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**PLANTING TECHNIQUES AND INTERCROPPING  
STUDIES IN COTTON**

By  
**P. RAGHU RAMI REDDY**

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THESIS SUBMITTED TO THE  
ACHARYA N.G. RANGA AGRICULTURAL UNIVERSITY  
IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR  
THE AWARD OF THE DEGREE OF

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IN THE FACULTY OF AGRICULTURE

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JULY, 2006

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**Mr. P. RAGHU RAMI REDDY** has satisfactorily prosecuted the course of research and that the thesis entitled "**PLANTING TECHNIQUES AND INTERCROPPING STUDIES IN COTTON**" submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that the thesis or part thereof has not been previously submitted by him for a degree of any University.

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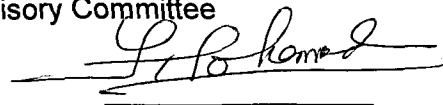
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No part of the thesis has been submitted for any other degree or diploma. The published part has been fully acknowledged. All assistance and help received during the course of the investigation have been duly acknowledged by the author of the thesis.



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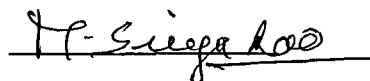


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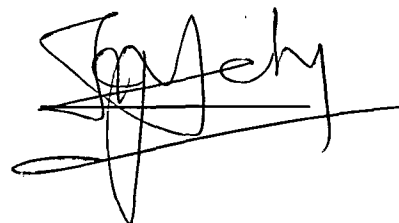
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## LIST OF SYMBOLS AND ABBREVIATIONS

°C	:	Degree centigrade
$\lambda$	:	Effective or desired
$\geq$	:	Equal to or not less than
$\geq$	:	Greater than or equal to
<	:	Less than
>	:	More than
<sup>-1</sup>	:	per
%	:	per cent
ATER	:	Area time equivalent ratio
AWHC	:	Available water holding capacity
CD	:	Critical difference
cm	:	Centimetre
cm <sup>2</sup>	:	Centimetre square
dSm <sup>-1</sup>	:	desi Siemen per metre
ECe	:	Electrico-Conductivity of earth
ELER	:	Effective land equivalent ratio
Eq	:	Equivalent
<i>et al.</i>	:	and others
Fig	:	Figure
g	:	gram
ha	:	hectare
K	:	Potassium
kg	:	kilogram
kg ha <sup>-1</sup>	:	kilogram per hectare
LER	:	Land equivalent ratio
LERc	:	Cotton land equivalent ratio
m	:	metre
mg	:	milligram
ml	:	millilitre
mm	:	millimetre
N	:	Nitrogen
NS	:	Non significant
P	:	Phosphorus
pH	:	Negative logarithm of hydrogen ion activity
P/PET	:	Precipitation / potential evapotranspiration
RNR	:	Relative net returns
Rs ha <sup>-1</sup>	:	Rupees per hectare
Rs Re <sup>-1</sup>	:	Rupees per rupee
SE m $\pm$	:	Standard error of mean
SLER	:	Staple land equivalent ratio
<i>viz.</i> ,	:	namely

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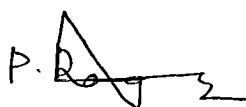
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## DECLARATION

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Date : 7-7-06  
Place : Hyderabad

  
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#### ABSTRACT

A field experiment was conducted at Agricultural Research Station, Warangal during *Kharif*, 2004 and 2005. The soil was sandy loam in texture with available water holding capacity of 110 mm per meter depth. There was a rainfall of 366.8 mm distributed in 10 weeks during crop growing period in 2004. A higher amount of 593.8 mm rainfall was distributed over a longer period of 14 weeks during the second year. Rainfall analysis represented by precipitation curve through plots of P/PET showed that the crop growing season ranged from 22 to 44 standard week. Crops of more than 160 days duration can be grown. The dependable rainfall of  $\geq 75\%$  probability range from 24 to 38 standard week. Therefore, crops maturing in about 110-120 days can be intercropped in long duration crops. Initial and conditional probabilities for expected threshold limits are provided for different weeks to plan different operations during the growing period. The budgeting of water showed that the water requirement satisfactory index was cent per cent upto 37 standard week in 2004 and 34 standard week in 2005. Moisture deficiency was recorded in the later weeks.

The lay out of the experiment was randomised block design with 14 treatments and 3 replications. Cotton was grown in 2 planting patterns *viz.*, uniform row spacing of 90 cm and paired rows of 120/60 cm with a common intra row spacing of 90 cm. They were evaluated in sole and intercropping systems. Two rows of soybean, greengram, blackgram, cowpea, groundnut or sesamum were flanked between the uniform rows and 3 intercrop rows between the paired rows of cotton.

The results showed that the vegetative growth, yield components, nutrient uptake, quality of seed cotton, yield and profits were not significantly different due to a change in the planting pattern.

The intercrop components *viz.*; sesamum, groundnut and soybean were relatively more competitive than cowpea, blackgram or greengram. They reduced the plant height and leaf area per plant of cotton at certain stages of crop growth. This ill-effect was more pronounced on phytomass accumulation per plant.

The days to 50% flowering and number of monopodials borne by cotton in all the intercropping systems were on par with the sole crop. The sympodials reduced significantly by intercropping sesamum, groundnut or soybean but not greengram, blackgram or cowpea during 2004 and 2005.

The number of bolls per plant, boll weight and seed cotton yield per plant were on par in cotton intercropped with cowpea and sole crop consistently during the two years. These parameters were also not affected by intercropping blackgram only in the first year. Cotton in general removed more quantity of N, P and K from the soil when intercropped with cowpea, greengram or blackgram than soybean, groundnut or sesamum. Cotton intercropped with cowpea produced mean seed cotton yield of 1202 kg ha<sup>-1</sup> in 2004 and 1476 kg ha<sup>-1</sup> in 2005. This was on par with the production of 1278 and 1564 kg ha<sup>-1</sup> seed cotton yield from the sole crop during the two years. The production of cotton due to intercropping of blackgram was unaffected only in the first year.

There were no distinct trends in the moisture content of soil estimated at different depths and intervals of time. There was no pertinent effect of bollworms on the percentage damage caused to the bolls at different stages of crop growth due to different intercropping systems in relation to sole cotton. The quality of

cotton *viz.*, ginning percentage, seed index, lint index or staple length did not change due to any intercropping system.

The vegetative growth and yield components of intercropped soybean, greengram, blackgram, cowpea, groundnut or sesamum were not substantially reduced in either of the two years compared to their respective sole crops. But, the removal of N P K and yields were substantially low in intercropping systems due to their low planting density than in sole crops. The reduction in yield was more pronounced in paired row planting. This was due to the accommodation of 50% sole optimum density of the intercrops. The density of intercrops was 66.66% of the sole optimum in the uniform row spaces of cotton.

The seed cotton equivalent yields increased significantly by intercropping blackgram, cowpea or greengram than sesamum, groundnut or soybean in cotton.

The most appropriate statistical approach – Bivariate analysis of variance established a negative correlation between the yield of intercrops and cotton as indicated by the  $Z_2$  axis. The values of  $d^2$  and circles of significant regions through the graphic representation of the ANOVA revealed that the intercropping system of cotton with cowpea or blackgram transformed to greengram seed equivalent were the best.

The efficacy of land use confirmed that all the six intercrops grown between the uniform rows of cotton were superior to those sown between the paired rows. The land equivalent ratios (LER) recorded 47 to 57 per cent increased total productivity per unit area by intercropping cowpea, greengram and blackgram than others. The area time equivalent ratios also registered 11 to 19 per cent efficiency of land and time utilization.

Shallow curves for standardized yield proportion of cotton to total productivity of intercropping system as effective land equivalent ratios ( $\lambda$ LER) are graphically displayed. This provides an option to select an intercropping system for desired expected minimum requirement of seed cotton yield. The curves for intercropping of cowpea or blackgram between uniform rows of cotton surpassed the others for any desired yield proportion upto 0.92 standardized yield of cotton.

Graphical presentation of staple land equivalent ratios (SLER) for predetermined minimum standardized seed cotton yield from different intercropping systems as proportion to sole cotton also indicated that the intercropping of cowpea or

blackgram between uniform row spaces of cotton were most effective compared to rest of the treatments. An array of options are furnished for a more desirable component to be intercropped while realising a minimum sacrifice of seed cotton yield in different intercropping systems by allocating part of the land for sole cropping and rest for intercropping both for  $\lambda$ LERs and SLERs.

An economic evaluation indicated that the intercropping of sesamum between uniform or paired rows of cotton fetched less profit per hectare and per rupee investment than the sole crop of cotton. Intercropping blackgram, greengram, or cowpea between the uniformly spaced rows of cotton fetched higher profits and were adjudged by the Relative net return indices as significantly superior over intercropping of soybean, sesamum or groundnut.

# ***Introduction***

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## CHAPTER - I

### INTRODUCTION

Cotton is the principal fibre and commercial crop of the world and India. It is the dominant raw material of the Indian *textile industry which contributes to more than 14% of the annual value addition of industrial production and more than 30% of the total exports and 4% of gross domestic production (Basu and Asif, 2005).*

More than 60 million people in India are engaged in cultivation, marketing, processing and other cotton related services. Among the cotton growing countries, India ranks first in area with over 9 million hectares and third in production with 23 million bales. The average productivity was 440 kg lint ha<sup>-1</sup> during 2004. This has improved from 330 kg lint ha<sup>-1</sup> since last decade. Still this is too low compared to the world average of 680 kg lint ha<sup>-1</sup> and Australia's average of whopping 1600 kg lint ha<sup>-1</sup> (Sreenivasan, 2006).

Indian textile industry is expected to have a share of 85 billion US dollars from domestic and global market with demand of 35 million bales by 2010.

Andhra Pradesh is one of the premier states in the country ranking third in area covering 11.78 lakh ha. It ranks third in production with 21.9 lakh bales. The productivity is 316 kg lint ha<sup>-1</sup> (CMIE, 2005). These trends pose a challenge to enhance the productivity per unit area and compete with the progressive regions. Traditionally, cotton is a major cash crop of Krishna-Godavari zone in the State. It's cultivation in Telangana region is expanding fast. It is mostly a rainfed crop grown on Alfisols of low to moderate fertility. It's performance is better in clay soils. It is a hardy crop with deep tap root system and hence tolerates the aberrant rainfall distribution to a great extent. It is at this merit, the farmers opt to sow this crop and ensure atleast low economic returns compared to several other crops. But, the major threat to this crop is severe infestation of sucking pests and bollworms. Severe loss in yield due to these hard to control pests has become a recurring menace, leading to suicides.

On this premise, it is pertinent that the scientists are ought to devise strategies to minimise the risk of crop failures. Intercropping of cotton with compatible intercrops is one of the possible approaches with a ray of hope to widen the vistas which provide some source of sustenance to the peasants in such abnormal situations. Planting patterns and intercrop components should be explored for specific agroecological regions to

enhance the total productivity, increase the income and diversify the crops to provide food and fodder.

Cotton is usually grown in wider rows of 90 to 120 cm. It grows slow during the initial stages and requires about 60 days to completely cover the ground. This period is highly congenial for the luxurious growth of weeds to compete with the crop. One of the possibilities to minimise the effect of weeds on one hand and exploit the initial low vigour of cotton on the other hand is to introduce intercrops. Successful cultivation of greengram, blackgram, soybean, cowpea, groundnut, rice, finger millet and sesamum as intercrops in rainfed cotton has been reported from different parts of country (Mudholkar and Basu, 1995). However, the relative superiority or otherwise of different intercrop components varies wide from region to region with varying rainfall patterns and edaphic conditions. This warrants the identification of compatible intercrops for specific agro ecological situation.

In addition to the factor of minimising the risk of complete crop failures, Sarkar *et al.* (1995) reported that intercropping system facilitate some of the speculated advantages such as higher seed equivalents and greater land use efficiency. Willey (1979) and Mandimba (1995) also narrated the oft cited advantage of improvement in soil fertility through the excretion of nitrogen fixed from the atmosphere by cultivation of legumes as

intercrops. Rao and Shetty (1977) enumerated the advantages of better management of weeds and pests through this technology. Ofori and Stern (1991) reminds the age old concept of insurance against aberrant weather conditions by combined cultivation of diverse crops.

One of the technical advances in intercropping research is the paired row planting technique. Wider spaces are created between the two rows of main crop to accommodate more number of rows of intercrop components. The main idea behind this is to tilt the competition between the two crops by providing more space to the intercrops and examine the possible benefits of different planting patterns with different intercrops of varying morphological structures, rooting depth, inherent competitive influences on resource utilisation and varying duration. Jain and Jain (1985) viewed this paired row planting as a improved system to enhance the total productivity with better utilisation of resources.

The Telangana Region of Andhra Pradesh is predominated with soils of low depth and aberrant monsoon which makes the cultivation of several rainfed crops to run the risk of severe losses in yield. Most often, these crops are of low market value. Therefore, farmers tempt to grow cotton mainly because of its high commercial value, inspite of its high risk to succumb to

the most often uncontrolled pest load. This background prompted, the evaluation of different intercrop components in cotton in the agro ecological Telangana region of Andhra Pradesh. To this end the present investigation entitled "Planting techniques and intercropping studies in Cotton" was conducted with the following objectives :

- 1) To evaluate suitable planting techniques for intercropping in cotton.
- 2) To find out best adoptable intercrop / intercrops with cotton.
- 3) To explore the possibilities of increasing total productivity per unit area.
- 4) To evaluate the economics of different intercropping systems.

# ***Review of Literature***

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## **CHAPTER – II**

### **REVIEW OF LITERATURE**

Literature pertaining to intercropping of cotton has been briefly reviewed under following heads

1. Importance of intercropping
2. Effect of cropping geometry
3. Intercropping in cotton
4. Evaluation of intercropping systems

#### **2.1 . IMPORTANCE OF INTERCROPPING**

Intercropping is a common and ancient practice in India and many other countries of the developing world where average holding is small. Such cropping system is more relevant in rainfed farming as there is risk of crop failure either due to changes in seasonal climate or rainfall pattern (Mudholkar and Basu, 1995).

Intercropping is practised in many parts of Africa, Asia and Latin America due to some of the established and speculated advantages such as higher grain yields or mitigate vagaries of the weather, as an insurance against crop failure, for better utilization of light, space, moisture, nutrients and time to meet the domestic

needs of the farmer and improvement of soil fertility through the addition of nitrogen fixation and excretion from component legumes (Mahrotra and Ali, 1970; Willey, 1979).

In their comprehensive review, Willey and Osiru (1972) noted that the yield of crops in intercropping together increased upto 55% compared to the sole crops grown separately. They attributed that this advantage may be due to better utilization of environmental resources possibly due to temporal complimentary of component crops (Snaydon and Harris, 1979). Dabholkar and Lal (1983) also attributed the usefulness of intercropping in increasing production potential per unit area due to better utilization of resources.

Baker and Norman (1975), Singh and Sharma (1985) and Tomar *et al.* (1994) reported that better water use by intercropping compared to sole crops was probably a common cause of yield advantage, since water is the basic limiting resource in semi-arid tropical areas.

Greatest stability of yields in intercropping, when compared to sole cropping over different seasons is the primary reason for its prevalence as a farming practice (Rao and Willey, 1980).

## 2.2 EFFECT OF CROPPING GEOMETRY

Sahasrabudhe (1973) reviewed the work done at Akola and Rajkot on cotton grown under rainfed conditions. It was reported that the paired row planting of cotton gave more yield (9%) than the uniform row planting. There was no significant difference between paired and uniform row system of cotton at Rajkot.

In the annual report of All India Co-ordinated Research Project on Cotton Improvement (Anonymous, 1974) it was reported that paired row method of planting in black heavy soils gave increased yield of seed cotton over normal method of planting at Indore, Khandwa, Delhi, Achalpur and Kutiki. The subsequent report revealed that the paired row planting gave 12-180 kg ha<sup>-1</sup> more seed cotton yield than the uniform row planting at Hisar, Parbhani, Achalpur, Amaravathi and Kutiki (Anonymous 1975).

Cotton being widely planted crop affords an excellent scope for growing companion crop. When the planting pattern is altered by orienting the rows of base crop to keep its plant population constant per unit area but allowing a companion crop to grow well, higher total productivity and better returns are generally realized. Paired row planting of cotton has been tried with this view in large number of experiments and this has led to better or

atleast comparable yield of cotton, as well as extra yield of companion crop (Singh, 1975; Giri and Upadhyay, 1980; Janardhan, 1982; Mannikar *et al.*, 1988 and Shanmugham and Basu, 1989).

The annual report of All India Co-ordinated Cotton Improvement Project (Anonymous, 1974) stated that irrespective of the pattern of cotton planting, the yields were depressed by growing an intercrop at Indore, Khandwa, Delhi and Kutiki, while at Achalpur intercrop of mung and at Kovilpatti setaria did not depress the yield so much. During 1975-76 studies on planting pattern and intercropping in cotton made at Parbhani revealed that all the intercrop reduced the yield of cotton, irrespective of the pattern of planting cotton.

The studies made at Kovilpatti on planting pattern and intercropping of cotton, indicated that normal planting of cotton recorded higher yield of seed cotton. There was a reduction of yield of seed cotton due to paired row and skip row planting and raising of intercrop. The reduction varied between 17 to 33 per cent (Anonymous, 1977).

Giri and Upadhyay (1980) from the results of study on planting pattern and intercropping of H4 cotton under rainfed conditions at Parbhani, reported that mung and groundnut

intercropping was beneficial as the yield of seed cotton in these treatments was at par with that obtained in solid or paired rows of cotton.

Jain and Jain (1985) indicated that cotton yield could possibly be pushed upto the range of 12 to 18% merely by paired row than solid system in medium black soils of Madhya Pradesh.

Studies conducted at Sriganganagar, Rajasthan revealed that the cotton yields invariably fall with intercropping system and the fall was more distinct when the conventional method of single row planting of cotton was practised. However, the yield obtained from the intercropped cotton, with the paired row system was found to be higher than that of conventional solid cotton crop (Mukerji *et al.*, 1987).

Deshpande *et al.* (1989), studied the effect of planting methods and intercrops on yield of hybrid cotton under rainfed conditions in black clayey soil. Solid planting and paired row planting were found to be on par in seed cotton yield.

In a field experiment at Dharwad the yield of seed cotton was 12.4% higher in paired row planting as compared to normal planting (Koraddi *et al.*, 1991). An experiment conducted on vertisols at Indore, Madhya Pradesh shown that there was no

significant difference in cotton yields by either square planting or paired row planting (Tomar *et al.*, 1994).

Kulandaivel *et al.* (2001) studied the effect of planting pattern supplemented with suitable intercrops in summer irrigated cotton at Madurai in Tamil Nadu. The planting of cotton with high density under paired row system significantly increased the seed cotton yield over normal density. Where as Khan *et al.* (2001), observed no significant effect of planting pattern on seed cotton yield.

In a field experiment conducted at Agricultural College Farm, Raichur during 1998-99, normal planting and paired row planting were found to be on par in seed cotton yield (Sanjay *et al.*, 2003). Experiments conducted at Akola revealed that planting pattern had no significant influence on the growth and yield of cotton (Deoche *et al.*, 2004).

### **2.3 INTERCROPPING IN COTTON**

Wide variety of crops like cereals, legume grains/fodders, oilseeds, vegetables etc., have been tried as intercrops in cotton. The choice of crops are determined primarily by the duration of crops and length of growing season.

### 2.3.1 Effect on growth and development

The response of cotton to growth and development is not always the same in intercropping systems as in sole crop. These responses are highly inconsistent from place to place and within the same place from season to season. A multitude of factors like length of crop growing season, rainfall distribution pattern, soil type, rooting depth and duration of component crops, soil fertility and choice of varieties etc., are some of the reasons. The inferences from several investigations are reviewed in this section to understand the effect of different intercrop components on growth and development of cotton.

Divekar and Kurtakoti (1961) reported that the pure cotton crop grew taller and commenced flowering one week earlier than cotton intercropped with groundnut. Reduced sympodial development was observed in cotton when blackgram was grown as intercrop (Varma and Kanke, 1969). Kairon and Avtar Singh (1972) from Hisar reported significant reduction in the height of cotton when cowpea was taken as an intercrop. Likewise intercropping of cowpea reduced the dry matter production of cotton (Sucha Singh *et al.*, 1972). However, Robinson (1973) found that the height of cotton increased due to blackgram and got reduced due to greengram intercropping. The number of sympodial branches increased in both the intercropping systems.

Reduction of plant height and dry matter production of cotton was observed due to mung and cowpea intercrops (Sucha Singh and Rajinder Singh, 1973). A row of mung grown in between two rows of normally spaced cotton retarded the vegetative growth of cotton plant to a little extent (Kairon *et al.*, 1975).

Devotta and Chowdappan (1976), Sheoran and Malik (1986) reported no reduction in number of monopodials and bolls per plant due to greengram intercropping. Kumaraswamy and Hosmani (1978) reported that on medium black soils of Dharwad one month advance in sowing of fodder cowpea, blackgram and greengram reduced the early growth of cotton, thereby reducing the number of monopodials and sympodials. Kunasekaran (1978) found that height and dry matter production of cotton were not significantly influenced by intercropping with greengram and also maximum number of sympodials were noticed in cotton + greengram intercropping system. Nagre (1979) reported no significant difference in height and branches per plant, when intercropped with arhar, cowpea and mung.

Rao (1982) observed that intercropping of mungbean (*Vigna radiata*) and fodder cowpea suppressed the production of monopodial branches and there was no adverse effect on plant height and number of sympodials per plant. The growth characters of cotton *viz.*, plant height, number of leaves and dry

matter production were not affected significantly by groundnut and blackgram intercrops (Reddy, 1982). The plant height of cotton was unaffected by intercropping with mung or urd or soybean (Jain *et al.*, 1982). Janardhanam (1983) observed no adverse effect on plant height and number of sympodial branches of cotton due to black gram intercropping. He further observed that there was no significant difference in number of days to 50 per cent flowering in cotton due to blackgram intercropping. Nehra and Kairon (1986) reported that different varieties of mung grown as intercrops in cotton at Hisar did not significantly affect the plant height of cotton. At the same location, Sheoran and Malik (1986) also observed that the plant height, number of monopodial and sympodial branches and dry matter produced were not significantly influenced by intercropping with mung.

On medium black clay soils of Akola, the main crop of cotton remained stunted with less biomass production, less number of squares and flowers when intercropped with mung and soybean (Deshpande *et al.*, 1989). At Bapatla on vertisols Rao (1990) observed no adverse effect on plant height, number of sympodial branches and number of bolls per plant due to either greengram or blackgram intercropping. Growth parameters *viz.*, plant height, number of sympodial branches and dry matter accumulation per plant were significantly influenced by

intercropping it with greengram (Sethi *et al.*, 1992). Reduction in plant height of intercropped cotton was also reported by Ramesh Babu *et al.* (1996). Intercropping cotton with greengram in 1 : 2 proportion recorded higher leaf area over sole cotton, whereas cowpea intercropping significantly depressed the leaf area per plant (Rao, 1997). Intercropping of cotton with different soybean varieties significantly increased the plant height of cotton. The number of monopodials and sympodials per plant were not affected in 1 : 1 row intercropping of cotton and soybean, but significantly decreased with 1 : 2 ratio (Pramila Rani *et al.*, 2000).

Sanjay *et al.* (2003) observed that the intercropping of cowpea reduced the dry matter production and sympodial branches per plant considerably. This reduction was less severe by intercropping greengram. They also recorded early flowering in sole compared to intercropped cotton.

Deoche *et al.* (2004) recorded lower plant height, sympodial branches and dry matter when cotton was intercropped with greengram, blackgram and soybean over sole cotton in clayey soils of Akola in Maharashtra.

### **2.3.2 Boll number, boll weight and seed cotton yield per plant**

An understanding of probable effects of choosing different intercrop components on the production of number of bolls, boll weight and thereby seed cotton yield per plant is of paramount importance. This gives a fair understanding of the likely reduction in production of seed cotton yield while circumventing this sacrifice being compensated or over compensated with the production of intercrop component to satisfy the diverse requirements of crops often expected by the farm families. To this end, a review is drawn from the available literature.

Most often, short duration legumes are intercropped in cotton with assumed advantages of their early duration and harvest before the active growth of cotton commence another speculated benefit is the excretion of nitrogen fixed from the atmosphere for the benefit of associated non-legume contrasting this hypothesis. Varma and Kanke (1969) observed that the intercropping of blackgram was highly competitive. It reduced number of bolls per plant and their weight significantly. Confirming this finding Kumaraswamy and Hosmani (1978) also observed a substantial reduction in number of bolls per plant and boll size by intercropping cowpea, blackgram or greengram.

The later investigations of Deshpande *et al.* (1989) also exhibited the highly competitive influence of intercropped greengram or soybean in reducing boll number per plant. Such an ill-effect leading to a reduction in the number of bolls per plant was also observed by intercropping cotton with cowpea or blackgram by Tomar and Kushwaha (1991) and by intercropping soybean (Satao *et al.*, 1993). The cultivation of non-leguminous oilseed crop sesamum as an intercrop in cotton was also reported to be highly competitive. It reduced both number and weight of bolls per plant of cotton (Nagre, 1979).

Few reports document the adoptability of short duration legumes as intercrops to realize a bonus production without affecting the yield components of cotton. Devotta and Chowdappan (1976) observed that number of bolls per plant was not affected by greengram in cotton. Nehra and Kairon (1986) also confirmed this finding and stated that both number of bolls per plant and boll weight were not affected by intercropping this legume. Similarly Sheoran and Malik (1986) documented that the number of bolls per plant and boll weight were not influenced by intercropping mung or urd.

Fairly wide investigations established complimentary effect of intercropping legumes in improving the yield components of cotton. Robinson (1973) and Kunasekaran (1978) reported that

intercropping of greengram or blackgram increased fruiting points, boll number and boll weight of cotton compared to sole cotton. Janardhanam (1983) observed that intercropping of blackgram in paired rows of cotton increased boll number per plant and did not increase their weight. Ramamoorthy *et al.* (1994) also recorded profuse increase in the number of bolls per plant of cotton by intercropping blackgram. Tomar *et al.* (1994) also recorded beneficial effect of intercropping greengram or soybean between paired rows of cotton resulting in substantial improvement in size of bolls.

Relatively differential effects of different intercrops in a set of experiments are also indicated in some of the investigations. Jain *et al.* (1982) reported that the intercropping of greengram or urd did not influence the number of bolls per plant of cotton. But, this parameter was deterred by intercropping soybean. In contrast to this observation Rao (1982) recorded substantial reduction in the number of bolls per plant and boll size by option of intercropping greengram. They also observed that intercropping of fodder cowpea did not influence these parameters. Reddy (1982) reported that the intercropping of blackgram had a similar effect as of sole crop. While intercropping groundnut increased the size of bolls. Deoche *et al.* (2004) observed that number of bolls and seed cotton yield per plant were similar in cotton

intercropped with blackgram and sole crop. But, the intercropping of greengram or soybean reduced number of bolls and seed cotton yield per plant.

### **2.3.3 Removal of major nutrients**

Christopher and Chinnaswami (1991), observed no significant difference in total N uptake, P uptake and K uptake between sole cotton and paired row planted cotton with greengram, whereas uniform row cotton, with greengram significantly recorded higher total N uptake and K uptake over sole cotton.

Ramamoorthy *et al.* (1994) found no significant differences in available soil status of N and P due to intercropping of cotton with blackgram or sole cotton. Whereas, Sagare and Kapgate (1994) revealed that cotton + greengram intercropping system recorded higher N extraction (32.48 kg ha<sup>-1</sup>) and K extraction (22.82 kg ha<sup>-1</sup>) over sole cotton (13.13 kg ha<sup>-1</sup> and 19.27 kg ha<sup>-1</sup> respectively).

### **2.3.4 Effect on seed cotton yield**

A plethora of information is available on the performance of cotton seed production in relation to its intercropping with different

components. These results are highly variable. They are reviewed for each of the intercropping system separately.

#### **2.3.4.1 Intercropping with soybean**

Several investigations indicated that intercropping of soybean lead to considerable reduction in yield of cotton. Birajdar *et al.* (1980); Giri and Upadhyay (1980); Shanthaveerabhadraiah and Patil (1986); Seshadri and Natarajan (1989); Deshpande *et al.* (1989); Gode *et al.* (1992); Mansur *et al.* (1993); Yadav *et al.* (1993); Wankhade (1994); Khaistaria *et al.* (1994); Ramesh Babu *et al.* (1996); Pramila Rani *et al.* (2000); Velayutham and Sanbagavalli (2002) and Ramanjaneyulu and Reddy (2002) reported that seed cotton yields was significantly reduced by intercropping of soybean. These findings did not confirm earlier report of Saxena (1971) that cotton intercropped with soybean yielded seed cotton per hectare on par with the sole crop. The investigations of Borthakur and Barthakur (1992) and Mansur *et al.* (1993) established that soybean has a complimentary effect on the production of seed cotton yield in the intercropping system. This review indicate that by and large soybean is a competitive crop. The complimentary effects reported by few research workers needs further investigations in identifying such genotypic combinations, appropriate planting geometry and resource management practices.

#### 2.3.4.2 Intercropping with greengram

Kairan and Nandal (1971) opined that greengram as best suitable intercrop in cotton as it did not depress the yield of seed cotton. Kairan and Avatar Singh (1972) found that on sandy loam soils of Hisar one row of mung with phosphorus application in normally sown cotton increased the yield of cotton. Rao and Ramachandran (1973) suggested mung as suitable intercrop in cotton with 1 : 2 ratio in the northern state of Punjab. Sucha Singh and Rajinder Singh (1973) reported that cotton to mung in 1 : 1 proportion produced 462 kg extra yield of mung with a nominal reduction in cotton yield and it increased the yield of succeeding wheat crop.

Kairan *et al.* (1975) found that green gram when intercropped with cotton, increased the seed cotton yield from 1426 kg ha<sup>-1</sup> in pure cotton to 1542 kg ha<sup>-1</sup> in cotton intercropped with greengram. Devotta and Chowdappan (1976) obtained increased seed cotton yield of 810 kg ha<sup>-1</sup> in addition to 358 kg greengram as against 758 kg of seed cotton in pure stand on heavy black soils of Parbhani. Kunasekaran (1978) obtained statistically similar cotton yields with an intercropping combination of either 2 or 3 rows of greengram as intercrop under irrigated conditions.

Sadaphal *et al.* (1978) found greengram as the most suitable intercrop with cotton. Kunasekaran and Iruthayraj (1981) found that intercropping of 2 or 3 rows of greengram in cotton gave slightly higher seed cotton yield than cotton in pure stand. The results of intercropping experiments conducted by Rao (1982) at Sirsa in Haryana revealed that intercropping of mung bean (*Vigna radiata*) in the interspace between either normal or paired rows of cotton slightly decreased the seed-cotton yield. On the other hand, Nehra and Kairon (1986) from Hisar reported that the intercropping of mung in cotton by skipping one row of cotton will not have any adverse effect on seed cotton yield compared with cotton grown in solid rows.

Sheoran and Malik (1986) reported that the seed cotton yield was not affected by intercropping with greengram on the sandy loam soils of Hissar. But Mukerji *et al.* (1987) found a significant reduction in seed cotton yield in single row system when intercropped with this legume. Likewise, Hasham and Sulistyowati (1989) found a reduction in seed cotton yield when two rows of mung were inter sown in cotton. Similar observations were made by Deshpande *et al.* (1989) and Sethi *et al.* (1992) based on intercropping experiments conducted on medium black soils of Akola with cotton + mung. Further Sethi *et al.* (1992) reported that the seed cotton yield in pure stand was 20.7% more

in comparison to cotton + greengram intercropping system. However, the intercropping experiments conducted by Prasad *et al.* (1993) gave variable results. The highest yield of cotton was recorded in sole cotton and the lowest in cotton intercropped with greengram in the first year. But in the subsequent year, the seed cotton yield was not affected by this intercrop. Satao *et al.* (1993) reported that higher yield of seed cotton (45%) was obtained in sole crop of cotton than cotton + mung intercropping system on sandy clay loam soils of Akola. Sarkar *et al.* (1995) reported that on clay loam soils of Neempithi in West Bengal, yield reduction in upland cotton with greengram was 11% compared with the sole crop.

Ramesh Babu *et al.* (1996) recorded as low as 1527 kg ha<sup>-1</sup> with cotton + greengram intercropping as against 2204 kg ha<sup>-1</sup> with sole cotton in medium black soils at Arabhavi in Karnataka, whereas Christopher and Chinnaswami (1996) found no significant difference in cotton yield, with greengram intercropping at Coimbatore. Similar results were reported by Tomar *et al.* (1997). Rao (1997) recorded highest seed cotton yields in cotton + greengram (1 : 2) intercropping system at Hyderabad.

Parlawar *et al.* (2000) revealed that incorporation of greengram after first pod picking, recorded mean seed cotton

yield of 1955 kg ha<sup>-1</sup> over sole cotton crop (1886 kg ha<sup>-1</sup>) in shallow soils of Yavatmal in Maharashtra. Sanjay *et al.* (2003) and Deoche *et al.* (2004) reported that the sole cotton produced significantly more yield than in intercropping system.

#### **2.3.4.3 Intercropping with blackgram**

Nimbole *et al.* (1980) found that cotton intercropped with blackgram produced significantly more seed cotton yields than in solid or paired or skipped rows. Growing cotton in paired rows and intercropped with blackgram was most advantageous in black soils of Guntur (Janardhanam, 1983). Sardar *et al.* (1988) reported that fibre yield of cotton was significantly more when two blackgram rows were sown between cotton rows than one row of blackgram.

Deshpande *et al.* (1989) reported a significant yield reduction in cotton when intercropped with blackgram on medium black clay soils. Tomar and Kushwaha (1991) reported that there was no significant reduction in seed cotton yield by intercropping of blackgram on sandy loam soils of Morena in Madhya Pradesh. Slightly higher seed cotton yields were obtained with cotton + blackgram compared to pure cotton under dry land conditions (Ramamoorthy *et al.*, 1994).

Rao (1997) recorded significantly higher seed cotton yield in cotton + blackgram (1 : 2) over sole cotton at Rajendranagar, Hyderabad, whereas Deoche *et al.* (2004) recorded the yields on par with sole cotton and cotton intercropped with blackgram in vertisols at Akola, Maharashtra.

#### **2.3.4.4 Intercropping with cowpea**

Kairon and Nandal (1971) found that cowpea was a suitable intercrop in cotton as it did not depress the yield of seed cotton significantly. But, Kairon and Avtar Singh (1972) and Sucha Singh *et al.* (1972) reported that this legume reduced the cotton yield.

Alves *et al.* (1972) from a five year field trial reported that cotton yields were reduced by 5-18% as a result of intercropping with cowpea. Sucha Singh and Rajinder Singh (1973) studied that under Punjab agroclimatic conditions cotton + cowpea combination was not beneficial. Experiments conducted by Raghumurthy *et al.* (1974) indicated that the seed cotton yield was 4.44 tons in pure cotton stand in comparison to 3.03 tons ha<sup>-1</sup> from cotton + cowpea combination. Likewise Sadaphal *et al.* (1978), Nagre (1979) and Giri and Upadhyay (1980) found that cowpea as an intercrop in cotton suppressed the yield of cotton. Similar results were reported by Seshadri and Natarajan

(1989), Prasad *et al.* (1989) and Tomar and Kushwaha (1991). Venkatesan *et al.* (1987) showed that under rainfed conditions of Paiyur, seed cotton yield was reduced when cotton was intercropped with cowpea, similar results were reported by Ramesh Babu *et al.* (1996). Cotton yields were reduced by 47 per cent when the planting pattern was one cotton, two cowpea row configuration (Myaka and Kabissa, 1996).

Rao (1997) recorded significantly lower seed cotton yields in cotton intercropping with cowpea in 1 : 1 or 1 : 2 ratios over sole cotton at Rajendranagar, Hyderabad. Similar results were reported by Sanjay *et al.* (2003). On the contrary, Khan *et al.* (2001) recorded no significant difference in seed cotton yield grown as a sole crop or intercropped with this component.

#### **2.3.4.5 Intercropping with groundnut**

Balasubramanian (1950) in his review on intercropping pointed out that cotton could be grown with groundnut. Anjaneyulu and Venkoba Rao (1959) recommended cotton groundnut combination in red soils of Andhra Pradesh. Rao *et al.* (1960) suggested the adoption of late type of cotton rather than early types for inter cropping with groundnut.

Seshadri *et al.* (1956) obtained maximum yield from cotton + groundnut combination. They further noticed that bunch

groundnut had depressing effect on yield of cotton than the spreading groundnut. Rayappapillai *et al.* (1957) also favoured the cotton groundnut combination despite some reduction in cotton yield when mixed with groundnut. Anjaneyulu and Venkoba Rao (1959) found that cotton : groundnut in the ratio of 1 : 1; 1 : 2 and 1 : 5 were equally good. Rao and Rao (1961) considered cotton + groundnut as best combination. Joshi and Joshi (1965) found that intercropping cotton with groundnut in 1 : 2 ratio was more remunerative. Cotton when grown alone gave an yield of 1417 kg ha<sup>-1</sup>, but when intercropped with groundnut it produced 1394 kg of seed cotton in addition to 1300 kg of groundnut pods per hectare (Varma and Kanke, 1969). Mathur *et al.* (1972) reported that cotton : groundnut intercropping in 1 : 1 ratio was more remunerative. Mahapatra *et al.* (1975) found that the yields of seed cotton were reduced upto 12 per cent due to intercropping of groundnut.

Three year data on intercropping in Nagpur, indicated that intercrops affected cotton yields to varying degree in relation to the period these occupied the field and their growth habits. Groundnut did not appear to be compatible intercrop in heavy clay vertisols of Nagpur (Mudholkar, 1989).

Ramanjaneyulu (2000), recorded mean seed cotton yield of 14.89 q ha<sup>-1</sup> under sole cotton, whereas intercropping with

groundnut recorded seed cotton yield of 15.45 q ha<sup>-1</sup> at Rajendranagar, Hyderabad.

#### **2.3.4.6 Intercropping with sesamum**

Sarkar *et al.* (1995) reported that the intercropping of one or two rows of sesamum between the paired rows of cotton reduced its yield by 27% over sole cotton at Neempith in West Bengal in coastal alluvial clay loam soil.

Sarma *et al.* (1997) observed that the combined cultivation of sesamum and cotton by broadcasting or intercropping 1 row of the former was a favorable proportion. The yield of cotton was not reduced in either case. Gnanasambandan *et al.* (2001) reported that the suppression of weeds by intercropping sesamum enhanced the seed cotton yield. But, Khan *et al.* (2001) reported that the intercropping of sesamum had an adverse effect on the yield of cotton.

#### **2.3.5 Effect on quality characters**

Balasubramanian (1950) noticed higher staple length and ginning percentage of cotton when grown in mixture with groundnut. Robinson (1973) reported that the mean halo-length, lint index, seed index and ginning percentage were unaffected by blackgram and green gram as intercrops in cotton. Similar

observation on quality parameters viz., lint index, seed index and ginning percentage of cotton were made by Reddy (1984) with blackgram and groundnut intercropping in cotton where as experiments conducted by Janardhan (1982) indicated that the halo-length was significantly influenced and ginning percentage was unaffected by intercropping blackgram in cotton. Jain and Jain (1985) found no difference in halo length, where as ginning percentage increased significantly by intercropping cotton with greengram.

Mukerji *et al.* (1987) reported that greengram as an intercrop had no influence on halo length and ginning percentage over pure crop of cotton.

Rao (1990) reported that the halo-length and ginning percentage were unaffected by blackgram and greengram grown as intercrops in cotton. Sethi *et al.* (1992) also reported that the quality attributes, viz., ginning percentage, 2.5% span length, uniformity ratio, fineness and maturity coefficient were not affected significantly by groundnut and green gram intercropping in cotton.

Balasubramanian and Subramanian (1993) observed no significant variation in lint index, seed index, ginning percentage and halo length between sole cotton and cotton intercropped with

blackgram. Similarly Sagare and Kapgate (1994) observed no variation in ginning percentage due to cotton alone or cotton intercropped with greengram. Contrarily, Tomar *et al.*, (1997) recorded higher ginning percentage with intercropping of soy bean and mung over sole cotton .

Rao (1997) and Ramanjaneyulu (2000) found no significant difference in quality parameters of cotton by intercropping at Rajendranagar, Hyderabad.

#### **2.3.6 Moisture extraction**

Padhi *et al.* (1993) observed that by intercropping cotton with greengram, blackgram or groundnut, there was no significant difference in soil moisture content (%), at 30-60 cm and 60-90 cm, whereas at 0-30 cm, higher soil moisture content was recorded in cotton uniform row and paired row crop. The amount of water used by sole and intercrops, were more or less same in clay loam soils of Coimbatore (Christopher and Chinnaswami, 1996). Contrary to this, Rao (1997) noticed by intercropping of greengram, blackgram or cowpea with cotton a steady decrease in soil moisture percentage with advancement of cotton growth, upto 140 days over sole cotton, in red soils of Rajendranagar, Hyderabad. Similar results of sole crop of cotton utilizing less soil moisture, which was reflected in higher soil moisture storage than

in intercropped cotton was reported by Solaippan and Dason. (1998).

### 2.3.7 Per cent boll damage in cotton

Natarajan and Seshadri (1988) observed shedding of fruiting parts of cotton caused by insect attack was significantly less in cotton + soybean (88 fruiting parts plot<sup>-1</sup>) as against sole cotton (142 plot<sup>-1</sup>) as natural enemies like coccinellids were encouraged which have taken care of cotton pests. Similar results were reported from the experiments conducted at Nandyal. Cotton + soybean, cotton + groundnut intercropping system recorded significantly lower population of sucking pest, less boll damage, square damage as compared to sole cotton (Annual Report, RARS, Nandyal, 1991-92 and 1996-97). Suresh *et al.* (1993) also endorsed above results with cotton + soybean intercropping at Kovilpatti.

Seshadri and Natarajan (1989) observed marginally (3.59%) less shedding of fruiting parts of cotton in cotton + cowpea intercropping system as compared to sole cotton. Ramalho and Gonzaga (1990) by inter planting cotton with maize did not found any difference in the pest population.

Studies conducted by Vennila *et al.* (2001) at Central Institute of Cotton Research, Nagpur revealed that intercropping

of blackgram, greengram and soybean as intercrops with cotton, have not shown any effect on incidence of jassids, aphids and with regard to bollworms, only the incidence of pink bollworm was significantly higher on cotton with blackgram as intercrop. They opined that intercrops serve mainly as risk responsive to adverse weather conditions than against pest attack.

