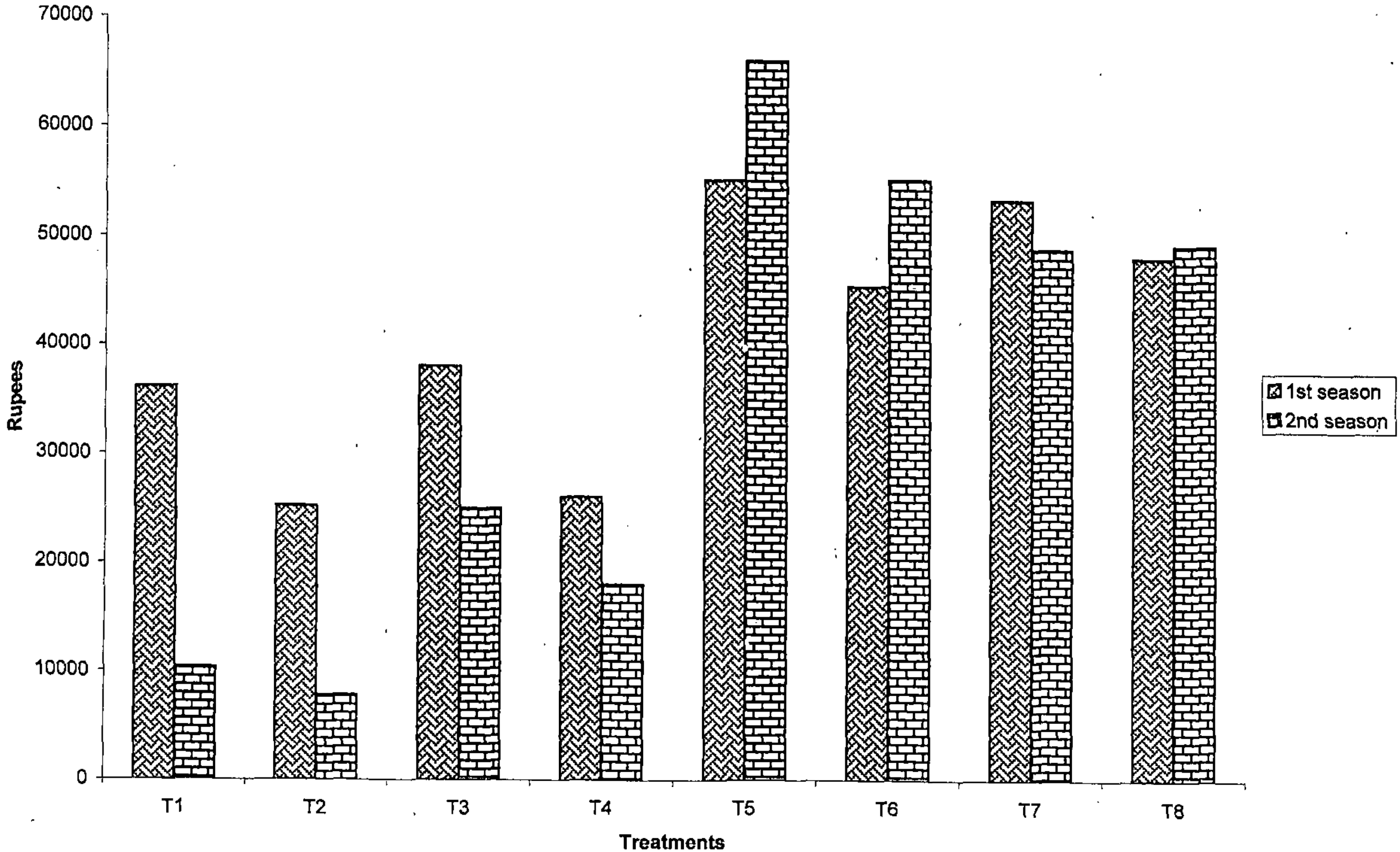
for the sole crop of okra at wider spacing during both the seasons(Fig.6). The net return was minimum in the okra + amaranthus combination at 100 × 45 cm spacing during the first season and in the pure crop of okra during the second season. Pure crop yield was very less during the second season. Hence as far as the net return to the farmer is considered intercropping of okra with cowpea at 60 cm × 45 cm spacing is beneficial. Increased gross and net return from intercropping as compared with sole cropping was reported by Amma and Ramadas (1991) in okra + amaranthus intercropping system, Prabhakar and Shukla (1991) in okra + radish/french bean intercropping system, Balan (1998) in ashgourd based cropping system and Rahman (1999) in wheat based intercropping system.

