

**STUDIES ON THE SPECTRAL RESPONSES OF IRRIGATED  
WINTER COTTON CULTIVARS UNDER VARYING PLANTING  
PATTERNS AND NITROGEN LEVELS**

Thesis submitted in partial fulfilment of the requirement for the award of the  
degree of DOCTOR OF PHILOSOPHY (Agriculture) in Agronomy to the  
Tamil Nadu Agricultural University, Coimbatore.

By

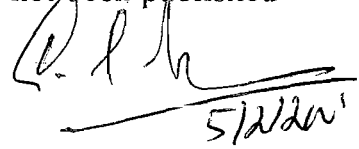
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## CERTIFICATE

This is to certify that the thesis entitled "Studies on the spectral responses of irrigated winter cotton cultivars under varying planting patterns and nitrogen levels" submitted in part fulfilment of the requirements for the degree of Doctor of Philosophy (Agriculture) in Agronomy to the Tamil Nadu Agricultural University, Coimbatore is a record of bonafide research work carried out by Mr.R.KRISHNAN under my supervision and guidance and that the part of this thesis has not been submitted for the award of any other degree, diploma, fellowship or other similar titles or prizes and that the work has not been published in part or full in any scientific or popular journal or magazine.



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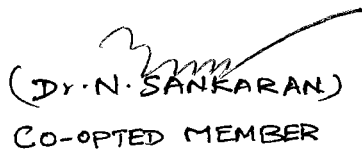
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## ABSTRACT

### STUDIES ON THE SPECTRAL RESPONSES OF IRRIGATED WINTER COTTON CULTIVARS UNDER VARYING PLANTING PATTERNS AND NITROGEN LEVELS

By

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Three field experiments were conducted at Tamil Nadu Agricultural University Farm, Coimbatore during 1992-'95 to study the spectral responses of winter irrigated cotton cultivars to different planting patterns and nitrogen levels. During the first and second years (1992-'93 and 1993-'94) of experimentation, the effect of planting patterns (Normal row, Paired row and Paired row with green gram intercrop), cultivars (TCHB 213 and MCU 11) and levels of nitrogen application (0,50,100 and 150 per cent of recommendation *viz.*, 0, 60, 120 and 180 kg ha<sup>-1</sup> for TCHB 213 and 0, 40, 80 and 120 kg ha<sup>-1</sup> for MCU 11) on spectral responses were studied in split plot design in three replications. During the third year (1994-'95), after short-listing of treatments, the effect of cultivars (TCHB 213 and MCU 11) and levels of nitrogen application (100,150 and 200 per cent of recommendation *viz.*, 120, 180 and 240 kg ha<sup>-1</sup> for TCHB 213 and 80, 120 and 160 kg ha<sup>-1</sup> for

MCU 11) on spectral responses were evaluated in FRBD in four replications. Spectral reflectance measurements were taken using a multiband ground truth radiometer in the visible and infrared bands along with biometric observations.

The results of first two years of experimentation revealed that normal planting pattern had recorded higher growth, development and yield of seed cotton. TCHB 213 was superior to MCU 11 in growth and yield. The cotton cultivars responded upto 150 per cent of recommended level of nitrogen (180 and 120 kg ha<sup>-1</sup> for TCHB 213 and MCU 11 respectively) for both growth and yield.

The results of third year experimentation showed that TCHB 213 was more efficient in terms of growth and yield than MCU 11. The response for plant growth was significant upto 200 per cent of recommended nitrogen (240 and 160 kg ha<sup>-1</sup> for TCHB 213 and MCU 11 respectively) while, the response for yield was at statistical par between 150 per cent (180 and 120 kg ha<sup>-1</sup> for TCHB 213 and MCU 11 respectively) and 200 per cent of recommended nitrogen (240 and 160 kg ha<sup>-1</sup> for TCHB 213 and MCU 11 respectively).