## **2.4 EVALUATION OF INTERCROPPING SYSTEMS**

Willey (1985) in his extensive review on evaluation and presentation of intercropping advantages pointed out this is the problematic area for quantitative evaluation. The major difficulties appear to identify sole crop systems with which intercropping should be compared and decide on the term or units in which advantages should be measured.

### **2.4.1 Seed equivalent yield**

To combine the total productivity of the intercropping system into a common term or unit for comparison with the sole crop yield equivalent of the more valuable crop was adopted by transforming the production of intercrops as seed equivalent yields.

Musande *et al.* (1981) observed that intercropping of cotton and groundnut was advantageous. It enhanced cotton seed

equivalents compared to the intercropping of cotton + greengram or blackgram. Prasad *et al.* (1993) also observed that cotton + groundnut intercropping system as more productive. The seed cotton equivalent yield was 26.3 q ha<sup>-1</sup> in contrast to 21 q ha<sup>-1</sup> of pure cotton. The experiments conducted by Khaistaria *et al.* (1994) in Rajkot also confirmed the beneficial effect of intercropping with this legume component. They observed that the cotton equivalent yield was 1038 kg ha<sup>-1</sup> by intercropping cotton with groundnut and 1008 kg ha<sup>-1</sup> by intercropping with soybean compared to seed cotton yield of 921 kg ha<sup>-1</sup> from sole cotton.

Birajdar *et al.* (1987) reported that intercropped with blackgram significantly increased cotton equivalent yields compared to sole crop of cotton.

In an intercropping experiment under irrigated conditions at Surat, Patel and Parmar (1995) recorded that intercropping of cotton with soybean produced cotton yield equivalent of 1975 kg ha<sup>-1</sup>, while the intercropping of groundnut resulted in cotton seed equivalent of 1894 kg ha<sup>-1</sup> compared to seed cotton yield of 1834 kg ha<sup>-1</sup> from sole crop of cotton.

Deviating from these production advantages Sanjay *et al.* (2003) recorded no significant improvement in cotton yield equivalents by intercropping cotton with greengram.

#### **2.4.2 Land equivalent ratio (LER)**

To calculate biological efficiency, Willey (1979) visualized that the productivities can be expressed in any units that provides a common base on which to combine and compare quite different crops. The general approach was referred to use relative units, of which the simplest is relative yield as described by dewit and Vander Bergh (1965). This was defined as the land equivalent ratio (LER). It indicates the relative land area required as sole crop to produce yields as achieved in intercropping system. Since the proposal of this concept, it was widely used in intercropping research.

Rao (1991) recorded an LER of 1.72 by the expedient of intercropping blackgram in cotton. Padhi *et al.* (1993) obtained an LER of 1.67 by intercropping blackgram and 1.47 by intercropping greengram in cotton. The intercropping of one or two rows non-leguminous oil seed crop – sesamum was detected to be inefficient as it reduced the LER to less than unity by Sarkar *et al.* (1995). Yadav *et al.* (1993), Patel *et al.* (1995), Satao *et al.* (1996), Pramila Rani *et al.* (1998) and Singh *et al.* (2000)

observed that intercropping one or two rows of soybean in cotton enhanced the LERs, thereby indicating increased productivity of the total system compared to their cultivation as sole crop.

#### **2.4.3 Area time equivalent ratio (ATER)**

Heibsch and McCollum (1987) considered the importance of land utilization in terms of the time scaling by the combined cultivation of two crops in addition to land use efficiency (LER) and proposed the concept of area time equivalent ratio. This index was utilized by Sarkar *et al.* (1995) in an intercropping experiment on intercropping of upland cotton with one or two rows of sesamum. They observed that intercropping of this component was inferior to sole crops, whereas intercropping of two rows of greengram between uniform cotton rows resulted in higher ATER values. Ramanjaneyulu and Reddy (2002) recorded high ATER values with intercropping of cotton with groundnut and soybean.

#### **2.4.4 Effective ( $\lambda$ ) land equivalent ratio (ELER)**

Mead and Willey (1980) pointed out that there is an inherent difficulty in using LER, since it assumed that the harvested proportion of the two crops in each situation is exactly the one required by farmer. To meet this difficulty they extended the concept of LER to effective land equivalent ratio (ELER or  $\lambda$  LER). This index measures the biological efficiency of an

intercropping system in which a desired yield proportion is set *a priori*. This concept was evaluated for agronomical experiments on intercropping of crops like maize + redgram (Mead and Willey, 1980), intercropping of Brussels with Summer Cabbage (Salter *et al.*, 1985) intercropping of wheat with chickpea (Bijan *et al.*, 1996), intercropping of castor with pearl millet or groundnut (Srinivas, 2003) and intercropping of toria with berseem (Vidyadhari, 2004). Such attempts are lacking in intercropping studies with cotton.

#### **2.4.5 Staple land equivalent ratio (SLER)**

Reddy and Chetty (1984) had put forth a very sensible and practical argument that in practice a more important criterion in intercropping is to maintain a particular yield level of one component crop defined as a minimum percentage of its yield in sole stand. In subsistence agriculture a farmer must normally meet his domestic requirements for a staple crop. However, he may obtain additional income from a second crop. It may therefore important to maintain their yield of staple crop at a minimum threshold or standardized proportion of its sole crop yield. To meet this condition they modified ELER to staple land equivalent ratio. This refined concept has been utilized in a limited number of investigations. This concept was utilized by Bina

(1989) in sunflower + groundnut intercropping system, Srinivas (2003) in castor, pearl millet or groundnut intercropping system and Vidyadhari (2004) in intercropping of toria with berseem.

#### **2.4.6 Bivariate analysis of variance**

Pearce and Gilliver (1978) argued that the quantitative analysis of data from intercropping experiments by converting the total yield of different crops into a single unit either monetary value, Calorific value or LER have inherent difficulties. The prerequisite for carrying out analysis of variance is the normal distribution. In number of situations it does not follow. They also stated that performance of two crops growing together is not always independent of their influence. In practical situations they may compete, compliment or do not influence each other. This effect cannot be visualized. They suggested bivariate analysis of variance on a sound statistical principles. This takes care of three types of situations and can be represented graphically for an instant understanding of the results. This help to interpret the results as well as the analysis of data along with the type of interaction between two crops involved more effectively. The application of this concept in intercropping systems with cotton are lacking.

Satisfactory efforts were made to draw more precise information on the efficiency of biological productivity of intercropping sorghum with pigeonpea by Chetty and Reddy (1984) and Choudhary and Bhargava (1986). Brussels sprouts with cabbage by Salter *et al.* (1985), sunflower with groundnut intercropping by Bina (1989), castor with pearl millet or groundnut by Srinivas (2003) and toria with berseem by Vidyadhari (2004).

#### **2.4.7 Economic evaluation**

The economics of a production system is often the most desired option while aiming to enhance the total productivity per unit area and obtain crops of diverse domestic and economic needs.

Ample literature is available to ascertain the relatively more economical intercropping system than several others in a given agro-ecological region. Several investigators evaluated the monetary advantage in terms of gross economic value.

Patil *et al.* (1984) recommended the intercropping of soybean in cotton to enhance monetary value of the total produce. This influence was further strengthened from the investigations of Mansur *et al.* (1993) that soybean intercropped with two or three rows in cotton was more remunerative.

Birajdar and Nankar (1978) observed that the monetary value of the total produce increased by intercropping greengram or groundnut in Parbhani. Musande *et al.* (1981) also reported that the gross monetary returns increased by intercropping greengram in cotton.

In red soils of Rajendranagar, Hyderabad, Reddy (1982) recorded an increased gross income of Rs 5265 ha<sup>-1</sup> by intercropping blackgram compared to Rs 4386 ha<sup>-1</sup> from the sole crop.

Venkatesan *et al.* (1987) observed that intercropping of cowpea reduced the monetary value of the intercropping system. But, Parlwar *et al.* (2000) obtained more gross returns through this intercropping system.

Greater monetary advantages by inter planting groundnut in cotton were confirmed. Rao and Rao (1961); Reddy (1961); Patel (1964); Joshi and Joshi (1965); Varma and Kanke (1969); Mathur *et al.* (1972). The evaluation of these productive systems for gross values is less meaningful. A particular intercropping system may provide higher gross value, sometimes the additional expenses on intercropping may also enhance the value of the products, while the net returns are low. Therefore, this specific

evaluation of intercropping system is not always a wise proportion.

A farmers' objective is to realize increased net profit per hectare. But, farmers who have a low investment capacity will be convinced with a productive system which fetch more income with less expenses rather than more profits with more expenses per unit of land. This option provides a farmer a choice to select intercropping system which maximizes the profit per unit area or per rupee investment. Very often the yield data from intercropping system is transformed to gross returns per hectare, net returns per hectare and per rupee investment for statistical comparison. This approach is subjected to criticism. To normalize this data, these economic values should be transferred to relative net returns (RNR) indices. This gives the relative superiority of different intercropping systems in terms of profit per unit area (Jain and Rao, 1980).

Sufficient information has been built up by several investigators on relative profits obtained per hectare and per rupee in cotton intercropped with other components. Deshpande *et al.* (1989), Seshadri and Natarajan (1989) and Pramila Rani (2005) reported that intercropping of soybean was uneconomical. It fetched substantially low net income per hectare. In consonance with these results Deoche *et al.* (2004) reported that

intercropping of soybean was uneconomical both in terms of net profit per hectare and per rupee investment.

A number of research findings confirmed that intercropping of greengram was highly profitable. Kairon and Avtar Singh (1972) and Kairon *et al.* (1975) reported that additional profit of Rs 687 to Rs 798 ha<sup>-1</sup> was realized from cotton greengram combination. Rao (1977) also realized an additional profit of Rs 784 ha<sup>-1</sup>, over sole cotton. Dayal and Kale (1978) suggested intercropping of two rows of greengram between two rows of cotton at Vasad, Gujarat to realize high profits. Kunasekaran (1978) recorded high net income of Rs 4514 ha<sup>-1</sup> by intercropping 3 rows of greengram and Rs 4221 ha<sup>-1</sup> with two rows compared to low net gain of Rs 3473 ha<sup>-1</sup> from sole cotton. Sadaphal *et al.* (1978) also found that greengram was most compatible intercrop consistently giving good profits without affecting yield of cotton compared to sole crop. Yadav (1978) suggested the intercropping of this legume not only to obtain extra income but to enrich the soil fertility.

Bavale and Vyahalkar (1981) observed that intercropping of greengram at Nanded reduced the seed cotton yield marginally, but this combination gave significantly higher net profits in comparison to sole cotton. Sankaran and Balasubramanian (1982) observed that the net profitability of intercropping system

in Tamilnadu accrued mainly through harvest of additional seed yield from intercropped greengram. Nehra and Kairon (1986) also realized an additional income of Rs 244 to 1466 ha<sup>-1</sup>, from this intercropping system. In Akola, Prasad *et al.* (1989) and Sethi *et al.* (1992) observed that intercropping of greengram was most profitable. Sarkar *et al.* (1995) recommended that production potential and monetary advantage can be increased by one or two rows of greengram than to confining sole crop of cotton. Despite the concrete outcome of all these investigation that the intercropping of greengram is a profitable venture. Prasad *et al.* (1993) at New Delhi explored that intercropping of greengram in cotton reduced the profit per hectare compared to sole crop.

Kumaraswamy and Hosmani (1978) recorded low net profit per hectare by intercropping blackgram in cotton. But, Chellamuthu *et al.* (1987) recommended inter planting of blackgram or cluster bean in cotton to realize higher profits during the years of low rainfall in rainfed black soils of Kovilpatti in Tamilnadu. The observation was also true in an investigation at Paiyur (Venkatesan *et al.*, 1987). The risk of loss in profit by the choice of intercropping blackgram in cotton was also reported by Deshpande *et al.* (1989); Tomar and Kushwaha (1991); Rao (1991); Ramamoorthy *et al.* (1994) and Tomar *et al.* (1994). But the results of Deoche *et al.* (2004) from Akola in Maharashtra

indicated that intercropping of blackgram in cotton as more profitable.

Results on the profitability of intercropping cowpea are highly contrasting. Rao (1977) suggested intercropping of cowpea for grain or fodder to increase the profits per hectare. Jain *et al.* (1982); Shaktawat and Singh (1985) also realized more profit per hectare from this system. Seshadri and Natarajan (1989) and Tomar and Kushwaha (1991) also suggested cultivation of cowpea as an intercrop to realize additional profit per hectare.

Kumaraswamy and Hosmani (1978) recorded a net loss of Rs.509 ha<sup>-1</sup> by intercropping cowpea. Nagre (1979) also registered a net loss of income by 11% compared to sole crop.

Divekar and Kurtakoti (1961) from Dharwad, Deshpande *et al.* (1989) from Akola and Koraddi *et al.* (1991) from Dharwad and Sethi *et al.* (1992) from Akola recorded increased profit per hectare by intercropping groundnut in cotton. But, Ramanjaneyulu and Reddy (2002) observed that profits due to this intercropping were marginal at Hyderabad.

Sarma *et al.* (1997) observed that broadcasting of sesamum in cotton at Diphu, Assam increased gross returns, net returns and net returns per rupee investment.

Considering the complexity of several methods to evaluate intercropping advantages for different objectives Mead and Stern (1979); Mead and Riley (1981) and Oyejola and Mead (1982) reported that there is no single straight forward criterion to adjudge the performance of different intercropping systems and concluded that various different aspects of yields should be considered to extract all the available information. This suggestion has been strengthened by Chetty and Reddy (1984) and Salter *et al.* (1985).

A limited number of research workers followed this criterion for a limited number of evaluation tools hitherto developed for holistic evaluation of intercropping systems. Sarkar *et al.* (1995) visualized from above criterion and recorded higher seed cotton equivalent, monetary advantage, LER and ATER by intercropping two rows of greengram between paired rows of cotton. Rao (1997) reported that intercropping of greengram, blackgram, cowpea in cotton resulted in higher seed equivalents, relative net return index, LER, gross and net monetary returns.

Deoche *et al.* (2004) also reported that intercropping of this component increased the seed cotton yield, gross returns, net income per hectare and per rupee investment.

# ***Material and Methods***



## CHAPTER – III

### MATERIAL AND METHODS

The investigation entitled “Planting techniques and intercropping studies in Cotton” was conducted during *Kharif* 2004 and 2005. The details of the experimental materials used and methods adopted in the present investigation are elucidated in this chapter under appropriate heads.

#### 3.1 DETAILS OF THE EXPERIMENTAL SITE

##### 3.1.1 Location

The present investigation was carried out at the Agricultural Research Station, Warangal. The farm is located at an altitude of 270 m above mean sea level on 18°03' North latitude and 79°22' East longitude. In the National Agricultural Research Project zonation it comes under the Northern Telangana region of Andhra Pradesh.

##### 3.1.2 Soil

A composite soil sample was drawn from 0 to 30 cm depth from different spots moving randomly in a zig zag manner from the entire field. It was analyzed for different physico-chemical

**Table 1 : Physico – chemical properties of the experimental site**

Sl. No.	Particulars	Results	Method adopted
1.	<b>Physical properties</b>		
	<b>Mechanical analysis</b>		
	<b>Soil fraction</b>	<b>% composition</b>	
	Sand	62.3	International pipette method (Page <i>et al.</i> , 1982)
	Silt	23.4	
	Clay	14.3	
	Textural class	Sandy loam	
2.	<b>Chemical analysis</b>		
	Soil reaction (pH)	7.23 (Neutral)	Glass electrode pH meter (Jackson, 1967)
	Electrical conductivity (dSm <sup>-1</sup> )	0.148 (Normal)	Digital EC meter (Jackson, 1967)
	Organic Carbon (%)	0.41 (low)	Walkley and Black (1934)
	Available nitrogen (Kg ha <sup>-1</sup> )	150.46 (low)	Modified alkaline permanganate method (Kjeltec Auto 1030 Analyser)
	Available phosphorus (kg ha <sup>-1</sup> )	26.40 (high)	Olsen method (Olsen <i>et al.</i> , 1954)
	Available Potassium (kg ha <sup>-1</sup> )	184.25 (medium)	Flame photometer method (Jackson, 1973)

properties by adopting standard procedures. The results are presented in table 1.

The soil was sandy loam in texture, neutral in reaction, low in organic carbon and available N ( $150.46 \text{ kg ha}^{-1}$ ), high in available P ( $26.4 \text{ kg ha}^{-1}$ ) and medium in K ( $184.25 \text{ kg ha}^{-1}$ ).

## **3.2 CLIMATE**

### **3.2.1 Weather conditions during crop growth**

The data pertaining to various weather elements during the crop growth period recorded at Agriculture Research Station, Warangal are presented in the Appendix I and II. A total rainfall of 366.8 and 593.8 mm was received during the entire crop period of *Kharif* 2004 and 2005 respectively. July was the wettest month in both the years. The temperatures ranged from  $18.8^{\circ}\text{C}$  to  $31.1^{\circ}\text{C}$  and  $17.5^{\circ}\text{C}$  to  $36.4^{\circ}\text{C}$  respectively during *Kharif* 2004 and 2005. The mean relative humidity ranged from 55.1 to 88.6% in first year and from 60.6 to 90.7% in second year.

### **3.2.2 Length of crop growing season**

Length of crop growing season was worked out as per the procedure outlined by Cocheme and Franquin (1967). The available weekly rainfall data of fourteen years at Agriculture Research Station, Warangal was used. The potential

evapotranspiration was worked out as per the procedure outlined by Blaney and Criddle (1950). The ratio of P/PET in each week was plotted on a graph and a smooth curve was drawn passing through these points. These are described in the chapter results and presented in fig.3.

### 3.2.3 Dependable rainfall

Dependable rainfall was worked out following the procedure outlined by Hargreaves (1971) at  $\geq 75\%$  probability.

For computing probability, the concerned time series rainfall data was arranged in a descending order. Then dependable rainfall was calculated as :

$$\text{Dependable rainfall} = \frac{n \times p}{100}$$

Where

n = sample size

p = probability required in percentage

These are described in the chapter results and presented in fig. 4.

### 3.2.4 First order Markov chain model

First order Markov Chain model gives the information on initial and conditional probabilities for various threshold limits of rainfall. Under initial probabilities, the probability of a given period is wet or dry is estimated while in the case of conditional probabilities, if given period is wet or dry, then the chances of  $(i + k)^{\text{th}}$  period is wet and given as wet/wet or wet/dry are estimated. A period is said to be wet when the weather parameter of that period exceeds a threshold limit.

The method of computing initial and conditional probabilities using the first order Markov Chain model described by Gabriel and Neumann (1962); Gates and Tong (1976) and Hann *et al.* (1976) was followed.

#### Step-1 :

Compute for each week the number of occasions the weekly rainfall of week  $i$  ( $R_i$ )  $\geq$  the threshold limit  $x$ . If this condition is satisfied in 'n' years out of the total  $N$  years then the probability of a given week  $i$  is wet ( $W_i$ ) is given as

$$W_i = (n/N) \times 100, \%$$

and thus a given week  $i$  is dry ( $D_i$ ) is given as

$$D_i = 100 - W_i, \%$$

These estimates present the initial probabilities of a given week  $i$  is wet or dry.

Step-2 :

Compute for each week, the number of occasions

$$R_i \geq x \quad \text{and} \quad R_{i+k} \geq x$$

It is seen in step-1 that of the  $N$  years in  $n$  years  $R_i \geq x$  in week  $i$  and thus if in  $n'$  years out of  $n$  years,  $R_{i+k} \geq x$ , then the probability of getting a wet on week  $i$  and week  $i + k$ , namely a wet week followed by a wet week (if  $k=1$  [cw/w]) is given as

$$(W/W)_i = (n'/n) \times 100, \%$$

and thus a dry week followed by a wet week, (D/W) is given as

$$(D/W)_i = 100 - (W/W)_i, \%$$

These two estimates present the conditional probabilities of a wet or dry week ( $i + 1$ ) followed by a wet week ( $i$ ).

Step-3 :

Compute for each week, the number of occasions,

$$R_i < x \quad \text{but} \quad R_{i+k} \geq x$$

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It is seen in step-1 that of the N years in N-n years  $R_i < x$  in week i and thus in n" years out of N – n years  $R_{i+k} \geq x$ , then the probability of getting dry on week i and wet on week i+k, namely a wet week followed by a dry week (if  $k = 1$ ) [(W/D)<sub>i</sub>] is given as

$$(W/D)_i = [n''/(N-n)] \times 100, \%$$

and thus a dry week followed by a dry week, (D/D) is given as

$$(D/D)_i = 100 - (W/D)_i, \%$$

These two estimates present the conditional probabilities of a wet or dry week (i + 1) followed by a dry week (i).

### 3.2.5 Water balance model

The FAO water balance model (Frere and Popov, 1979; FAO, 1986) as given by Reddy (1991) was used in the present investigation. The crop coefficients were extracted from FAO, Irrigation and Drainage, paper No. 33 (Doorenbos and Kassam, 1979). The details of method adopted are :

Compute the total water requirement (TWR) as

$$TWR = \sum_{j=1}^i [PE_y \times Kc_j] + \sum_{j=i+1}^k [PE_n \times Kc_j]$$

Where j = 1 refers to planting week ;

j = k refers to the Harvesting week

i refers to current week;

PE<sub>y</sub> = Current potential evapotranspiration

K<sub>c</sub> = Crop coefficients; PE<sub>n</sub> = Normal potential evapotranspiration

Compute water requirement (WR) for a given week i as :

$$WR_i = (PE_y \times K_c)_i$$

Compute rainfall deficit or surplus (WR') for a given week i as :

$$WR'_i = (R_y - WR)_i$$

Where R<sub>y</sub> = Current rainfall, WR = Water requirement

If WR'<sub>i</sub> > 0 then surplus or if WR'<sub>i</sub> < 0 then deficit.

Compute soil moisture reserve (SM) for a given week i as :

$$SM'_i = SM_{i-1} + WR'_i$$

If SM'<sub>i</sub> < 0 then D<sub>i</sub> = SM'<sub>i</sub>, SM<sub>i</sub> = 0 and S<sub>i</sub> = 0

Where D = Deficit

If SM'<sub>i</sub> > AWC then S<sub>i</sub> = SM'<sub>i</sub> - AWC, SM<sub>i</sub> = AWC and D<sub>i</sub> = 0

AWC = Water holding capacity of soil

If  $0 \leq SM'_i \leq AWC$  then S<sub>i</sub> = D<sub>i</sub> = 0 and SM<sub>i</sub> = SM'<sub>i</sub>

Compute water requirement satisfaction index (I) for a given week

i as

On planting week i is given as  $I = 100\%$

On subsequent weeks, if deficit (i.e.  $D_i < 0$ ) then

$$I_i = I_{i-1} - (D_i / TWR) \times 100$$

### 3.3 CROPPING HISTORY

The cropping history of the experimental site for the previous three years is summarized below :

**Table 2 : Previous cropping history of the experimental site**

S. No.	Year	Season	Cropping pattern
1.	2001-02	<i>Kharif</i>	Cotton
		<i>Rabi</i>	
		Summer	Greengram
2.	2002-03	<i>Kharif</i>	Cotton
		<i>Rabi</i>	
		Summer	Greengram
3.	2003-04	<i>Kharif</i>	Greengram
		<i>Rabi</i>	Fallow
		Summer	Greengram
4.	2004-05	<i>Kharif</i>	Present investigation
		<i>Rabi</i>	
		Summer	Fallow
5.	2005-06	<i>Kharif</i>	Present investigation
		<i>Rabi</i>	

## **3.4 EXPERIMENTAL DETAILS**

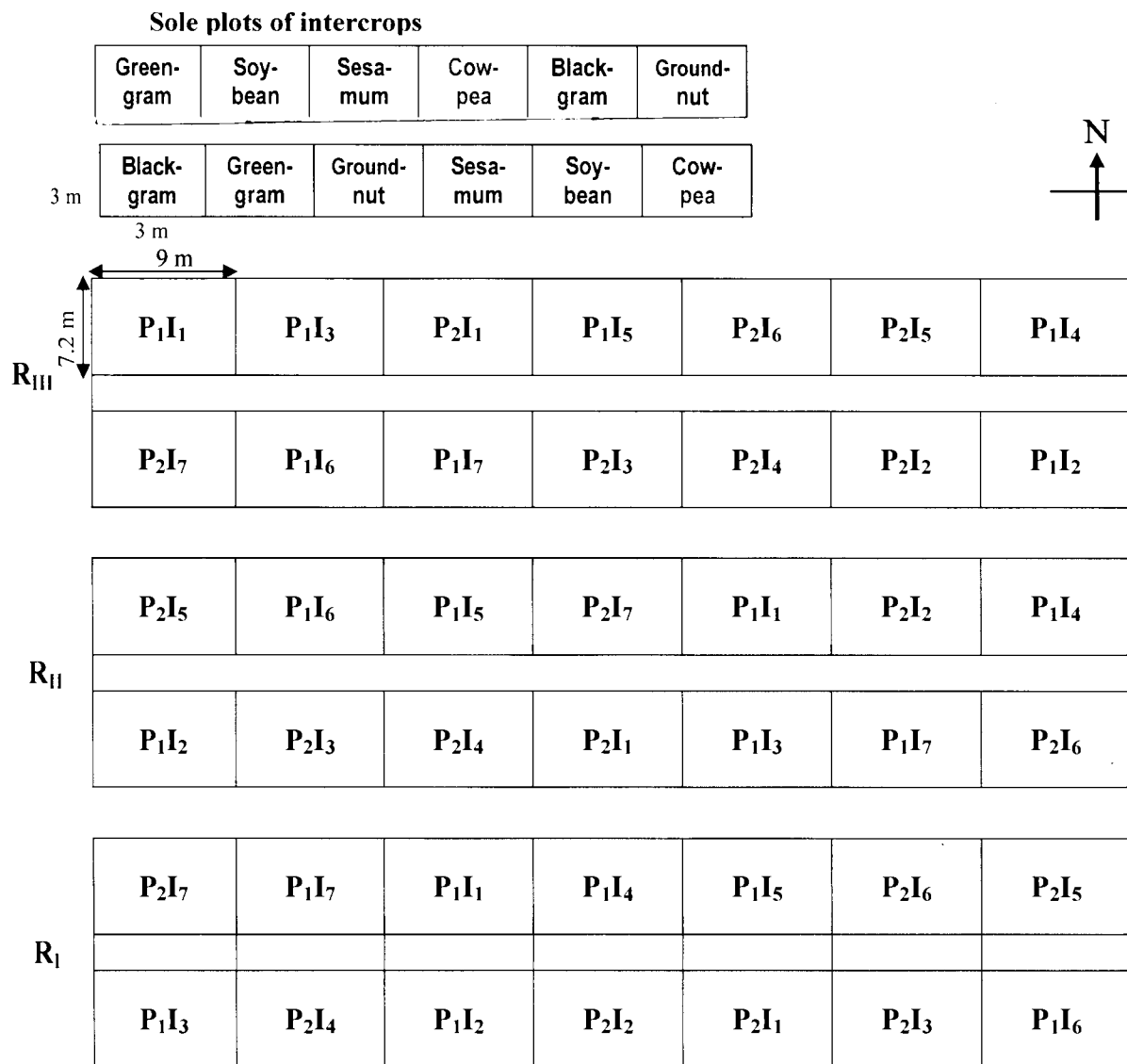
### **3.4.1 Design and lay out**

The experiment was laid out in Randomised Block Design with three replications. The lay out plan of the experiment presented in fig. 1 and the planting patterns are shown in fig. 2.

General view of the experimental field, planting patterns of cotton under sole cropping and with different intercropping components are presented in plates 1 to 4.

### **3.4.2 Treatmental details**

There were 14 treatments. They involved planting pattern of cotton in uniform row spacing of 90 cm and paired row planting at 120/60 cm. Spacing between the plants within the rows was 90 cm in both the planting patterns. Cotton was grown as a sole crop in both the patterns and intercropped with soybean, greengram, blackgram, cowpea, groundnut or sesamum. Two rows of these components were intercropped between two rows of cotton in uniform row planting and 3 rows between the paired rows in the paired row planting. Each of the intercrop was also raised as sole crops in two plots adjacent to the experiment for their use in the calculation of land equivalent ratios.

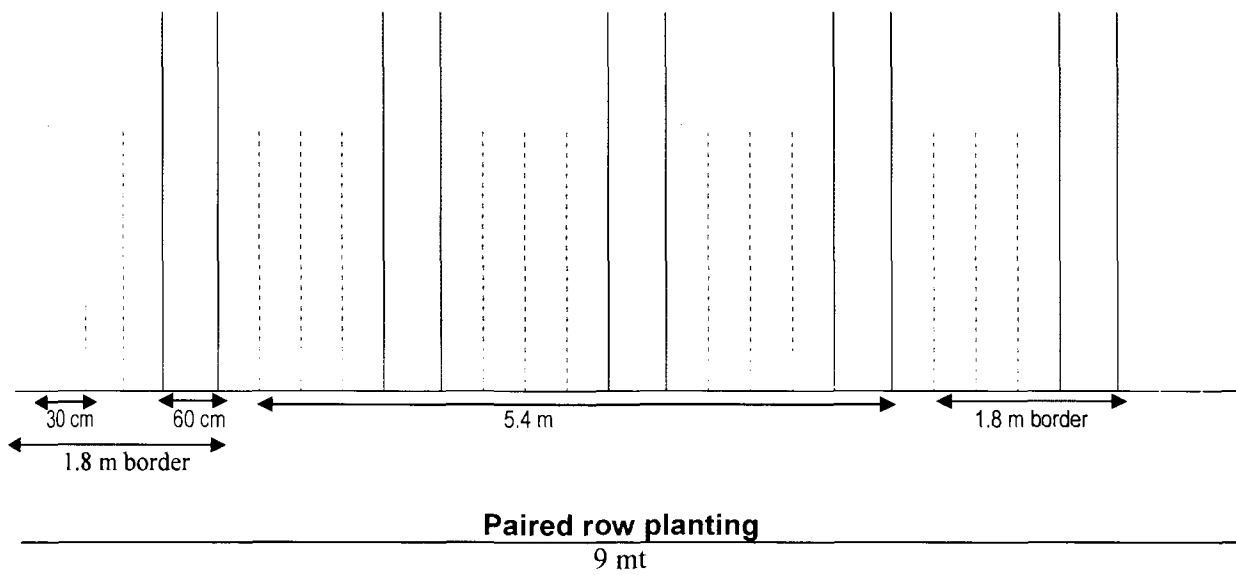
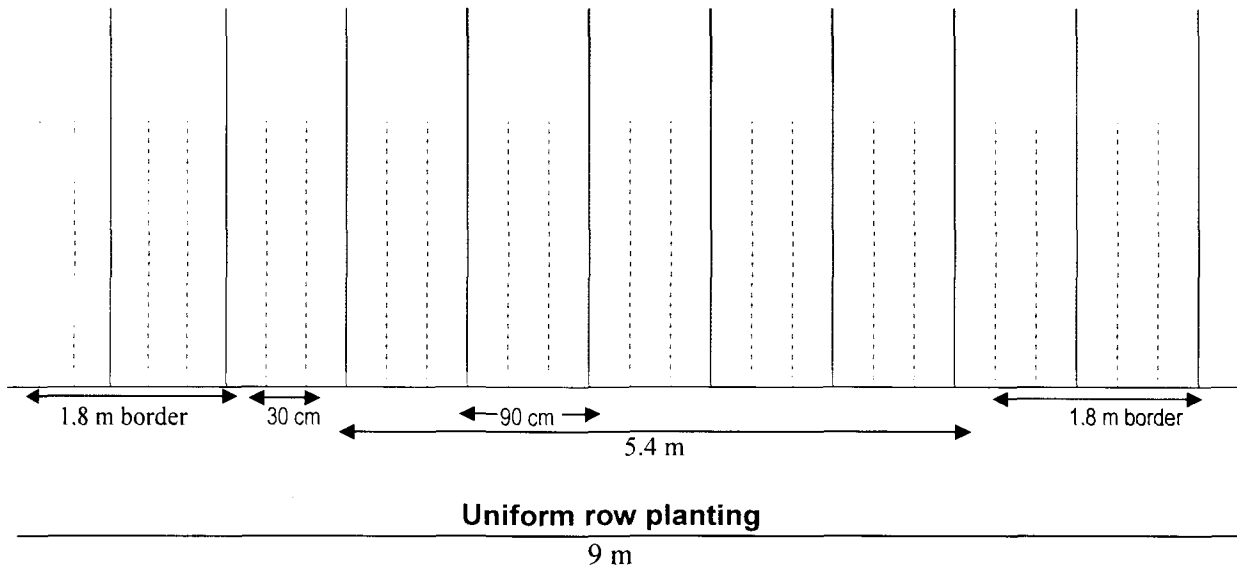


### Treatment details

	Planting pattern	Intercrops
Design : RBD	P <sub>1</sub> : Uniform row planting (90 x 90 cm)	I <sub>1</sub> : Sole cotton
Treatments : 14	P <sub>2</sub> : Paired row planting (120 / 60 x 90 cm)	I <sub>2</sub> : Cotton + soybean
Replications : 3		I <sub>3</sub> : Cotton + Greengram
Plot size		I <sub>4</sub> : Cotton + Blackgram
Gross : 9 x 7.2 m		I <sub>5</sub> : Cotton + Cowpea
Net : 5.4 x 5.4 m		I <sub>6</sub> : Cotton + groundnut
		I <sub>7</sub> : Cotton + Sesamum

Fig. 1 : Layout plan of the experiment

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— Cotton  
----- Intercrops

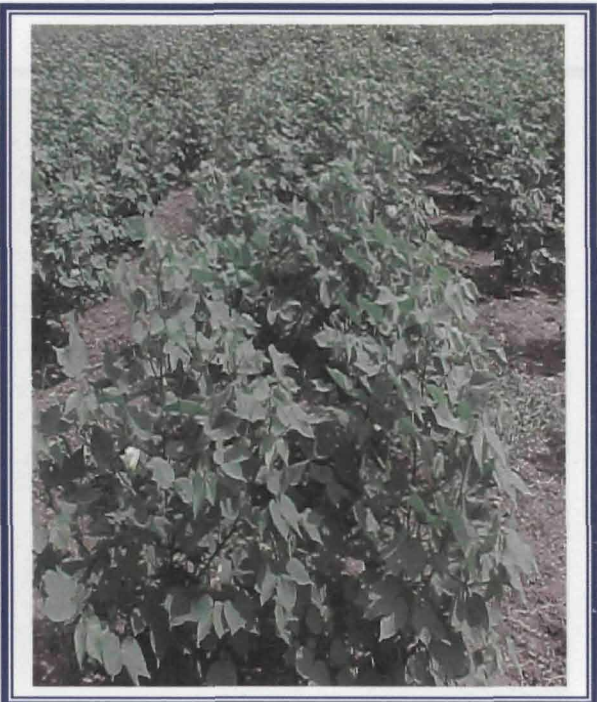
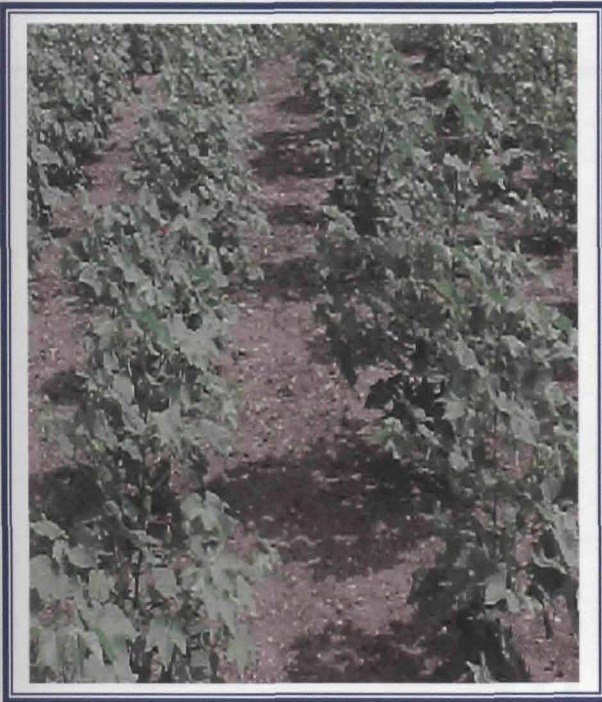
**Fig. 2 : Configuration of planting pattern**

Uniform rows General view of experimental field Paired rows



Uniform rows

Paired rows

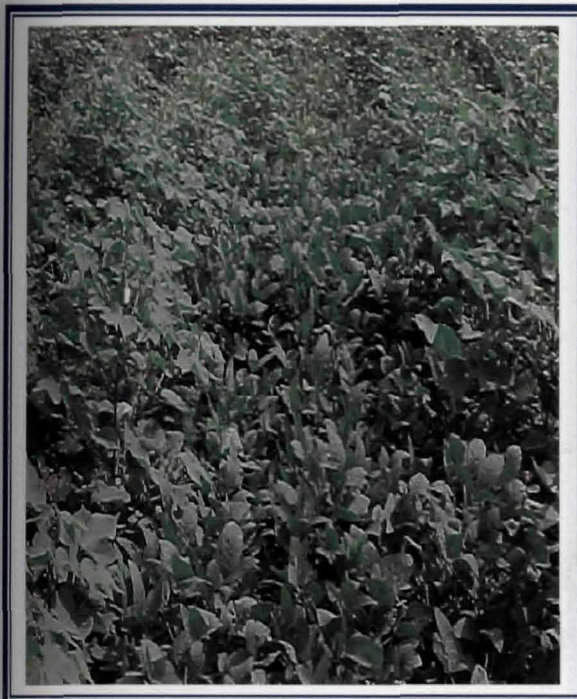


Sole cotton

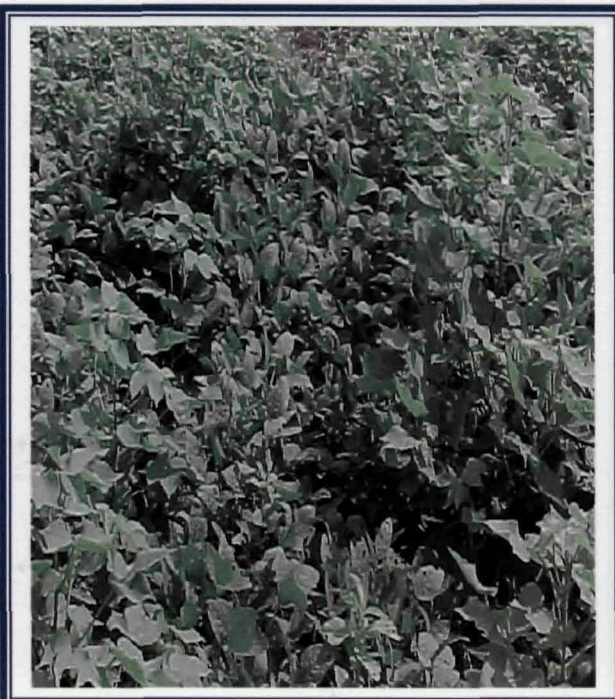
Cotton + Green gram

Plate 1 : General view of experimental field, sole cotton uniform and paired rows

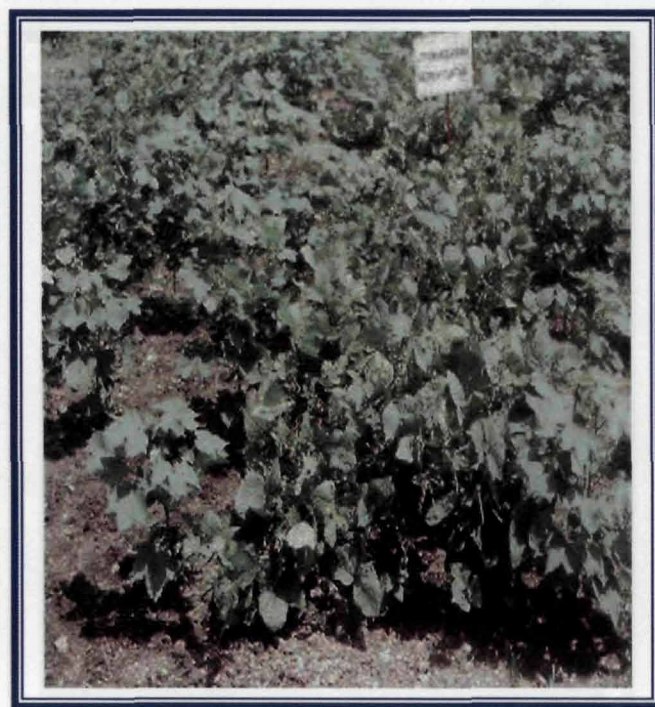
Uniform rows



Paired rows



Cotton + Soybean

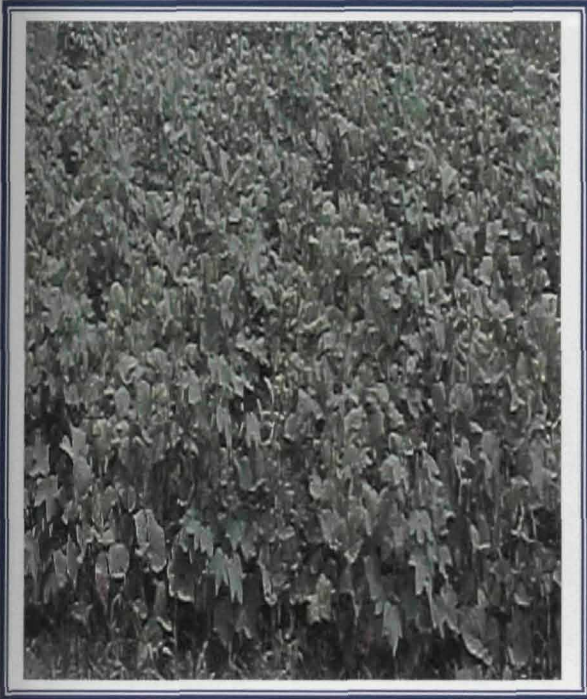


Cotton + Green gram

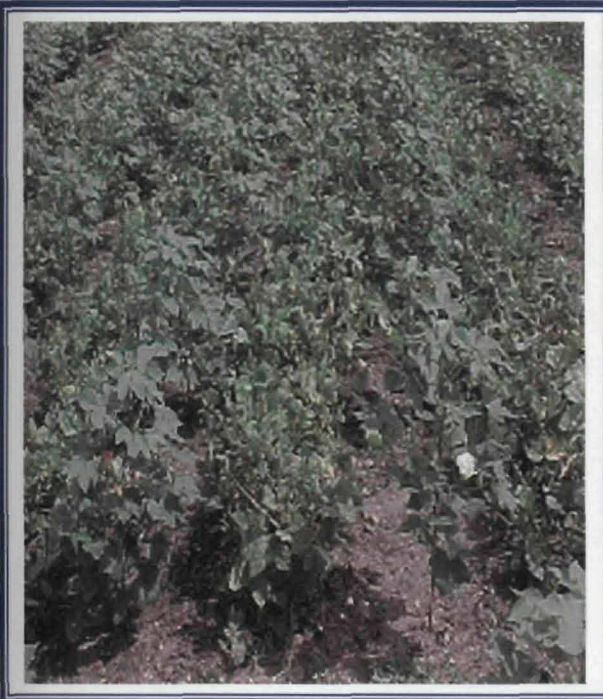
Plate 2 : Cotton + Soybean and cotton + Greengram uniform and paired rows

Uniform rows

Paired rows



Cotton + Black gram



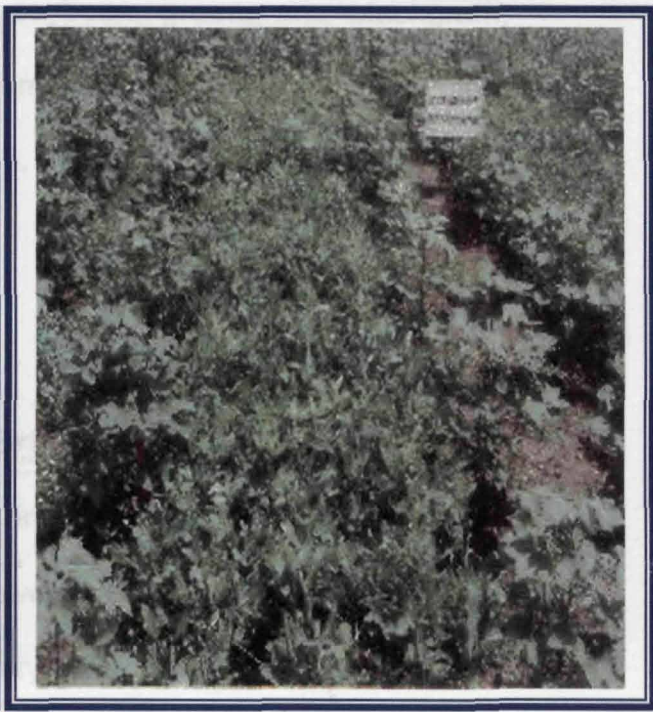
Cotton + Cowpea

Plate 3 : Cotton + Blackgram and Cotton + Cowpea uniform and paired rows

3.4.3 Variation

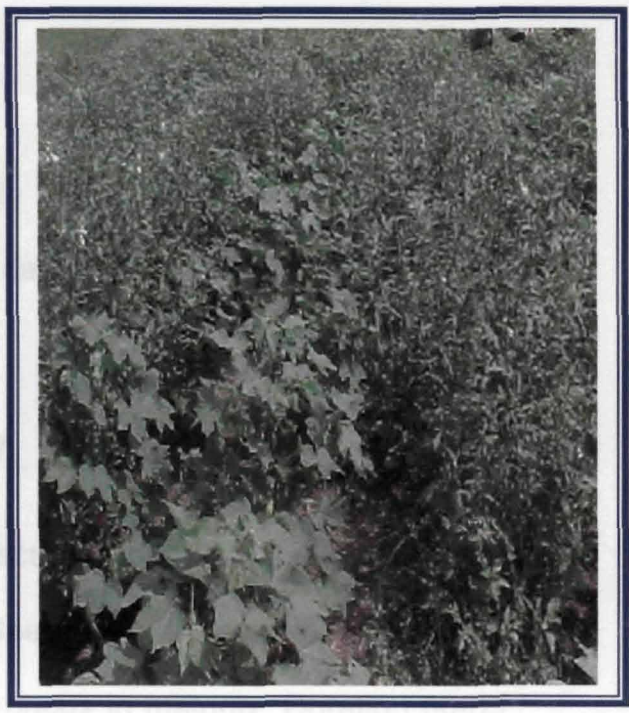
Uniform rows

Paired rows



Cotton + Groundnut

is buff and bolts duration of the crop is 140-150 days



Cotton + Sesamum

days. Resistant to yellow mosaic virus

Plate 4 : Cotton + Groundnut and Cotton + Sesamum uniform and paired rows

### **3.4.3 Varieties**

The varieties of cotton, soybean, greengram, blackgram, cowpea, groundnut and sesamum tried in the present experiment were NCS-145 (Bunny), JS 335, WGG 37, LBG20, Local, TMV2 and Madhavi respectively.