Benefit cost ratio provides an estimate of the benefit the farmer derives for the expenditure incurred in adopting a particular cropping system. BC ratio was significantly influenced by the intercrops only in the second season (Table 27). During both the seasons okra intercropped with cowpea at 100 × 45 cm spacing gave the highest value (2.93 and 3.43 during the first and second season respectively). This is in line with the results obtained by Balan (1998) in ashgourd based cropping system where intercropped treatments recorded higher BC ratio than sole crop.

Intercropping system involves high labour involvement. Since labour is a very costly input an estimate on labour utilization efficiency is needed while going for an intercropping practice. Hence return per rupee invested on labour was also calculated. The results showed that okra intercropped with cowpea at wider spacing gave the highest return per rupee invested on labour (Table 28). In the first season this was on par with all other treatments except those intercropped with amaranthus.

Fertilizer is another input, which mainly influence the total cost of cultivation. The results revealed that the return per rupee invested on fertilizer was significantly influenced by intercropping and spacing in the second season

Fig. 6. Effect of intercropping and spacing on gross return (I and II Season)



(Table 28). Okra + cowpea combinations gave the highest return. This might be due to the higher returns and market price of cowpea.

Thus based on the economic parameters it can be concluded that okra + cowpea at lower spacing (60 × 45 cm) is highly economical followed by okra + cowpea at 100 × 45 cm spacing.

5.5 Pest and disease incidence of okra

In general the incidence of pest was severe in the second season, which led to considerable yield reduction during that season. Kadam and Khaire (1995) reported that *Earias vitella* infestation in okra was low to moderate from the end of May to the beginning of October. Thereafter it increased rapidly and become severe from first of November to December last.

Sole crop recorded the maximum incidence of fruit and shoot borer (*Earias vitella*) during both the seasons (Table 9). Percentage incidence was minimum for okra intercropped with cowpea and amaranthus during the first and second season respectively. The reduction of pest is due to the inclusion of intercrops belonging to different families. Khorsheduzzaman *et al.* (1997) reported that intercropping coriander with brinjal was an effective measure against brinjal fruit and shoot borer.

Incidence of yellow vein mosaic virus disease was noticed only in the first season (Table 9). Occurence was maximum in sole crop at wider spacing.Nath and Saikai (1995) reported that the incidence of yellow vein mosaic was severe in okra sown between early April and end of June.

Studies by Sharaiha *et al.* (1989) showed that intercropping reduced the incidence of alternaria leaf spot on faba beans and rust on maize.

5.6 Soil nutrient status

The organic carbon and available nitrogen content of soil showed a declining trend, when okra was grown as a sole crop in both spacings. When a wider spacing was adopted, a steady increase in both these factors was noticed, irrespective of season (Table 29). This indicates that okra cultivation at closer spacing is causing soil deterioration leading to breakdown of soil organic matter and exploitation of nitrogen content of soil.

Intercropping amaranth with okra led to an increased soil organic carbon and available nitrogen status. But after the second experiment, the content were reduced inspite of lower yield production of okra (Table 29). However, yield of amaranth increased in the second season. This may be probably because amaranth is a C_4 plant, capable of producing more dry matter per unit quantity of nutrient.

Intercropping with cowpea led to a significant increase in the organic carbon and available nitrogen contents of the soil and the decline in content after the second season was marginal. The beneficial effect of biological nitrogen fixation by cowpea was evident in the yields of both okra and cowpea, indicating that cowpea is a crop compatible for okra intercropping. Soil sustainability was also maintained. Singh (1991) found that inclusion of cowpea in a cropping system improves the soil nutrient status.