The comprehensive analysis of spectral reflectance of all the three years revealed that the spectral reflectance in blue, green and infrared bands found increased with increasing crop growth, whereas the reflectance was found decreasing in red band.

Planting patterns, cultivars and nitrogen levels were discriminated through spectral reflectance from 45 DAS onwards. The ideal stage for spectral measurement studies for cotton was around 75 DAS.

Red and infrared bands were consistent in discriminating the planting patterns, cultivars and nitrogen levels unlike blue and green bands. Red to infrared reflectance ratio (IR-R) discriminated the planting pattern, cultivars and nitrogen levels throughout the crop growth stages, but at earlier stage of crop growth, the discrimination was stronger in Perpendicular Vegetation Index (PVI).

Red band had a negative and non-significant correlation with LAI, chlorophyll content, nitrogen content, DMP, leaf angle, leaf thickness and yield except canopy ground cover, while infrared band had positive and significant correlation with the above parameters. Ground cover was best estimated from red band while, LAI was inferred from infrared band.

LAI, total chlorophyll content, nitrogen content and ground cover were estimated from spectral reflectance and vegetation indices, at 75 DAS, using allometric relationship.

The yield forecast for cotton from spectral reflectance in red and infrared bands and vegetation indices at 75 DAS had a relative deviation from (-) 5 to (+) 13 per cent from the observed yield data.

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Introduction

*Chapter I*  
**INTRODUCTION**

Cotton is a very important commercial fibre crop in India. It provides gainful employment to millions of people in the country, who are engaged mostly in its cultivation, trading, processing, manufacturing, fabricating and marketing. In 1997-'98, India earned more than Rs.13,000 crores in foreign exchange from the export of cotton yarn, thread, fabrics, apparel and made-ups. It sustains the country's cotton textile industry which is the largest segment of organised industries. At present, cotton accounts for 44 per cent of all fibres used in the world.

The increasing demand of an exploding population for food and fibre necessitates accurate and timely inventories of agricultural resources and early detection of soil and plant related problems. Improved methods of describing the growth and forecasting the yields of crops could aid in planning for the development of sustainable agronomic management strategies. A reliable methodology to monitor crops during its season on a regular basis is required to identify the constraints of crop production as early as possible and also to obtain the pre-harvest forecast with high accuracy.

Remote sensing is a potential scientific tool for obtaining accurate and timely information on earth and bio-resources especially the condition and yield of crops. Accurate assessment of crop condition would be more useful in managing the crop resources including biotic and abiotic stresses.

Crop identification and its acreage estimation in a single crop dominated regions have been the main concern of remote sensing in agriculture for quite some time. Of late, the technique of remote sensing has undergone revolutionary changes in the methods of study and survey of land use types and forecasting of crop yield.

Assessment of crop condition over large areas and development of production forecast require accurate estimate of appropriate indicators of crop vigour and growth. Forecasting crop production is crucial for decision making by the policy makers. In contrast to traditional methods, remote sensing based approaches have certain inherent advantages like crop specificity, large area coverage and timeliness. Remote sensing data provide information on spectral - plant parametric functional relations in agriculture, which is of immense value.

The technique of remote sensing has not been exploited to study the spectral response of cotton in relation to agronomic management practices like planting geometry, cropping system (like intercrops), genetic diversity and identification of nutrient status especially nitrogen. The deficiency of nitrogen is universal and symptom expression is fairly uniform over the leaf surface in contrast to the marbling and interveinal chlorosis associated with other elemental deficiencies. Moreover, the information on spectral profile of cotton and possibilities of seed cotton yield forecast are not available presently. Hence, this study was undertaken with the following objectives.

- ◆ To study the spectral responses of irrigated winter cotton cultivars under varying levels of applied nitrogen and planting patterns.
- ◆ To identify the crop stage and spectral bands at which the discrimination could be done more precisely.
- ◆ To relate the measurements of canopy spectral responses to agronomic parameters and seed cotton yield and
- ◆ To assess the possibility of issuing yield forecast in irrigated cotton.