#### **3.4.3.1 Cotton : NCS-145**

This cotton hybrid NCS-145 of M/s. Nuziveedu Seeds Limited, Secunderabad, is an intra specific hybrid, bushy with open growth at bottom. The leaves are dark green, broad lobed, small to medium in size and hairy. The petals are creamy, pollen is buff and bolls are medium sized. The duration of the crop is 140-150 days.

#### **3.4.3.2 Soybean : JS 335**

JS 335 is medium in twig height and semi-determinate in growth habit. It matures in 90 days. Flower colour is purple and no hair on pod.

#### **3.4.3.3 Greengram : WGG 37**

WGG 37 is medium erect and determinate with bearing mainly only top of the plant. Seeds medium bold and attractive shining green in colour. Synchronous in maturity. Duration 60-65 days. Resistant to yellow mosaic virus.

#### **3.4.3.4 Blackgram : LBG 20**

LBG 20 is dwarf, bushy with dark green foliage. Seed colour is shining black. Duration 65-70 days. Moderately resistant to yellow mosaic virus.

#### **3.4.3.5 Cowpea : Local**

Local Cowpea is medium erect with white medium sized seed. Duration is 60-65 days.

#### **3.4.3.6 Groundnut : TMV-2**

The TMV-2 is a Spanish bunch variety with erect growth. It produces two seeded small pods with rose coloured testa. It matures in about 105 days. It is a non-dormant variety.

#### **3.4.3.7 Sesamum : Madhavi**

Madhavi is a selection from local material of Vishakapatnam. Matures in 80 days. The seeds are light brown in colour.

### **3.5 CULTIVATON DETAILS**

All the requisite operations were carried out as briefed in table 3.

Table 3 : Calendar of operations

S. No.	Operation	Date		
		<i>Kharif-2004</i>	<i>Kharif-2005</i>	
1.	Preparatory cultivation			
	a. Ploughing	07-06-2004	16-06-2005	
	b. Harrowing	09-06-2004	22-06-2005	
	c. Levelling	13-06-2004	23-06-2005	
	d. Layout	15-06-2004	24-06-2005	
	e. Leveling of individual treatment plots	16-06-2004	25-06-2005	
2.	Fertilizer application			
	a. Basal	13-07-2004	26-06-2005	
	b. Topdressing	14-08-2004	25-07-2005	
	i. Sesamum	14-08-2004	25-07-2005	
	ii. Cotton	14-08-2004	24-07-2005	
		14-09-2004	25-08-2005	
	06-10-2004	23-09-2005		
3.	Seeds and sowing			
	a. Sowing	13-07-2004	26-06-2005	
	b. Thinning/gap filling	22-07-2004	04-07-2005	

4.	Weeding		
	a. Rotary weeder	04-08-2004 15-08-2004	17-07-2005 28-07-2005
	b. Hand weeding	13-08-2004 02-09-2004	23-07-2005 06-08-2005
5.	Plant protection		
	a. Spraying acephate	15-09-2004	28-08-2005
	b. Spraying endosulfan	13-10-2004	23-09-2005
	c. Spraying chloropyriphos	30-10-2004	03-10-2005
6.	Harvesting		
	a. Greengram	08-09-2004 13-09-2004	23-08-2005 29-08-2005
	b. Cowpea	12-09-2004	27-08-2005
	c. Blackgram	14-09-2004	29-08-2005
	d. Sesamum	25-09-2004	13-09-2005
	e. Soybean	12-10-2004	28-09-2005
	f. Groundnut	26-10-2004	10-10-2005
	g. Cotton – first picking	03-11-2004	21-10-2005
	- Second picking	24-11-2004	08-11-2005
	- Final picking	02-12-2004	22-11-2005

### 3.5.1 Preparatory cultivation

The land preparation commenced by ploughing the field with a tractor drawn cultivator followed by harrowing with a cattle drawn Guntaka. The required number of plots were made using a cattle drawn bund former. Previous crop stubbles were removed manually.

### 3.5.2 Plot size

	Dimensions (m)	Area (m <sup>2</sup> )
Gross plot :	9 x 7.2	64.80
Net plot :	5.4 x 5.4	29.16

Six rows of cotton both in uniform and paired row planting were taken as the net plot.

### 3.5.3 Sowing

The seeds of the crops were sown simultaneously according to their respective row ratio on 13-7-04 during first year and 26-6-05 in second year.

Sole plots of intercrops were also sown on the same day separately.

### 3.5.3.1 Seed rate

Seed rate adopted for cotton was 1 kg ha<sup>-1</sup> where as for intercrops the seed rate was adopted according to their population.

**Table 4 : Seed rate adopted (kg ha<sup>-1</sup>)**

Crop	Uniform row planting (kg ha <sup>-1</sup> )	Paired row planting (kg ha <sup>-1</sup> )
Soybean	33	25
Greengram	11	8
Blackgram	12	9
Cowpea	33	25
Groundnut	80	60
Sesamum	2.5	2

### 3.5.3.2 Method of sowing

Seeds were sown by dibbling cotton as per the planting patterns. The intercrops seeds were also dibbled at 30 x 10 cm between the rows of cotton.

### 3.5.3.3 Thinning – plant spacing

The seedlings were thinned out to maintain single plant per hill at 10 days after sowing.

Table 5 : Schedule of fertilizer application (kg ha<sup>-1</sup>)

Treatment	Crop	Basal N : P <sub>2</sub> O <sub>5</sub> : K <sub>2</sub> O	Top dress N : P <sub>2</sub> O <sub>5</sub> : K <sub>2</sub> O	Total N : P <sub>2</sub> O <sub>5</sub> : K <sub>2</sub> O
Uniform row Planting	Soybean	40 : 40 : 26.66	--	40 : 40 : 26.66
	Greengram	13.33 : 33.33 : 13.33	--	13.33 : 33.33 : 13.33
	Blackgram	13.33 : 33.33 : 13.33	--	13.33 : 33.33 : 13.33
	Cowpea	13.33 : 33.33 : 13.33	--	13.33 : 33.33 : 13.33
	Groundnut	13.3 : 26.66 : 20	--	13.3 : 26.66 : 20
	Sesamum	13.33 : 40 : 26.66	13.33 : 0 : 0	26.66 : 40 : 26.66
Paired row planting	Soybean	30 : 30 : 20	--	30 : 30 : 20
	Greengram	10 : 25 : 10	--	10 : 25 : 10
	Blackgram	10 : 25 : 10	--	10 : 25 : 10
	Cowpea	10 : 25 : 10	--	30 : 30 : 20

Treatment	Crop	Basal N : P <sub>2</sub> O <sub>5</sub> : K <sub>2</sub> O	Top dress N : P <sub>2</sub> O <sub>5</sub> : K <sub>2</sub> O	Total N : P <sub>2</sub> O <sub>5</sub> : K <sub>2</sub> O
	Groundnut	10 : 20 : 15	--	10 : 20 : 15
	Sesamum	10 : 30 : 20	10	20 : 30 : 20
Sole crops	Cotton	0 : 60 : 0	40 : 0 : 20	120 : 60 : 60
			40 : 0 : 20	
			40 : 0 : 20	
	Soybean	60 : 60 : 40	--	60 : 60 : 40
	Greengram	20 : 50 : 20	--	20 : 50 : 20
	Blackgram	20 : 50 : 20	--	20 : 50 : 20
	Cowpea	20 : 50 : 20	--	20 : 50 : 20
	Groundnut	20 : 40 : 30	--	20 : 40 : 30
	Sesamum	20 : 60 : 40	20 : 0 : 0	40 : 60 : 40

### **3.5.4 Fertiliser application**

#### **3.5.4.1 Cotton**

A dosage of 120 : 60 : 60 kg ha<sup>-1</sup> Nitrogen, Phosphorus and Potassium was adopted for cotton. Phosphorus was applied basally. Nitrogen and potassium were applied in 3 equal splits at 30, 60 and 90 days after sowing.

#### **3.5.4.2 Inter crops**

The schedule of recommended level of NPK as sole crops and the quantity applied in intercropping systems relative to their sole optimum density are furnished in table 5.

### **3.5.5 Weeding**

Rotary weeder was run twice to have similar effect as inter cultivation and two weedings were completed to maintain the crop in weed free condition.

### **3.5.6 Plant protection**

The details of the pesticide used against specific pests along with their dosage are presented in table 6.

**Table 6 : Plant protection measures**

Spray	Crop	Pest	Insecticide	Dosage	Days after sowing	
					First year	Second year
First	Cotton	Sucking pests	Acephate	1.3 g per litre	52	63
Second	Cotton	<i>Helicoverpa armigera</i>	Endo-sulphan	2 ml per litre	78	87
Third	Cotton	-do-	Chloropyriphos	2.5 ml per litre	95	98

### 3.6 BIOMETRIC OBSERVATIONS IN COTTON

Biometric observations on the morpho-physiological parameters were taken on five representative plants tagged in each plot and the mean values were recorded. These observations were made at 30 days interval from 30 days upto final picking.

#### 3.6.1 Plant height (cm)

The plant height was measured using a linear meter scale from the base of the stem to the apex.

#### 3.6.2 Leaf area (cm<sup>2</sup>) per plant

Leaf area was calculated for cotton crop only. Leaf weight was taken for the destructively sampled plants at regular intervals. Linear regression coefficients were developed between

leaf dry weight and actual area measured on a LI 3100 leaf area meter for 45 leaves at different stages of sampling. The equations are

$$Y = 3.91 + 199.02x \text{ at 30 days}$$

$$Y = 19.70 + 127.26x \text{ at 60 days}$$

$$Y = 39.42 + 113.48x \text{ at 90 days}$$

$$Y = 42.13 + 98.26x \text{ at 120 days and final picking}$$

Where, Y = leaf area per plant in  $\text{cm}^2$

X = leaf weight per plant in g

The dry weight of leaves per plant was multiplied with specific growth stage equation to estimate the leaf area per plant.

### **3.6.3 Phytomass accumulation (g) per plant**

Three representative plants were destructively sampled from each plot at regular intervals by cutting at the base. The plants were initially dried in the shade and later in a hot air oven at  $65^\circ\text{C}$ . The weight of oven dried plants were recorded using an electronic balance of 0.001 g precision and the mean value was recorded as the phytomass accumulation g per plant of cotton.

### **3.6.4 Days to 50 per cent flowering**

The number of days required for 50 per cent of the plants to attain flowering was recorded by visual observation.

### **3.6.5 Yield and yield attributes of cotton**

#### **3.6.5.1 Number of monopodia per plant**

The monopodial branch is an exact replica of the main stem. These branches are formed at the base of the plant and does not bear flowers and bolls directly. Fruiting bodies are formed on further branches of monopodia. These were counted from labeled plants and average number of monopodia per plant was worked out.

#### **3.6.5.2 Number of sympodia per plant**

The branches formed above the growing shoots inside the axils of 4<sup>th</sup> or 5<sup>th</sup> leaf which bear flowers at each node and grow horizontally are called sympodials. These were counted from labelled plants and average number of sympodials per plant was worked out.

#### **3.6.5.3 Number of bolls per plant**

The total number of opened bolls picked from the tagged plants were counted and the average was worked out and expressed as number of bolls per plants.

#### **3.6.5.4 Boll weight (g)**

The seed cotton yield obtained from tagged plants weighed was divided with number of bolls and the average boll weight in grams was worked out.

#### **3.6.5.5 Seed cotton yield per plant (g)**

The seed cotton yield obtained from tagged plants was weighed and average was worked out and expressed as seed cotton yield per plant.

### **3.7 NUTRIENT REMOVAL (mg plant<sup>-1</sup>)**

The plant samples collected for dry matter estimation were finely ground in an electric grinding machine. They were passed through 20 mesh sieve and used for chemical analysis. The estimation of N, P and K was carried out following the procedure outlined by Judith and Webb (1970).

Nutrient removal of cotton was calculated at different intervals using the formula.

$$\text{Nutrient removal (mg plant}^{-1}\text{)} = \text{Phytomass (mg)} \times \frac{\text{Nutrient}\%}{100}$$

### 3.8 SEED COTTON YIELD

At each picking, seed cotton was weighed on a sensitive balance of 0.001 g precision. The total seed cotton yield was obtained by adding the weight from each of these pickings and expressed as kg ha<sup>-1</sup>.

### 3.9 QUALITY PARAMETERS

#### 3.9.1 Ginning percentage

It is the weight of the lint expressed as a percentage to the weight of seed cotton. A sample of 500 g seed cotton was taken from each treatment to calculate ginning percentage with the following formula

$$\text{Ginning percentage} = \frac{\text{Weight of lint (g)}}{\text{Weight of seed cotton (g)}} \times 100$$

#### 3.9.2 Seed index

Seed index is test weight. In other words it is the weight of 100 seeds expressed in grams.

### 3.9.3 Lint index

Lint index was calculated as

$$\text{Lint index} = \frac{\text{Weight of 100 seeds}}{100 - \text{Ginning percentage}} \times \text{Ginning percentage}$$

### 3.9.4 Staple length

Staple length is the arithmetic mean of the length of all fibres present in a sample of cotton. It is measured in millimeters with the help of a digital fibrograph. Readings were taken by this instrument in each treatment. The average was recorded as mean staple length and it was expressed in mm.

## 3.10 OBSERVATIONS IN INTERCROPS

### 3.10.1 Plant height (cm)

Plant height (cm) was measured from the base of the plant to the terminal bud of main stem, with a linear meter scale.

### 3.10.2 Phytomass accumulation ( $\text{g plant}^{-1}$ )

Five plants were removed in each treatment for destructive sampling. All the plants after initial drying in the shade were oven dried at  $65^{\circ}\text{C}$  for 24 hours and average dry weight in  $\text{g plant}^{-1}$  was worked out.

### **3.10.3 Days to 50 per cent flowering**

The number of days required for 50 per cent of the plants to reach flowering was recorded by visual observation.

### **3.10.4 Number of pods/siliquae per plant**

The total number of pods/ siliquae present on the five labeled plants were counted and the average number of pods / siliquae per plant was worked out.

### **3.10.5 Pod length**

Pod length of all the pods of five tagged plants were measured and expressed per pod in cm, except for groundnut.

### **3.10.6 Number of seeds per pod/siliquae**

The total number of seeds of all the pods / siliquae of five tagged plants were counted, averaged and expressed per pod.

### **3.10.7 Nutrient removal**

The removal of nutrients were calculated by multiplying the per cent nutrient concentration with the respective phytomass production of the crop and expressed in kg ha<sup>-1</sup>.

$$\text{Nutrient removal (kg ha}^{-1}\text{)} = \frac{\text{Nutrient concentration (\%)}}{100} \times \text{Phytomass (kg ha}^{-1}\text{)}$$

### 3.10.8 Seed yield/pod yield (kg ha<sup>-1</sup>)

The seed of intercrops obtained from net plot were sun dried to constant weight and expressed as yield in kg ha<sup>-1</sup>. In case of groundnut, pod weight was taken and expressed as pod yield kg ha<sup>-1</sup>.

### 3.10.9 Haulm/stalk yield (kg ha<sup>-1</sup>)

Haulm/stalk yield obtained from each net plot were weighed and expressed as kg ha<sup>-1</sup>.

### 3.11 Soil moisture studies

Soil samples were drawn from every 15 cm upto a depth of 45 cm using an auger and the moisture content was determined gravimetrically at regular intervals. The soil moisture content was determined by using the formula.

$$\text{Mass water content (\%)} = \frac{\text{Mass of moist soil} - \text{Mass of oven dried soil}}{\text{Mass of oven dried soil}} \times 100$$

### 3.12 PER CENT BOLL DAMAGE

The number of bolls on plants were counted and examined for bollworm infestation. The per cent infested bolls was calculated using method of Gururaj *et al.* (2002).

$$\text{Percent boll damage} = \frac{\text{Number of bolls infested}}{\text{Total number of bolls}} \times 100$$

### 3.13 EVALUATION OF INTERCROPPING SYSTEM

#### 3.13.1 SEED COTTON EQUIVALENT YIELD ( $\text{kg ha}^{-1}$ )

Cotton equivalent yields was computed by converting the yield of intercrops into seed cotton yield on the basis of prevailing market prices with the help of following formula

$$\text{Seed cotton equivalent yield (kg ha}^{-1}\text{)} = \frac{Y_i \times P_i}{P_{sc}} + \text{Seed cotton yield (kg ha}^{-1}\text{)}$$

Where  $Y_i$  = Yield of intercrop ( $\text{kg ha}^{-1}$ )

$P_i$  = Price of intercrop ( $\text{Rs kg}^{-1}$ )

$P_{sc}$  = Price of seed cotton ( $\text{Rs kg}^{-1}$ )

#### 3.13.2 Land Equivalent Ratio (LER)

Land equivalent ratio was calculated using the formula proposed by Willey and Osiru (1972) as,

$$\text{LER} = (Y_{ij} / Y_{ii}) + (Y_{ji} / Y_{jj})$$

Where,

$Y$  is the yield per unit area.

$Y_{ii}$  and  $Y_{jj}$  are sole crop yields of the component crops  $i$  and  $j$  and

$Y_{ij}$  and  $Y_{ji}$  are intercrop yields.

The partial LER values,  $L_i$  and  $L_j$  represent the ratios of the yields of crops  $i$  and  $j$  when grown as intercrops, relative to sole crop yields.

$$\text{Thus, } L_i = \frac{Y_{ij}}{Y_{ii}} \quad \text{and} \quad L_j = \frac{Y_{ji}}{Y_{jj}}$$

LER is the sum of two partial land equivalent ratios so that

$$\text{LER} = L_i + L_j$$

### 3.13.3 Area time Equivalent Ratio (ATER)

The area time equivalent ratio proposed by Hiebsch and McCollum (1987) is a modification of LER and computed as

$$\text{ATER} = \frac{L_i t_i + L_j t_j}{T}$$

Where

$L_i$  and  $L_j$  = partial LERs of component crops  $i$  and  $j$

$t_i$  and  $t_j$  = the duration in days for crops of  $i$  and  $j$

$T$  = the duration in days of the whole intercropping System

**3.13.4 Effective ( $\lambda$ ) land equivalent ratio (ELER)**

Effective land equivalent ratio is a measure of biological efficiency of an intercropping system in which a desired yield proportion is set *a priori* (Willey, 1979). This was calculated as

$$\lambda \text{ LER} = \frac{M_B S_A}{(S_A - M_A) + \lambda (\text{LER} - S_A)} \quad (1) \text{ and}$$

$$\frac{M_A S_B}{M_A - \lambda (\text{LER} - S_B)} \quad (2)$$

Where,

$M_A$  is the component LER or Standardized yield of A

$M_B$  is the component LER or standardized yield of B

$S_A = X_A / X_{A1}$  and  $S_B = X_B / X_{B1}$

$X_A$  is the sole crop yield per unit area of A grown under the same conditions as the crop A when intercropped and  $X_{A1}$  and  $X_{B1}$  are the standardized sole crop yields of A and B grown under different conditions and with which the intercrop yields are to be compared.

$$= \frac{kM_A + (1-k) S_A}{k (M_A - M_B) + (1-k) S_A} \quad \text{for equation 1}$$

$$= \frac{kM_A}{k (M_A + M_B) + (1-k) S_B} \quad \text{for equation 2}$$

$k$  = desired yield proportion

A general method of obtaining the proportion of intercropping (k) for a required proportion (p) of crop A was calculated as (Mead and Willey, 1980)

$$k = \frac{(1 - p)}{pL_B - (1 - p)L_A + (1 - p)}$$

the ELER was calculated as

$$ELER = \frac{L_B}{(1 - L_A) + (LER - 1)p}$$

### 3.13.5 Staple land equivalent ratio (SLER)

Reddy and Chetty (1984) defined the staple land equivalent ratio (SLER) for a crop in terms of the ratio of the required yield to the sole crop yield per unit area with standardization by the corresponding sole crop yields grown under the same condition as the intercrop. The diagram of SLER values plotted against the standardized yields of sole crop  $Y_{ij}$  in various treatments indicate that the three vertices of the triangle represent the standardized yield values when the entire area is planted to the sole crop  $Y_{ij}$ , sole crop  $Y_{ij}$  and intercropping  $Y_{ij}$  respectively.

The SLER values were calculated as,

$$\begin{aligned} \text{SLER} &= L - \frac{(L'A - LA)}{(1 - LA)} (L-1) && \text{if } L'A > LA \\ & && \text{if } L'A = LA \\ &= L - \frac{(LA - L'A)}{(LA)} (L-1) && \text{if } L'A < LA \end{aligned}$$

Where,

$$L = \text{LER}$$

$$L'A = \frac{Y'A}{Y_A} \quad (\text{Proportion of the required yield of crop A relative to its pure crop yield})$$

$$LA = \text{Partial LER of crop A}$$

This concept further considers an alternative that the farmer may have an option of realizing the proportion of required yield ( $L'A$ ) either by growing the crop I in an intercropping system with crop II over the whole of the unit area or alternatively by planting a pure stand of the crop I on part of the land and using the rest of the land for intercropping.

Following relationships were used to compute the proportion of land required for intercropping and sole crop as an alternative option if his requirement of crop I is more than the yield obtainable from intercropping that area.

$$P_{ij} = (Y_{ii} - Y_i) / (Y_{ii} - Y_{ij})$$

$$P_{ii} = (Y_i - Y_{ij}) / (Y_{ii} - Y_{ij})$$

and if the requirement of crop I is less

$$P_{ij} = \frac{Y_i}{Y_{ij}}, \quad P_{ii} = 1 - P_{ij}$$

Where

- $P_{ij}$  = Proportion of land area to be allocated to intercropping
- $P_{ii}$  = Proportion of land area to be allocated to sole crop
- $Y_i$  = Required yield
- $Y_{ij}$  = Maximum sole crop yield
- $Y_{ij}$  = Yield of crop i in intercrop system

### 3.13.6 Economics

The economics of intercropping systems were evaluated in terms of gross returns, net returns, net return per rupee investment and the relative net return index (RNR).

#### 3.13.6.1 Gross returns (Rs ha<sup>-1</sup>)

The prevailing market price of each crop component at the time of harvest were considered for the monetary values of the produce obtained from each treatment. The market price

considered for the crop components are furnished in the cost of cultivation (Appendix III).

### 3.13.6.2 Net returns (Rs ha<sup>-1</sup>)

The net returns were worked out after deducting the operational cost, input expenditure and other items from the gross emoluments per hectare.

### 3.13.6.3 Net returns per rupee investment (Rs)

The net profit per rupee investment for different treatments were worked out as the quotient of total cost of cultivation over the net profit per hectare for a given treatment.

### 3.13.6.4 Relative net returns (RNR)

The relative net returns index proposed for any intercropping system to be compared with the major sole crop was worked out following the approach suggested by Jain and Rao (1980) as

$$\text{RNR} = \frac{(P_i Y_i + P_j Y_j) \pm D_{ij}}{P_i Y_{ii}}$$

Where

$Y_i$  and  $Y_j$  = the yields of  $i^{\text{th}}$  major crop per hectare and  $j^{\text{th}}$  intercrop per hectare on  $i, j^{\text{th}}$  crop combination

- $P_i$  and  $P_j$  = the prices of  $i^{\text{th}}$  major crop and  $j^{\text{th}}$  intercrop, respectively
- $Y_{ii}$  = the yield of  $i^{\text{th}}$  sole crop per hectare and
- $D_{ij}$  = the differential cost of cultivation of  $i, j^{\text{th}}$  crop combination in comparison to  $i^{\text{th}}$  sole crop.

### 3.14 STATISTICAL ANALYSIS

Analysis of variance technique was adopted for a 2 x 7 factorial approach as suggested by Panse and Sukhatme (1978) and critical difference for examining treatment means for their significance was calculated at 5 per cent level of probability ( $P=0.05$ ).

#### Bivariate Analysis of Variance

The yield data from intercrop treatments were also compared simultaneously by a more acceptable statistical approach – the Bivariate analysis of variance as suggested by Pearce and Gilliver (1978). The yield of cotton and intercrops as greengram seed equivalents in intercrop system were transformed and plotted on skew axes ( $Z_1$  and  $Z_2$ ), the angle  $\theta$  being such that its cosine is the correlation coefficient of the yield data between  $X_1$  and  $X_2$ .

$$\text{Cos } \theta = V_{12} / \sqrt{V_{11} V_{22}}$$

The transformation of yield data into  $Y_1$  and  $Z_1$  values for cotton and  $Y_2$  and  $Z_2$  values for greengram seed equivalent were performed as follows.

$$Y_1 = X_1 / \sqrt{V_{11}}$$

$$Z_1 = X_1 / \sqrt{V_{11'}} \quad \text{Where, } V_{11'} = V_{11} - (V_{12})^2 / V_{22}$$

$$Y_2 = X_2 - \frac{(V_{12} X_1)}{V_{11}} / \sqrt{V_{22'}}$$

$$Z_2 = X_2 / \sqrt{V_{22'}} \quad \text{Where } V_{22'} = V_{22} - (V_{12})^2 / V_{11}$$

The variates  $V_{11}$  and  $V_{22}$  are the error variances and  $V_{12}$  is the error co-variance.  $V_{11'}$  and  $V_{22'}$  are the variances after adjusting each variate by the other.  $X_1$  and  $X_2$  are the mean yields of cotton and intercrops for each intercropping pattern.

The significance of the treatment effects was judged by calculating  $d^2 = (\text{difference in } Y_1)^2 + (\text{corresponding difference in } Y_2)^2$ , which if exceeds  $4 \text{ eFc} / n (e-1)$  would be significant. The region of non significance at 5% probability has been shown by drawing a circle around the mean intercrop treatment point in the diagram.

Where,

FC = Critical value of F for 2 and (e-1) degrees of freedom at the significance level required

e = error degrees of freedom and

n = number of observations

# ***Results***

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## CHAPTER - IV

### RESULTS

The research findings from the experiment "Planting techniques and intercropping studies in cotton" conducted for two years are presented with statistical evaluation in tables and sketches. These are moderately narrated in this chapter.

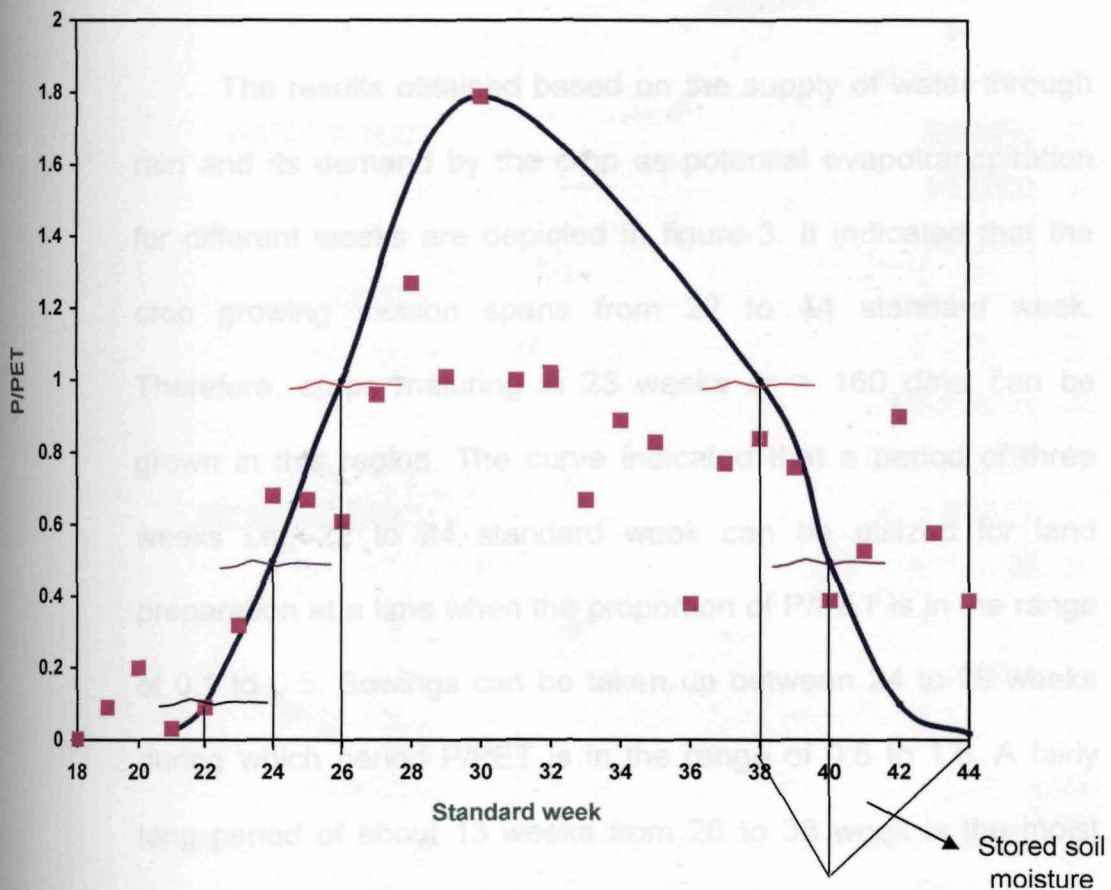
#### 4.1 CROP PLANNING PERSPECTIVES

##### 4.1.1 Rainfall distribution

The mean seasonal precipitation of Warangal district during South-West monsoon from 22 to 44 standard meteorological week is 758.1 mm in 44.7 rainy days. But, the estimated dependable precipitation at 75% probability is 670.3 mm. The potential evapotranspiration range from 3.15 mm to 5.05 mm day<sup>-1</sup> with 11.78% coefficient of variation. But, the rainfall distribution is extremely variable with coefficient of variation of 49.23%.

##### 4.1.2 Precipitation curve

The choice of crop or cropping systems mainly depends not only on the seasonal precipitation but more strongly on its distribution pattern relative to the water requirement of the crop



**Fig. 3 : Rainfall curve to estimate length of crop growing season (Cocheme and Franquin, 1967)**

and its retention in the soil. To this end, Cocheme and Franquin (1967) proposed a schematic presentation to estimate the length of crop growing season so as to devise a sowing plan for crops of different duration and appropriate cropping systems to exploit the finite natural resources in the best possible way to increase the production and profitability.

The results obtained based on the supply of water through rain and its demand by the crop as potential evapotranspiration for different weeks are depicted in figure-3. It indicated that the crop growing season spans from 22 to 44 standard week. Therefore, crops maturing in 23 weeks or  $> 160$  days can be grown in this region. The curve indicated that a period of three weeks i.e., 22 to 24 standard week can be utilized for land preparation at a time when the proportion of P/PET is in the range of 0.1 to 0.5. Sowings can be taken up between 24 to 26 weeks during which period P/PET is in the range of 0.5 to 1.0. A fairly long period of about 13 weeks from 26 to 38 week is the moist period which can be best exploited by the peak vegetative and reproductive growth of crops. Another six weeks period is available for the crops to be nurtured on the stored soil moisture along with low spells of  $< 75\%$  probability of rainfall. The medium black clay soils and sandy loams with water holding capacity of 110 mm per metre depth in this region is an added advantage for

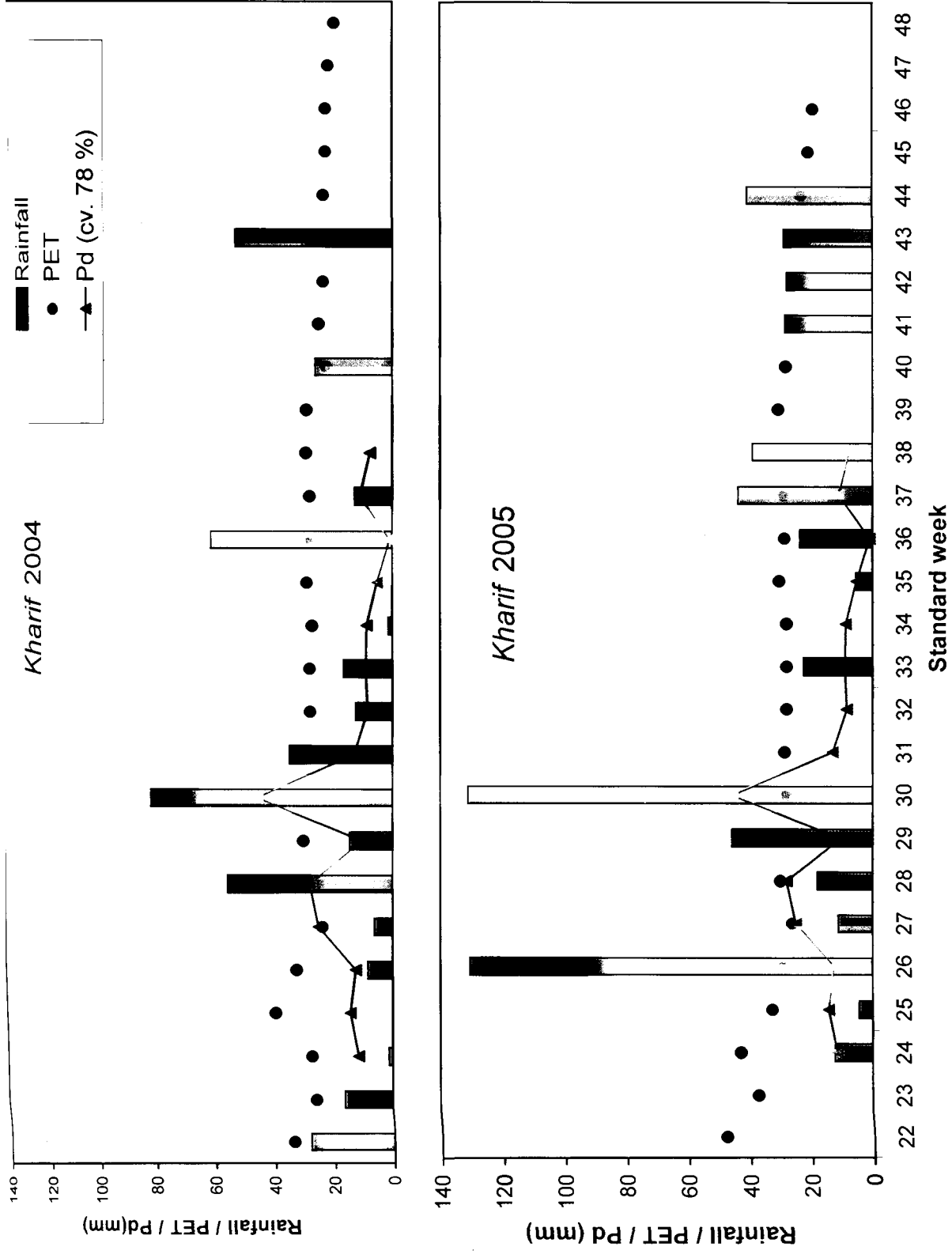


Fig. 4 : Rainfall, potential evapotranspiration (PET) and dependable precipitation (Pd) during the crop growing season

intensive cropping by growing short duration crops as companions in long duration crop to maximize the production and profitability. Cotton variety 'Bunny' selected in this study with a duration of 150 days therefore finds a suitable niche vis-à-vis the exploitation of fairly good moisture holding capacity of the soil through compatible, productive and profitable intercrops.

Considering the dependable rainfall, with  $\leq 75\%$  probability, the length of crop growing season seem to be limited to 38 standard week (Fig 4). Still, rains of less than 75% probability and the assured 110 mm stored soil moisture can be exploited by the crop during its very low water requiring senile phase and ripening during the later part.

In the first year of this experiment, the P/PET was 0.83 in the 22 week and 0.63 in the 23 week. This helped in land preparation in accordance with the precipitation curve. But, the subsequent 24 and 25 weeks did not receive any rain. The P/PET was 0.25 both in 26 and 27 weeks. Hence, sowing was not possible. In the 28 week P/PET was 0.87. This helped in sowing of crops. In the second year, land preparation was possible consequent to the rainfall proportion of 0.29 to PET during 24 week. Sowing was done during 26 week. This was very wet. The proportion of P/PET was 4.49. The water was surplus. These

results confirmed the predictions from the precipitation curve for sowing plan.

#### **4.1.3 First order Markov chain model for initial and conditional probability of rainfall**

The initial and conditional probability estimates of rainfall for different standard weeks are presented in table 7. The probability of  $\geq 30$  mm rainfall in 22 standard week was 7%. The conditional probability for 23 week also to be wet was 50% of the previous wet weeks. In 23 standard week, the initial probability for this threshold value of rainfall was 14% and the conditional probability for following week to be wet was 17%. In 24 week, the initial probability of this rainfall was 43% and the conditional probability of 25 week being wet was 50% out of the initial probability. In the 24 week, the probability of receiving less than 30 mm rainfall was 57% but the following 25 week is expected to receive more than 30 mm rainfall in 25 out of the 57% level of initial probability. The land preparation can be done between 22 to 24 week when the soils are partially moist and are not saturated to create any problem for land preparation.