Cucumber intercropping resulted in an increase in organic carbon and available nitrogen after the first season. But declined after the second season. Yield of both okra and cucumber were reduced greatly, indicating that cucumber is not a compatible crop. Sustainability of soil was eroded, leading to decline of yield.

Intercropping situations lead to over exploitation of soil. When fertilizer nitrogen is added, native organic carbon in the soil breaks down and organic carbon content in the soil is depleted. Hence in these situations supplementation of organic carbon is essential. Addition of higher quantities of organic matter becomes necessary.

Intercropping was seen to have a more beneficial effect on soil K status in comparison to sole cropping of okra and the effect was seen to be cumulative, with the content increasing to greater levels after the second crop. Higher K content due to intercropping can be explained by organic matter addition to the soil by way of litter and plant roots. Decomposition of organic matter and subsequent production of organic acids resulted in release of K from the soil, causing higher K content in soil.

Summary

SUMMARY

The present investigation was undertaken at the Vegetable Research Farm of the Department of Olericulture in College of Horticulture, Vellanikkara to evaluate the productivity of okra as influenced by crop combinations at different spacings.

The main crop of okra was planted at two different spacings (60 × 45 cm and 100 × 45 cm) and three intercrops viz., amaranthus, cowpea and cucumber were raised in the interspaces of okra. In addition to these combinations, pure stand of all these crops were raised as control treatments.

The experiment was laid out in Randomised Block Design with three replications during two seasons. Observations on growth, yield and yield attributing characters were taken. Competition functions and economic indices were worked out to assess the biosuitability and economic feasibility of the intercropping system. The results obtained are summarised as follows.

1. Intercropping and spacing did not significantly influence the growth characters like plant height, number of branches, internodal length, number of internodes, root spread and canopy spread at final harvest of okra.
2. The yield attributing characters like days to first flowering, first flowering node and fruit characters like length, girth and single fruit weight of okra were not influenced by intercropping and spacing.
3. Fruit yield per plant of okra was maximum in sole crop at wider spacing during the first season while in the second season okra intercropped with cowpea at 100 × 45 cm gave the highest fruit yield and number per plant.
4. Fruit yield per hectare of okra was maximum in the sole crop during the first season and in the second season it was superior in okra +cowpea, both at lower spacing.

5. Pod yield and number per plant of cowpea were highest when grown as intercrop with okra at 100 × 45 cm spacing. Pod number per plant was 18.70 and 23.60 and pod yield per plant was 91.45 and 117.12 g during the first and second season respectively.
6. Sole crop of cowpea recorded maximum incidence of aphid (75.40% and 79.43% during the first and second season respectively).Minimum incidence of aphid was noticed in cowpea intercropped with okra at 60×45 cm spacing. (63.15 and 63.07% during the first and second season respectively).
7. Sole crop of cucumber recorded maximum incidence of fruitfly with 17.31% and 21.67% during the first and second season respectively.Cucumber grown as intercrop with okra at closer spacing recorded the lowest incidence of fruitfly with 7.07 and 15.57%.
8. Evaluation of biological efficiency showed higher aggressivity values for the combination of okra+cucumber at wider spacing during both the seasons.
9. Negative aggressivity values for treatments containing cowpea and amaranthus indicated the aggressive nature of intercrops.
10. Higher LER (1.85), LEC (0.88) and ATER.(1.80) values were recorded by okra+cucumber combination at lower spacing during the first season.
11. Okra equivalent yield was highest for the combination of okra+cowpea at lower spacing with 7906.55 and 8708.63 kg ha^{-1} during the first and second season respectively.
12. Lowest okra equivalent yield was recorded for the combination of okra +amaranth at wider spacing.
13. Highest total biomass production was obtained from okra+cowpea combination at lower spacing during both the seasons.
14. Effective weed suppression was possible with okra+cowpea combination at closer spacing of 60×45 cm.
15. Fresh weight of weeds from the sole crop plot of okra was maximum at wider spacing during both the seasons.