The period between 24 to 26 standard week is estimated to be the sowing time when the P/PET range from 0.5 to 1.0. Rainfall of  $\geq 30$  mm per week is expected to ensure good

Table 7 : First order Markov chain model for initial and conditional probability of rainfall in Warangal

Date - Month	Standard week	Minimum threshold rainfall (mm)	Initial probability wet %	Conditional probability %			
				Wet Wet	Dry Wet	Wet Dry	Dry Dry
28 May 3 June	22-23	30	7	50	50	0	100
4-10 June	23-24	30	14	17	83	13	87
11-17 June	24-25	30	43	50	50	25	75
18-24 June	25-26	30	36	20	80	44	66
25 June - 1 July	26-27	30	29	20	80	50	50
2-8 July	27-28	10	86	40	60	0	100
9-15 July	28-29	10	79	71	29	86	14
16-22 July	29-30	15	50	54	46	0	100
23-29 July	30-31	15	93	89	11	10	90
30 July - 5 Aug	31-32	15	64	63	37	67	33
6-12 Aug	32-33	15	57	10	90	40	60
13-19 Aug	33-34	30	29	50	50	13	87
20-26 Aug	34-35	30	43	50	50	33	67
27 Aug 2 Sep	35-36	30	57	50	50	58	42
3-9 Sep	36-37	30	14	14	86	14	86
10-16 Sep	37-38	30	50	67	33	38	62
17-23 Sept	38-39	30	43	67	33	25	75
24-30 Sep	39-40	30	43	67	33	37	73
1-7 Oct	40-41	30	21	0	100	25	75
8-14 Oct	41-42	20	36	20	80	11	89
15-21 Oct	42-43	20	36	20	80	44	56
22-28 Oct	43-44	20	36	80	20	11	89

germination. The initial probability for this threshold value was 43% in 24 week, 36% in 25 week and 29% in 26 week. The conditional probabilities for the subsequent 25, 26 and 27 weeks also being wet were 50, 20 and 20 % respectively. Dry seeding can be done during this period. The moist period range from 26 to 38 meteorological weeks. A minimum of  $\geq 10$  mm rainfall is considered essential for the establishment of seedlings. The probability of this threshold limit was 86% in 27 standard week and 79% in 28 week. The conditional probabilities for the subsequent weeks being wet are fairly high. The estimated conditional probability was 40% in 28 week and 71% in 29 week being wet. A threshold limit of  $\geq 15$  mm rainfall during next four weeks is considered optimum to meet the water requirement of cotton. The probability of this rainfall ranged from 50 to 93% during this period. Water requirement of crop increase from 33 to 40 standard weeks. During this crucial period of peak reproductive growth, a rainfall of  $\geq 30$  mm is expected to adequately meet the water requirement of the crop. But, the initial probabilities showed that such events are not fairly high. The probability ranged from 29 to 57% during this period except in 36 week when the chance of getting  $\geq$  than 30 mm rainfall was only 14%. The conditional probabilities of the subsequent wet weeks ranged from 50 to 67% except in 37 week which had a probability

of only 14% to be wet. However, the stored soil moisture during this period is likely to partly compensate the shortfall in precipitation during years of less than the threshold limit of rainfall. The plots of P/PET in the precipitation curve indicate that the rains from 42 to 44 standard week compensate the evapotranspiration losses. The water requirement of the crop is also less and is mainly dependent on stored soil moisture. The expected  $\geq$  20 mm rainfall from 41 to 43 standard weeks had an initial probability of 36%. The conditional probability for this threshold value of rainfall was 20% during the subsequent 42 and 43 week and 80% during 44 week. These trends imply that the relatively low probability for a threshold limit of 30 mm rainfall per week from 33 to 40 week is the major constraint for significant variation in seed cotton yield in different years.

#### **4.1.4 Weekly water balance**

A detailed account of the budgeting of soil moisture through demand and supply by the crop and rainfall are furnished in tables 8 and 9.

The potential evapotranspiration per week ranged from 19.67 to 30.03 mm during crop growth period in 2004. The actual evapotranspiration was less than the potential evapotranspiration from 28 to 33 standard week. The trend

Table 8 : Weekly water balance pertaining to cotton crop *Kharif*, 2004

AWHC=110 mm

Standard week	Potential evapo transpiration (mm)	Crop coefficient	Actual evapo transpiration (mm)	Precipitation (mm)	Precipitation-actual evapo transpiration (mm)	Soil moisture retention (mm)	Surplus (mm)	Deficit (mm)	Water requirement satisfaction index
28	29.54	0.50	14.77	55.2	40.43	40.43	--	--	100.00
29	30.03	0.50	15.02	14.4	-0.62	39.81	--	--	100.00
30	27.79	0.54	15.09	81.2	66.11	105.92	--	--	100.00
31	27.93	0.80	22.34	34.4	12.06	110.00	7.98	--	100.00
32	27.72	0.80	22.18	12.2	-9.98	100.02	--	--	100.00
33	27.79	0.80	22.23	16.3	-5.93	94.09	--	--	100.00
34	27.02	1.06	28.56	1.2	-27.36	66.73	--	--	100.00
35	28.91	1.25	36.14	--	-36.14	30.59	--	--	100.00
36	27.65	1.25	34.56	60.9	26.34	56.93	--	--	100.00
37	27.86	1.25	34.83	12.5	-22.33	34.60	--	--	100.00
38	29.05	1.25	36.31	--	-36.31	--	--	1.71	99.66
39	28.84	1.25	36.05	--	-36.05	--	--	37.76	92.35
40	22.12	1.25	27.65	25.8	-1.85	--	--	39.61	84.68
41	24.85	1.25	31.06	--	-31.06	--	--	70.67	71.00
42	23.38	1.25	29.23	--	-29.23	--	--	99.90	51.67
43	24.64	0.90	22.18	52.7	-30.52	30.52	--	69.38	38.24
44	23.17	0.90	20.85	--	-20.85	--	--	90.23	-0.61
45	22.54	0.90	20.29	--	-20.29	--	--	110.52	-25.55
46	22.54	0.81	18.35	--	-18.35	--	--	128.87	-20.78
47	21.77	0.70	15.24	--	-15.24	--	--	144.11	-53.44
48	19.67	0.70	13.77	--	-15.24	--	--	157.88	-84.00
	522.77	0.99	516.70	366.8	-149.90		7.98	157.88	

reversed from 34 to 42 week. Again it tilted back to low actual evapotranspiration than the potential evapotranspiration from 43 to 48 standard week. The first six weeks commencing from 28 to 33 weeks were continuously exposed to moist conditions with rainfall ranging from 12.2 to 81.2 mm. This helped the soil to store sufficient moisture. The receipt of rains in excess of the actual evapotranspiration during 28, 30 and 31 week charged the soil to hold 110 mm water with a surplus of 7.98 mm. But, rains were less than the actual evapotranspiration during 32 to 34 week. This resulted in a low amount of 66.73 mm water available in the soil. The 35 week was free of rain. This triggered a void in the available water content of the soil to as low as 30.59 mm. Yet, rains during the subsequent 36 and 37 weeks recharged the soil with water to the extent of 56.9 and 34.6 mm. The soil virtually recorded no moisture deficit until the 37 week. Hence, the water requirement satisfaction indices were 100 for any week from 28 to 37 week. From 38 to 48 week there were no rains except 25.8 mm in 40 week and 52.7 mm in 43 week. The soil ran off the moisture showing a consistent increase in its deficiency from 1.71 mm in 38 week to 99.90 mm in 42 week. However, the soil could retain 30.52 mm water during the 43 week and thereby narrowed the deficit by 69.38 mm. But lack of rains in the subsequent weeks consistently increased the deficit from 90.23 mm in 44

Table 9 : Weekly water balance pertaining to cotton crop *Kharij*, 2005

AWHC=110 mm

Standard week	Potential evapo transpiration (mm)	Crop coefficient	Actual evapo transpiration (mm)	Precipitation (mm)	Precipitation-actual evapo transpiration (mm)	Soil moisture retention (mm)	Surplus (mm)	Deficit (mm)	Water requirement satisfaction index
26	28.98	0.50	14.49	130.0	115.81	110.00	5.81	--	100.00
27	26.18	0.50	13.09	11.1	-1.99	108.01	--	--	100.00
28	29.96	0.71	21.40	17.8	-3.60	104.41	--	--	100.00
29	27.02	0.80	21.62	45.4	23.78	110.00	18.19	--	100.00
30	27.02	0.80	21.62	131.1	109.48	110.00	109.48	--	100.00
31	28.07	0.86	24.35	--	-24.35	85.65	--	--	100.00
32	28.56	1.25	35.70	--	-35.70	49.95	--	--	100.00
33	27.86	1.25	34.83	22.2	-12.63	37.32	--	--	100.00
34	27.86	1.25	34.83	--	-34.83	2.49	--	--	100.00
35	30.38	1.25	37.98	5.3	-32.68	--	--	30.19	94.46
36	28.56	1.25	35.70	23.4	-12.30	--	--	42.49	86.65
37	28.84	1.25	36.05	43.5	7.45	7.45	--	35.04	80.22
38	28.07	1.25	35.09	38.8	3.71	3.71	--	31.33	74.47
39	30.52	1.25	38.15	--	-38.15	--	--	69.48	61.72
40	28.14	1.05	29.55	--	-29.55	--	--	99.03	43.55
41	25.20	0.90	22.68	28.2	5.52	5.52	--	93.51	26.39
42	24.50	0.90	22.05	27.6	5.55	5.55	--	87.96	10.25
43	23.59	0.90	21.23	28.6	7.37	7.37	--	80.59	4.54
44	23.03	0.70	16.12	40.5	24.38	24.38	--	56.20	0.06
45	20.86	0.70	14.60	--	-14.60	--	--	70.81	-12.93
46	19.39	0.70	13.57	--	-13.57	--	--	84.38	-28.41
	561.59	0.97	544.70	593.8	49.10		133.48	84.38	

week to 157.8 mm in 48 week. The water requirement satisfaction index showed that none of the weeks from 38 to 48 standard week had adequate moisture to meet the optimum water requirement. This affect was more serious with advancing age of the crop.

In 2005, the crop water requirement was adequately satisfactory for nine weeks from 26 to 34 standard week in contrast to 10 week adequacy from 28 to 37 standard week in the previous year. The soil retained 104.41 to 110 mm moisture for five weeks from 26 to 30 week. But, in the previous year, the soil retained only about 40 mm moisture in the first two weeks and 100 to 110 mm in subsequent three week period. The moisture retention reduced sharply later on from 31 to 34 weeks. This was remarkably less than the previous year. Water deficit commenced from 35 standard week and increased in magnitude until 46 week. The water requirement satisfaction index recorded consistent reduction in the amount of moisture needed for optimum crop growth. A transparent observation is that though the precipitation of 593.8 mm during crop growing period was slightly more than the actual evapotranspiration of 544.7 mm, only the first 9 weeks provided a satisfactory supply of moisture to the crop. On the other hand, the rainfall of 366.8 mm during crop growing season of 2004 was much less than the actual evapotranspiration of

516.7 mm. The intensity and distribution of rainfall in the beginning of the season supplied the crop with satisfactory amount of water during first 10 weeks.

## **4.2 PERFORMANCE OF COTTON**

### **4.2.1 Plant height (cm)**

The mean plant height of cotton was not influenced by a change in the planting pattern from the uniform row spacing of 90 cm to paired rows of 120/60 cm (Table 10). This trend was consistent for the observations recorded at 30 days interval beginning one month after sowing until harvest during 2004 and 2005. The choice of intercrops had a significant impact. In the first year, the mean plant height of cotton was significantly reduced from 90 days after sowing until harvest when it was intercropped with groundnut. Such adverse effect was evident only at 60 and 90 days after sowing in the subsequent year. Intercropping of sesamum significantly reduced the mean plant height of cotton, from 90 days in the first year and from 60 days until harvest in the second year. The responses due to intercropping of soybean were inconsistent. The plant height of cotton was not affected by this intercrop in the first year at any stage. But, there was a significant reduction of this variable consistently from 60 days after sowing until harvest in second year. Blackgram was the

Table 10 : Plant height (cm) of cotton at different crop growth stages as influenced by planting pattern and intercrops

Treatment	Kharif-2004						Kharif-2005								
	Days after sowing			At harvest	Days after sowing			At harvest	Days after sowing			At harvest			
	30	60	90		120	30	60		90	120					
<b>Planting pattern</b>															
Uni. rows	20.98	61.81	76.92	87.85	89.98	21.15	63.17	81.99	96.87	89.98	21.15	63.17	81.99	96.87	89.98
Paired rows	21.53	60.61	76.67	87.70	89.65	21.25	63.07	81.63	96.64	89.65	21.25	63.07	81.63	96.64	89.65
SE m $\pm$	0.28	0.84	0.76	1.32	1.32	0.30	0.94	0.75	1.33	1.32	0.30	0.94	0.75	1.33	1.41
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
<b>Intercropping</b>															
Sole cotton	22.61	64.07	82.80	93.83	95.91	22.40	69.00	87.82	103.03	95.91	22.40	69.00	87.82	103.03	105.50
Cotton + Soybean	20.39	60.92	79.58	90.35	92.44	20.06	60.08	81.32	93.18	92.44	20.06	60.08	81.32	93.18	95.18
Cotton + Greengram	20.90	61.30	79.56	89.65	92.08	20.71	61.71	84.63	99.03	92.08	20.71	61.71	84.63	99.03	101.69
Cotton + Blackgram	21.66	59.67	76.04	87.20	89.04	21.45	66.26	84.61	99.03	89.04	21.45	66.26	84.61	99.03	102.03
Cotton + Cowpea	21.44	60.24	76.23	87.50	89.45	21.16	63.51	81.26	96.54	89.45	21.16	63.51	81.26	96.54	99.11
Cotton + Groundnut	21.01	62.11	72.79	84.19	86.25	20.71	62.13	78.00	96.26	86.25	20.71	62.13	78.00	96.26	98.30
Cotton + Sesamum	20.79	60.15	70.55	81.41	83.56	20.75	61.05	75.04	90.24	83.56	20.75	61.05	75.04	90.24	92.69
SE m $\pm$	0.54	1.54	1.42	2.48	2.47	0.57	1.77	1.41	2.50	2.47	0.57	1.77	1.41	2.50	2.64
CD at 5%	NS	NS	4.13	7.21	7.18	NS	5.14	4.09	7.26	7.18	NS	5.14	4.09	7.26	7.67
<b>Interaction</b>															
SE m $\pm$	0.76	2.22	2.01	3.50	3.50	0.81	2.50	1.99	3.54	3.50	0.81	2.50	1.99	3.54	3.74
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

most compatible intercrop. It did not reduce the plant height of cotton at any stage during the two years except at 90 days during 2004.

The interaction effects owing to planting pattern of cotton and intercrops were not significant at any sampling stage during the two years.

#### **4.2.2 Leaf area (cm<sup>2</sup>) per plant**

The data on leaf area (cm<sup>2</sup>) per plant of cotton in response to a change in planting pattern with different intercrop components are furnished in table 11.

The crop displayed an equivocal leaf area per plant both in uniform and paired row planting pattern during each and every sampling stage in 2004 and 2005.

There were no significant variations in the leaf area per plant of one month old cotton grown alone or intercropped with different components. During subsequent growth stages in the first year, cotton produced significantly less leaf area per plant in all the intercropping treatments from 60 to 120 days after sowing. The only exception to this trend was that the estimated leaf area of cotton intercropped with cowpea was on par with sole cotton at 120 days after sowing. But, in the second year there was no

Table 11 : Leaf area (cm<sup>2</sup>) per plant of cotton at different growth stages as influenced by planting pattern and intercrops

Treatment	Kharif-2004						Kharif-2005					
	Days after sowing						Days after sowing					
	30	60	90	120	At harvest		30	60	90	120	At harvest	
<b>Planting pattern</b>												
Uni. rows	718	2468	5109	2617	844		759	2670	5436	2768	909	
Paired rows	708	2391	5105	2608	843		786	2636	5495	2752	927	
SE m±	38	92	142	97	43		39	96	153	98	49	
CD at 5%	NS	NS	NS	NS	NS		NS	NS	NS	NS	NS	
<b>Intercropping</b>												
Sole cotton	687	3206	6538	3224	854		785	3468	6364	3130	983	
Cotton + Soybean	728	2186	4483	2287	797		779	2762	5382	2750	876	
Cotton + Greengram	715	2425	5130	2649	869		762	2525	5558	2768	925	
Cotton + Blackgram	720	2491	5270	2692	862		774	2763	5755	2901	924	
Cotton + Cowpea	720	2123	5319	2720	815		779	2949	5717	2856	908	
Cotton + Groundnut	729	2352	4871	2510	857		764	2388	5315	2701	899	
Cotton + Sesamum	694	2221	4198	2203	850		765	1724	4168	2145	910	
SE m±	73	175	271	182	81		75	183	290	189	91	
CD at 5%	NS	508	788	530	NS		NS	535	842	548	NS	
<b>Interaction</b>												
SE m±	97	242	376	260	109		102	253	408	263	123	
CD at 5%	NS	NS	NS	NS	NS		NS	NS	NS	NS	NS	

significant reduction in leaf area intercropped with cowpea compared to sole cotton throughout the crop growing period. On the other hand cotton intercropped with sesamum consistently recorded significantly less leaf area compared to sole crop from 60 to 120 days after sowing, both during 2004 and 2005.

#### **4.2.3 Phytomass (g) per plant**

The data presented in table 12, indicated that the cotton crop responded to accumulate phytomass per plant on par in uniform and paired row planting. This trend was persistent throughout the crop growth period during the two years.

The phytomass per plant of cotton intercropped with different components was not altered relative to its sole planting at 30 days after sowing during the first year. The phytomass however significantly reduced in all the intercropping treatments except with soybean at 30 days after sowing in the second year. In the subsequent stages of crop growth cotton accumulated significantly less phytomass per plant in all the intercropping treatments relative to sole crop during both the years. This reduction was in general more severe by intercropping cotton with groundnut or sesamum than with greengram, blackgram or cowpea.

Table 12 : Phytomass (g) per plant of cotton at different crop growth stages as influenced by planting pattern and intercrops

Treatment	Kharif-2004												Kharif-2005											
	Days after sowing						At harvest						Days after sowing						At harvest					
	30	60	90	120	At harvest	120	30	60	90	120	At harvest	30	60	90	120	At harvest								
<b>Planting pattern</b>																								
Uni. rows	10.66	64.84	161.04	107.41	75.69	107.41	12.27	66.42	159.27	101.37	71.21	12.27	66.42	159.27	101.37	71.21								
Paired rows	10.62	63.44	160.18	107.21	74.98	107.21	12.09	66.21	158.81	114.25	70.94	12.09	66.21	158.81	114.25	70.94								
SE m±	0.12	1.21	2.56	1.79	1.27	1.79	0.15	0.70	2.51	2.12	1.16	0.15	0.70	2.51	2.12	1.16								
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS								
<b>Intercropping</b>																								
Sole cotton	10.82	76.00	186.12	132.61	93.09	132.61	13.82	80.47	184.42	138.27	98.32	13.82	80.47	184.42	138.27	98.32								
Cotton + Soybean	10.64	59.06	138.17	99.24	69.42	99.24	13.64	63.23	147.29	112.24	74.28	13.64	63.23	147.29	112.24	74.28								
Cotton + Greengram	10.63	66.68	155.20	110.44	77.64	110.44	11.63	63.29	163.88	116.18	82.29	11.63	63.29	163.88	116.18	82.29								
Cotton + Blackgram	10.58	65.81	157.85	112.08	78.74	112.08	11.64	68.32	166.38	118.34	82.43	11.64	68.32	166.38	118.34	82.43								
Cotton + Cowpea	10.59	60.42	150.26	107.00	74.97	107.00	11.61	67.38	158.73	113.34	79.94	11.61	67.38	158.73	113.34	79.94								
Cotton + Groundnut	10.59	63.21	132.46	94.38	66.42	94.38	11.31	64.36	141.05	100.33	70.99	11.31	64.36	141.05	100.33	70.99								
Cotton + Sesamum	10.62	57.83	133.60	95.41	67.06	95.41	11.60	57.15	141.55	101.05	71.07	11.60	57.15	141.55	101.05	71.07								
SE m±	0.30	2.27	4.80	3.35	2.38	3.35	0.28	1.36	4.70	3.97	2.18	0.28	1.36	4.70	3.97	2.18								
CD at 5%	NS	6.61	13.96	9.76	6.91	9.76	0.81	3.94	13.62	11.50	6.33	0.81	3.94	13.62	11.50	6.33								
<b>Interaction</b>																								
SE m±	0.42	3.21	6.78	4.75	3.37	4.75	0.40	1.93	6.66	5.61	3.09	0.40	1.93	6.66	5.61	3.09								
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS								

There was no significant variation in the phytomass per plant of cotton due to combined influence of changed planting pattern and option of intercrop.

#### **4.2.4 Days to 50 per cent flowering, number of monopodia and sympodia per plant**

The data on mean number of monopodia, sympodia per plant and days to 50% flowering presented in table 13, showed that these parameters were not significantly influenced by the option of paired row planting compared to conventional uniform rows.

The number of monopodial branches per plant and number of days to attain 50% flowering of cotton intercropped with different components were on par with sole crop both during 2004 and 2005. There was a definite impact on the production of sympodial branches. They were significantly reduced in both the years by intercropping cotton with soybean, groundnut or sesamum. Intercropping of greengram, blackgram or cowpea did not exert a significant influence on number of sympodia per plant.

There were no significant deviations in the response factors of cotton in different intercropping systems due to a changed planting pattern from uniform to paired rows.

Table 13 : Days to 50 per cent flowering, number of monopodia and sympodia per plant of cotton as influenced by planting pattern and intercrops

Treatment	Kharif-2004			Kharif-2005		
	Days to 50% flowering	Number of monopodia per plant	Number of sympodia per plant	Days to 50% flowering	Number of monopodia per plant	Number of sympodia per plant
<b>Planting pattern</b>						
Uniform rows	56.64	1.55	12.28	57.71	1.59	18.40
Paired rows	56.62	1.43	12.26	57.27	1.47	18.23
SE m±	0.32	0.05	0.31	0.26	0.04	0.30
CD at 5%	NS	NS	NS	NS	NS	NS
<b>Intercropping</b>						
Sole cotton	56.01	1.41	14.17	57.25	1.52	20.04
Cotton + Soybean	57.08	1.47	11.66	56.85	1.52	17.91
Cotton + Greengram	56.60	1.51	13.85	57.18	1.61	19.97
Cotton + Blackgram	56.78	1.51	13.24	57.48	1.62	19.30
Cotton + Cowpea	56.76	1.53	13.03	57.95	1.63	19.04
Cotton + Groundnut	56.21	1.47	10.11	56.85	1.40	16.05
Cotton + Sesamum	56.96	1.54	9.85	58.90	1.43	15.90
SE m±	0.59	0.10	0.58	0.49	0.08	0.57
CD at 5%	NS	NS	1.70	NS	NS	1.67
<b>Interaction</b>						
SE m±	0.84	0.15	0.82	0.69	0.11	0.81
CD at 5%	NS	NS	NS	NS	NS	NS

#### **4.2.5 Boll number, boll weight and seed cotton yield (g) per plant**

The number of bolls, boll weight and seed cotton yield per plant did not show a differential response to a change in the manipulation of spatial configuration from uniform row spacing to paired rows (Table 14).

Sole crop of cotton produced maximum number of bolls per plant and thereby maximum seed cotton yield per plant during the two years. There was no significant reduction in these parameters by intercropping cotton with cowpea in either of the two years. The responses due to intercropping of blackgram were inconsistent. The number of bolls and seed cotton yield per plant were on par with sole cotton during first year and reduced substantially in the following year. But, intercropping of greengram significantly reduced these two yield components during both the years. This effect was more severe due to intercropping of groundnut or sesamum.

The interaction effects showed that there was no significant change in the number of bolls per plant, boll weight or seed cotton yield due to combined influence of two factors *viz.*, planting pattern and cropping system.

Table 14 : Boll number, boll weight and seed cotton yield (g) per plant of cotton as influenced by planting pattern and intercrops

Treatment	Kharif-2004			Kharif-2005		
	Boll number per plant	Boll weight (g)	Seed cotton yield (g) per plant	Boll number per plant	Boll weight (g)	Seed cotton yield (g) per plant
<b>Planting pattern</b>						
Uniform rows	19.25	4.66	87.82	20.62	4.65	104.04
Paired rows	18.34	4.60	82.98	20.79	4.63	105.26
SE m±	0.52	0.08	2.06	0.40	0.07	2.06
CD at 5%	NS	NS	NS	NS	NS	NS
<b>Intercropping</b>						
Sole cotton	22.75	4.62	104.95	25.98	4.52	130.57
Cotton + Soybean	15.24	4.58	66.58	17.19	4.65	87.79
Cotton + Greengram	19.43	4.60	88.42	22.57	4.59	113.52
Cotton + Blackgram	20.80	4.76	97.32	23.25	4.88	117.86
Cotton + Cowpea	21.38	4.66	98.45	24.55	4.63	123.68
Cotton + Groundnut	14.75	4.55	65.44	16.61	4.65	83.73
Cotton + Sesamum	17.23	4.64	76.64	14.80	4.59	75.40
SE m±	0.97	0.16	3.86	0.76	0.14	3.85
CD at 5%	2.84	NS	11.24	2.22	NS	11.18
<b>Interaction</b>						
SE m±	1.38	0.23	5.46	1.08	0.20	5.45
CD at 5%	NS	NS	NS	NS	NS	NS

## 4.2.6 Removal of major nutrients (mg plant<sup>-1</sup>)

### 4.2.6.1 Nitrogen

The data on the quantity of nitrogen removed by cotton grown in different planting patterns with different intercropping components are furnished in table 15.

The crop removed almost equal quantity of this nutrient when its planting pattern was changed from the uniform row spacing of 90 cm to paired rows of 120/60 cm at every stage of sampling from 30 days after sowing until harvest. This trend was persistent both during 2004 and 2005.

There was a tremendous reduction in the quantity of nitrogen removed by cotton in different intercropping systems compared to its solitary stand during different stages of crop growth. The only exception to this trend was at 30 days after sowing during *Kharif*, 2004. Cotton intercropped with groundnut, soybean or sesamum removed less nitrogen. The interaction effects were not significant at any stage.

### 4.2.6.2 Phosphorus

The data on the phosphorus removed by cotton growing in different planting patterns and intercropping systems are presented in table 16.

Table 15 : Nitrogen removed (mg plant<sup>-1</sup>) by cotton at different intervals as influenced by planting pattern and intercrops

Treatment	Kharif-2004						Kharif-2005					
	Days after sowing			At final picking	Days after sowing			At final picking				
	30	60	90		120	30	60		90	120	At final picking	
<b>Planting pattern</b>												
Uniform rows	233	1169	1925	1105	616	297	1286	2111	1196	745		
Paired rows	234	1139	1905	1097	615	292	1280	2115	1159	767		
SE m±	4	22	33	19	11	3	16	34	22	11		
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		
<b>Intercropping</b>												
Sole cotton	243	1417	2438	1425	787	333	1568	2615	1438	967		
Cotton + Soybean	225	1022	1722	973	545	327	1208	1907	1118	665		
Cotton + Greengram	232	1207	1972	1138	633	282	1235	2180	1202	787		
Cotton + Blackgram	243	1198	2053	1160	673	282	1322	2233	1225	803		
Cotton + Cowpea	232	1100	1968	1150	615	281	1310	2175	1195	775		
Cotton + Groundnut	227	1102	1590	892	518	277	1227	1833	1062	642		
Cotton + Sesamum	233	1032	1663	968	537	282	1108	1847	1000	653		
SE m±	7	41	62	35	20	6	30	63	41	20		
CD at 5%	NS	119	182	103	58	17	86	183	121	58		
<b>Interaction</b>												
SE m±	10	58	88	50	28	8	42	89	50	28		
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		

There were no significant differences in the quantity of this nutrient removed by cotton at any stage of growth during the two years by sowing the crop in uniform or paired row planting patterns.

Intercropping had a deleterious effect. Phosphorus was removed in significantly larger quantities by cotton grown as a sole crop at every stage of sampling interval from 30 days after sowing until final picking both during 2004 and 2005. Exceptionally, the quantity of phosphorus removed by cotton grown as a sole crop or intercropped with cowpea was on par at 30 days only during 2004. Cotton intercropped with groundnut or sesamum removed significantly less quantity of phosphorus compared to its intercropping with greengram, blackgram or cowpea from 60 days after sowing until final harvest during 2004.

In the subsequent year, cotton intercropped with groundnut or sesamum removed less quantity of phosphorus than when intercropped with greengram, blackgram or cowpea from 30 days after sowing until harvest. However, at 60 days cotton intercropped with groundnut removed significantly low quantity of phosphorus than that intercropped with cowpea.

Table 16 : Phosphorus removed (mg plant<sup>-1</sup>) by cotton at different intervals as influenced by planting pattern and intercrops

Treatment	Kharif-2004						Kharif-2005					
	Days after sowing						Days after sowing					
	30	60	90	120	At final picking		30	60	90	120	At final picking	
<b>Planting pattern</b>												
Uniform rows	53	257	600	291	168		67	329	650	373	210	
Paired rows	54	249	601	297	170		68	323	645	375	217	
SE m±	1	5	11	5	3		1	4	11	6	3	
CD at 5%	NS	NS	NS	NS	NS		NS	NS	NS	NS	NS	
<b>Intercropping</b>												
Sole cotton	58	335	857	385	228		80	410	837	477	285	
Cotton + Soybean	57	218	520	253	122		75	303	567	360	185	
Cotton + Greengram	48	263	590	315	175		63	313	688	378	218	
Cotton + Blackgram	52	260	640	337	213		63	328	673	408	235	
Cotton + Cowpea	55	242	600	300	183		68	340	667	368	212	
Cotton + Groundnut	52	237	483	212	123		60	305	572	322	182	
Cotton + Sesamum	53	213	515	258	140		62	283	532	303	178	
SE m±	2	9	21	10	6		1	8	20	14	6	
CD at 5%	4	26	62	28	17		4	22	58	41	17	
<b>Interaction</b>												
SE m±	2	13	30	14	8		2	11	28	20	8	
CD at 5%	NS	NS	NS	NS	NS		NS	NS	NS	NS	NS	

The interaction effects due to planting pattern and its intercropping with different components had no significant influence on the nutrient removal of cotton.

#### 4.2.6.3 Potassium

The data on influence of growing cotton in different planting patterns and intercropping systems on removal of potassium are presented in table 17.

The crop did not exhibit a differential response to this variable due to a change in the planting pattern from uniform to paired row.

Different intercropping systems had a remarkable influence on removal of potassium by cotton. The sole crop removed substantially large quantities of potassium at every stage from 60 days after sowing in the first year and from 30 days after sowing until harvest in the second year. Cotton intercropped with sesamum or groundnut removed least quantity of potassium.

The interactions owing to planting pattern and cropping systems did not exert a significant influence on the response of crop to remove potassium from the soil.



#### 4.2.7 Seed cotton yield (kg ha<sup>-1</sup>)

The data on seed cotton yield as influenced by planting pattern of cotton and intercropping systems are furnished in table 18.

The mean seed cotton yield, was low from the first picking and was maximum from the second. The yield was relatively low in the third picking compared to first picking. There were no significant differences in seed cotton yield due to the differential planting pattern of the crop in the uniform rows of 90 cm and paired rows of 120 / 60 cm.

Sole cotton produced maximum yield in each of the three pickings during the two years. This was on par with the yield of cotton intercropped with cowpea. The total seed cotton yield of 1278 kg ha<sup>-1</sup> in sole crop was on par with the total yield of 1202 kg ha<sup>-1</sup> by intercropping cotton with cowpea in 2004. The total yield of 1564 kg ha<sup>-1</sup> from sole crop during 2005 was also on par with seed cotton yield of 1476 kg ha<sup>-1</sup> when intercropped with cowpea. Similarly, there was no significant reduction in yield of cotton by intercropping blackgram during first year. The reduction in yield of seed cotton was severe by intercropping soybean, groundnut or sesamum.

Table 18 : Picking wise seed cotton yield (kg ha<sup>-1</sup>) as influenced by planting pattern and intercrops

Treatment	Kharif-2004				Kharif-2005			
	Seed cotton yield (kg ha <sup>-1</sup> )				Seed cotton yield (kg ha <sup>-1</sup> )			
	First picking	Second picking	Final picking	Total	First picking	Second picking	Final picking	Total
<b>Planting pattern</b>								
Uniform rows	276	590	202	1068	314	641	284	1240
Paired rows	261	538	209	1008	316	647	289	1254
SE m±	6	15	9	25	6	12	11	25
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS
<b>Intercropping</b>								
Sole cotton	325	695	258	1278	394	810	360	1564
Cotton + Soybean	246	418	153	817	263	549	223	1035
Cotton + Greengram	274	595	205	1074	342	660	356	1358
Cotton + Blackgram	303	661	233	1197	358	736	310	1404
Cotton + Cowpea	305	665	232	1202	372	764	340	1476
Cotton + Groundnut	202	443	153	798	253	530	215	998
Cotton + Sesamum	227	467	210	904	226	463	204	893
SE m±	12	28	17	47	11	22	20	46
CD at 5%	35	82	49	137	33	64	58	134
<b>Interaction</b>								
SE m±	17	40	24	67	16	31	28	66
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS

There were no significant interaction effects on production of seed cotton yield during the three pickings and on the total production due to the combined influence of planting pattern of cotton and choice of cropping system.

#### **4.2.8 Quality parameters**

The data on quality parameters of cotton as influenced by planting pattern and cropping systems are furnished in table 19.

The ginning percentage, seed index, lint index or staple length were not significantly influenced by the planting patterns. Cotton intercropped with soybean, greengram, blackgram, cowpea, groundnut and sesamum recorded no drastic alterations in ginning percentage, seed index, lint index or staple length compared to sole crop of cotton. This trend was akin during both the years of study. The qualitative assessment also recorded no significant interactive impacts due to the planting pattern and cropping system.

### **4.3 PERFORMANCE OF INTERCROPS**

#### **4.3.1 Soybean**

##### **4.3.1.1 Vegetative crop growth**

The data on mean plant height and phytomass of soybean in intercropping treatments in contrast to sole cropping are

Table 19 : Quality parameters of cotton as influenced by planting pattern and intercrops

Treatment	Kharif-2004				Kharif-2005			
	Ginning percentage	Seed index	Lint index	Staple length (mm)	Ginning percentage	Seed index	Lint index	Staple length (mm)
<b>Planting pattern</b>								
Uniform rows	36.22	9.25	5.24	32.48	35.70	9.20	5.08	32.62
Paired rows	36.33	9.16	5.27	32.32	36.03	9.18	5.12	32.68
SE m±	0.19	0.06	0.04	0.23	0.28	0.06	0.08	0.20
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS
<b>Intercropping</b>								
Sole cotton	35.96	9.28	5.26	32.34	35.98	9.25	5.21	32.86
Cotton + Soybean	36.29	9.30	5.39	32.12	35.66	9.20	5.10	32.81
Cotton + Greengram	36.51	9.24	5.32	32.46	35.71	9.19	5.11	32.59
Cotton + Blackgram	36.39	9.13	5.17	32.30	35.78	9.19	5.12	32.53
Cotton + Cowpea	36.39	9.18	5.30	32.76	35.99	9.24	5.15	32.43
Cotton + Groundnut	36.24	9.17	5.16	32.41	36.11	9.14	5.03	32.72
Cotton + Sesamum	36.15	9.14	5.20	32.42	35.83	9.11	5.00	32.62
SE m±	0.36	0.11	0.07	0.43	0.53	0.12	0.15	0.38
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS
<b>Interaction</b>								
SE m±	0.52	0.16	0.10	0.62	0.76	0.17	0.21	0.54
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS

furnished in table 20. The crop did not show a remarkable impact on its plant height in response to its intercropping with 66.66% sole optimum population between the uniform row spacing of cotton or with 50% sole optimum density between the paired rows. This trend was persistent at every stage of crop growth from 15 days after sowing until harvest both during 2004 and 2005. Similarly, the phytomass accumulation per plant did not show a substantial variation due to intercropping of soybean in uniform or paired row planting of cotton in contrast to its sole planting at any one of the sampling frequencies.

#### **4.3.1.2 Days to 50 per cent flowering and yield components**

The data in table 21 indicate the influence of intercropping soybean in cotton in relation to its sole crop on days to 50 per cent flowering, yield components, removal of N, P and K seed and haulm yield.

The days needed to 50% flowering were not altered by intercropping soybean in uniform or paired row planting of cotton compared to the sole crop in either of the two years. The yield components *viz.*, number of pods per plant, pod length, and number of seeds per pod were also independent of the treatment effects.

Table 20 : Growth characters of Soybean as influenced by intercropping in cotton with different planting patterns

Character / Treatment	Kharif, 2004							Kharif, 2005						
	Days after sowing							Days after sowing						
	15	30	45	60	75	At harvest	15	30	45	60	75	At harvest		
<b>Plant height (cm)</b>														
Sole soybean	9.34	19.20	36.97	57.12	59.78	60.24	10.23	20.30	32.56	49.26	55.94	57.02		
Uniform row planting of cotton + soybean (66.66% sole optimum density)	10.12	18.60	35.87	55.05	58.82	59.80	9.89	20.10	30.89	47.97	54.77	56.29		
Paired row planting of cotton + soybean (50% sole optimum density)	9.89	18.48	36.27	56.78	59.13	61.11	10.12	20.35	27.13	46.44	55.70	56.39		
<b>Phytomass (g plant<sup>-1</sup>)</b>														
Sole soybean	2.80	4.27	9.64	16.26	21.53	23.82	2.83	4.96	10.99	14.52	18.98	21.04		
Uniform row planting of cotton + soybean (66.66% sole optimum density)	2.91	3.90	8.58	16.10	20.50	22.54	2.44	4.81	10.08	14.00	18.42	20.86		
Paired row planting of cotton + soybean (50% sole optimum density)	2.75	4.14	9.43	16.00	21.04	22.89	2.76	4.84	10.01	13.98	18.49	20.59		

#### 4.3.1.3 Removal of nutrients (kg ha<sup>-1</sup>)

The intercrop removed substantially low quantity of nutrients. Sole crop of soybean removed 80.6 kg N ha<sup>-1</sup> in 2004 and 74.5 kg N ha<sup>-1</sup> in 2005. When intercropped in the uniform rows of cotton, the removal of this nutrient was enormously reduced to 50.9 and 50.2 kg ha<sup>-1</sup> during the corresponding years. This reduction was more remarkable by intercropping soybean between the paired rows of cotton. The crop removed 39.3 and 35.8 kg N ha<sup>-1</sup> during the two years.

Sole soybean removed 12.4 kg P ha<sup>-1</sup> in the first year and 11.5 kg ha<sup>-1</sup> in the second year. When intercropped in uniform and paired rows, it removed 9.6 and 7.6 kg P ha<sup>-1</sup> during the first year. Soybean removed 8.1 and 6.1 kg P ha<sup>-1</sup> in these intercropping treatments during the subsequent year.

The intercropped soybean also removed relatively less quantity of 28.9 and 22.1 kg K ha<sup>-1</sup> in uniform and paired row planting of cotton compared to a substantially large quantity of 39.8 kg K ha<sup>-1</sup> removed by the sole crop during the first year. Similarly it extracted a low quantity of 25.1 and 19.3 kg K ha<sup>-1</sup> from the corresponding intercropping treatments in contrast to 36 kg ha<sup>-1</sup> from the sole crop during 2005.

Table 21 : Days to 50 per cent flowering, yield components, nutrient removal and yield ( $\text{kg ha}^{-1}$ ) of Soybean as influenced by intercropping in cotton with different planting patterns

Treatment	Kharif, 2004									
	Days to 50 per cent flowering	Number of pods per plant	Pod length (cm)	Number of seeds per pod	Nutrient removal ( $\text{kg ha}^{-1}$ )			Seed yield ( $\text{kg ha}^{-1}$ )	Haulm yield ( $\text{kg ha}^{-1}$ )	
					N	P	K			
Sole soybean	33.32	31.89	4.27	2.94	80.6	12.4	39.8	1615	1689	
Uniform row planting of cotton + soybean (66.66% sole optimum density)	32.83	30.92	4.23	2.92	50.9	9.6	28.9	937	1032	
Paired row planting of cotton + soybean (50% sole optimum density)	32.89	31.23	4.26	2.93	39.3	7.6	22.1	710	783	
Kharif, 2005										
Sole soybean	26.12	29.28	4.21	2.91	74.5	11.5	36.0	1406	1438	
Uniform row planting of cotton + soybean (66.66% sole optimum density)	26.39	28.92	4.24	2.89	50.2	8.1	25.1	844	896	
Paired row planting of cotton + soybean (50% sole optimum density)	25.84	29.23	4.20	2.90	35.8	6.1	19.3	605	682	

#### 4.3.1.4 Seed and haulm yield (kg ha<sup>-1</sup>)

Seed yield of 937 kg ha<sup>-1</sup> and haulm yield of 1032 kg ha<sup>-1</sup> was reaped from soybean intercropped in the uniform row planting pattern of cotton during 2004. The corresponding production was 844 kg ha<sup>-1</sup> and 896 kg ha<sup>-1</sup> during 2005. The production of seed was further reduced to 710 and 605 kg ha<sup>-1</sup> and that of haulms to 783 and 682 kg ha<sup>-1</sup> in soybean intercropped between the paired rows of cotton during 2005. Sole soybean yielded 1615 and 1406 kg seed ha<sup>-1</sup> during the two years. The haulm yield was 1689 kg ha<sup>-1</sup> during 2004 and 1438 kg ha<sup>-1</sup> during 2005.

### 4.3.2 GREENGRAM

#### 4.3.2.1 Vegetative crop growth

The data on mean plant height and phytomass accumulation per plant of greengram in response to its intercropping with different planting patterns of cotton in relation to sole crop are furnished in table 22.

There were no striking variations in the mean plant height of greengram by intercropping between uniform or paired rows of cotton compared to sole crop at any stage throughout its growth period. There were no substantial deflections in the phytomass

Table 22 : Growth characters of Greengram as influenced by intercropping in cotton with different planting patterns

Character / Treatment	Kharif, 2004				Kharif, 2005			
	Days after sowing				Days after sowing			
	15	30	45	At harvest	15	30	45	At harvest
<b>Plant height (cm)</b>								
Sole greengram	11.02	24.22	42.06	46.53	10.28	25.27	41.82	43.29
Uniform row planting of cotton + greengram (66.66% sole optimum density)	10.25	23.69	41.99	47.73	9.84	24.56	39.70	41.97
Paired row planting of cotton + greengram (50% sole optimum density)	10.62	22.65	41.42	47.81	9.79	24.65	40.03	42.15
<b>Phytomass (g plant<sup>-1</sup>)</b>								
Sole greengram	3.34	5.78	9.01	10.18	3.82	5.12	8.39	9.52
Uniform row planting of cotton + greengram (66.66% sole optimum density)	3.25	5.69	8.62	10.10	3.14	4.69	8.17	9.44
Paired row planting of cotton + greengram (50% sole optimum density)	3.18	5.72	8.52	9.61	3.76	4.80	8.10	9.38

accumulation per plant of greengram in the two intercropping systems compared to sole crop.

#### **4.3.2.2 Days to 50 per cent flowering and yield components**

The data presented in table 23 indicated that the intercropping of greengram in uniform rows of cotton or between paired rows virtually had no differentially remarkable response on days to 50% flowering, number of pods per plant, pod length and number of seeds per pod compared to sole crop.

#### **4.3.2.3 Removal of nutrients (kg ha<sup>-1</sup>)**

The removal of the three major nutrients was enormously low by greengram intercropped in cotton. The sole crop removed 48.9 kg N, 3.8 kg P and 44.2 kg K ha<sup>-1</sup> during 2004. Greengram intercropped between uniform rows of cotton removed 35 kg N, 3.2 kg P and 31.7 kg K ha<sup>-1</sup>. It removed further low quantity of 24.0, 2.0 and 20.4 kg N P and K ha<sup>-1</sup> when intercropped between the paired rows. This trend was similar in second year. Large quantity of 49.1, 3.9 and 44.9 kg N P and K ha<sup>-1</sup> was removed by the sole crop of greengram. The removal of these nutrients was reduced to 36.0, 3.1 and 32.8 kg N P and K ha<sup>-1</sup> when it was intercropped between the uniform rows of cotton. Least quantity of 24 kg N, 2.1 kg P and 21.6 kg K ha<sup>-1</sup> was removed by greengram intercropped between paired rows of cotton.

Table -23 : Days to 50 per cent flowering, yield components, nutrient removal and yield (kg ha<sup>-1</sup>) of Greengram as influenced by intercropping in cotton with different planting patterns

Treatment	Kharif, 2004									
	Days to 50 per cent flowering	Number of pods per plant	Pod length (cm)	Number of seeds per pod	Nutrient removal (kg ha <sup>-1</sup> )			Seed yield (kg ha <sup>-1</sup> )	Haulm yield (kg ha <sup>-1</sup> )	
					N	P	K			
Sole greengram	29.82	17.48	5.55	10.68	48.9	3.8	44.2	935	1929	
Uniform row planting of cotton + greengram (66.66% sole optimum density)	30.13	17.70	5.59	10.67	35.0	3.2	31.7	598	1214	
Paired row planting of cotton + greengram (50% sole optimum density)	30.25	17.66	5.62	10.69	24.0	2.0	20.4	449	873	
Kharif, 2005										
Sole greengram	29.42	16.34	5.53	10.62	49.1	3.9	44.9	962	1889	
Uniform row planting of cotton + greengram (66.66% sole optimum density)	29.78	16.55	5.55	10.49	36.0	3.1	32.8	606	1238	
Paired row planting of cotton + greengram (50% sole optimum density)	30.15	16.19	5.48	10.54	24.0	2.1	21.6	452	924	

#### **4.3.2.4 Seed and haulm yield (kg ha<sup>-1</sup>)**

The intercropped greengram produced less quantity of seed and haulms. It yielded 598 kg seed and 1214 kg haulm ha<sup>-1</sup> when intercropped in the uniform rows of cotton. The sole crop produced seed yield of 935 kg ha<sup>-1</sup> and haulm yield 1929 kg ha<sup>-1</sup> during the first year. In the subsequent year, intercropped greengram yielded 606 kg seed and 1238 kg haulms ha<sup>-1</sup> in this intercropping treatment compared to higher production of 962 kg seed ha<sup>-1</sup> and 1889 kg haulm ha<sup>-1</sup> in the solitary stand. The reduction in yield was more severe by intercropping greengram between paired rows. Low seed yield of 449 and 452 kg ha<sup>-1</sup> was realized during the corresponding years. The haulm yield was also minimised to 873 and 924 kg ha<sup>-1</sup>.

#### **4.3.3 BLACKGRAM**

##### **4.3.3.1 Vegetative crop growth**

Blackgram did not record a substantial variation in mean plant height or phytomass accumulation plant<sup>-1</sup> at any stage during the crop growth period by flanking two rows between the uniform rows or three rows between the paired rows of cotton (Table 24).

Table 24 : Growth characters of Blackgram as influenced by intercropping in cotton with different planting patterns

Character / Treatment	Kharif, 2004				Kharif, 2005			
	Days after sowing				Days after sowing			
	15	30	45	At harvest	15	30	45	At harvest
<b>Plant height (cm)</b>								
Sole blackgram	10.26	19.21	23.12	26.06	11.24	19.06	25.17	28.19
Uniform row planting of cotton + blackgram (66.66% sole optimum density)	9.89	18.75	22.29	25.18	10.96	18.38	24.42	27.03
Paired row planting of cotton + blackgram (50% sole optimum density)	10.13	18.03	23.06	25.89	11.02	18.13	24.92	26.20
<b>Phytomass (g plant<sup>-1</sup>)</b>								
Sole blackgram	3.30	5.43	7.98	9.12	4.21	6.34	8.04	9.13
Uniform row planting of cotton + blackgram (66.66% sole optimum density)	3.26	5.39	7.85	9.06	4.09	6.48	7.92	9.02
Paired row planting of cotton + blackgram (50% sole optimum density)	3.32	5.36	7.95	8.74	4.16	6.02	7.98	9.00

#### **4.3.3.2 Days to 50 per cent flowering and yield components**

The observations on days to 50 per cent flowering, number of pods per plant, pod length and number of seeds per pod exhibited that there were no significant deviations in these characters by the option of intercropping blackgram in differential planting patterns or its sole stand (Table 25).

#### **4.3.3.3 Removal of nutrients (kg ha<sup>-1</sup>)**

The nutrient removal recorded credible differences. Maximum quantity of 43.5 kg N, 4.9 kg P and 38.4 kg K ha<sup>-1</sup> was removed by the sole crop of blackgram during 2004. In the subsequent year, it removed 40.9, 4.9 and 36.1 kg ha<sup>-1</sup> NPK. When intercropped between the uniform rows of cotton, blackgram removed 30.2, 3.8 and 28.4 kg ha<sup>-1</sup> N P and K in the first year. It removed 31.2, 3.6 and 29.1 kg ha<sup>-1</sup> of these nutrients in the second year. Least quantity of 20.2, 2.4 and 18.4 kg ha<sup>-1</sup> NPK was removed by blackgram intercropped between paired rows of cotton during the first year. In the second year, it removed 20.3, 2.4 and 16.1 kg ha<sup>-1</sup> N P and K in this treatment.

#### **4.3.3.4 Seed yield and haulm yield (kg ha<sup>-1</sup>)**

The sole crop of blackgram yielded 752 kg seed and 1486 kg haulms ha<sup>-1</sup> during 2004. It produced 766 kg seed and 1502 kg

**Table 25: Days to 50 per cent flowering, yield components, nutrient removal and yield (kg ha<sup>-1</sup>) of Blackgram as influenced by intercropping in cotton with different planting patterns**

<b>Kharif, 2004</b>									
Treatment	Days to 50 per cent flowering	Number of pods per plant	Pod length (cm)	Number of seeds per pod	Nutrient removal (kg ha <sup>-1</sup> )			Seed yield (kg ha <sup>-1</sup> )	Haulm yield (kg ha <sup>-1</sup> )
					N	P	K		
Sole blackgram	31.93	12.35	4.97	6.62	43.5	4.9	38.4	752	1486
Uniform row planting of cotton + blackgram (66.66% sole optimum density)	32.01	12.33	4.58	6.69	30.2	3.8	28.4	466	894
Paired row planting of cotton + blackgram (50% sole optimum density)	32.53	12.36	4.95	6.60	20.2	2.4	18.4	353	685
<b>Kharif, 2005</b>									
Sole blackgram	32.13	12.61	4.96	6.60	40.9	4.9	36.1	766	1502
Uniform row planting of cotton + blackgram (66.66% sole optimum density)	31.89	12.49	4.52	6.72	31.2	3.6	29.1	467	914
Paired row planting of cotton + blackgram (50% sole optimum density)	31.47	12.28	4.78	6.73	20.3	2.4	16.1	345	678

haulms  $\text{ha}^{-1}$  in the second year. When intercropped between uniform rows of cotton seed and haulm yield reduced to 466  $\text{kg ha}^{-1}$  894  $\text{kg ha}^{-1}$  in the first year and 467  $\text{kg ha}^{-1}$  and 914  $\text{kg ha}^{-1}$  in the second year. Low seed yield of 353  $\text{kg ha}^{-1}$  and haulm yield of 685  $\text{kg ha}^{-1}$  was realized when blackgram was grown between the paired rows of cotton during 2004. Low seed yield of 345  $\text{kg ha}^{-1}$  and haulm yield of 678  $\text{kg ha}^{-1}$  was obtained from this treatment during the subsequent year.

#### **4.3.4 COWPEA**

##### **4.3.4.1 Vegetative crop growth**

The data on mean plant height and phytomass of cowpea in intercropping treatments in contrast to sole cropping are furnished in table 26.

The crop did not show a remarkable impact on its plant height in response to its intercropping with uniform or paired rows of cotton and sole crop. This trend was persistent at every stage of crop growth till harvest both during 2004 and 2005. Similarly, phytomass accumulation per plant did not show a substantial variation due to intercropping of cowpea in uniform or paired row planting of cotton in contrast to its sole planting at any one of the sampling frequencies.

Table 26 : Growth characters of Cowpea as influenced by intercropping in cotton with different planting patterns

Character / Treatment	Kharif, 2004				Kharif, 2005			
	Days after sowing				Days after sowing			
	15	30	45	At harvest	15	30	45	At harvest
<b>Plant height (cm)</b>								
Sole cowpea	11.29	20.86	45.16	47.04	10.86	25.61	34.07	41.53
Uniform row planting of cotton + cowpea (66.66% sole optimum density)	10.94	20.43	44.87	46.99	10.94	25.28	32.91	39.71
Paired row planting of cotton + cowpea (50% sole optimum density)	11.06	20.27	42.33	45.06	11.08	25.03	33.36	40.24
<b>Phytomass (g plant<sup>-1</sup>)</b>								
Sole cowpea	3.54	6.89	9.59	8.84	4.82	7.02	10.11	9.46
Uniform row planting of cotton + cowpea (66.66% sole optimum density)	3.29	6.45	9.07	8.21	4.29	6.54	10.04	9.21
Paired row planting of cotton + cowpea (50% sole optimum density)	3.72	6.32	9.02	8.76	4.35	6.62	10.08	9.10

#### **4.3.4.2 Days to 50 per cent flowering and yield components**

The data in table 27 indicate the influence of intercropping cowpea in cotton in relation to its sole crop on days to 50 per cent flowering, yield components, removal of N, P, K, seed and haulm yield.

The days needed to 50% flowering were not altered by intercropping cowpea in uniform or paired row planting of cotton compared to the sole crop in either of the two years. The yield components *viz.*, number of pods per plant, pod length and number of seeds per pod were also independent of the treatment.

#### **4.3.4.3 Removal of nutrients (kg ha<sup>-1</sup>)**

Sole crop of cowpea removed 40.1 kg N ha<sup>-1</sup> in 2004 and 41.3 kg N ha<sup>-1</sup> in 2005. When intercropped in the uniform rows of cotton, the removal of this nutrient was enormously reduced to 29.3 and 30.4 kg ha<sup>-1</sup> during the corresponding years. This reduction was more remarkable by intercropping cowpea between the paired rows of cotton. The crop removed 19.1 and 19.0 kg N ha<sup>-1</sup> during the two years. Sole cowpea removed 3.6 kg P ha<sup>-1</sup> during first year and 3.7 kg ha<sup>-1</sup> in the second year. When intercropped in uniform and paired rows, it removed 2.2 and 1.6 kg P ha<sup>-1</sup> during the first year. Cowpea removed 2.0 and 1.8 kg P ha<sup>-1</sup> in these intercropping treatments during the subsequent

**Table 27: Days to 50 per cent flowering, yield components, nutrient removal and yield (kg ha<sup>-1</sup>) of Cowpea as influenced by intercropping in cotton with different planting patterns**

Treatment	<i>Kharif, 2004</i>									
	Days to 50 per cent flowering	Number of pods per plant	Pod length (cm)	Number of seeds per pod	Nutrient removal (kg ha <sup>-1</sup> )			seed yield (kg ha <sup>-1</sup> )	Haulm yield (kg ha <sup>-1</sup> )	
					N	P	K			
Sole cowpea	33.18	11.31	10.17	12.35	40.1	3.6	34.9	847	1878	
Uniform row planting of cotton + cowpea (66.66% sole optimum density)	32.84	11.24	10.22	12.36	29.3	2.2	26.2	551	1310	
Paired row planting of cotton + cowpea (50% sole optimum density)	32.75	11.38	10.18	12.10	19.1	1.6	17.3	415	945	
<i>Kharif, 2005</i>										
Sole cowpea	32.53	11.33	10.22	12.26	41.3	3.7	35.7	905	2018	
Uniform row planting of cotton + cowpea (66.66% sole optimum density)	33.04	11.22	10.13	12.36	30.4	2.0	27.9	579	1237	
Paired row planting of cotton + cowpea (50% sole optimum density)	32.89	11.37	10.10	12.05	18.0	1.8	16.3	416	942	

year. The intercropped cowpea also removed relatively less quantity of 26.2 and 17.3 kg K ha<sup>-1</sup> in uniform and paired row planting of cotton compared to a substantially large quantity of 34.9 kg K ha<sup>-1</sup> by the sole crop during the first year. Similarly, it extracted a low quantity of 27.9 and 16.3 kg K ha<sup>-1</sup> from the corresponding intercropping treatments in contrast to 35.7 kg K ha<sup>-1</sup> from the sole crop during 2005.

#### **4.3.4.4 Seed and haulm yield (kg ha<sup>-1</sup>)**

Seed yield of 551 kg ha<sup>-1</sup> and haulm yield of 1310 kg ha<sup>-1</sup> was reaped from cowpea intercropped in the uniform row planting pattern during 2004. The corresponding production was 579 kg ha<sup>-1</sup> and 1237 kg ha<sup>-1</sup> during 2005. The production of seed was further reduced to 415 and 416 kg ha<sup>-1</sup> and that of haulms to 945 and 942 kg ha<sup>-1</sup> in cowpea intercropped between the paired rows of cotton during 2005. Sole cowpea yielded 847 and 905 kg seed ha<sup>-1</sup> during the two years. The haulm yield was 1878 kg ha<sup>-1</sup> during 2004 and 2018 kg ha<sup>-1</sup> during 2005.

#### **4.3.5 GROUNDNUT**

##### **4.3.5.1 Vegetative crop growth**

Groundnut did not record a substantial variation in mean plant height or phytomass accumulation per plant at any stage

**Table 28 : Growth characters of Groundnut as influenced by intercropping in cotton with different planting patterns**

Character / Treatment	Kharif, 2004										Kharif, 2005					
	Days after sowing										Days after sowing					
	15	30	45	60	75	90	At harvest	15	30	45	60	75	90	At harvest		
<b>Plant height (cm)</b>																
Sole groundnut	6.89	13.99	25.83	37.18	42.08	42.36	42.53	7.53	13.02	24.13	37.18	42.94	43.16	44.50		
Uniform row planting of cotton + groundnut	6.14	13.73	27.00	36.54	41.35	41.95	42.08	7.13	12.54	23.72	36.30	39.31	42.20	43.59		
Paired row planting of cotton + groundnut	6.76	13.68	24.66	36.07	39.39	40.26	41.89	7.24	12.32	24.65	34.70	41.91	43.88	44.26		
<b>Phytomass (g plant<sup>-1</sup>)</b>																
Sole groundnut	7.84	10.92	13.92	17.59	20.10	21.28	22.31	6.49	10.04	13.04	17.09	18.75	19.14	20.46		
Uniform row planting of cotton + groundnut	7.24	10.69	13.69	17.33	19.42	21.16	21.99	5.82	10.28	12.28	16.32	17.52	18.99	19.24		
Paired row planting of cotton + groundnut	7.28	10.80	13.80	17.46	20.14	21.15	21.69	6.50	10.21	12.21	16.77	18.14	19.09	19.29		

during the crop growth period by flanking two rows between the uniform rows of cotton or three rows between the paired rows (Table 28).

#### **4.3.5.2 Days to 50 per cent flowering and yield components**

The observations on days to 50 per cent flowering, number of pods per plant and number of seeds per pod exhibited that there were no significant deviations in these characters by the option of intercropping groundnut in differential planting pattern or its sole stand (Table 29).

#### **4.3.5.3 Removal of nutrients (kg ha<sup>-1</sup>)**

The nutrient removal recorded credible differences. Maximum quantity of 94.3 kg N, 9.1 kg P and 79.5 kg K ha<sup>-1</sup> was removed by the sole crop of groundnut during 2004. In the subsequent year, it removed 89.7, 8.9 and 76.0 kg ha<sup>-1</sup> N P and K. When intercropped between the uniform rows of cotton groundnut removed 75.8, 6.5 and 61.7 kg ha<sup>-1</sup> N P and K in the first year. It removed 72.8, 5.9 and 57.8 kg ha<sup>-1</sup> of these nutrients in the second year. Least quantity of 53.9, 4.3 and 44.7 kg ha<sup>-1</sup> N P and K was removed by groundnut intercropped between paired rows of cotton during the first year. In the second year, it removed 50.3, 4.1 and 42.2 kg ha<sup>-1</sup> N P and K in this treatment.

**Table 29 : Days to 50 per cent flowering, yield components, nutrient removal and yield (kg ha<sup>-1</sup>) of Groundnut as influenced by intercropping in cotton with different planting patterns**

Treatment	Kharif, 2004									
	Days to 50 per cent flowering	Number of pods per plant	Number of seeds per pod	Nutrient removal (kg ha <sup>-1</sup> )			Pod yield (kg ha <sup>-1</sup> )	Haulm yield (kg ha <sup>-1</sup> )		
				N	P	K				
Sole groundnut	26.38	18.34	1.87	94.3	9.1	79.5	1150	1982		
Uniform row planting of cotton + groundnut (66.66% sole optimum density)	26.02	18.22	1.82	75.8	6.5	61.7	690	1180		
Paired row planting of cotton + groundnut (50% sole optimum density)	25.93	17.99	1.85	53.9	4.35	44.7	529	972		
Kharif, 2005										
Sole groundnut	26.04	17.16	1.86	89.7	8.9	76.0	1071	1874		
Uniform row planting of cotton + groundnut (66.66% sole optimum density)	25.98	17.02	1.85	72.8	5.9	57.8	621	1069		
Paired row planting of cotton + groundnut (50% sole optimum density)	25.83	16.94	1.88	50.5	4.1	42.2	471	806		

#### **4.3.5.4 Pod and haulm yield (kg ha<sup>-1</sup>)**

The sole crop of groundnut yielded 1150 kg pods and 1982 kg haulms ha<sup>-1</sup> during 2004. It produced 1071 kg pods and 1874 kg haulms ha<sup>-1</sup> in the second year. When intercropped between uniform rows of cotton, pod and haulm yield reduced to 690 kg ha<sup>-1</sup>, 1180 kg ha<sup>-1</sup> in the first year and to 621 and 1069 kg ha<sup>-1</sup> in the second year. Low pod yield of 529 kg ha<sup>-1</sup> and haulm yield of 972 kg ha<sup>-1</sup> was realized when groundnut was grown between the paired rows of cotton during 2004. Low pod yield of 471 kg ha<sup>-1</sup> and haulm yield of 806 kg ha<sup>-1</sup> was obtained from this treatment during the next year.

#### **4.3.6 SESAMUM**

##### **4.3.6.1 Vegetative crop growth**

The data on mean plant height and phytomass accumulation per plant of sesamum in response to its intercropping with different planting patterns of cotton in relation to sole crop are furnished in table 30.

There were no striking variations in the mean plant height of sesamum by intercropping between uniform or paired rows of cotton compared to sole crop at any stage throughout its growth period. There were no substantial deflections in the phytomass

**Table 30 : Growth characters of Sesamum as influenced by intercropping in cotton with different planting patterns**

Character / Treatment	Kharif, 2004					Kharif, 2005				
	Days after sowing					Days after sowing				
	15	30	45	60	At harvest	15	30	45	60	At harvest
<b>Plant height (cm)</b>										
Sole sesamum	6.28	17.82	44.83	58.22	70.94	9.14	17.85	60.28	94.09	102.53
Uniform row planting of cotton + sesamum (66.66% sole optimum density)	5.94	16.80	45.11	56.42	69.00	9.26	18.12	63.52	97.56	105.10
Paired row planting of cotton + sesamum (50% sole optimum density)	6.06	17.79	46.24	57.91	70.36	9.39	17.42	58.46	95.54	103.29
<b>Phytomass (g plant<sup>-1</sup>)</b>										
Sole sesamum	2.26	5.12	6.89	9.06	9.53	2.60	5.95	9.58	11.09	11.26
Uniform row planting of cotton + sesamum (66.66% sole optimum density)	2.12	4.56	6.41	8.92	9.03	2.48	5.76	9.39	10.98	11.04
Paired row planting of cotton + sesamum (50% sole optimum density)	2.18	4.67	6.32	8.76	9.24	2.52	5.93	9.36	10.83	10.98

accumulation per plant of sesamum in the two intercropping systems compared to sole crop.

#### **4.3.6.2 Days to 50 per cent flowering and yield components**

The data presented in table 31 indicated that the intercropping of sesamum in uniform rows of cotton or between paired rows had no influence on days to 50 per cent flowering, number of siliquae per plant and number of seeds per siliqua compared to the sole crop.

#### **4.3.6.3 Removal of nutrients (kg ha<sup>-1</sup>)**

The removal of the three major nutrients was enormously low by sesamum when intercropped with cotton. The sole crop removed 39.5 kg N, 9.2 kg P and 32.5 kg K ha<sup>-1</sup> during 2004. When intercropped between uniform rows of cotton sesamum removed 27.5 kg N, 5.7 kg P and 21.6 kg K ha<sup>-1</sup>. It removed further low quantity of 21.1, 4.5, 15.1 kg N P and K ha<sup>-1</sup> when intercropped with paired rows. This trend was similar in second year. Large quantity of 48.8, 13.5 and 41.3 kg N P and K ha<sup>-1</sup> was removed by the sole crop of sesamum. The removal of these nutrients was reduced to 38.9, 10.3 and 29.3 kg N P and K ha<sup>-1</sup> when it was intercropped between the uniform rows of cotton. Least quantity of 31.6 kg N, 8.9 kg P and 20.5 kg K ha<sup>-1</sup> was

**Table 31: Days to 50 per cent flowering, yield components, nutrient removal and yield (kg ha<sup>-1</sup>) of Sesamum as influenced by intercropping in cotton with different planting patterns**

Treatment		Kharif, 2004							
		No. of siliqua per plant		No. of seed per siliqua	Nutrient removal (kg ha <sup>-1</sup> )			Seed yield (kg ha <sup>-1</sup> )	Stalk yield (kg ha <sup>-1</sup> )
					N	P	K		
		38.26	15.65	27.86	39.5	9.2	32.5	386	794
	Sole sesamum								
	Uniform row planting of cotton + sesamum (66.66% sole optimum density)	37.92	15.83	27.41	27.5	5.7	21.6	243	513
	Paired row planting of cotton + sesamum (50% sole optimum density)	38.43	15.21	27.57	21.1	4.5	15.1	181	375
Treatment		Kharif, 2005							
		No. of siliqua per plant		No. of seed per siliqua	Nutrient removal (kg ha <sup>-1</sup> )			Seed yield (kg ha <sup>-1</sup> )	Stalk yield (kg ha <sup>-1</sup> )
					N	P	K		
		37.58	29.82	30.13	48.8	13.5	41.3	810	1718
	Sole sesamum								
	Uniform row planting of cotton + sesamum (66.66% sole optimum density)	38.02	29.13	29.82	38.9	10.3	29.3	518	1099
	Paired row planting of cotton + sesamum (50% sole optimum density)	37.94	29.46	30.26	31.6	8.9	20.5	389	832

removed by sesamum intercropped between paired rows of cotton.

#### **4.3.6.4 Seed and stalk yield (kg ha<sup>-1</sup>)**

The intercropped sesamum produced less quantity of seed and stalk. It yielded 243 kg seed and 513 kg stalk ha<sup>-1</sup> when intercropped in the uniform rows of cotton in contrast to the sole crop seed yield of 386 kg ha<sup>-1</sup> and stalk yield of 794 kg ha<sup>-1</sup> during the first year. In the subsequent year, sesamum yielded 518 kg seed ha<sup>-1</sup> and 1099 kg stalk ha<sup>-1</sup> in this intercropping treatment compared to higher production of 810 kg seed ha<sup>-1</sup> and 1718 kg stalk ha<sup>-1</sup> in the solitary stand. The reduction in yield was more severe by intercropping sesamum between the paired rows. Low seed yield of 181 and 389 kg ha<sup>-1</sup> was realized during the corresponding years. The stalk yield also minimized to 375 and 832 kg ha<sup>-1</sup>.

#### **4.4 SOIL MOISTURE**

The data on soil moisture content at 15, 30 and 45 cm depth recorded at different frequencies are furnished in table 32, 33 and 34. The soil had relatively more moisture content in the top 15 cm layer from 30 days after sowing until 120 days in field plots sown with cotton compared to the intercrop treatments during 2004. Similarly, the soil cultivated with sole cotton retained

Table 32 : Soil moisture content (%) at 15 cm depth as influenced by planting pattern and intercrops

Treatment	Kharif-2004						Kharif-2005					
	Days after sowing						Days after sowing					
	30	60	90	120	30	60	90	120	30	60	90	120
<b>Uniform row planting</b>												
Sole cotton	9.2	7.4	6.6	5.4	10.2	6.5	6.6	7.8				
Cotton + Soybean	8.9	6.9	6.0	3.7	9.8	6.9	6.9	7.5				
Cotton + Greengram	8.4	7.0	6.4	5.3	9.9	6.2	6.8	7.2				
Cotton + Blackgram	8.4	6.8	5.2	5.8	10.4	6.3	7.2	7.6				
Cotton + Cowpea	8.7	6.8	6.0	5.1	10.1	6.5	6.8	7.5				
Cotton + Groundnut	8.8	6.7	6.6	5.0	9.5	7.1	7.0	7.7				
Cotton + Sesamum	9.1	6.4	5.9	6.0	9.7	6.9	6.8	7.2				
<b>Paired row planting</b>												
Sole cotton	8.1	8.5	6.2	6.0	10.0	7.0	7.1	7.5				
Cotton + Soybean	7.6	6.9	7.1	5.2	9.6	6.5	6.5	6.9				
Cotton + Greengram	8.8	6.2	6.1	5.0	10.2	6.8	6.8	7.8				
Cotton + Blackgram	9.3	6.3	6.8	4.5	9.5	6.9	6.9	7.4				
Cotton + Cowpea	8.5	7.3	6.2	5.2	9.3	6.6	7.0	7.3				
Cotton + Groundnut	7.2	7.9	6.0	5.2	9.4	6.8	6.6	7.9				
Cotton + Sesamum	8.3	5.6	5.1	5.5	9.7	6.7	6.7	7.5				

Table 33 : Soil moisture content (%) at 30 cm depth as influenced by planting pattern and intercrops

Treatment	Kharif-2004						Kharif-2005					
	Days after sowing						Days after sowing					
	30	60	90	120	30	60	90	120	30	60	90	120
<b>Uniform row planting</b>												
Sole cotton	10.3	7.8	6.6	5.6	11.3	7.5	7.7	8.2				
Cotton + Soybean	9.4	7.3	6.1	4.8	10.4	7.4	7.2	8.0				
Cotton + Greengram	8.0	6.9	6.7	4.0	10.8	7.8	7.4	8.4				
Cotton + Blackgram	9.0	7.4	6.7	6.9	10.7	7.2	7.5	8.5				
Cotton + Cowpea	7.8	7.0	6.2	5.2	10.9	7.5	7.1	8.3				
Cotton + Groundnut	10.1	7.0	7.0	5.0	10.6	6.9	7.3	8.5				
Cotton + Sesamum	9.4	7.3	7.1	5.2	11.0	7.1	7.0	8.1				
<b>Paired row planting</b>												
Sole cotton	9.8	6.9	6.7	4.8	11.2	7.2	7.4	8.5				
Cotton + Soybean	8.2	7.2	5.9	5.3	10.5	6.8	7.0	8.0				
Cotton + Greengram	7.9	7.1	7.3	5.4	10.2	7.0	7.2	8.2				
Cotton + Blackgram	7.9	7.8	7.3	5.2	10.9	6.9	7.1	8.4				
Cotton + Cowpea	8.1	7.1	6.1	5.5	10.5	7.2	7.3	8.8				
Cotton + Groundnut	9.6	6.8	6.9	5.3	10.8	7.5	6.9	8.5				
Cotton + Sesamum	8.8	6.7	6.1	4.5	11.0	7.4	7.0	8.2				

Table 34 : Soil moisture content (%) at 45 cm depth as influenced by planting pattern and intercrops

Treatment	Kharif-2004						Kharif-2005					
	Days after sowing						Days after sowing					
	30	60	90	120	30	60	90	120	30	60	90	120
<b>Uniform row planting</b>												
Sole cotton	10.8	8.5	7.2	6.4	11.9	8.1	8.3	8.9				
Cotton + Soybean	10.9	8.2	7.0	5.4	12.2	7.7	8.2	8.4				
Cotton + Greengram	10.4	8.1	7.1	6.6	11.5	8.0	8.0	8.7				
Cotton + Blackgram	11.3	8.3	7.1	6.4	11.7	7.7	7.9	8.6				
Cotton + Cowpea	11.2	7.8	7.4	6.3	12.1	7.8	7.5	8.7				
Cotton + Groundnut	10.6	8.2	6.3	6.2	11.8	7.7	7.8	8.9				
Cotton + Sesamum	10.8	8.3	7.5	6.6	11.9	7.5	7.5	8.4				
<b>Paired row planting</b>												
Sole cotton	11.4	9.2	7.1	7.1	12.1	8.0	7.8	8.7				
Cotton + Soybean	9.9	8.5	7.5	5.4	11.5	7.5	7.7	8.2				
Cotton + Greengram	9.4	8.2	7.1	6.5	11.3	7.7	7.9	8.5				
Cotton + Blackgram	10.4	7.9	6.8	6.2	11.8	7.5	7.8	8.8				
Cotton + Cowpea	11.0	8.1	6.8	6.2	11.9	7.8	8.0	8.9				
Cotton + Groundnut	11.8	7.6	7.4	6.1	12.0	7.9	7.7	8.7				
Cotton + Sesamum	11.2	8.8	7.2	6.1	11.7	8.0	7.6	8.5				

more moisture at 30 cm depth upto 60 days after sowing. Such a trend was not transparent at 45 cm depth during any stage of crop growth. In the second year, the variations in moisture retention at different depths and days after sowing were not distinct between the sole and intercrop treatments.

#### **4.5 PER CENT BOLL DAMAGE IN COTTON**

The data on per cent boll damage recorded at 75, 90, 105 and 120 days after sowing are presented in table 35.

At all the crop stages sampled, per cent boll damage was found to be less during the second year. The mean maximum per cent damage was observed at 75 days during first year and 90 days in next year.

Sowing of different intercrops in uniform or paired rows of cotton did not reduce the incidence of damage by this pest. The interaction effects were also not significant.

#### **4.6 EVALUATION OF INTERCROPING SYSTEMS**

Intercropping systems were evaluated by adopting the most widely recognized approaches.

Table 35: Per cent boll damage as influenced by planting pattern and intercrops in cotton

Treatment	Kharif-2004						Kharif-2005					
	Days after sowing						Days after sowing					
	75	90	105	120	75	90	105	120	75	90	105	120
<b>Planting pattern</b>												
Uniform rows	21.92	19.54	20.61	11.60	10.52	13.76	12.26	8.74				
Paired rows	21.05	19.53	20.57	11.10	10.95	14.04	12.68	8.40				
SE m±	0.57	0.45	0.68	0.38	0.74	0.56	0.62	0.54				
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS				
<b>Intercropping</b>												
Sole cotton	21.62	19.79	19.99	12.68	11.27	14.09	12.40	8.42				
Cotton + Soybean	21.88	19.60	20.72	12.17	11.04	13.96	12.51	7.95				
Cotton + Greengram	20.98	19.43	20.71	11.14	10.34	13.95	12.49	9.12				
Cotton + Blackgram	22.83	19.44	21.08	10.71	11.00	13.94	12.64	8.68				
Cotton + Cowpea	21.61	19.84	20.85	10.62	10.82	14.11	12.69	8.89				
Cotton + Groundnut	21.09	19.13	20.14	11.28	10.64	13.77	12.44	7.97				
Cotton + Sesamum	20.39	19.52	20.65	10.86	10.13	13.47	12.16	8.94				
SE m±	1.08	0.84	1.28	0.71	1.39	1.06	1.17	1.02				
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS				
<b>Interaction</b>												
SE m±	1.53	1.19	1.81	1.01	1.94	1.50	1.66	1.39				
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS				

#### 4.6.1 Seed cotton equivalent yield ( $\text{kg ha}^{-1}$ )

The data presented in table 36 revealed significantly higher seed cotton equivalent yields by intercropping different components in the uniformly spaced rows of cotton than paired rows. An equivalent mean seed yield of  $1533 \text{ kg ha}^{-1}$  was realised from the uniform row planting pattern compared to  $1361 \text{ kg ha}^{-1}$  from paired rows during 2004. In the second year, the seed cotton equivalent yield was  $1739 \text{ kg ha}^{-1}$  from the former treatment and  $1623 \text{ kg ha}^{-1}$  from the latter.

The option of intercropping component established that cowpea, blackgram or greengram significantly enhanced the seed cotton equivalent yields compared to soybean, groundnut or sesamum. The yield of sole cotton was on par with seed cotton equivalent yield realized by intercropping soybean, groundnut or sesamum during the two years. The interactions were not significant in either of the two years.

#### 4.6.2 Bivariate analysis

A statistical comparison of intercropping systems through the bivariate analysis of variance by transforming the yield data in terms of greengram seed equivalent yield presented in table 37, is made through the  $d^2$  values in tables 38 and 39. A graphical presentation of this approach (Fig. 5 and 6) indicated that the

Table 36 : Seed cotton equivalent yield (kg ha<sup>-1</sup>) as influenced by planting pattern and intercrops

Treatment	Kharif-2004				Kharif-2005			
	Yield (kg ha <sup>-1</sup> )				Yield (kg ha <sup>-1</sup> )			
	Seed cotton	Intercrop	Seed cotton equivalent	Seed cotton	Seed cotton equivalent	Intercrop	Seed cotton equivalent	Seed cotton equivalent
<b>Planting pattern</b>								
Uniform rows	--	--	1533	--	--	--	1739	
Paired rows	--	--	1361	--	--	--	1623	
SE m±	--	--	25	--	--	--	26	
CD at 5%	--	--	71	--	--	--	73	
<b>Intercropping</b>								
Sole cotton	1278	--	1278	1564	--	--	1564	
Cotton + Soybean	817	824	1294	1035	724	--	1454	
Cotton + Greengram	1074	523	1652	1358	530	--	1944	
Cotton + Blackgram	1197	409	1714	1404	407	--	1918	
Cotton + Cowpea	1202	483	1634	1476	498	--	1922	
Cotton + Groundnut	798	609	1407	998	547	--	1545	
Cotton + Sesamum	904	212	1149	893	454	--	1419	
SE m±	--	--	46	--	--	--	47	
CD at 5%	--	--	133	--	--	--	137	
<b>Interaction</b>								
SE m±	--	--	65	--	--	--	67	
CD at 5%	--	--	NS	--	--	--	NS	

angle between the Y1 and Z1 was negative. It was  $10.71^\circ$  during 2004 and  $2.43^\circ$  during 2005. The transformed sole crop yield of cotton and greengram are presented as solid line. The component yield of cotton and greengram equivalent seed yield of different intercrop systems are plotted as points for transformed yield of cotton representing on Y1 axis and greengram seed equivalents on Y2 axis. Each of these yield data points are encircled with regions of 5 per cent confidence interval to delineate the influence of different intercrops on the production of intercropping systems.

Intercropping of cowpea between the uniform rows of cotton was most outstanding system. It was statistically on par with the intercropping of blackgram or greengram between the uniform rows of cotton but significantly superior over rest of the treatments. This trend was similar during 2004 and 2005. Intercropping of sesamum between the uniform rows of cotton was on par with greengram only in the first year. In turn intercropping of groundnut or sesamum were on par with that of soybean during the two years. The paired row planting pattern intercropped with different components were statistically uncomparable to the intercropping of respective components between the uniform rows of cotton.

Table 37 : Transformed data for bivariate analysis of variance of seed yield

Treatment	Kharif - 2004						Kharif-2005					
	Mean yield			Transformed yield			Mean yield			Transformed yield		
	Seed Cotton	Y <sub>1</sub> Seed cotton	Intercrops Green gram seed equivalent	Y <sub>2</sub> Intercrops Green gram seed equivalent	Z <sub>1</sub> Seed cotton	Z <sub>2</sub> Intercrops Green gram seed equivalent	Seed Cotton	Y <sub>1</sub> Seed cotton	Intercrops Green gram seed equivalent	Y <sub>2</sub> Intercrops Green gram seed equivalent	Z <sub>1</sub> Seed cotton	Z <sub>2</sub> Intercrops Green gram seed equivalent
<b>Uniform row planting</b>												
Cotton + Soybean	852	7.63	11.98	7.77	10.53	1013	8.42	15.98	8.43	15.62		
Cotton + Greengram	1105	9.90	13.47	10.08	11.59	1349	11.22	16.97	11.23	16.49		
Cotton + Blackgram	1216	10.89	13.26	11.09	11.20	1425	11.85	16.51	11.86	16.01		
Cotton + Cowpea	1211	10.85	13.80	11.04	11.75	1458	12.12	17.22	12.13	16.71		
Cotton + Groundnut	831	7.44	12.25	7.58	10.84	982	8.17	15.56	8.17	15.21		
Cotton + Sesamum	934	8.37	12.99	8.52	11.41	875	7.28	17.08	7.28	16.77		
<b>Paired row planting</b>												
Cotton + Soybean	781	7.00	9.31	7.12	7.99	1057	8.79	11.58	8.80	11.20		
Cotton + Greengram	1043	9.34	10.47	9.51	8.70	1368	11.37	12.78	11.38	12.30		
Cotton + Blackgram	1178	10.55	10.48	10.74	8.48	1384	11.51	12.32	11.52	11.83		
Cotton + Cowpea	1193	10.69	10.88	10.88	8.85	1495	12.44	12.53	12.45	12.00		
Cotton + Groundnut	764	6.84	9.60	6.97	8.30	1015	8.44	11.90	8.45	11.54		
Cotton + Sesamum	873	7.82	9.97	7.96	8.49	912	7.58	12.91	7.59	12.59		
Sole crop	1278	11.45	20.67	11.66	18.17	1564	13.00	26.61	13.01	26.01		

Table 38 : d<sup>2</sup> Bivariate analysis of variance for transformed values of intercrops as greengram seed equivalents in different intercropping systems Kharif, 2004

Treatment	Uniform row						Paired row					
	Cotton + Soybean	Cotton + G. gram	Cotton + B. gram	Cotton + Cowpea	Cotton + G. nut	Cotton + Sesamum	Cotton + Soybean	Cotton + G. gram	Cotton + B. gram	Cotton + Cowpea	Cotton + G. nut	Cotton + Sesamum
<b>Uniform rows</b>												
Cotton + Soybean	--	7.37*	12.27*	13.68*	0.15	1.56	7.52*	5.20*	10.78*	10.57*	6.29*	4.07
Cotton + Greengram	--	--	1.02	1.23	7.54*	2.57	25.71*	9.31*	9.36*	7.33*	24.33*	16.58*
Cotton + Blackgram	--	--	--	0.29	12.92*	6.42*	30.73*	10.18*	7.84*	5.70*	29.79*	20.24*
Cotton + Cowpea	--	--	--	--	14.03*	6.81*	24.01*	13.36*	11.11*	8.52*	33.72*	23.84*
Cotton + Groundnut	--	--	--	--	--	1.41	8.84*	6.78*	12.46*	12.43*	7.38*	5.31*
Cotton + Sesamum	--	--	--	--	--	--	15.42*	7.29*	11.05*	9.83*	13.83*	9.42*
<b>Paired rows</b>												
Cotton + Soybean	--	--	--	--	--	--	--	6.82*	13.96*	16.07*	0.16	1.10
Cotton + Greengram	--	--	--	--	--	--	--	--	1.46	1.99	7.00*	2.56
Cotton + Blackgram	--	--	--	--	--	--	--	--	--	0.18	14.66*	7.78*
Cotton + Cowpea	--	----	--	--	--	--	--	--	--	--	16.46*	9.05*
Cotton + Groundnut	--	--	--	--	--	--	--	--	--	--	--	1.10
Cotton + Sesamum	--	--	--	--	--	--	--	--	--	--	--	--

CD at 5% = 4.84      \*Significant at 5% probability

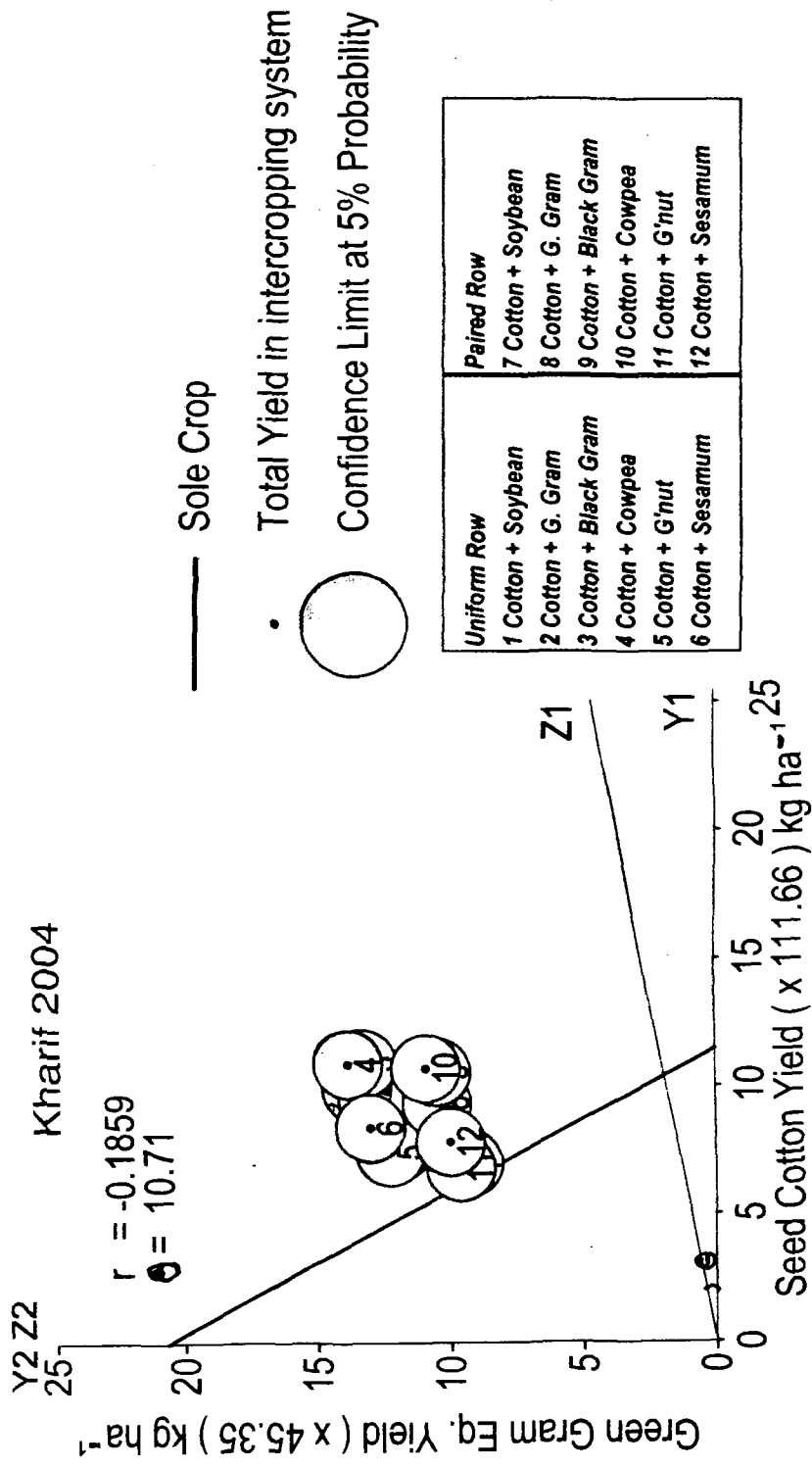


Fig. 5 : Bivariate analysis of variance for Intercropping System in Cotton

Table 39 :  $d^2$  Bivariate analysis of variance for transformed values of intercrops as greengram seed equivalents in different intercropping systems Kharif, 2005