16. Economic indices revealed that gross return was highest for okra+cowpea combination at 60×45 cm with Rs.55305.20/- and Rs.66198.31/- per ha in the first and second season respectively.
17. Return per rupee invested on labour was highest for okra+cowpea at 100 × 45 cm spacing (Rs.5.62/- and Rs.6.55/- in the first and second season respectively).
18. Okra cultivation at closer spacing is soil deteriorating leading to breakdown of soil organic matter and exploitation of nitrogen content of soil.
19. Intercropping with cowpea maintains the sustainability of soil.

Based on the discussions it can be concluded that okra + cowpea combination at 60 × 45 cm recorded the highest okra equivalent yield, lower weight of weeds from the interspace, and highest gross return during both the seasons. In addition, highest net return and per day return were also recorded from the same treatment during the second season. These conclusions revealed that intercropping could be adopted in okra even without increasing the recommended spacing.

Yield reduction was observed in individual crops due to intercropping, but when the system as a whole is taken, there were both yield advantage and monetary advantage. Also in situations where the main crop failed to perform well due to the vagaries of atmospheric conditions or incidence of pests and diseases, intercropping is a viable proposition.

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Appendix

Appendix –1

Standard meteorological week number	Temperature (°C)		Relative humidity (%)		Rainfall (mm)
	Max	Min	Morning	Afternoon	
First season (18/06/2000 to 23/09/2000)					
25	29.6	23.2	95	74	55.9
26	29.4	22.5	94	75	104.3
27	28.9	22.0	93	76	87.8
28	29.2	21.5	94	74	170.0
29	30.1	22.8	93	66	48.9
30	30.9	23.2	92	62	5.9
31	31.1	23.6	92	69	9.0
32	29.0	22.8	94	80	93.3
33	29.4	22.6	93	78	139.5
34	27.7	22.0	95	88	232.8
35	29.4	22.1	94	73	44.2
36	30.6	22.9	92	69	31.9
37	31.2	23.3	90	65	0.0
38	30.4	22.9	92	72	16.2
Second season (15/10/2000 to 31/12/200					
41	30.9	22.1	91	65	18.1
42	30.6	23.6	92	72	160.8
43	31.7	19.8	90	58	6.8
44	32.6	23.3	88	57	0.4
45	33.4	23.0	73	47	0.0
46	32.5	24.1	67	48	0.0
47	32.6	23.9	82	64	23.1
48	31.1	20.8	86	60	5.4
49	31.1	23.3	69	53	0.0
50	31.0	21.5	65	36	0.0
51	31.5	22.6	67	42	0.0
52	30.7	21.4	75	55	8.0

PRODUCTIVITY OF OKRA (*Abelmoschus esculentus* (L.) Moench) AS INFLUENCED BY CROP COMBINATIONS

By
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ABSTRACT OF THE THESIS

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ABSTRACT

Investigations on the productivity of okra as influenced by crop combinations were conducted at the Vegetable Research Farm of the Department of Olericulture, College of Horticulture, Vellanikkara during 2000-2001.

The experiment was laid out in randomised block design with three replications during two seasons. The base crop okra was raised at two different spacings along with intercrops amaranthus, cowpea and cucumber. Sole crops were also raised as control. Observations were made on growth characters, yield and yield attributing characters. Biological efficiency and economic suitability of the system were worked out using different indices.

The results revealed that intercropping and spacing did not significantly influence the growth characters in okra, amaranthus, cowpea and cucumber. Yield per ha was higher at closer spacing of okra while the per plant performance was superior at wider spacing. Fruit characters like length, girth and single fruit weight of okra were not significantly influenced by spacing and intercropping.

LER, LEC, ATER, aggressivity values and total biomass production revealed the biosuitability of okra based cropping system. LER was found to be more than unity in all the combinations, indicating the possibility of intercropping in okra. Aggressivity values clearly pointed out that cowpea and amaranthus were dominant over okra while cucumber was dominated.

Economic analysis revealed that gross return, net return and per day return were highest for the combination of okra +cowpea at 60×45cm spacing. Effective weed suppression and reduction in pest incidence was also noticed in this system. Intercropping with cowpea led to a significant increase in the organic carbon and available nitrogen contents of the soil.

Thus the study conclusively revealed the scope of recommending okra+cowpea at 60×45cm spacing as an economically viable, biologically suitable and sustainable cropping system to increase the productivity of vegetables.