Treatment	Uniform row						Paired row					
	Cotton + Soybean	Cotton + G. gram	Cotton + B. gram	Cotton + Cowpea	Cotton + G. nut	Cotton + Sesamum	Cotton + Soybean	Cotton + G. gram	Cotton + B. gram	Cotton + Cowpea	Cotton + G. nut	Cotton + Sesamum
<b>Uniform rows</b>												
Cotton + Soybean	--	8.82*	12.04*	15.23*	0.23	2.51	19.49*	18.94*	22.94*	28.06*	16.64*	10.13*
Cotton + Greengram	--	--	0.61	0.87	11.29*	15.53*	34.95*	17.58*	30.03*	21.20*	33.43*	29.73*
Cotton + Blackgram	--	--	--	0.58	14.44*	21.20*	33.67*	14.14*	17.67*	16.19*	32.88*	31.19*
Cotton + Cowpea	--	--	--	--	18.36*	23.44*	42.89*	20.27*	24.38*	22.10*	41.84*	39.18*
Cotton + Groundnut	--	--	--	--	--	3.10	16.22*	17.97*	21.65*	27.41*	13.47*	7.37*
Cotton + Sesamum	--	--	--	--	--	--	32.53*	35.22*	40.55*	47.33*	28.18*	17.48*
<b>Paired rows</b>												
Cotton + Soybean	--	--	--	--	--	--	--	8.09*	7.94*	14.22*	0.22	3.23
Cotton + Greengram	--	--	--	--	--	--	--	--	0.23	1.20	9.36*	14.38*
Cotton + Blackgram	--	--	--	--	--	--	--	--	--	0.91	9.60*	15.79*
Cotton + Cowpea	--	----	--	--	--	--	--	--	--	--	16.39*	23.76*
Cotton + Groundnut	--	--	--	--	--	--	--	--	--	--	--	1.76
Cotton + Sesamum	--	--	--	--	--	--	--	--	--	--	--	--

CD at 5% = 4.84

\*Significant at 5% probability

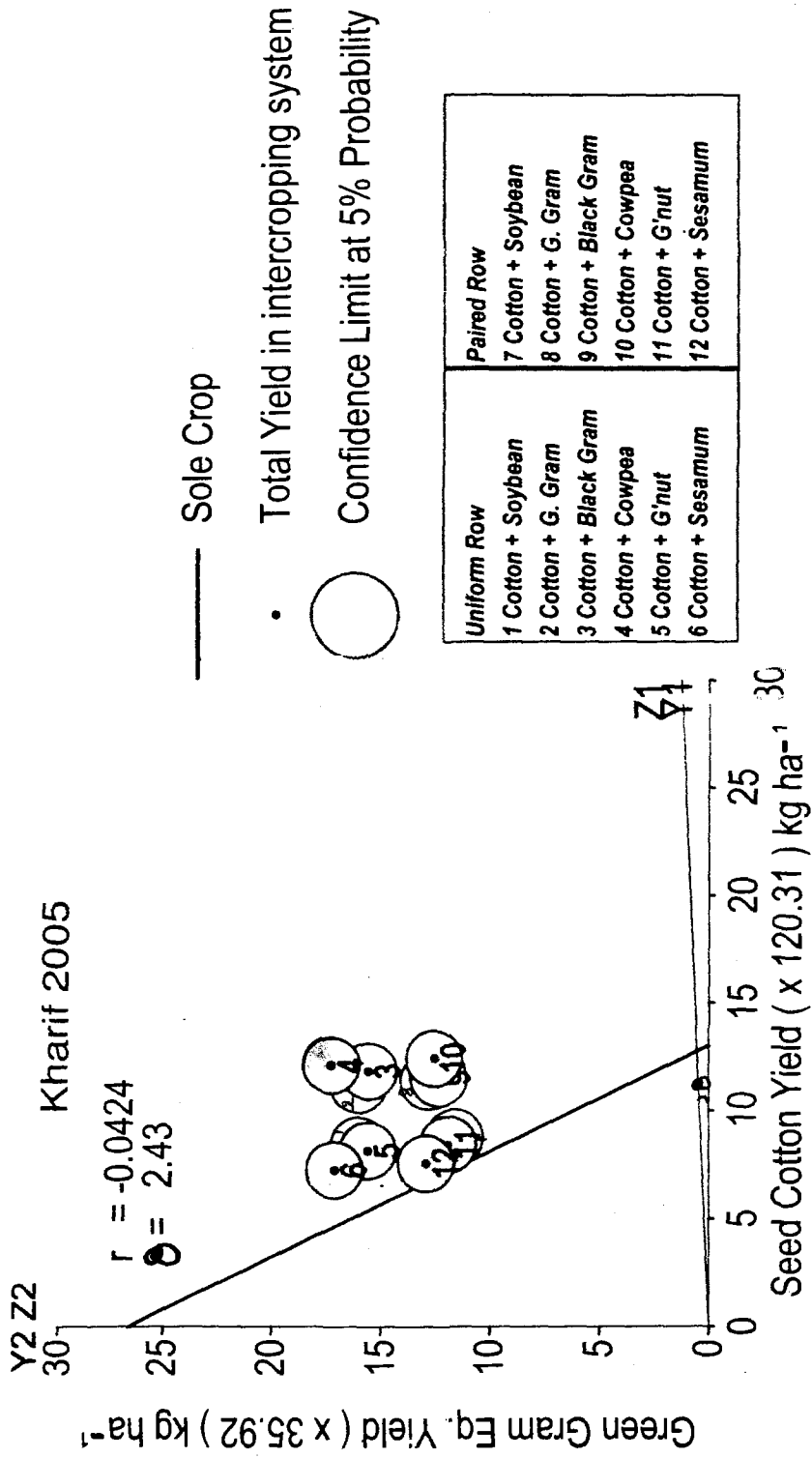


Fig.6 : Bivariate analysis of variance for Intercropping System in Cotton

A comparison of intercropping systems between paired rows of cotton exhibited that cowpea intercropping was equivocal to greengram or blackgram.

#### **4.6.3 Land equivalent ratio (LER)**

The data on efficiency of land utilization in terms of productivity per unit area of land as well as time are furnished in table 40.

The partial land equivalent ratios indicated that the relative yield proportion of cotton (LER<sub>c</sub>) was more by intercropping greengram, blackgram or cowpea in paired than uniform rows of cotton during 2004. The partial LER<sub>c</sub> was 0.83 by intercropping greengram in cotton spaced in uniform rows compared to 0.85 in paired rows. Similarly, the partial LER<sub>c</sub> of 0.92 due to intercropping of blackgram in uniform rows increased to 0.96 in paired row planting. The partial LER<sub>c</sub> with cowpea intercropping raised from 0.92 to 0.97 in the corresponding planting pattern treatments of cotton. In the second year, paired row planting was advantageous to record relatively better partial LER of cotton by intercropping soybean, greengram, cowpea, groundnut and sesamum. But, the partial LERs of the six intercrop components inadvertently registered grand reduction in the paired than uniform row spacing of cotton both during 2004 and 2005. Among

Table 40 : Land equivalent ratios (LER) and area time equivalent ratios (ATER) as influenced by planting pattern and intercrops

Treatment	Kharif - 2004			ATER	Kharif - 2005			ATER
	Land equivalent ratio				Land equivalent ratio			
	Cotton	Intercrop	Total		Cotton	Intercrop	Total	
<b>Uniform row planting</b>								
Cotton + Soybean	0.64	0.58	1.22	1.00	0.64	0.60	1.24	1.02
Cotton + Greengram	0.83	0.64	1.47	1.11	0.85	0.63	1.48	1.13
Cotton + Blackgram	0.92	0.62	1.54	1.20	0.90	0.61	1.51	1.17
Cotton + Cowpea	0.92	0.65	1.57	1.20	0.92	0.64	1.56	1.19
Cotton + Groundnut	0.63	0.60	1.23	1.07	0.62	0.58	1.20	1.03
Cotton + Sesamum	0.76	0.63	1.39	1.09	0.55	0.64	1.19	0.89
<b>Paired row planting</b>								
Cotton + Soybean	0.64	0.44	1.08	0.92	0.68	0.43	1.11	0.95
Cotton + Greengram	0.85	0.48	1.33	1.06	0.88	0.47	1.35	1.09
Cotton + Blackgram	0.96	0.47	1.43	1.17	0.89	0.45	1.34	1.09
Cotton + Cowpea	0.97	0.49	1.46	1.18	0.96	0.46	1.42	1.16
Cotton + Groundnut	0.62	0.46	1.08	0.96	0.66	0.44	1.10	0.97
Cotton + Sesamum	0.71	0.47	1.18	0.96	0.59	0.48	1.07	0.84

the different intercropping systems, intercropping option of blackgram or cowpea in uniform rows of cotton had an edge over others. Maximum LER of 1.54 and 1.57 were recorded in these two intercropping treatments during 2004. The LERs were 1.51 and 1.56 from the respective intercropping systems during the second year. The LERs were relatively low in paired than in uniform row orientation of cotton for all the intercropping systems.

#### **4.6.4 Area time equivalent ratio (ATER)**

The Area time equivalent ratios recorded best advantage of increased productivity per unit land and time by intercropping either blackgram or cowpea between the rows of cotton uniformly spaced at a distance of 90 cm. The efficiency of intercropping blackgram between uniform rows of cotton indicated that this system required 1.17 and 1.20 hectare days during 2005 and 2004 to maximize the total productivity of the system. The ATER values for cotton + cowpea intercropping were 1.19 and 1.20 in the corresponding years. The area time equivalent ratios were relatively low in paired than in uniform row orientation of cotton for intercropping.

#### **4.6.5 Effective ( $\lambda$ ) land equivalent ratio (ELER)**

The data on standardized or desired yield proportion of cotton relative to the total productivity of the intercropping system

**Table 41: Effective land equivalent ratios ( $\lambda$  LER) of different intercropping treatments**

Treatment	K	Kharif-2004		Kharif-2005	
		$\lambda$	$\lambda$ LER	$\lambda$	$\lambda$ LER
Cotton + Soybean Uniform row planting	0.2	0.13	1.04	0.12	1.05
	0.4	0.24	1.09	0.23	1.10
	0.6	0.34	1.13	0.34	1.14
	0.8	0.44	1.18	0.43	1.19
	1.0	0.53	1.22	0.53	1.24
	0.2	0.89	1.04	0.89	1.05
	0.4	0.79	1.09	0.78	1.10
	0.6	0.69	1.13	0.69	1.14
	0.8	0.61	1.18	0.60	1.19
	1.0	0.53	1.22	0.52	1.24
Cotton + Greengram Uniform row planting	0.2	0.12	1.09	0.16	1.10
	0.4	0.23	1.19	0.29	1.19
	0.6	0.39	1.28	0.40	1.29
	0.8	0.48	1.36	0.49	1.38
	1.0	0.56	1.47	0.57	1.48
	0.2	0.88	1.09	0.89	1.10
	0.4	0.78	1.19	0.79	1.19
	0.6	0.70	1.28	0.71	1.29
	0.8	0.63	1.38	0.64	1.38
	1.0	0.56	1.47	0.57	1.48
Cotton + Blackgram Uniform row planting	0.2	0.17	1.11	0.16	1.11
	0.4	0.30	1.22	0.30	1.20
	0.6	0.42	1.32	0.41	1.31
	0.8	0.51	1.43	0.51	1.41
	1.0	0.60	1.54	0.60	1.51
	0.2	0.89	1.10	0.89	1.10
	0.4	0.80	1.22	0.80	1.21
	0.6	0.72	1.32	0.72	1.31
	0.8	0.65	1.43	0.65	1.41
	1.0	0.58	1.54	0.60	1.51
Cotton + Cowpea Uniform row Planting	0.2	0.17	1.11	0.17	1.11
	0.4	0.30	1.23	0.30	1.23
	0.6	0.41	1.34	0.41	1.34
	0.8	0.51	1.46	0.51	1.45
	1.0	0.59	1.57	0.59	1.56
	0.2	0.88	1.11	0.89	1.11
	0.4	0.79	1.23	0.79	1.22
	0.6	0.71	1.34	0.71	1.34
	0.8	0.64	1.46	0.65	1.45
	1.0	0.58	1.57	0.59	1.56

Treatment	K	Kharif-2004		Kharif-2005	
		$\lambda$	$\lambda$ LER	$\lambda$	$\lambda$ LER
Cotton + Groundnut Uniform row planting	0.2	0.20	1.05	0.12	1.04
	0.4	0.23	1.09	0.23	1.08
	0.6	0.33	1.39	0.33	1.12
	0.8	0.43	1.18	0.43	1.16
	1.0	0.51	1.23	0.52	1.20
	0.2	0.89	1.05	0.89	1.04
	0.4	0.78	1.09	0.79	1.08
	0.6	0.68	1.14	0.69	1.12
	0.8	0.59	1.18	0.60	1.16
	1.0	0.51	1.23	0.52	1.20
Cotton + Sesamum Uniform row planting	0.2	0.14	1.08	0.11	1.01
	0.4	0.26	1.16	0.20	1.08
	0.6	0.37	1.23	0.30	1.11
	0.8	0.46	1.31	0.38	1.15
	1.0	0.55	1.39	0.46	1.19
	0.2	0.88	1.08	0.88	1.04
	0.4	0.78	1.16	0.76	1.08
	0.6	0.69	1.23	0.66	1.11
	0.8	0.62	1.31	0.56	1.15
	1.0	0.55	1.39	0.46	1.19
Cotton + Soybean Paired row planting	0.2	0.13	1.09	0.13	1.02
	0.4	0.25	1.03	0.26	1.04
	0.6	0.37	1.08	0.38	1.07
	0.8	0.48	1.06	0.50	1.09
	1.0	0.60	1.08	0.61	1.11
	0.2	0.91	1.01	0.92	1.02
	0.4	0.83	1.03	0.84	1.04
	0.6	0.75	1.09	0.76	1.07
	0.8	0.67	1.06	0.68	1.09
	1.0	0.59	1.08	0.61	1.11
Cotton + Greengram Paired row planting	0.2	0.16	1.07	0.16	1.07
	0.4	0.30	1.13	0.31	1.14
	0.6	0.43	1.20	0.44	1.21
	0.8	0.54	1.26	0.55	1.28
	1.0	0.64	1.33	0.65	1.35
	0.2	0.91	1.07	0.91	1.07
	0.4	0.83	1.13	0.84	1.14
	0.6	0.76	1.19	0.77	1.21
	0.8	0.69	1.26	0.71	1.28
	1.0	0.64	1.33	0.65	1.35
Cotton + Blackgram Paired row planting	0.2	0.18	1.09	0.17	1.07
	0.4	0.33	1.18	0.31	1.14
	0.6	0.46	1.28	0.44	1.20

Treatment	K	Kharif-2004		Kharif-2005	
		$\lambda$	$\lambda$ LER	$\lambda$	$\lambda$ LER
	0.8	0.57	1.34	0.56	1.28
	1.0	0.67	1.43	0.66	1.34
	0.2	0.91	1.09	0.92	1.07
	0.4	0.84	1.17	0.84	1.14
	0.6	0.78	1.26	0.78	1.20
	0.8	0.72	1.34	0.72	1.27
	1.0	0.67	1.43	0.66	1.34
	Cotton + Cowpea Paired row planting	0.2	0.18	1.09	0.18
0.4		0.33	1.18	0.33	1.17
0.6		0.46	1.28	0.46	1.25
0.8		0.57	1.37	0.57	1.34
1.0		0.66	1.46	0.68	1.42
0.2		0.91	1.09	0.92	1.08
0.4		0.83	1.18	0.84	1.17
0.6		0.77	1.28	0.78	1.25
0.8		0.71	1.37	0.72	1.34
1.0		0.66	1.46	0.68	1.42
Cotton + Groundnut Paired row planting	0.2	0.12	1.02	0.13	1.02
	0.4	0.24	1.03	0.25	1.04
	0.6	0.35	1.05	0.37	1.06
	0.8	0.47	1.06	0.49	1.08
	1.0	0.57	1.08	0.60	1.10
	0.2	0.91	1.02	0.91	1.02
	0.4	0.82	1.03	0.83	1.04
	0.6	0.74	1.05	0.75	1.06
	0.8	0.65	1.06	0.67	1.08
	1.0	0.57	1.08	0.60	1.10
Cotton + Sesamum Paired row planting	0.2	0.14	1.04	0.12	1.01
	0.4	0.26	1.07	0.23	1.03
	0.6	0.38	1.11	0.34	1.04
	0.8	0.49	1.14	0.45	1.06
	1.0	0.60	1.18	0.55	1.07
	0.2	0.91	1.04	0.91	1.01
	0.4	0.82	1.07	0.81	1.03
	0.6	0.75	1.11	0.72	1.04
	0.8	0.67	1.14	0.64	1.06
	1.0	0.60	1.18	0.55	1.07

K – Proportionate area to be intercropped

$\lambda$  - Proportionate desired yield of cotton

$\lambda$ LER – Effective land equivalent ratio

are presented in table 41. These are also depicted through the shallow curves with a desired yield proportion of cotton on the X axis and corresponding Effective ( $\lambda$ ) LER on Y axis (Figure 7).

The maximum land use efficiency was recorded by intercropping cowpea between uniform rows of cotton for any threshold limit of the cotton crop upto 59% of the total productivity during the two years. The next best option was blackgram or greengram. High LER values of 1.54 and 1.51 were recorded by intercropping blackgram between the uniform rows of cotton in the two years with standardized cotton yield proportion of 60% in both the years. The ELERs were 1.47 in 2004 and 1.48 in 2005 by intercropping greengram between the uniform rows for standardized seed cotton yield of 56 and 57% during two years.

If the farmers interest is to ascertain relatively more proportionate harvested area of cotton then the option would be to prefer paired row of cotton for intercropping. The standardized yields were 66 and 68% during 2004 and 2005 by intercropping cowpea in this row orientation technique. But, the ELERs were reduced to 1.46 and 1.42. Intercropping of blackgram between paired rows of cotton was also a preferable system for desired cotton yield proportion estimated at 67% in 2004 and 66% in 2005 with ELERs 1.43 and 1.34 respectively. Intercropping of

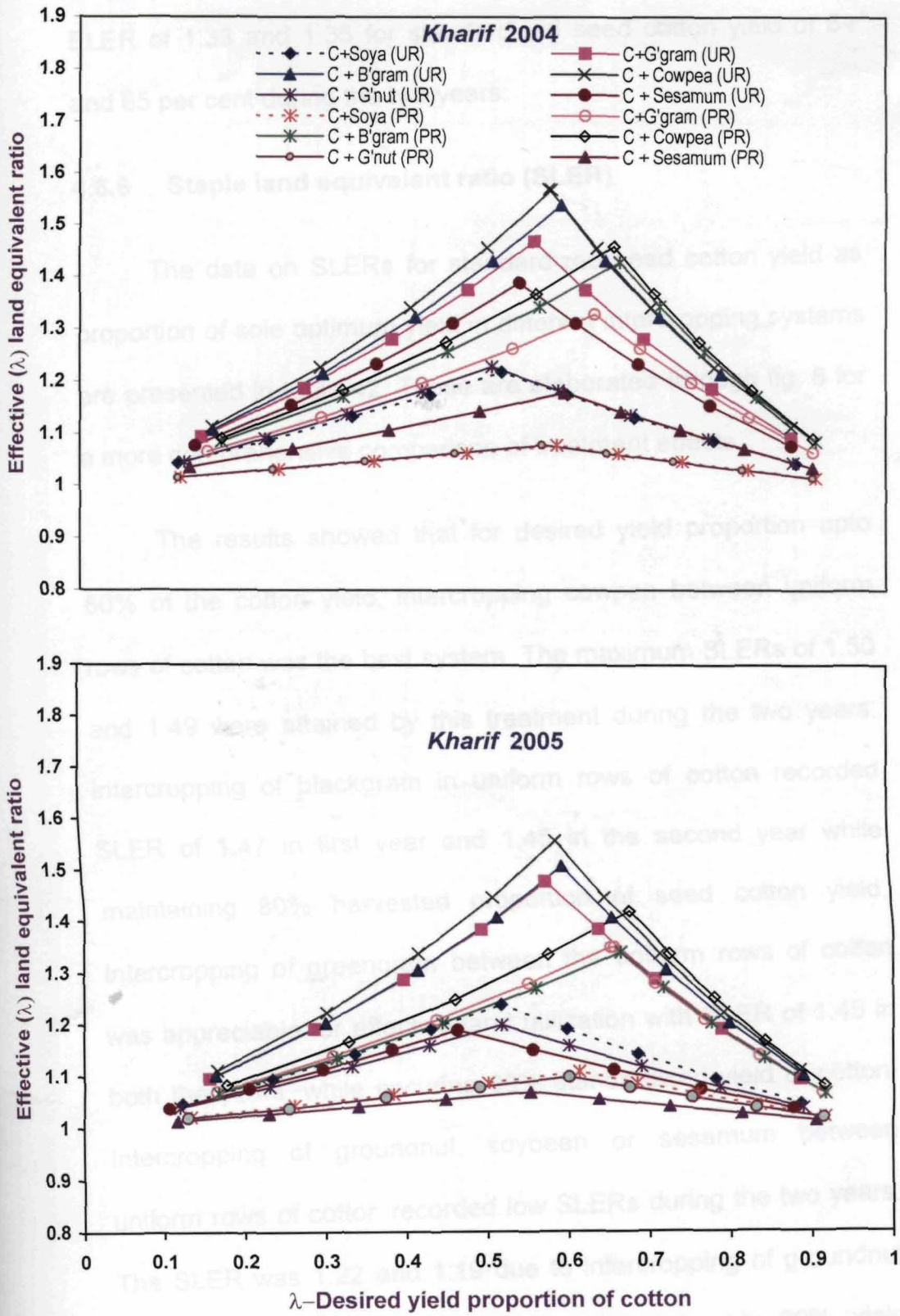


Fig. 7 : Effective ( $\lambda$ ) land equivalent ratios plotted against the required yield ratios of cotton in cotton - intercropping system

greengram in paired row planting was next preferable option with ELER of 1.33 and 1.35 for standardized seed cotton yield of 64 and 65 per cent during the two years.

#### **4.6.6 Staple land equivalent ratio (SLER)**

The data on SLERs for standardized seed cotton yield as proportion of sole optimum yield in different intercropping systems are presented in table 42. These are elaborated through fig. 8 for a more comprehensive comparison of treatment effects.

The results showed that for desired yield proportion upto 80% of the cotton yield, intercropping cowpea between uniform rows of cotton was the best system. The maximum SLERs of 1.50 and 1.49 were attained by this treatment during the two years. Intercropping of blackgram in uniform rows of cotton recorded SLER of 1.47 in first year and 1.45 in the second year while maintaining 80% harvested proportion of seed cotton yield. Intercropping of greengram between the uniform rows of cotton was appreciable for effective land utilization with SLER of 1.45 in both the years, while securing 80% standardized yield of cotton. Intercropping of groundnut, soybean or sesamum between uniform rows of cotton recorded low SLERs during the two years. The SLER was 1.22 and 1.19 due to intercropping of groundnut between two rows of cotton while securing only 60% yield

Table 42: Staple land equivalent ratios (SLER) of different intercropping treatments

Treatment	Kharif-2004			Kharif-2005		
	Proportionate area to be intercropped	Desired yield proportion	Staple land equivalent ratio	Proportionate area to be intercropped	Desired yield proportion	Staple land equivalent ratio
Cotton + Soybean Uniform row planting	0.31	0.2	1.07	0.31	0.2	1.08
	0.63	0.4	1.14	0.63	0.4	1.15
	1	0.6	1.21	1	0.6	1.23
Cotton + Greengram Uniform row planting	0.56	0.8	1.12	0.56	0.8	1.13
	0.24	0.2	1.11	0.24	0.2	1.12
	0.48	0.4	1.23	0.47	0.4	1.23
Cotton + Blackgram Uniform row planting	0.72	0.6	1.34	0.71	0.6	1.34
	1	0.8	1.45	1	0.8	1.46
	0.22	0.2	1.12	0.22	0.2	1.11
Cotton + Cowpea Uniform row planting	0.43	0.4	1.24	0.44	0.4	1.23
	0.65	0.6	1.35	0.67	0.6	1.34
	1	0.8	1.47	1	0.8	1.45
Cotton + Groundnut Uniform row Planting	0.32	0.2	1.13	0.22	0.2	1.12
	0.43	0.4	1.28	0.43	0.4	1.24
	0.65	0.6	1.38	0.65	0.6	1.37
Cotton + Sesamum Uniform row planting	1	0.8	1.50	1	0.8	1.49
	0.32	0.2	1.07	0.32	0.2	1.06
	0.63	0.4	1.15	0.65	0.4	1.13
Cotton + Sesamum Uniform row planting	1	0.6	1.22	1	0.6	1.19
	0.54	0.8	1.12	0.53	0.8	1.11
	0.26	0.2	1.11	0.36	0.2	1.07
Cotton + Sesamum Uniform row planting	0.53	0.4	1.21	0.73	0.4	1.14
	0.79	0.6	1.31	1	0.6	1.17

Treatment	Kharif-2004			Kharif-2005		
	Proportionate area to be intercropped	Desired yield proportion	Staple land equivalent ratio	Proportionate area to be intercropped	Desired yield proportion	Staple land equivalent ratio
	1	0.8	1.33	0.44	0.8	1.08
Cotton + Soybean	0.31	0.2	1.03	0.29	0.2	1.03
Paired row planting	0.63	0.4	1.05	0.59	0.4	1.07
	1	0.6	1.08	1	0.6	1.10
	0.56	0.8	1.04	0.63	0.8	1.07
Cotton + Greengram	0.24	0.2	1.08	0.23	0.2	1.08
Paired row planting	0.47	0.4	1.16	0.45	0.4	1.16
	0.71	0.6	1.23	0.68	0.6	1.24
	1	0.8	1.31	1	0.8	1.32
Cotton + Blackgram	0.30	0.2	1.09	0.22	0.2	1.08
Paired row planting	0.42	0.4	1.18	0.45	0.4	1.15
	0.63	0.6	1.27	0.67	0.6	1.23
	1	0.8	1.36	1	0.8	1.31
Cotton + Cowpea	0.21	0.2	1.09	0.21	0.2	1.09
Paired row planting	0.41	0.4	1.19	0.42	0.4	1.18
	0.62	0.6	1.28	0.63	0.6	1.26
	1	0.8	1.38	1	0.8	1.35
Cotton + Groundnut	0.32	0.2	1.03	0.30	0.2	1.03
Paired row planting	0.65	0.4	1.05	0.61	0.4	1.06
	1	0.6	1.08	1	0.6	1.10
	0.53	0.8	1.04	0.59	0.8	1.06
Cotton + Sesamum	0.28	0.2	1.06	0.34	0.2	1.02
Paired row planting	0.56	0.4	1.10	0.68	0.4	1.05
	1	0.6	1.15	1	0.6	1.07
	0.69	0.8	1.12	0.49	0.8	1.03

proportion of cotton. Similarly the proportionate cotton yield was 60% by intercropping sesamum in second year and soybean in both the years.

Intercropping of cowpea, blackgram or greengram in paired row planting was less efficient with substantial reduction in SLERs for the same level of desired level of 80% of cotton. The intercropping of sesamum, groundnut or soybean between paired rows of cotton further reduced the SLERs compared to their intercropping in uniform rows.

An array of options for a minimum standardised yield of cotton relative to its sole optimum and respective SLERs in different intercropping system are furnished in table 42.

For example intercropping of soybean in uniform rows of cotton over an hectare of land provided 60% seed cotton yield relative to its sole optimum. The SLER was maximized to 1.21. If the desired threshold is only 40% sole optimum yield of cotton in the intercropping system he can allocate 0.63 ha to cotton and rest 0.37 ha to the sole crop of soybean. The SLER in this instance is reduced to 1.14. If the farmer's choice is to realise a higher proportion of cotton relative to its sole optimum than that realised from the intercropped area he can exercise option to allocate part of the land to intercropping and rest to sole crop. For

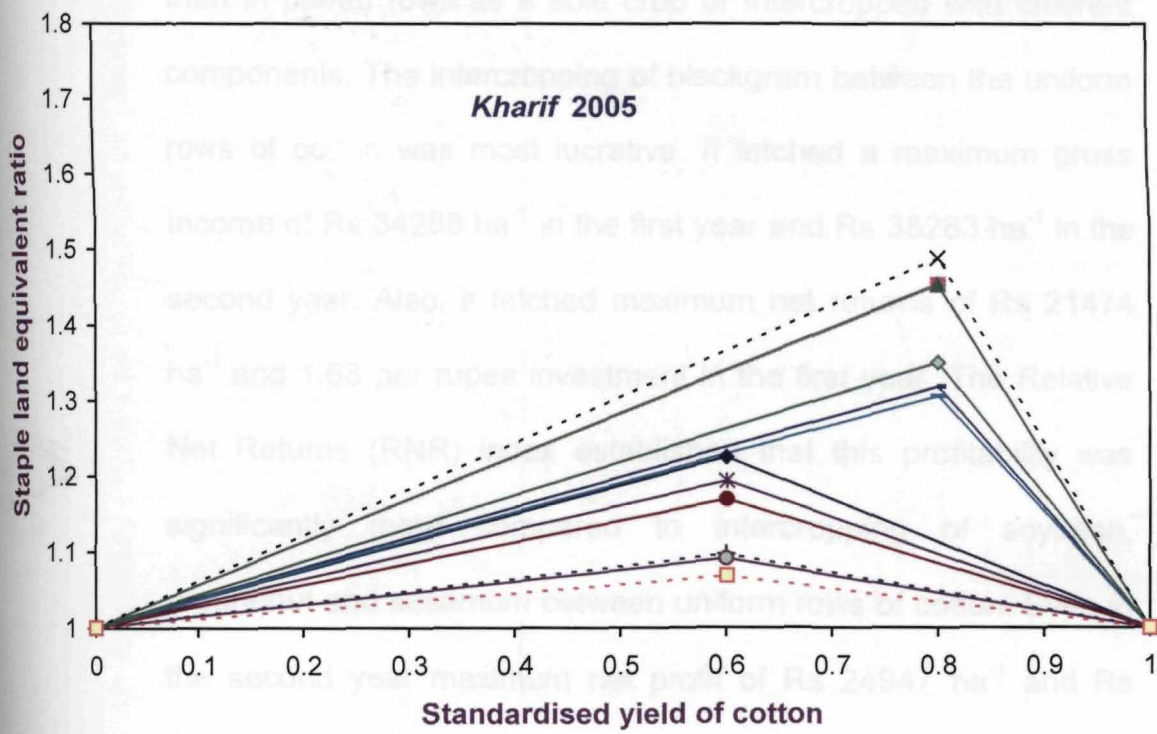
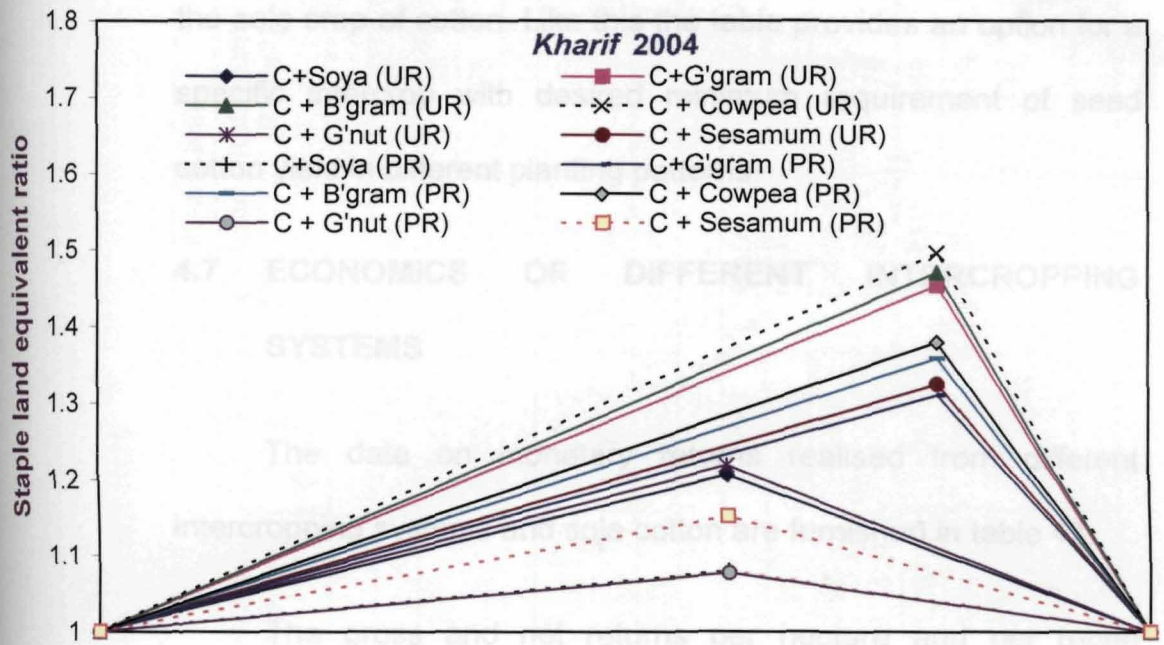


Fig. 8 : Staple land equivalent ratios plotted against the standardised yield of cotton in cotton-intercropping system

example, if the choice is to realise 80% sole optimum yield of cotton, he should allocate 0.56 ha for intercropping and 0.44 ha to the sole crop of cotton. Like this the table provides an option for a specific intercrop with desired minimum requirement of seed cotton yield in different planting patterns.

#### **4.7 ECONOMICS OF DIFFERENT INTERCROPPING SYSTEMS**

The data on monetary returns realised from different intercropping systems and sole cotton are furnished in table 43.

The gross and net returns per hectare and per rupee investment were consistently more from cotton grown in uniform than in paired rows as a sole crop or intercropped with different components. The intercropping of blackgram between the uniform rows of cotton was most lucrative. It fetched a maximum gross income of Rs 34288 ha<sup>-1</sup> in the first year and Rs 38283 ha<sup>-1</sup> in the second year. Also, it fetched maximum net returns of Rs 21474 ha<sup>-1</sup> and 1.68 per rupee investment in the first year. The Relative Net Returns (RNR) index established that this profitability was significantly more compared to intercropping of soybean, groundnut and sesamum between uniform rows of cotton. Even in the second year maximum net profit of Rs 24947 ha<sup>-1</sup> and Rs 1.87 per rupee investment accrued from this treatment. The

**Table 4.3: Monetary returns as influenced by planting pattern and intercrops**

Treatments	Kharif-2004				Kharif-2005			
	Gross returns (Rs ha <sup>-1</sup> )	Net returns (Rs ha <sup>-1</sup> )	Net returns (Rs Re <sup>-1</sup> )	Relative net returns	Gross returns (Rs ha <sup>-1</sup> )	Net returns (Rs ha <sup>-1</sup> )	Net returns (Rs Re <sup>-1</sup> )	Relative net returns
<b>Uniform row planting</b>								
Sole cotton	25232	14226	1.29	--	30020	18384	1.58	--
Cotton + Soybean	26495	13512	1.04	1.13	28531	15347	1.16	1.00
Cotton + Greengram	33553	20341	1.54	1.42	38357	24535	1.78	1.35
Cotton + Blackgram	34288	21474	1.68	1.43	38283	24947	1.87	1.33
Cotton + Cowpea	32376	19035	1.43	1.38	37545	23586	1.69	1.33
Cotton + Groundnut	28899	15223	1.11	1.25	29957	15906	1.13	1.08
Cotton + Sesamum	23092	10939	0.90	0.96	28021	16016	1.33	0.95
<b>Paired row planting</b>								
Sole cotton	23332	12576	1.17	--	29412	17856	1.55	--
Cotton + Soybean	22649	10698	0.90	1.02	26738	14097	1.12	0.95
Cotton + Greengram	29246	17379	1.46	1.30	35484	22804	1.79	1.24
Cotton + Blackgram	30854	18719	1.54	1.38	34576	21926	1.73	1.21
Cotton + Cowpea	29722	17145	1.36	1.35	35477	22145	1.66	1.27
Cotton + Groundnut	24567	11816	0.93	1.14	28234	15128	1.15	1.01
Cotton + Sesamum	20569	9423	0.85	0.90	25886	14370	1.25	0.88
SE m±				0.06				0.05
CD at 5%				0.17				0.15

statistical evaluation through RNR index also confirmed the significant superiority of this intercropping system over soybean, groundnut or sesamum. Intercropping of blackgram or greengram between uniform rows of cotton were also equally profitable on the basis of net returns per hectare as confirmed by RNR index which revealed that these treatments were on par during both the years. The profits per rupee investment were also high by intercropping blackgram or greengram. Intercropping of sesamum was uneconomical. It reduced the gross and net returns per hectare as well as the net returns per rupee investment compared even to sole crop both in uniform and paired row planting of cotton. The RNR indices were also least. Thus intercropping 2 rows of cowpea, blackgram or greengram between uniform rows of cotton spaced at 90 cm were more rewarding than others.

## ***Discussion***

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## CHAPTER - V

### DISCUSSION

The results of present investigation "Planting techniques and intercropping studies in cotton" are discussed in this chapter. Interpretation is made on probable cause and effects influencing the performance of cotton and the intercrop components – soybean, greengram, blackgram, cowpea, groundnut and sesamum on their vegetative and reproductive growth parameters, nutrients removed and yield. The overall efficiency of intercropping systems was gauged through the more versatile and refined approaches. This is preceded by discussion on rainfall pattern and the performance of crops in different years.

#### 5.1 RAINFALL vs CROP GROWTH

The performance of crops was influenced by the rainfall and its distribution pattern during the two years. There was a rainfall of 366.8 mm during the crop growing season in 2004. This was less than the actual evapotranspiration of 516.7 mm by the cotton crop. In the second year, the rainfall was 593.8 mm during the crop growing period. This was in excess of the water demand of 544.7 mm by the crop. During the first year, rains commenced in 28 standard week and terminated in 43 week. Entire

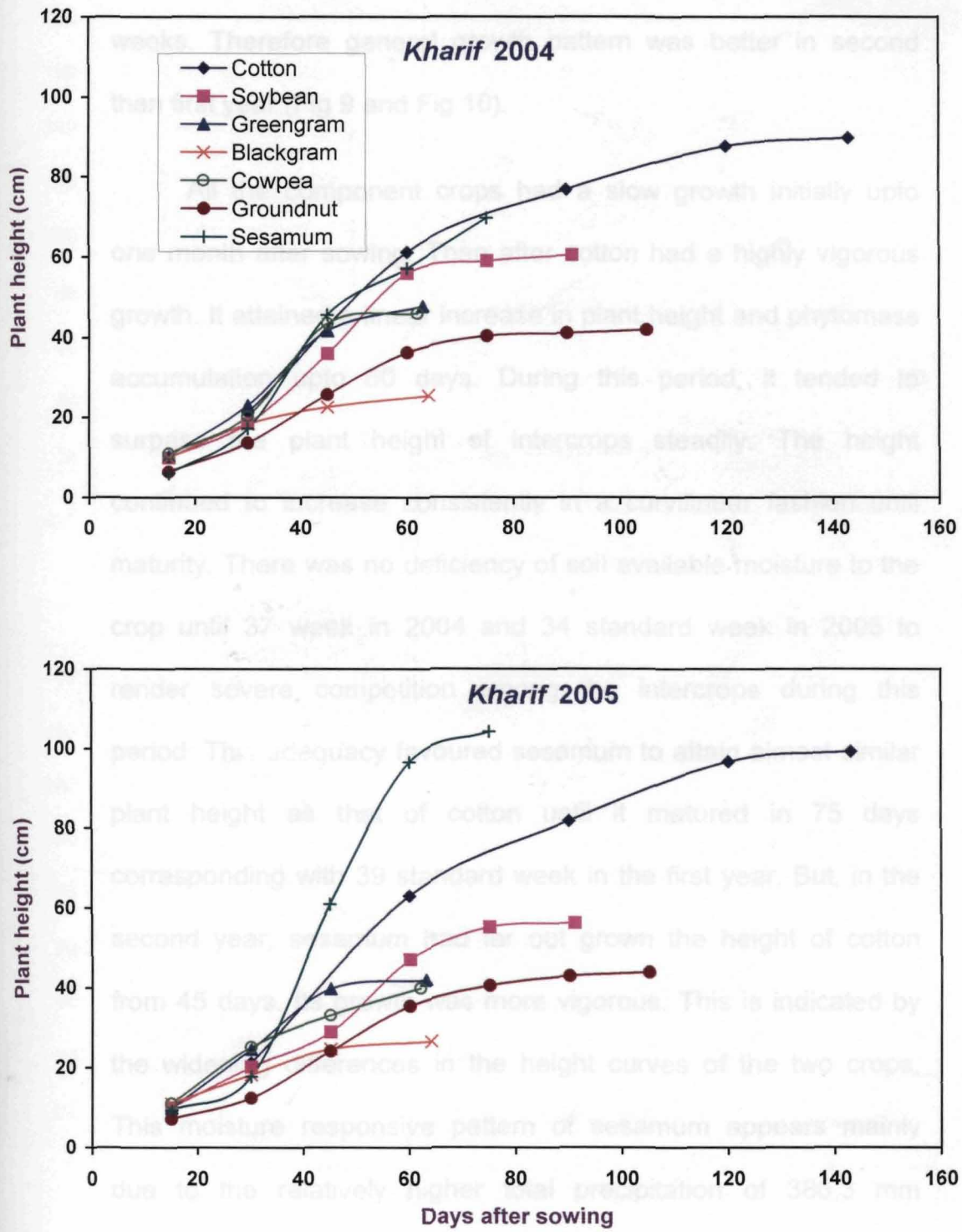


Fig. 9 : Mean plant height (cm) of cotton and intercrops

precipitation within this period was distributed in 10 weeks. But, in second year rains commenced early by 26 week and terminated late by 44 week while it was distributed over a longer period of 14 weeks. Therefore general growth pattern was better in second than first year (Fig 9 and Fig 10).

All the component crops had a slow growth initially upto one month after sowing. Then after cotton had a highly vigorous growth. It attained a linear increase in plant height and phytomass accumulation upto 60 days. During this period, it tended to surpass the plant height of intercrops steadily. The height continued to increase consistently in a curvilinear fashion until maturity. There was no deficiency of soil available moisture to the crop until 37 week in 2004 and 34 standard week in 2005 to render severe competition among the intercrops during this period. This adequacy favoured sesamum to attain almost similar plant height as that of cotton until it matured in 75 days corresponding with 39 standard week in the first year. But, in the second year, sesamum had far out grown the height of cotton from 45 days. Its growth was more vigorous. This is indicated by the widening differences in the height curves of the two crops. This moisture responsive pattern of sesamum appears mainly due to the relatively higher total precipitation of 386.3 mm

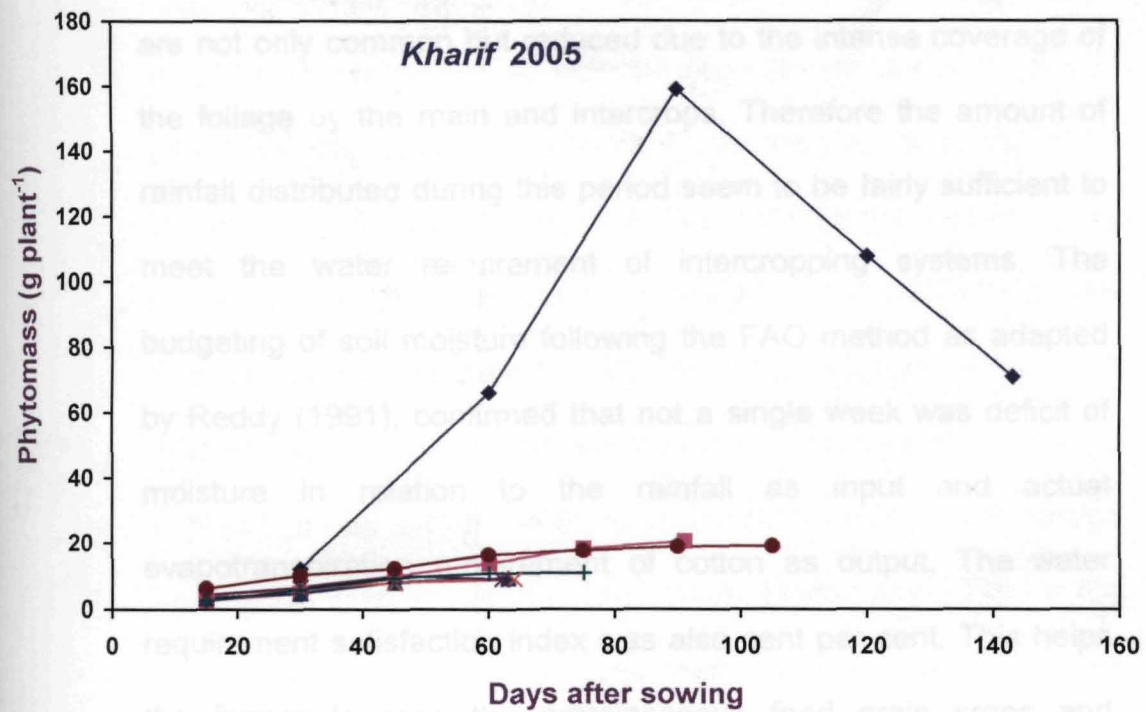
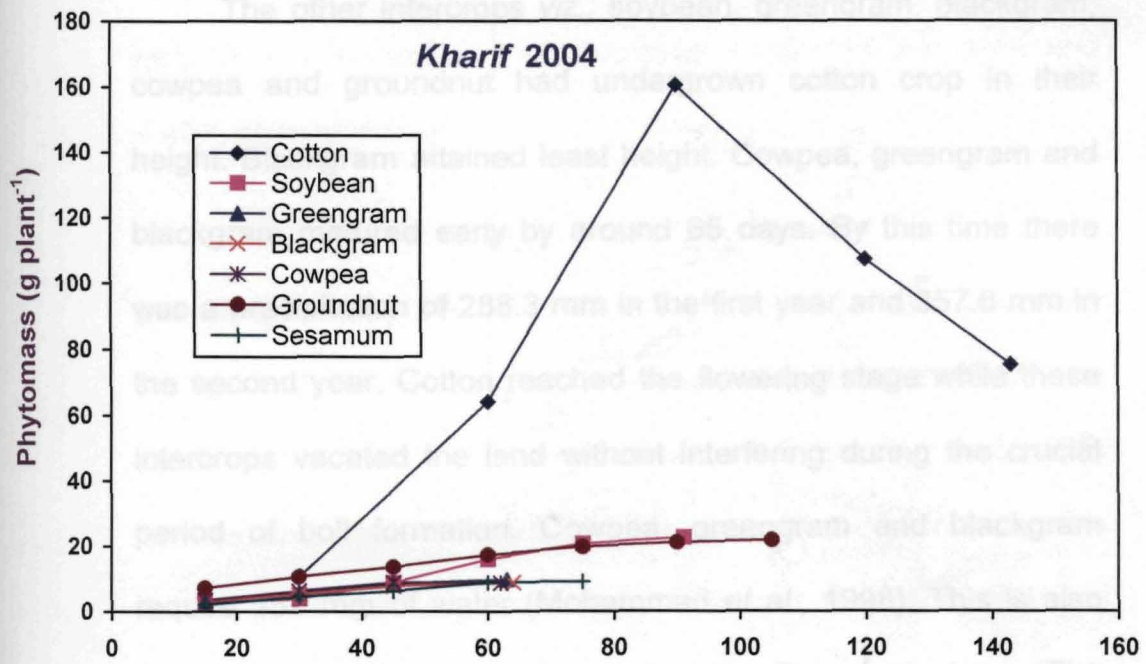


Fig. 10 : Mean phytomass (g plant<sup>-1</sup>) of cotton and intercrops

distributed in 8 weeks during its growth period than 288.3 mm distributed within the same period in the previous year.

The other intercrops viz., soybean, greengram, blackgram, cowpea and groundnut had undergrown cotton crop in their height. Blackgram attained least height. Cowpea, greengram and blackgram matured early by around 65 days. By this time there was a precipitation of 288.3 mm in the first year and 357.6 mm in the second year. Cotton reached the flowering stage while these intercrops vacated the land without interfering during the crucial period of boll formation. Cowpea, greengram and blackgram require 150 mm of water (Mohammad *et al.*, 1998). This is also the water requirement of cotton upto flowering stage. The evaporation losses per unit of land in these intercropping system are not only common but reduced due to the intense coverage of the foliage by the main and intercrops. Therefore the amount of rainfall distributed during this period seem to be fairly sufficient to meet the water requirement of intercropping systems. The budgeting of soil moisture following the FAO method as adapted by Reddy (1991), confirmed that not a single week was deficit of moisture in relation to the rainfall as input and actual evapotranspiration requirement of cotton as output. The water requirement satisfaction index was also cent per cent. This helps the farmer to reap the proteinaceous food grain crops and

nutritious fodder within a very short period of time by reducing the evaporation losses from the land surface and utilizing part of this conserved moisture for their transpiration. These intercrops were harvested when cotton had displayed < 50% of leaf area and < 40% of its phytomass.

The initial probability estimates of rainfall proposed by Markov quoted by Gabriel and Neumann (1962); Gates and Tong (1976) and Hann *et al.* (1976) showed that the likelihood of receiving more than 15 mm rainfall per week ranged from 50-93% until second week of August. At this stage, these intercrops were in the reproductive growth stage with pod formation and pod filling.

Sesamum matured in 75 days. Its estimated water requirement is 200 mm as with the requirement of cotton by this time. The precipitation was 288.3 in the first year and 386.3 mm in the second year. In the first year the period between the harvest of cowpea, greengram, blackgram and the sesamum was free of rains. This may not be fairly sufficient to support the intercropping of cotton with sesamum at a stage when cotton is highly vigorous with a tremendous increase in canopy coverage and accumulating large quantity of phytomass. The water requirement satisfaction indices were cent per cent for sole cotton. But the additional growth of sesamum as an intercrop is

likely to interfere with the available moisture for cotton. Therefore cultivation of sesamum seem to be competitive.

Soybean matured in 91 days. Its water requirement is 300 mm. The precipitation was 314.1 mm during this period in the first year and 468.6 mm during the second year. By this time, the estimated water requirement of cotton was 376.8 mm in the first year and 404.9 mm in the subsequent year. This was the peak period of canopy development and phytomass accumulation by cotton.

The amount of moisture shared by this legume component would starve the component crops depending on their competitive ability. Although 154 mm higher rainfall occurred during the second than in the first year, moisture deficit was recorded from 35 standard week. This coincided with the flowering and first boll formation. The soil moisture deficit from 35 standard week inspite of more rainfall was mainly due to the surplus rainfall of 5.81 mm in 26 week, 18.19 mm in 29 week and 109.48 mm in 30 week beyond the water holding capacity of 110 mm by the soil.

Groundnut was harvested still late at 105 days. Its water requirement is 500 mm. By this time cotton removed about 428 and 457 mm water during the first and second year respectively. At this stage cotton was in boll development and maturity stage.

The rainfall received was 367 mm in the first year and 497 mm in the second year. This severe imbalance between the demand and supply of moisture between the intercropped cotton and groundnut might have created a severe moisture stress. This is evident from the increasing deficit of moisture from 37 to 41 standard week in 2004 and from 35 to 40 standard week in 2005.

## **5.2 PERFORMANCE OF COTTON**

### **5.2.1 Influence of planting pattern**

Cotton is a wide spaced crop. This help to grow intercrops. The paired row planting technique is useful to accommodate more number of intercrop rows provided there is no intraspecific competition. This is dependent on several factors like crop growth characteristics, soil fertility and the extent of space between and within the pairs. Hence literature search reveal highly variable results.

Deshpande *et al.* (1989), Tomar *et al.* (1994), Sanjay *et al.* (2003) and Deoche *et al.* (2004) observed that cotton is amenable to the configuration of paired row planting technique with no severe repercussions on its vegetative growth, yield components and seed cotton yield grown under rainfed conditions. Contrary to this, the research conducted at Tamilnadu showed that the paired row planting technique was inferior to uniform rows (Anonymous,

1977). The investigations of Jain and Jain (1985), Mukerji *et al.* (1987) and Koraddi *et al.* (1991) showed that the paired row planting was more advantageous to harvest more seed cotton yield.

This inconsistency in the response of cotton to variable planting patterns warrant location specific investigation for specific varieties of crops, before attempting to introduce the compatible intercrops.

The results of our investigation confirmed that even in the highly variable pattern of rainfall distribution and its quantity during the two years the cotton hybrid 'Bunny' performed equally well in paired row of 120/60 cm and in the uniform rows of 90 cm. This gives a scope to investigate the possibility of accommodating more number of rows of the intercrop and thereby bring a change in the interspecific competition than in the uniform rows of cotton.

## **5.2.2 Influence of intercropping**

### **5.2.2.1 Vegetative and reproductive growth**

The growth of cotton was slow initially during one month after sowing. None of the intercrops interfered with its growth during this period. Consequent to a grand improvement in growth of cotton in the later period, the intercrops exercised a competitive

effect. The plant height of cotton was significantly reduced at some sampling stages. This effect was more serious by intercropping sesamum, soybean or groundnut than greengram, blackgram or cowpea.

The sensitivity of cotton to the competitive effect of intercropping was more serious on its leaf area. Throughout the crop growth period cotton produced less leaf area per plant in any intercropping system during first year. This was true when cotton was intercropped with sesamum, soybean, or groundnut in the second year.

Variable responses of cotton to the intercropping competition in the two years may be perhaps the result of the interaction of the rainfall and its distribution pattern. Since there was a relatively more precipitation of 93.8 mm distributed in 14 weeks during 2005, these vegetative growth characters were relatively less affected than in the previous year which had a precipitation 366.8 mm distributed in 10 weeks.

The investigation of Kunasekaran (1978), Nagre (1979), Jain *et al.* (1982), Rao (1982), Nehra and Kairon (1986), Rao (1990) and Sanjay *et al.* (2003) showed that the intercropping of greengram had no adverse effect on plant height of cotton. Jain *et al.* (1982), Rao (1982), Janardhanam (1983) and Rao (1990) also

reported that intercropping of blackgram had no deleterious effect on plant height of cotton.

In contrast Divekar and Kurtakoti (1961), Robinson (1973), Deshpande *et al.* (1989) and Ramesh Babu *et al.* (1996) observed that the cotton succumbed to the intercrop competition by groundnut and reduced its plant height substantially. Deoche *et al.* (2004) also reported that the plant height of cotton reduced significantly due to intercropping competition both by greengram, blackgram and soybean.

Reduction in plant height of cotton intercropped with cowpea was also recorded by Kairon and Avtar Singh (1972) and Sucha Singh and Rajinder Singh (1973). Substantial reduction in leaf area per plant of cotton due to intercropping of cowpea was also reported by Rao (1977). Reduction in plant height of cotton due to intercropping of soybean was recorded by Deshpande *et al.* (1989). Later, Pramila Rani *et al.* (2000) on the other hand observed that intercropping of soybean crop benefited cotton to grow tall.

The results of present investigation and those reviewed highlight that though the intercrop components are harvested much earlier, they interfere with the improvement in growth of cotton. The magnitude of this interference is mainly governed by

the distribution of rainfall in addition to several other interactive forces.

None of the intercrops delayed the number of days needed for 50% flowering in cotton. Janardhanam (1983) also observed that the time needed to 50% flowering of cotton was similar by growing cotton as a sole crop or intercropped with blackgram. But, Divekar and Kurtakoti (1961) observed that the time to flowering of cotton was extended by a week when it was intercropped with groundnut.

#### **5.2.2.2 Yield components**

The number of monopodial branches in cotton were on par in all the intercropping systems and sole crop. Previous literature showed contrasting results. Investigation of Devotta and Chowdappan (1976) and Sheoran and Malik (1986) confirmed our observations that the monopodial branches of cotton were unaffected by intercropping greengram. This observation contradicts the results obtained by Rao (1982) that the monopodial branches were significantly reduced by intercropping greengram. The intercropping of soybean was also reported to have such a negative effect (Pramila Rani *et al.*, 2000). These variable responses in different investigations could probably be partly due to the magnitude of competition in the intercropping

system grown in variable geometry and varieties of crops with varying competitive ability.

The number of sympodial branches per plant of cotton were on par when it was intercropped with greengram, blackgram or cowpea and sole crop. This had a significant impact on the production of seed cotton yield because they are the main fruit bearing branches and are more in number compared to monopodials. The results of Kunasekaran (1978), Janardhanam (1983) and Rao (1990) also corroborated with the present findings that sympodial branches were not affected by intercropping with the short duration legumes like greengram, blackgram and cowpea. Relative extension in period of maturity of soybean to 75 days, sesamum to 91 days and groundnut to 105 days significantly reduced the number of these fruiting branches. The harmful effect of intercropping soybean in cotton was also discovered by Pramila Rani *et al.* (2000) and Deoche *et al.* (2004).

Although cotton intercropped with greengram did not produce less number of sympodial or monopodial branches it produced less number of bolls per plant during both the years. Therefore recovery of seed cotton yield per plant was also less than the sole crop. The number of bolls per plant were also reduced by intercropping blackgram only in the second year. But,

the intercropping of cowpea enabled cotton to produce the same number of bolls with equivalent production of seed cotton per plant as sole crop in the two years. The intercropping of sesamum, soybean and groundnut severely reduced the number of bolls and seed cotton yield per plant. This is the expected response. Cowpea, greengram and blackgram were harvested by about 65 days when cotton was at flowering stage. Since the peak moisture requirement and input utilization of these components terminated much ahead of the crucial peak flowering stage of cotton, these yield components were not severely affected. The other three intercrop components shared resources with cotton for a longer time and created a stiff competition thereby hindering the optimum growth and development of sympodial branches and thereby reduced the recovery of seed cotton yield per plant. Deshpande *et al.* (1989) and Deoche *et al.* (2004) reported that the intercropping of greengram or soybean had such a negative effect on these yield components. Nagre (1979) also confirmed that the intercropping of sesamum severely reduced the fruiting branches of cotton and seed cotton yield per plant.

### 5.2.2.3 Phytomass accumulation, nutrient removal and seed cotton yield

Cotton removed progressively larger quantities of N, P and K upto 90 days age of the crop. This coincided with peak load of bolls and thereby maximum phytomass accumulation. The intercrop components competed to share these nutrients. Therefore, cotton removed less quantity of N, P and K in all the intercropping systems. Though the legumes fix up the atmospheric nitrogen, it was not sufficient to meet the requirement of cotton. Although the short duration cowpea, blackgram and greengram matured by about 65 days there was no improvement in the quantity of nutrients removed by cotton even in the later stages. This was perhaps due to the relatively low vigour of the plants that grew under competition for about two months and did not regain their vigour on par with the sole crop which was clearly reflected in phytomass accumulation per plant.

Earlier investigations also confirmed similar reduction in dry matter production due to greengram and cowpea (Sucha Singh and Rajinder Singh, 1973) greengram and soybean (Deshpande *et al.*, 1989), cowpea (Sanjay *et al.*, 2003) greengram, blackgram and soybean intercropping (Deoche *et al.*, 2004).

Cotton removed less N, P and K when intercropped with sesamum, soybean and groundnut than greengram, blackgram or cowpea. This was obviously due to a longer competitive period for nutrient absorption by these crops. Literature on the pattern of nutrient removal by cotton in different intercropping systems is scanty. Christopher and Chinnaswami (1991), Sagare and Kapgate (1994) observed that cotton intercropped with greengram removed more nitrogen and potassium than the sole crop, whereas Ramamoorthy *et al.* (1994) found no significant difference in available N and P due to intercropping of cotton with blackgram or sole cotton. This contradicts our observation. These deviations could probably be due to the different nutrients availability status of soil, nutrient added, planting geometry of intercrops and differentially nutrient responsive varieties of crops.

The second flush of flowering is more important. The bolls formed from these flowers contributed 52-54% of the total seed cotton yield per hectare. The contribution from the first formed bolls was 25-26% and bolls from third picking contributed 20-23% of the total yield. This imply that severe moisture stress during the *flowering, boll formation and development of second flush* will have more harmful effect on yield than its occurrence with the period coinciding with flowering, boll formation and their development during first and third flushes.

The precipitation curve for this agro-ecological region show that the moist period with P/PET being 1 is upto 38 standard week. This stage was coincident with this week in the second year. In 2004, peak flowering was in 41 standard week. This is the time when the stored soil moisture tend to recede and the yield may not be optimum unless the unprecedented rains recharge the soil for a short period. The total seed yield per hectare from three pickings was on par in cotton intercropped with cowpea and grown as a sole crop during the two years. This observation was in line with the earlier investigations of Kairon and Nandal (1971) and Khan *et al.* (2001) who affirmed the compatibility of intercropping this legume in cotton. But, several research workers documented that the cotton yield was significantly lost to competition by the intercropped cowpea (Alves *et al.*, 1972; Kairon and Avtar Singh, 1972; Sucha Singh and Rajinder Singh, 1973; Raghumurthy *et al.*, 1974; Sadaphal *et al.*, 1978; Nagre, 1979; Giri and Upadhay, 1980 and Myaka and Kabissa, 1996).

Cotton intercropped with blackgram also yielded on par with sole crop in the first year. But the interspecific competition was severe and the yield reduced significantly in second year. Therefore, intercropping of blackgram is likely to be a less competitive component in years of low rainfall. This trend explains

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the contrasting reports available in literature. Deoche *et al.* (2004) recorded no significant variation in yield by growing cotton as a sole crop or intercropped with blackgram. Deshpande *et al.* (1989) and Tomar and Kushwaha (1991) recorded significant loss in yield of cotton intercropped with this legume component. Some of the research findings of Nimbole *et al.* (1980), Sardar *et al.* (1988), Ramamoorthy *et al.* (1994) and Rao (1997) recorded a complimentary effect of intercropped blackgram in increasing the yield of cotton.

Unlike blackgram, intercropping of greengram had a competitive influence on the yield of cotton both during relatively low and high rainfall years with variable distribution pattern. Cotton intercropped with greengram produced 204 kg less yield  $\text{ha}^{-1}$  in 2004 compared to the sole crop. In the subsequent year, the yield reduced by 208 kg  $\text{ha}^{-1}$ . Reduction in seed cotton yield due to intercropping of greengram was also reported by several research workers (Mukerji *et al.*, 1987; Deshpande *et al.*, 1989; Hasham and Sulistyowati, 1989, Sethi *et al.*, 1992, Satao *et al.*, 1993, Sarkar *et al.*, 1995, Ramesh Babu *et al.*, 1996, Sanjay *et al.*, 2003 and Deoche *et al.*, 2004).

The longer the duration of the intercrop component more was the reduction in yield of cotton. Sesamum matured in 75

days. It reduced the seed cotton yield by 374 kg ha<sup>-1</sup> in the first year and 671 kg ha<sup>-1</sup> in the second year. This trend revealed that the availability of moisture for a long time with more amount of rainfall distributed over a long time favoured luxurious growth of sesamum during the second year. The competition was less intense in the first year due to the relatively shorter period of rainfall distribution. Hence the reduction in yield of cotton was less than in the second year. The investigation of Sarkar *et al.* (1995) and Khan *et al.* (2001) also confirmed that the intercropped sesamum competed to lower the yield of cotton. But Sarma *et al.* (1997) and Gnanasambandham *et al.* (2001) identified this component to be complementary. The logic for this result is not clear.

Reduction in yield of cotton was more intense by intercropping soybean. In the first year cotton yielded 461 kg less seed cotton ha<sup>-1</sup>. It reduced by 529 kg ha<sup>-1</sup> in the second year. Soybean competed with cotton crop relatively for a longer time of 91 days than the aforesaid intercrops. Several reports documented that the intercropped soybean drastically reduced the yield of cotton (Birajdar *et al.*, 1980; Giri and Upadhyay, 1980; Shanthaveerabhadraiah and Patil, 1986; Seshadri and Natarajan, 1989; Gode *et al.*, 1992; Yadav *et al.*, 1993; Khaistaria *et al.*, 1994; Wankhade, 1994; Ramesh Babu *et al.*, 1996; Pramila Rani

*et al.*, 2000; Ramanjaneyulu and Reddy, 2002 and Deoche *et al.*, 2004). But the research findings of Saxena (1971) and Borthakur and Barthakur (1992) and Mansur *et al.* (1993) documented that the intercropping of soybean in cotton was highly encouraging. The seed cotton yield was reported to have increased by adopting this system.

The long duration intercropped groundnut maturing in 105 days drastically reduced the seed cotton yield by 480 kg ha<sup>-1</sup> in the first year and 566 kg ha<sup>-1</sup> in the second year. Obviously, this reduction was mainly due to the competition for resources for a longer time. Mahapatra *et al.* (1975) also registered a reduction in seed cotton yield by intercropping groundnut. Mudholkar (1989) also inferred that groundnut is not a compatible intercrop in cotton. Ramanjaneyulu (2000) on the other hand, observed that the intercropped groundnut enhanced the yield of seed cotton. The claims of increase in seed cotton yield by intercropping legume components mainly vests with the assumption that the atmospheric nitrogen fixed by these components was transferred to cotton which benefited its production.

Although the seed cotton yield was reduced by different intercropping systems, it is likely that this loss is compensated by additional production of diversified crops. These are likely to meet the choice of domestic needs or increased profitability vis-à-vis

exploiting the land more efficiently. The large spaces between the cotton rows unexploited during early part of its growth can be efficiently utilized by these intercrops. Farmers who do not desire to sacrifice the yield of valuable cotton crop can do so, while obtaining a bonus yield of cowpea even under a season to season and within the season rainfall variability pattern recorded in the present investigation.

### 5.3 PERFORMANCE OF INTERCROPS

The mean plant height, phytomass accumulation per plant, days to 50% flowering and yield components of six intercrops viz. soybean, greengram, blackgram, cowpea, groundnut and sesamum were not substantially influenced by intercropping them between the uniform or paired row spaces of cotton compared to the respective sole crops. This could be probably due to the reason that the inter and intra row spacing of these intercrops was similar to their solitary stand. The interspecific competition expected due to the deep rooted and profuse development of cotton crop was not observed in the present context of low rainfall of 366.8 mm in the first year than 593.8 mm in the second year. However, the quantity of N, P and K removed by these crops was considerably low than their sole crops. Obviously, this reduction in the amount of nutrients removed was mainly due to the low sole optimum density of 66.66% intensity intercropped between

uniform rows of cotton and only 50% between paired rows. The seed yield was also low in the intercrop treatments in accordance with the planting density maintained in the intercrops.

#### **5.4 SOIL MOISTURE**

The soil moisture content was less in all the intercropping systems compared to the sole crop in the surface 15 cm depth of soil during the first year. This distinction was masked at 30 and 45 cm depth of the soil. The competition for moisture by different intercrops was more from the surface layers throughout the crop growth period. Padhi *et al.* (1993) also recorded depletion of moisture in the top layer of soil by adopting different intercropping systems in cotton. In the second year, the rainfall was more and distributed over a long time. Therefore, the relative moisture content of the soil supporting the sole crop or intercropping system did not show a distinct variability even in the top layer of soil. Christopher and Chinnaswamy (1996) also observed that the moisture content of soil cultivated with sole cotton or intercropped with pulses did not vary substantially.

#### **5.5 BOLL DAMAGE IN COTTON**

In general the per cent boll damage was found to be less during the second year of study. This may be due to well distributed rainfall and unfavourable weather conditions for boll

worms. Sowing of different intercrops did not influence the per cent incidence of bollworms. These results imply that the intercrops may be grown largely to averse the untoward effects of weather aberrations rather than a fool proof to secure cotton from the attack of boll worms. Similar research findings were reported by Ramalho and Gonzaga (1990) and Vennila *et al.* (2001) whereas Natarajan and Seshadri (1988) and Suresh *et al.* (1993) recorded lower incidence of bollworm pests due to intercropping of soybean in cotton.

## 5.6 EVALUATION OF INTERCROPPING SYSTEMS

Statistical procedures are well documented to evaluate the performance of individual crops influenced by different treatments. Difficulty arises to evaluate the combined yield of crops grown in intercropping system. No two crop species are similar in their yield potential and duration. They are not equal in monetary value, calorific or nutrient value and their requirement for the farmer may be highly divergent like food, fibre, oil etc. Attempts to evaluate the total productivity of two crops in different intercropping systems through the transformation of output values into a single variate either monetary value, calorific value or land equivalent ratio have been reviewed by Choudhary and Bhargava (1986). Pearce and Gilliver (1978) also enumerated the possible approaches of statistical evaluation, their merits and demerits.

They stated that in the past the statistical problems have sometimes been evaded by combining crops on some basis such as total calorific value, monetary value or even total yield, i.e. an essentially multivariate problem has been reduced to a univariate one. Although such an approach is not necessarily wrong, it is open to certain objections. For example, monetary value is subject to market conditions, which is by no means constant. It might well be better to clarify the agronomic results and to consider what relative prices would make this treatment or that treatment preferable. Again, calorific value may appeal to the dietician, but it does not enter into the consciousness of peasant farmer, who is one to be persuaded.

Willey and Osiru (1972) pointed out the danger of comparing a combined intercrop yield with a combined sole crop yield on the basis of the same sown proportions, because competition in intercropping usually results in a different proportion of final yields than from sole cropping. Of the possible ways available to overcome this problem, Willey (1979) concluded that the most generally useful single index for expressing the yield advantage is probably the land equivalent ratio (LER), defined as the relative land area required as sole crops to produce the same yield as intercropping. Mead and Willey (1980) later extended this concept to Effective ( $\lambda$ ) Land

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Equivalent Ratio (ELER) in which a desired yield proportion of a more valuable crop is set *a priori* to maintain a particular yield level defined as minimum percentage of the total yield in a intercropping system. Reddy and Chetty (1984) proposed the concept of staple land equivalent ratio (SLER) which considers to maintain a minimum percentage of the yield of one of the crops in intercropping system relative to its yield in the sole crop.

Pearce and Gilliver (1978) observed that in the conventional univariate approach of analysis, each set of cropping figures separately as if the two species are grown independently of one another. This is open to objection. In this context, they proposed a bivariate method in which two crops are studied together.

Mead and Stern (1979) and Oyejola and Mead (1982) reported that no single form of analysis is appropriate for all intercropping experiments and that several different analysis should be used for most intercropping experiments.

To this end an earnest effort is made to critically discuss the intercropping advantages of cotton with other components by adopting the popular approaches.

### 5.6.1 Seed cotton equivalent yield ( $\text{kg ha}^{-1}$ )

Intercropping greengram, blackgram or cowpea significantly enhanced the seed cotton equivalent yield by over compensating the little reduction of cotton yield by high yield levels of these legume components. Farmers can opt any one of these three for their pulse requirement as bonus production from the same piece of land cultivated with cotton. If the choice is specific for sesamum, soybean or groundnut the reduction in seed cotton yield is severe. Yet, the total productivity of these intercropping systems was not inferior to sole cotton in terms of seed cotton yield.

The inferences of Birajdar *et al.* (1987) also indicated that the strategy of evaluation brought out distinct advantage of intercropping cotton with blackgram. Prasad *et al.* (1993) and Khaistaria *et al.* (1994) recorded higher seed cotton yield equivalents by intercropping groundnut. Musande *et al.* (1981) reported that this intercropping system was superior to intercropping of greengram and blackgram. The intercropping advantage with soybean in increasing the seed cotton equivalent yields was also observed by Patel and Parmar (1995).

### 5.6.2 Bivariate analysis of variance

Choudhary and Bhargava (1986) reported that the analysis of yield data by converting it into single variate is invalid. The basic limitation is that for a number of situations the normal distribution, which is a pre-requisite for carrying out an analysis, is not followed.

The bivariate analysis of variance suggested by Pearce and Gilliver (1978) is useful in proper interpretation of results with information on the interaction between two crops involved. This is also supported by a graphical representation with 5% non significant regions to identify the statistical significance of different intercropping systems. The performance of two crops growing simultaneously is influenced by the use of resources which may have a differential effect. They may have a complimentary effect with a positive correlation or a competitive effect with negative correlation or at times no interaction. The conventional univariate approach assume that the productivity of the crops growing together is free of complimentary or competitive effect. In field conditions this is not always true and the relationships are highly unpredictable. Bivariate analysis has a merit that it considers these interactive influences in the statistical evaluation of different intercropping systems.

The negative correlations registered in the present investigation document competitive effects of the intercropping systems. The yield of cotton and intercrops transformed to greengram seed equivalent are furnished as intersects on Z1 and Z2 axis together with circles which correspond to 5% non significance regions for the treatment means. The solid line corresponds to the values expected from the sole crop means. If the non significance regions for a treatment does not intersect the circles of other treatments then it is considered to give significantly different yields.

This technique indicated that large quantity of seed cotton yield, grain yield of greengram and its equivalent yield from cowpea or blackgram were obtained by intercropping these components between the uniform rows of cotton. Intercropping of sesamum, soybean or groundnut even between the uniform rows of cotton were inferior. This type of analysis was reported to have provided different inferences than from the univariate approach by intercropping pearl millet or groundnut in castor (Srinivas, 2003) and in toria + berseem intercropping (Vidyadhari, 2004).

### **5.6.3 Land equivalent ratios (LER)**

Land equivalent ratios proposed by Willey (1979) are universally adopted to evaluate the intercropping efficiency by

transforming the yield components to a univariate in terms of relative yield advantage of the intercropping system over sole crop. The continuously squeezing per caput land holding and exploding population are the major obstacles to sustain the ever increasing dietary requirements of food and fodder to man and animals. In such a situation evaluation of intercropping experiments for relative land use efficiency to produce enhanced total yield per unit area become more imperative to identify the most potential system.

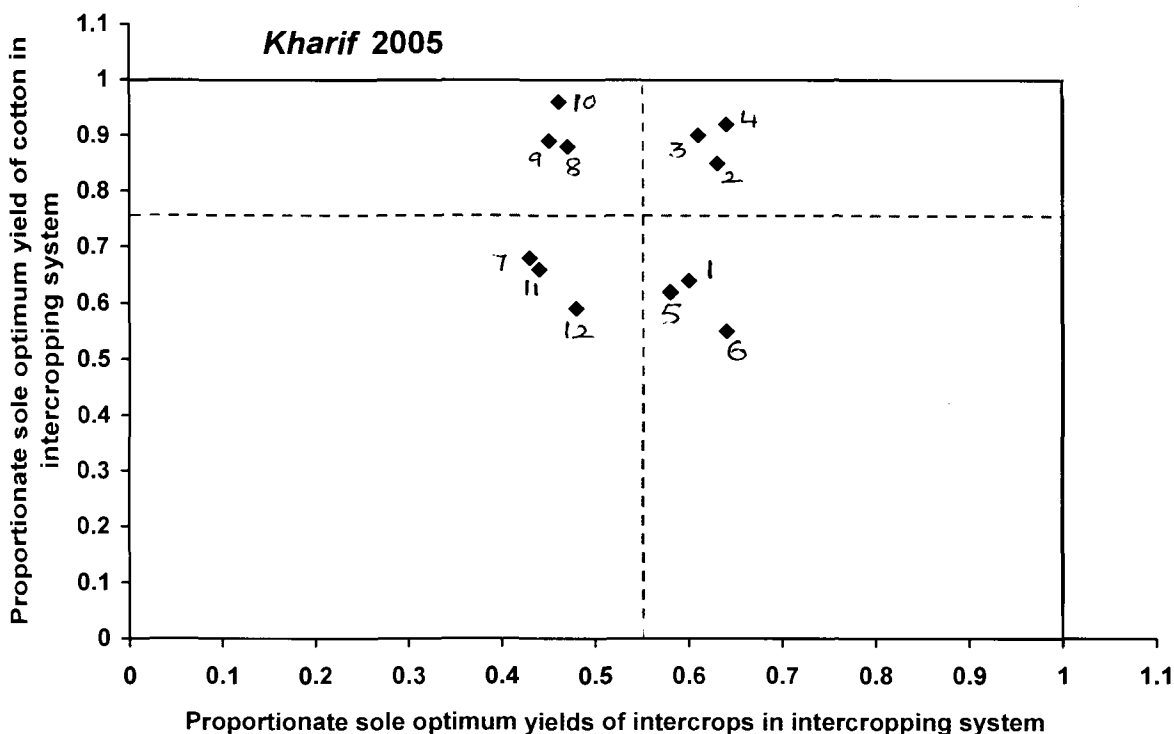
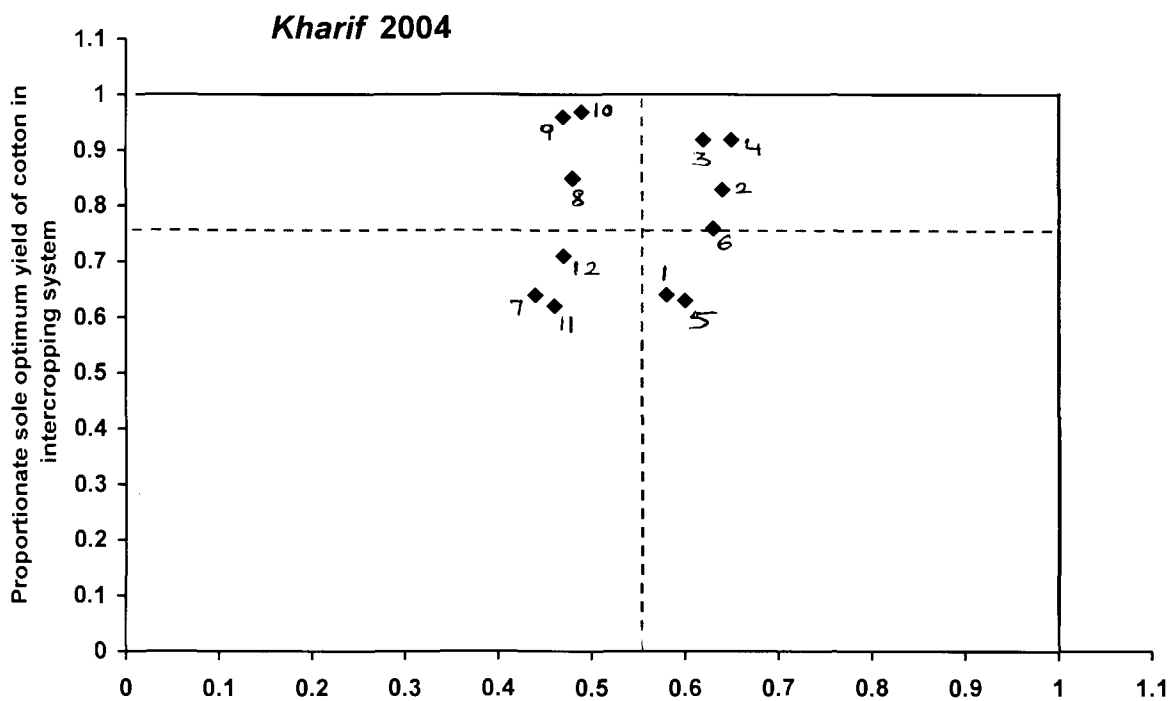
The plots of partial LERs (Fig. 11) showed that the intercropping of sesamum, soybean or groundnut between uniform or paired rows of cotton reduced its yield enormously. The yield of these intercrops sown between the paired rows was drastically reduced compared to those interplanted between paired than between the uniform rows of cotton. Maximum biological yield efficiency was realized by intercropping greengram, blackgram or cowpea. The partial LERs of both cotton and the intercrops were largest by adopting the uniform row orientation of cotton. Though large yield proportions of cotton were harvested in the paired row planting pattern the intercrop yield proportions were low due to sole optimum density of only 50% between paired rows.

**Uniform row**

- 1. Cotton + soybean
- 2. Cotton + G.gram
- 3. Cotton + Black gram
- 4. Cotton + Cowpea
- 5. Cotton + G'nut
- 6. Cotton + Sesamum

**Paired row**

- 7. Cotton + soybean
- 8. Cotton + G.gram
- 9. Cotton + Black gram
- 10. Cotton + Cowpea
- 11. Cotton + G'nut
- 12. Cotton + Sesamum



**Fig. 11 : Graphical assessment of competition between cotton and intercrops under varied planting pattern**

The total LERs of 1.47 to 1.57 in the first year and 1.48 to 1.56 in the second year due to intercropping of cowpea, greengram or blackgram between the uniform rows of cotton suggest that these are the practically viable options. Thus 47 to 57% enhanced total productivity could be obtained from unit land area. In other words it could also mean that 47 to 57% extra land would have been required for these crops when they were sown alone to obtain the same yield from the intercropping systems. The advantages of intercropping sesamum, soybean or groundnut were relatively low. Yet, LERs were more than unity. Therefore, irrespective of the total relative advantage between different intercropping systems if the farmers has a choice for a specific crop, he can adopt it with more yield advantage than from the sole crops.

Literature shows that experiments conducted by Sarkar *et al.* (1995) recorded an LER of less than unity by intercropping sesamum in cotton. A number of investigators detected that the intercropping of soybean in cotton was invariably an advantageous proposition with high LERs (Yadav *et al.*, 1993; Patel *et al.*, 1995; Satao *et al.*, 1996 and Pramila Rani *et al.*, 1998). The intercropping of groundnut in cotton was also reported to be advantageous in enhancing the total productivity of the

system as indicated by an LER value of 1.40 in an experiment conducted at Ghumusar Udayagiri in Orissa (Padhi *et al.*, 1993).

#### **5.6.4 Area time equivalent ratio (ATER)**

One of the critic against the concept of LER was that it provide more emphasis to better land use efficiency but not to the time the field was occupied by the crops for production. Therefore, the area time equivalent ratio (ATER) was considered to be more refined to assess the relative efficiency of intercropping system by considering both the requirement of land as well as time for a better production oriented intercropping system. Among the different intercropping systems flanking two rows of either blackgram or cowpea between the cotton rows uniformly spaced at 90 cm recorded best advantage. The ATER was 0.92 by intercropping soybean between the paired rows of cotton in the first year. It was 0.84 by intercropping sesamum in the second year. These two intercropping systems can be regarded as inferior to the sole crop. Sarkar *et al.* (1995) noticed high ATER value with paired row cotton + 2 rows of greengram intercropping similarly, Ramanjaneyulu and Reddy (2002) also observed high ATER values by groundnut or soybean intercropping in cotton.

### 5.6.5 Effective ( $\lambda$ ) Land Equivalent Ratio (ELER)

Mead and Willey (1980) reported that if LER is taken as a measure of the available yield advantage, there is an implicit assumption that the yield proportions embodied in that LER are those required or acceptable by the farmer. This raises particular difficulties in comparisons between LERs of different yield proportions. A method of comparing LERs which takes into account of their different yield proportions and can relate these to farmers requirements is most appropriate. This difficulty is overcome by calculating the ELERs. This approach is substantiated by plotting ELERs for different cropping systems against a range of required proportions ( $\lambda$ ) of cotton. This is more explicitly supported by the range of proportions of intercropping systems for desired yield proportion of cotton in fig.7.

Largest ELERs were attained by intercropping entire area with cowpea, greengram or blackgram between the uniform rows of cotton. The proportion of seed cotton yield was 59% in cowpea, 60% in blackgram and 56 to 57% in greengram intercropping. If these proportions are not satisfied the farmers have an option to intercrop these legumes between the paired rows of cotton. Maximum proportion of cotton yield can be raised to 66 to 68% by intercropping cowpea or blackgram and 64 to 65% by

intercropping greengram. However, the total land use efficiency reduced remarkably compared to the intercropping system in uniform rows of cotton.

A range of options for desired harvested proportions of cotton for less than or more than the LERs for cropping systems, the relative land area to be allocated for intercropping of the two species and sole cropping one of them are furnished in table 41. For example intercropping of greengram between the uniform rows of cotton provided an ELER of 1.47 and harvested proportion of cotton was 56% by intercropping entire area in 2004. If the standardized or required proportion of 39% cotton yield satisfy the farmer then the ELER is 1.28. In this situation he can intercrop greengram between uniform rows of cotton over an area of 0.6 ha. Rest of the 0.4 ha land should be cultivated with greengram. Conversely, if the set objective of the farmer is not to attain less than 88% seed cotton yield relative to the total yield in intercropping system, then he has to intercrop greengram between uniform rows of cotton only on an area of 0.20 ha and allocate rest of land to sole cultivation of cotton. The ELER in this situation reduced to 1.09. This table provides a wide range of options for different intercropping systems to allocate part of land for intercropping and rest of the area to the sole crops

corresponding for any desired cotton yield for less than or more than the LERs.

This concept was evaluated for maize + redgram (Mead and Willey, 1980) and for brussels with summer cabbage (Salter *et al.*, 1996). Information on this approach is not available for intercropping of cotton from the previous investigations.

#### **5.6.6 Staple land equivalent ratio (SLER)**

SLERs sketched out as triangles show that the vertices at the base represent LERs of 1 for the entire area allocated to cotton or any one of the intercrop components (Fig. 8). The vertex at the top represent the SLER for each intercropping system. This graphical approach indicate the proportionate yield of seed cotton in different intercropping systems relative to its sole population. A wide range of options are available to select an intercrop based on the choice for a fixed proportion of seed cotton yield.

If the farmers objective is to maximize the total productivity from the intercropping system and at the same time to obtain not less than 80% of seed cotton yield relative to its sole optimum then he can intercrop greengram, cowpea or blackgram, between the uniform rows of cotton.

If the specific choice is for soybean or groundnut to be intercropped between the uniform rows then the farmer must be prepared to sacrifice about 40% of sole optimum yield of cotton. The land use efficiency or total productivity reduce substantially. The intercropping yield advantage was recorded with SLERs of 1.21 in 2004 and 1.23 in 2005 by intercropping soybean. The SLERs were 1.22 and 1.19 by intercropping groundnut with cotton during the two years. Therefore, farmers could achieve a twin objective of obtaining not less than 60% sole proportionate yield of cotton in the intercropping system and utilize the land more efficiently by harvesting total higher productivity than their cultivation as sole crops.

This concept was utilized by Bina (1989) in sunflower + groundnut intercropping system, Srinivas (2003) in castor, pearl millet or groundnut intercropping system and Vidyadhari (2004) in intercropping of toria with berseem. Information on this approach is not available for intercropping of cotton from the previous investigations.

A comparative statement furnished in table 44 provide a range of options where the farmer has an option of different intercrop components and still obtain a predetermined threshold limit of cotton as obtained from another intercropping system. For example the intercropping of cowpea between the uniform rows of

Table 4# : Proportion of land allocation for sole and intercropping systems to attain equivalent ELER and SLER as that of cotton intercropped with cowpea

Treatments	Kharif-2004						Kharif-2005							
	LER/LER <sub>c</sub>	Sole proportion	Intercrop proportion	λLER	Sole proportion	Intercrop proportion	SLER	LER/LER <sub>c</sub>	Sole proportion	Intercrop proportion	λLER	Sole proportion	Intercrop proportion	SLER
<b>Uniform row planting</b>														
Cotton + Soybean	1.22/0.64	0.16	0.84	1.19	0.74	0.26	1.15	1.24/0.64	0.18	0.82	1.20	0.78	0.22	1.12
Cotton + Greengram	1.47/0.83	0.08	0.92	1.44	0.48	0.52	1.30	1.48/0.85	0.06	0.94	1.45	0.47	0.53	1.30
Cotton + Blackgram	1.54/0.92	--	--	--	--	--	--	1.51/0.90	--	--	--	--	--	--
Cotton + Cowpea	1.57/0.92	--	--	--	--	--	--	1.56/0.92	--	--	--	--	--	--
Cotton + Groundnut	1.23/0.63	0.19	0.81	1.19	0.76	0.24	1.14	1.20/0.62	0.17	0.83	1.17	0.80	0.20	1.11
Cotton + Sesamum	1.39/0.76	0.13	0.87	1.29	0.70	0.30	1.16	1.19/0.55	0.23	0.27	1.14	0.83	0.17	1.10
<b>Paired row planting</b>														
Cotton + Soybean	1.08/0.64	0.17	0.83	1.06	0.92	0.08	1.04	1.11/0.68	0.19	0.81	1.09	0.89	0.11	1.05
Cotton + Greengram	1.33/0.85	0.07	0.93	1.31	0.81	0.19	1.09	1.35/0.88	0.11	0.89	1.31	0.71	0.29	1.12
Cotton + Blackgram	1.43/0.96	--	--	--	--	--	--	1.34/0.89	0.06	0.94	01.32	0.68	0.32	1.13
Cotton + Cowpea	1.46/0.97	--	--	--	--	--	--	1.42/0.96	--	--	--	--	--	--
Cotton + Groundnut	1.18/0.62	0.21	0.79	1.06	0.92	0.08	1.04	1.10/0.66	0.22	0.78	1.07	0.90	0.10	1.04
Cotton + Sesamum	1.18/0.71	0.17	0.83	1.15	0.90	0.10	1.05	1.07/0.59	0.31	0.69	1.05	0.92	0.08	1.02

cotton recorded LERc of 0.92 both during 2004 and 2005. Intercropped soybean was highly competitive. It reduced the LER of cotton to 0.64. If the farmer intends to grow soybean in lieu of cowpea and still desire to obtain LERc as 0.92, then he has to grow cotton in intercropping system on part of the land and grow sole crop on rest of the land. If the standardized proportion of 0.92 is relative to the total productivity of cotton + soybean intercropping system then cotton should be allocated as sole crop over an area of 0.16 ha and it should be intercropped with soybean on 0.84 ha of land. The ELER was 1.19 in 2004 and 1.20 in 2005. This shows the advantage of increased productivity from the intercropped area by 19 to 20%. If the desired proportion of 0.92 is relative to the sole crop of cotton then the farmer should allocate 0.74 ha area to sole crop and rest to the intercropping system as evident from the data of 2004. The SLER of 1.15 indicate an yield advantage of 15% from the intercropping system allocated on 0.26 ha of land. Analogous to this manipulation for any particular choice of an intercrop in different planting patterns with a set standardized seed yield of cotton, the estimated allocation of land for sole and intercropping proportion can be obtained as a ready reckoner from this table.

### 5.6.7 Economics

The most appealing criterion to farmer most often is the economic output. Sometimes it is more important than the conviction of better land use efficiency or higher productivity, nutrient value or increased productivity in a given time etc.

Intercropping of blackgram between the uniform row spacing of cotton was most profitable. Jain and Rao (1980) suggested that the measure of profitability through statistical evaluation is invalid through the net returns obtained from different intercropping systems. They suggested such economic evaluation should be based on Relative net return (RNR) index. Considering this criterion, it was observed that the intercropping of greengram or cowpea between uniform rows of cotton was statistically on par with blackgram. The relative net returns per rupee investment is more important to farmers whose purse is most often severely tight. Considering even this criterion, these three intercropping systems were highly lucrative. Earlier investigations made by Reddy (1982), Chellamuthu *et al.* (1987) and Ramamoorthy *et al.* (1994) also indicated that the intercropping of blackgram in cotton fetched more profit than sole crop. Rao (1997) adjudged the relative profitability by employing RNR and found that the net profits obtained by intercropping

blackgram in cotton were significantly more compared to sole crop of cotton.

Gode *et al.* (1992), Mansur *et al.* (1993) and Ramanjaneyulu and Reddy (2002) documented that the profits were significantly enhanced by intercropping soybean in cotton compared to sole crop. Kairon and Avtar Singh (1972), Prasad *et al.* (1989) and Sankar *et al.* (1995) and Rao (1997) suggested the intercropping of greengram in cotton as a profitable proposition. Shaktawat and Singh (1985), Seshadri and Natarajan (1989), Tomar and Kushwaha (1991) and Parlawar *et al.* (2000) on the other hand ranked cowpea as a more profitable component to increase the net income of the cropping system. Deshpande *et al.* (1989), Padhi *et al.* (1993) and Ramanjaneyulu and Reddy (2002) suggested that the intercropping of groundnut was a more profitable venture. Sarma *et al.* (1997) confirmed that intercropping of sesamum in cotton was also profitable. But, in the present investigation cotton + sesamum accrued substantially less profit per hectare as well as per rupee and the RNR index confirmed that this was a statistically inferior intercropping system.

The extremely wide suggestions of a particular intercrop to be grown with cotton for maximum profitability owe to a range of fluctuations in the productivity of the component crops governed

by extreme variability in rainfall distribution pattern, choice of varieties and their inherent competitive or complementary influences, the variable cost of cultivation from place to place and fluctuating market prices among the commodities.

From the present investigation it is inferred that the intercropping of cowpea, greengram or blackgram between uniform row spacing pattern of cotton is highly compatible. The total productivity of intercropping system more than unity. Maximum LERs were attained by intercropping cowpea, greengram or blackgram with the added advantage of obtaining commendable yield of pulses within a short time of two months in addition to the proteinaceous fodder for animals. A range of desired yield proportions of cotton with respective ELERs, and SLERs are also furnished to exercise a selection option by allocating a part of the land for intercropping of two species and rest to sole crop of either components. The bivariate analysis of variance technique confirmed that the total productivity of these intercropping systems was significantly superior over intercropping of soybean, sesamum or groundnut. All the intercropping systems barring cotton + sesamum were also highly profitable. The best economic option also relied with intercropping of cowpea, greengram or blackgram between uniform rows of cotton.

# ***Summary***

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## CHAPATER – VI

### SUMMARY

A field experiment was conducted on “planting techniques and intercropping studies in cotton” at Agriculture Research Station, Warangal during *kharif*, 2004 and 2005. The soil was sandy loam in texture. The E<sub>Ce</sub> was 0.148 dS m<sup>-1</sup> and pH was 7.23. It had a water holding capacity of 110 mm per meter depth. It had 150.46, 26.4, 184.25 kg ha<sup>-1</sup> available N, P and K. The nutrient status was low, high and medium respectively.

Cotton variety 'Bunny' maturing in 150 days was tested for its relative performance in two planting patterns with a row orientation of a uniform distance of 90 cm and paired row planting with a spacing of 120/60 cm with or without intercrops. The intra row spacing was 90 cm in both the planting patterns of cotton. Two rows of intercrops *viz.*, soybean, greengram, blackgram, cowpea, groundnut and sesamum were interspersed at 30 cm row spacing in cotton uniformly spaced at 90 cm between the rows. Three rows of each intercrop were accommodated between paired rows. The density of each intercrop component was 66.66% of sole optimum between the uniform rows and 50% between the paired rows of cotton. These 14 treatments were laid out in Randomised Block Design with 3 replications. Sole crops of

each component were additionally raised by the side of the experiment for their utility in working out the land use efficiency.

Rainfall analysis was done from fourteen years available data to obtain precipitation curve represented by P/PET. The result showed that the crop growing season commence from 22 standard week and terminate by 44 standard week. This estimate is a guideline to select crops or cropping systems that complete their life cycle in about 160 days. The P/PET of 0.1 to 0.5 ratio ranged from 22 to 24 standard week. This is the likely ideal time for land preparation. The P/PET values ranged from 0.5 to 1 in 24-26 standard week. This is the time when the dry seeding of rainfed crops is possible. The  $P/PET \geq$  threshold expected limit of 1 ranged from 26 to 38 standard week. This is the moist period during which the crop water requirement is fully met. Therefore sowing date adjustment should be such that the peak vegetative growth and the reproductive phase should fall between 26-38 standard week. The crops then depend on undependable and less predictable rainfall of < 75% probability and on stored soil moisture upto 44 week. This curve further indicated that the intercrops maturing in about 110-120 days can be taken up with a long duration crop like cotton in this region.

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The estimates of initial and conditional probabilities of first order Markov chain analysis was also worked out during the crop growing period to assess the likely wet and dry weeks for any two consecutive weeks for effective planning of field operations.

The present experiment confirmed the predictability of the precipitation curve. Cotton was successfully grown upto 150 days. The life cycle of intercrops coincided well with the moist period. Hence, there was no severe competition to cotton for moisture. During the later period cotton depended on the stored soil moisture and the undependable rainfall.

The water requirement satisfactory indices were cent per cent from 28 to 37 standard week in the first year and from 26 to 34 standard week in second year. This confirmed that there was no moisture stress for the growth of intercrops until this period.

The vegetative crop growth, yield components, qualitative characters of seed cotton, removal of NPK and seed cotton yield per plant were not significantly influenced by a change in planting geometry from uniform row spacing of 90 cm to paired row spacing of 120/60 cm. The vegetative growth, phytomass accumulation and yield components in each of the six intercrops viz., soybean, greengram, blackgram, cowpea, groundnut and sesamum flanked between two rows of uniformly spaced cotton

or three rows between the paired rows were also unaffected. But, the removal of N, P and K was substantially low mainly due to the intercropping density of 66.66% sole optimum between uniform rows and 50% between paired rows. Since the harvested proportion of intercrops were more in uniformly spaced rows the LER, ATER, ELER and SLER recorded higher intercropping yield advantage over paired rows.

The performance of cotton depended on the choice of intercrops. The mean plant height of cotton was significantly reduced from 90 days after sowing in 2004 and from 60 days until harvest in 2005 due to the competition exerted by intercropped sesamum. Groundnut and soybean intercropping also adversely affected the mean plant height of cotton at certain growth stages of cotton. Intercropping of blackgram was most compatible. It did not reduce the plant height of cotton at any stage. The leaf area per plant was significantly lowered due to the associated cultivation of any crop from 60 to 120 days in the first year. Reduction in leaf area per plant during this period was recorded in cotton intercropped with sesamum during the second year. The intercropping of cowpea did not show adverse effect at any stage in this year.

Phytomass accumulation in cotton was highly sensitive to intercropping. It reduced from 60 days until harvest of the crop in

all the intercropping treatments. This reduction was more severe by intercropping sesamum or groundnut.

None of the intercropping systems altered the days needed to 50% flowering or the number of monopodial branches per plant of cotton. But, the number of sympodial branches reduced by intercropping sesamum, groundnut or soybean. However, they were not affected by intercropping cowpea, blackgram or greengram.

The number of bolls and seed cotton yield per plant were on par in cotton grown alone or intercropped with cowpea during both the years. They were also unaffected by intercropping blackgram only in first year. The weight of bolls were not influenced by any intercrop.

The removal of N, P and K was severely reduced in all the intercropping systems from 60 days after sowing until harvest. This effect was more severe by intercropping sesamum, groundnut and soybean than with cowpea, blackgram or greengram.

The seed cotton yield per hectare in each of the three pickings and total quantity reaped in each year was on par with cotton grown as sole crop and intercropped with cowpea. Similarly, there were no significant differences in seed cotton yield

by intercropping cotton with blackgram during the first year. The yield reduction was severe by intercropping sesamum, groundnut or soybean.

The moisture content in the upper 15 cm depth of the soil was more in sole crop than the intercropping treatments. This trend was consistent from 30 to 120 days after sowing. However, this distinction was not persistent at 45 and 60 cm depth of the soil. Sowing of different intercrops did not reduce the incidence of damage by bollworms to cotton.

The total intercropping productivity was transformed into seed cotton equivalent yield for relative comparison. The intercropping of cowpea, greengram or blackgram were significantly superior while the intercropping of groundnut, sesamum and soybean were on par with sole cotton.

The bivariate analysis technique was employed by transforming the intercrop yields into greengram seed equivalents and displayed on Z axes in figure 5 and 6. The productivity of cotton intercropped with cowpea was the best and on par with the intercropping of blackgram or greengram and significantly superior to others.

The land equivalent ratios also revealed that the intercropping of cowpea between the uniform rows of cotton was

the best choice with 1.57 and 1.56 efficiency during the two years. The LERs were 1.54 and 1.51 in 2004 and 2005 by intercropping blackgram in uniformly spaced cotton. The intercropping of greengram also recorded high LERs of 1.47 and 1.48 in the two years. The area time equivalent ratios were also more in these intercropping treatments. Intercropping of groundnut, soybean and seasmum also recorded LER exceeding unity. But, they were relatively low than the intercropping of cowpea, greengram or blackgram.

Graphical representations are furnished to choose a more desired intercrop to attain a threshold minimum standardized yield of cotton for ELERs and SLERs. An alternative option for farmers who desire to obtain maximum ELER of cotton as in cowpea but with different option of any other intercrop for any socio-economic reason are furnished in table 44. This indicates the proportion of land area to be allocated to cotton as a sole crop and intercropping in rest of the area while obtaining minimum yield requirement of cotton with less concern on the yield of choicest crop.

An economic evaluation revealed that the intercropping of sesamum and soybean in cotton is not a viable option. It reduced the net profits per hectare compared to sole crop of cotton during the two years. Intercropping of groundnut fetched low net income

per hectare during the second year. But, the intercropping of cowpea, blackgram or greengram were more profitable over sole cotton during the two years. The relative net return (RNR) indices established that the profits from these intercropping systems were significantly more. The per rupee net returns were also high in these treatments. Intercropping between the paired rows of cotton was less remunerative.

The results amply demonstrated that the length of growing season of 160 days duration and dependable rainfall upto 38 standard week in the sandy loam soils with 110 mm per metre available water holding capacity support inter cropping systems with no severe moisture limitation. Cowpea, blackgram, greengram were harvested by about 65 days at a time when cotton was in flowering phase. The total productivity per unit area increased by 48 to 57%. It would also mean that 0.48 - 0.57 ha extra land would have been needed by the sole crops to attain the same yield as in intercropping systems. Thus, the intercropping of these short duration legumes are highly compatible, more productive and economical with 13 to 18% higher expenses than the sole crops.

### **Future thrust of work**

Considering the inferences drawn from the precipitation curve and the probable weeks of wet and dry situations depending upon the actual water requirement of a particular crop compatible intercrops are ought to be worked out for traditional long duration crops like redgram and non-traditional crops like castor in Warangal. The intercropping experiments should be conducted at different locations in the district for not less than 5 years. This will help to pick out the most stable intercropping system under the year to year and within the season rainfall fluctuations in time, intensity and quantity. The technique of stability analysis proposed by Eberhart and Russel (1966) would be a very useful tool for making a sound and viable recommendation to averse the risk of low productivity for sensitive intercropping systems in years of abnormal fluctuations in rainfall distribution pattern. Varietal choice of the main crop and intercrop components are also of great significance for future research and implementation by the farmer. Studies on nutrient supplements optimum for crop production under such rainfall situations may also go a long way for better and economic crop production. Trials on crop sequences under rainfall conditions can also make a dent to exploit the possible crops and their strains to increase the production and profitability.

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\*Original not seen

# ***Appendices***

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**APPENDIX I**  
**Weekly meteorological data recorded during crop growth period (Kharif, 2004)**

Week Number	Period	Temperature (°C)		Relative humidity (%)		Rainfall (mm)	Number of rainy days
		Maximum	Minimum	0716 hours	1416 hours		
28	9-15 July	31.2	26.3	81.1	79.6	55.2	4
29	16-22	32.0	26.6	86.8	80.7	14.4	3
30	23-29	28.7	25.2	88.6	85.4	81.2	6
31	30-5 Aug	28.8	23.7	85.3	76.9	34.4	4
32	6-12	30.2	25.5	78.9	71.3	12.2	2
33	13-19	29.4	26.5	84.3	77.3	16.3	1
34	20-26	30.4	23.8	82.3	76.0	1.2	--
35	27-2 Sept	31.3	27.7	86.3	76.4	--	--
36	3-9	32.1	25.7	82.9	80.1	60.9	3
37	10-16	31.0	27.2	80.3	75.1	12.5	1
38	17-23	32.8	28.0	81.3	75.0	--	--
39	24-30	33.1	27.2	81.9	78.3	--	--
40	1-7 Oct	27.5	21.8	78.4	74.7	25.8	3
41	8-14	29.3	26.5	82.1	74.0	--	--
42	15-21	29.1	23.1	78.3	66.7	--	--
43	22-28	30.5	24.8	81.6	73.6	52.7	3
44	29-4 Nov	28.2	24.5	78.4	69.7	--	--
45	5-11	28.7	23.7	77.3	68.9	--	--
46	12-18	30.5	21.9	78.4	61.4	--	--
47	19-25	30.1	20.4	75.0	63.1	--	--
48	26-2 Dec	27.0	18.8	65.4	55.1	--	--

**APPENDIX II**  
**Weekly meteorological data recorded during crop growth period (Kharif-2005)**

Week Number	Period	Temperature (°C)		Relative humidity (%)		Rainfall (mm)	Number of rainy days
		Maximum	Minimum	0716 hours	1416 hours		
26	25-1 July	30.8	25.6	76.6	67.7	130.3	5
27	2-8	31.0	25.3	71.9	65.7	11.1	2
28	9-15	26.7	23.9	80.4	71.4	77.8	3
29	16-22	33.3	25.1	81.1	64.1	45.4	3
30	23-29	28.0	24.3	86.6	72.0	131.1	4
31	30-5 Aug	31.1	25.4	90.7	74.4	--	--
32	6-12	30.7	26.9	80.7	71.6	--	--
33	13-19	30.1	26.3	88.3	74.7	22.2	2
34	20-26	30.0	26.1	80.7	80.0	--	--
35	27-2 Sept	33.8	27.7	88.6	69.4	5.3	1
36	3-9	32.5	27.2	85.1	77.7	23.4	3
37	10-16	32.9	27.4	87.3	80.1	43.5	2
38	17-23	32.8	25.8	88.4	85.7	38.8	3
39	24-30	36.4	27.6	89.9	85.3	--	--
40	1-7 Oct	33.3	27.6	82.7	74.4	--	--
41	8-14	30.8	25.8	72.6	72.3	28.2	3
42	15-21	28.5	26.4	80.4	72.3	27.6	4
43	22-28	27.8	24.9	77.3	75.4	28.6	3
44	29-4 Nov	27.7	213.7	82.1	81.9	40.5	3
45	5-11	29.1	19.2	78.7	63.6	--	--
46	12-18	28.0	17.5	72.7	60.6	--	--

APPENDIX III

Cost of cultivation (Rs ha<sup>-1</sup>) for different treatments

Particulars	Uniform row Planting						Paired row planting					
	Cotton + Soybean	Cotton + G.gram	Cotton + B.gram	Cotton + Cowpea	Cotton + G.nut	Cotton + Sesamum	Cotton + Soybean	Cotton + G.gram	Cotton + B.gram	Cotton + Cowpea	Cotton + G. nut	Cotton + Sesamum
Land preparation	900	900	900	900	900	900	900	900	900	900	900	900
Cost of seed	2025	1445	1485	2025	3285	1285	1800	1395	1800	2745	1245	
Cost of fertilizer	4600	4061	4061	4061	3967	4455	4221	3817	3817	3746	4113	
Fertilizer application & sowing	600	600	600	600	600	600	550	550	550	550	550	
Weeding	600	600	600	600	600	600	600	600	600	600	600	
Plant protection	1278	1278	1278	1278	1278	1278	1278	1278	1278	1278	1278	
Harvesting / Picking 2004	2680	3428	3590	3577	2743	2735	2352	3107	3345	2682	2210	
Harvesting / picking 2005	3082	4038	4112	4195	3121	2587	3042	3920	3860	3037	2580	
Marketing and transport	250	250	250	250	250	250	200	200	200	200	200	
Land revenue	50	50	50	50	50	50	50	50	50	50	50	
Total 2004	12983	13212	12814	13341	13673	12153	11951	11867	12135	12577	11146	
Total 2005	13184	13822	13336	13959	14051	12005	12641	12680	12650	13332	11516	

Continued...

Particulars	Sole Cropping							
	Cotton	Soybean	G. gram	B. gram	Cowpea	G. nut	Sesamum	
Land preparation	900	900	900	900	900	900	900	
Cost of seed	1125	1350	480	540	1350	3240	240	
Cost of fertilizer	3083	2276	1467	1467	1467	1326	2059	
Fertilizer application & sowing	500	500	500	500	500	500	500	
Weeding	600	600	400	400	400	500	500	
Plant protection	1278	410	410	410	410	410	410	
Harvesting / Picking 2004	Uniform 3320 Paired 3070	800	1000	800	800	1000	600	
Harvesting / picking 2005	Uniform 3950 Paired 3870	800	1000	800	800	1000	600	
Marketing and transport	150	150	150	150	150	150	150	
Land revenue	50	50	50	50	50	50	50	
Total 2004	Uniform 11006 Paired 10756	7036	5357	5217	6027	8076	5409	
Total 2005	Uniform 11636 Paired 11556	7036	5357	5217	6027	8076	5409	

	Seed cost kg <sup>-1</sup>	Marketed produce cost kg <sup>-1</sup>	Fertilizer cost	Pesticide cost
Cotton	Rs 1125	Rs 19	Urea Rs 250 per 50 kg bag = Rs 5 kg <sup>-1</sup>	Monocrotophos Rs 230 litre <sup>-1</sup>
Soybean	Rs 27	Rs 11	SSP Rs 175.50 per 50 kg bag = Rs 3.5 kg <sup>-1</sup>	Chloropyriphos Rs 150 litre <sup>-1</sup>
Greengram	Rs 30	Rs 21	MOP Rs 235 per 50 kg bag = Rs 4.7 kg <sup>-1</sup>	Acephate Rs 350 kg <sup>-1</sup>
Blackgram	Rs 30	Rs 24		
Cowpea	Rs 27	Rs 17		
Groundnut	Rs 27	Rs 19		
Sesamum	Rs 60	Rs 22		

## APPENDIX IV

### Calculations for Bivariate Analysis of variance

When more than one intercrop raised in the intercropping system, convert the yield of intercrops to equivalent yields of any intercrop. In the present investigation all inter crop yields are converted into greengram seed equivalent yields.

#### **Kharif, 2004**

Sole crop yields of Inter crops (Kg ha<sup>-1</sup>)

Inter crop	yield	Conversion factor
Soybean	1615	935/1615 = 0.58
Greengram	935	1
Blackgram	752	935/752 = 1.24
Cowpea	847	935/847 = 1.10
Groundnut	1150	935/1150 = 0.81
Sesamum	386	935/386 = 2.42

Using these factors, convert replication wise yield of inter crops to greengram equivalent yields

	RI	RII	RIII
Soybean actual yield	842	910	1059
Greengram equivalent yield (842 x 0.58)	488	528	614

Enter the data into M.stat C package and do co-variance analysis. It will display the tables along with values on the screen

From these displayed tables take only "Unadjusted sum of products"

#### UNADJUSTED SUM OF PRODUCTS

Source	Degrees of Freedom	V4 x V4	V4 x V3	V3 x V3
Replication	2	1002.722	4742.833	27920.667
Factor A	1	181050.250	67441.750	25122.250
Factor B	5	11621.806	82380.417	1014388.250
AB	5	625.583	-679.250	3172.250
Error	22	60637.278	-23978.833	274117.333
Total	35	254937.639	129906.917	1344720.750

With these calculate the following

$$\text{Cotton } V_{11} = \frac{V_3 \times V_3}{22} = \frac{274117.33}{22} = 12459.88$$

$$\text{Inter crop } V_{22} = \frac{V_4 \times V_4}{22} = \frac{60637.28}{22} = 2756.24$$

$$\text{Cotton x Inter crop } V_{12} = \frac{V_4 \times V_3}{22} = \frac{-23978.83}{22} = -1089.94$$

$$\begin{aligned} V_{11}' &= V_{11} - \frac{V_{12}^2}{V_{22}} \\ &= 12459.88 - \frac{(-1089.94)^2}{2756.24} \\ &= 12459.88 - (1187969.2) \\ &\quad \quad \quad 2756.24 \\ &= 12459.88 - 431.01 = 12028.87 \end{aligned}$$

$$\begin{aligned} V_{22}' &= V_{22} - \frac{V_{12}^2}{V_{11}} \\ &= 2756.24 - \frac{(-1089.94)^2}{12459.88} \\ &= 2660.90 \end{aligned}$$

$$\sqrt{V11} = \sqrt{12459.88} = 111.62$$

$$\sqrt{V11'} = \sqrt{12028.87} = 109.68$$

$$\sqrt{V22'} = \sqrt{2660.90} = 51.58$$

Calculate Y1 and Z1

$$Y1 = \frac{X1}{\sqrt{VII'}} \quad Z1 = \frac{X1}{\sqrt{V11'}} \quad \text{Where } X1 = \text{mean seed yield of cotton}$$

$$\begin{aligned} (T1) \quad Y1 &= \frac{\text{Mean yield of cotton in cotton + soybean uniform row planting}}{\sqrt{V11}} & (T1) \quad Z1 &= \frac{852}{109.68} = 7.77 \\ &= \frac{852}{111.62} = 7.63 \end{aligned}$$

Like this calculate for each treatment

(T2)	Y1	=	9.90	Z1	=	10.08
(T3)	Y1	=	10.89	Z1	=	11.09
(T4)	Y1	=	10.85	Z1	=	11.04
(T5)	Y1	=	7.44	Z1	=	7.58
(T6)	Y1	=	8.37	Z1	=	8.52
(T7)	Y1	=	7.00	Z1	=	7.12
(T8)	Y1	=	9.34	Z1	=	9.51
(T9)	Y1	=	10.55	Z1	=	10.74
(T10)	Y1	=	10.69	Z1	=	10.88
(T11)	Y1	=	6.84	Z1	=	6.97
(T12)	Y1	=	7.82	Z1	=	7.96

Then calculate Y2 and Z2

$$Y2 = X2 - \frac{V12 X1}{\frac{VII}{\sqrt{V22'}}} \quad Z2 = \frac{X2}{\sqrt{V22'}}$$

Where X2 = mean seed yield of inter crop

(T1)	Y2	=	11.98	Z2	=	10.53
(T2)	Y2	=	13.47	Z2	=	11.59
(T3)	Y2	=	13.26	Z2	=	11.20
(T4)	Y2	=	13.80	Z2	=	11.75
(T5)	Y2	=	12.25	Z2	=	10.84
(T6)	Y2	=	12.99	Z2	=	11.41
(T7)	Y2	=	9.31	Z2	=	7.99
(T8)	Y2	=	10.47	Z2	=	8.70
(T9)	Y2	=	10.48	Z2	=	8.48
(T10)	Y2	=	10.88	Z2	=	8.85
(T11)	Y2	=	9.60	Z2	=	8.30
(T12)	Y2	=	9.97	Z2	=	8.49

From these values, table to be formed (Table Number 37)

$$\begin{aligned} \text{Correlation Value} &= \frac{V_{12}}{\sqrt{V_{11} V_{22}}} = \frac{-1089.94}{\sqrt{12459.88 \times 2756.24}} \\ &= \frac{-1089.94}{5860.24} = -0.185 \end{aligned}$$

$$\cos \theta = \sin^{-1}(-0.185) = -10.71$$

$$\theta = -10.71^\circ$$

To test the significance of bivariate test

$$T_{11} = V_3 \times V_3 \times \left[ \frac{1}{\sqrt{V_{11}}} \right]^2$$

$$T_{12} = V_3 \times V_3 \times \left[ \frac{1}{\sqrt{V_{11}}} \right] \times \left[ \frac{V_{12}/V_{11}}{\sqrt{V_{22}'}} \right] + V_4 \times V_4 \times \left[ \frac{1}{\sqrt{V_{11}}} \right] \times \left[ \frac{1}{\sqrt{V_{22}'}} \right]$$

$$T_{22} = V_4 \times V_4 \times \left[ \frac{V_{12}}{V_{11}} \right]^2 + 2(V_4 \times V_3) \left( \frac{1}{\sqrt{V_{22}'}} \right) \left[ \frac{V_{12}}{V_{11}} \right] + V_4 \times V_4 \left[ \frac{1}{\sqrt{V_{22}'}} \right]^2$$

$$T_{11} = 83.68$$

$$T_{12} = 17.73$$

$$T_{22} = 65.84$$

$$B = (T_{11} + e)(T_{22} + e) - T_{12}^2$$

$$B = 8968.48$$

$$A = \frac{e^2}{B} \quad t = e = \text{error degree of freedom (22)}$$

$$\begin{aligned} &= \frac{484}{8968.48} = 0.05 \end{aligned}$$

$$\begin{aligned} F_{cal} &= \frac{1 - \sqrt{A}}{\sqrt{A}} \times \frac{e-1}{t} \\ &= 3.37 \end{aligned}$$

F table value at 22,42 degree of freedom = 1.93

Treatment factor  $5 + 5 + 1 = 11 \times 2 = 22$

Error =  $22 \times 2 = 44 - 2 = 42$

Since F calculated > F table value, the bivariate analysis was significant

The significance of treatments can be judged using  $\frac{4 e F_c}{n (e-1)}$

Where

e = error degree of freedoms

Fc = critical value of F for 2 (e-1) degree of freedom at the required level of significance here, Fc 2,21 = 3.47

n = number of replications

$$= \frac{4 \times 22 \times 3.467}{3 (22-1)} = \frac{305.10}{63} = 4.84$$

### **d<sup>2</sup> value**

$d^2 = (\text{difference between } Y_1)^2 + (\text{difference in } Y_2)^2$

If  $d^2 > \frac{4e F_c}{n (e-1)}$  then the treatments are significantly different

Soybean – greengram

$$d^2 = (7.63-9.90)^2 + (11.98-13.47)^2$$

$$= 7.37 \text{ significant}$$

Soybean-blackgram

$$d^2 = (7.63-10.89)^2 + (11.98-13.26)^2$$

$$= 12.27 \text{ significant}$$

In this way d<sup>2</sup> values can be calculated

The bivariate diagram can be represented by drawing radius

$$= \sqrt{\frac{4 e F_c}{n (e-1)}} \approx \sqrt{4.84} = 2.20$$

If the mean of a treatment falls within the non significance region of another treatment, then the two treatments are not significantly different. Such an influence from bivariate graph coincides with the d<sup>2</sup> table.

APPENDIX V

Calculations for Effective ( $\lambda$ ) land equivalent ratio (ELER)

$$\lambda \text{ LER} = \frac{M_B S_A}{(S_A - M_A) + \lambda (\text{LER} - S_A)} \quad (1) \text{ and}$$

$$\frac{M_A S_B}{M_A - \lambda (\text{LER} - S_B)} \quad (2)$$

Where,

$M_A$  is the component LER or Standardized yield of A

$M_B$  is the component LER or standardized yield of B

$S^*_A = X_A / X_{A1}$  and  $S^*_B = X_B / X_{B1}$

$X_A$  is the sole crop yield per unit area of A grown under the same conditions as the crop A when intercropped and  $X_{A1}$  and  $X_{B1}$  are the standardized sole crop yields of A and B grown under different conditions and with which the inter crop yields are to be compared.

\* In present calculation,  $S_A$  and  $S_B$  are taken as 1 as the yields obtained are same as standardized sole crop yields.

$$= \frac{kM_A + (1-k) S_A}{k (M_A - M_B) + (1-k) S_A} \quad \text{for equation 1}$$

$$= \frac{kM_A}{k (M_A + M_B) + (1-k) S_B} \quad \text{for equation 2}$$

$k$  = desired yield proportion

Cotton + Greengram uniform row planting, kharif 2004

$$M_A = 0.83, \quad M_B = 0.64, \quad LER = 1.47, \quad S_A = 1, \quad S_B = 1$$

$$\begin{aligned} \lambda &= \frac{kM_A + (1-k) S_A}{k (M_A + M_B) + (1-k) S_A} \\ &= \frac{0.2 \times 0.83 + (1-0.2) \times 1}{0.2 (1.47) + (1-0.2) \times 1} = 0.8829 \\ &= \frac{0.4 \times 0.83 + (1-0.4) \times 1}{0.4 (1.47) + (1-0.4) \times 1} = 0.7845 \end{aligned}$$

Similarly calculate for 0.6, 0.8 and 1.0

$$\lambda LER = \frac{M_B S_A}{(S_A - M_A) + \lambda (LER - S_A)}$$

$$0.2 LER = \frac{0.64 \times 1}{(1-0.83) + 0.8829 (1.47-1)}$$

Similarly calculate for 0.4, 0.6, 0.8 and 1.0

$$\begin{aligned} \lambda &= \frac{kM_A}{k (M_A + M_B) + (1-k) S_B} \\ &= \frac{0.2 \times 0.83}{0.2 (1.47) + (1-0.2) \times 1} = \frac{0.166}{0.294 + 0.8} = \frac{0.166}{1.094} = 0.1517 \end{aligned}$$

Similarly calculate for 0.4, 0.6, 0.8 and 1.0

$$\lambda \text{ LER} = \frac{M_A S_B}{M_A - \lambda (\text{LER} - S_B)}$$

$$= \frac{0.83 \times 1}{0.83 - 0.1517 (1.47 - 1)} = \frac{0.83}{0.83 - 0.1517 (0.47)} = \frac{0.83}{0.7587} = 1.0945$$

Similarly calculate for 0.4, 0.6, 0.8 and 1.0

Table Effective LER for cotton + Greengram uniform row planting

Proportionate area to be intercropped	Proportionate desired yield of cotton	ELER
0.2	0.12	1.09
0.4	0.23	1.19
0.6	0.39	1.28
0.8	0.48	1.36
1.0	0.56	1.47
0.2	0.88	1.09
0.4	0.78	1.19
0.6	0.70	1.28
0.8	0.63	1.38
1.0	0.56	1.47

## APPENDIX VI

Calculations for Staple land equivalent ratio (SLER)

SLER values were calculated as

If  $L'A \geq LA$

$$SLER = L' - \frac{(L'A - LA)}{(1 - LA)} (L - 1)$$

If  $L'A < LA$

$$SLER = \frac{L - (LA - L'A)}{(LA)} (L - 1)$$

Where

$L = LER$

$L'A = \frac{Y'A}{Y_A}$  (Proportion of the required yield crop 'A' relative to its pure crop yield)

$LA =$  Partial LER of crop A

Cotton + Groundnut uniform row planting, Kharif 2004

$LA = 0.63, LER = 1.23$

L'A	<	LA
0.2	<	0.63
0.4	<	0.63
0.6	<	0.63
0.8	<	0.63

L'A < LA

$$\text{SLER} = \frac{L - (LA - L'A)(L-1)}{LA}$$

$$0.2 = \frac{1.23 - (0.63 - 0.2)(1.23 - 1)}{0.63}$$

$$= \frac{1.23 - (0.43)(1.23 - 1)}{0.63} = 1.07$$

$$0.4 = \frac{1.23 - (0.63 - 0.4)(1.23 - 1)}{0.63} = 1.15$$

$$0.6 = \frac{1.23 - (0.63 - 0.6)(1.23 - 1)}{0.63} = 1.22$$

L'A > LA

$$\text{SLER} = \frac{L - (L'A - LA)(L-1)}{(1-LA)}$$

$$0.8 = \frac{1.23 - (0.8 - 0.63)(1.23 - 1)}{(1 - 0.63)} = 1.12$$

The proportion of land required for intercropping

*If desired proportion is > SLER*

$$\text{Inter crop area} = (1 - L_i') / (1 - L_i)$$

*If desired proportion is < SLER*

$$\text{Inter crop area} = L_i' / L_i$$

Cotton + Groundnut uniform row planting (LERc = 0.63)

0.2  
0.4  
0.6 1  
0.8

0.2, 0.4 less than desired yield proportion

Inter crop area =  $L_i/L_c$

For 0.2 =  $0.20/0.63 = 0.32$

0.4 =  $0.40/0.63 = 0.63$

0.8 more than desired yield proportion

Inter crop area =  $(1-L_i) / (1-L_c)$   
=  $(1-0.8) / (1-0.63)$   
= 0.54

Table Staple LER for cotton + Groundnut uniform row planting

Proportionate area to be intercropped	Desired yield proportion	SLER
0.32	0.2	1.07
0.63	0.4	1.15
1	0.6	1.22
0.54	0.8	1.12

## APPENDIX VII

Calculations for proportion of land allocation for sole and intercropping systems to attain equivalent ELER and SLER as that of cotton intercropped with cowpea

ELER

Cotton + Groundnut uniform row planting, kharif 2004

	Inter cropping system 1	Inter cropping system 2
	Cotton + Cowpea	Cotton + Groundnut
Cotton yield	1211	831
Intercropping yield	551	690
LERs		
Cotton	0.92	0.63
Inter crop	0.65	0.60
Total	1.57	1.23
Yield proportion of cotton (LER <sub>c</sub> ) Total LER	0.59	0.51

The required proportion  $\frac{\text{Cotton}}{\text{Cotton + Groundnut}}$

$$0.59 = \frac{0.63 + E}{1.23 + E}$$

Where E = Additional sole cotton area

$$0.59 \times 1.23 + E \times 0.59 = 0.63 + E$$

$$0.7257 - 0.63 = E - E \times 0.59 \quad (1 - 0.59)$$

$$0.0957 = E \times 0.41$$

$$E = \frac{0.0957}{0.41}$$

$$E = 0.23$$

Required proportion of 0.59 would be achieved from 1 hectare of inter crop 1 and 0.23 ha of sole cotton; on unit area basis this would be equivalent to Proportional area of 0.81 to 0.19

$$\frac{0.23}{1.23} = 0.19 \quad (1-0.19 = 0.81)$$

Biological efficiency (ELER) calculated as follows

From 0.81 ha of inter cropping      Yield      LER      Proportions

Groundnut      559      0.49      0.41

(Yield in inter cropping system x Proportionate land area) 690 x 0.81

Cotton	673	0.51	} 0.59
From 0.19 ha sole cotton			
Cotton	252	0.19	

## SLER

Cotton + Groundnut uniform row planting, *Kharif* 2004

Crop	1	2	Sole crop yields	Partial LERs	
				0.92	0.83
Cotton	1211	831	1328	0.92	0.83
Cowpea/Groundnut	551	690	847/1150	0.65	0.64
LER				1.57	1.47

If farmer want to have same yield of cotton as in system 1, with inter crop as in system 2.

$$= \frac{(1211-831)}{(1328-831)} = \frac{380}{497} = 0.76$$

$$SLER = 1.57 - (0.76 \times 0.57) = 1.14$$

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