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Review of Literature

*Chapter, II*

## REVIEW OF LITERATURE

Agricultural farm decision making depends on the accessibility to information from various production functions. Real time estimate of crop condition and its spread are important for the formulation of strategies especially for contingency situation. Remote sensing, an emerging applied science offers such opportunity in the present day situation.

The growth of a crop is conditioned by its genotype, soil characters, cultural practices given, nutrient availability, pest and disease incidence and prevailing weather conditions. The stresses from these factors except genotype cause physiological changes which tend to alter the optical and thermal properties of the leaves and their reflectance of the canopy.

The spectral profile of a crop is the integrated manifestation of the effect of all the growth factors. Monitoring and assessment of crop growth through reflectance measurement at regular intervals during growth cycle are essential to take appropriate curative measures to improve growth and production. The vegetation indices calculated from reflectance are surrogate measures of crop condition assessment.

The spectral measurements or spectral profile of a crop and vegetation indices can also be used to estimate the growth parameters, nutrient content besides acreage estimation and yield forecasting. The relevant literature

pertaining to the study area are reviewed in this chapter and presented here under.

## **2.1. Spectral properties of crop**

### **2.1.1. Crop canopy reflectance**

The reflecting power of crop canopy gets changed with the plant species. Under field condition, the reflecting power was determined by foliage density, plant height, growth habit, plant vigour and its maturity. Environmental factors such as soil salinity, moisture availability and nutrient toxicity or its deficiency affected the optical and radiation properties of plants. In this context, remote sensing of energy reflected or emitted from plant canopy offered a possible means for determining crop species, its maturity, vigour, diseases incidence and probable yield to be obtained (Thomas *et al.*, 1967).

Reports from studies on cotton conducted indicated that the reflectance from leaves got increased with increase in soil salinity, leaf moisture deficit and chlorine content since, the same plant and soil factors affected the yield. The regression equation developed between reflectance and yield accounted for 51 to 71 per cent of the variation in yield (Mass, 1997).

Gauseman *et al.* (1969) reported that osmotic stress caused a slight decrease in reflectance and a greater increase in transmittance of cotton plants. Young cotton leaves would have lower reflectance than matured leaves in the near infrared region.

The characteristics of plant spectral reflectance and transmittance were the function of leaf geometry, morphology, physiology and biochemistry of the plants. They were also influenced by soil and climatic condition and nutrient status. Excess or deficiency of an essential element might cause visible abnormalities in pigmentation, size and shape of leaves and thus led to appearance of various other symptoms (Al Abbas *et al.*, 1974).

Leamer *et al.* (1978) reported that the proportion of the ground, covered by plants was more important than developmental stages of the plants in determining spectral responses except at the end of the season when the plants got senesced and lost pigmentation. Kollenkark *et al.* (1982) indicated that cultural practices produced differences in per cent soil cover and leaf area index which in turn manifested in the spectral reflectance characteristics of crop canopies.

Jackson and Pinter (1986) reported that during the period of peak green leaf area index, the ratio of near infrared/red reflectance for the erectophile canopy was about 30 per cent higher than for the planophile canopy. Daniel Lord *et al.* (1988) reported that the red reflectance values were higher at the beginning and at the end of growing season than in the middle when the visible radiation absorbing pigments were at a maximum.

Gupta and Krishna Rao (1989) reported that in red spectral region, the reflectance from plant leaves was dependent on the chlorophyll content while

in near infrared spectral region the reflectance was primarily related to Leaf Area Index (LAI) and green biomass only.

### **2.1.2. Reflectance in spectral bands**

For all the crops, the reflectance in red region got decreased, while there was increase in infrared region as the crops grew upto a certain stage. This was because of the chlorophyll concentrations and green leaf biomass which increased with plant growth and absorbed more radiation in red regions and reflected more in near infrared region of the spectrum. At maturity stage, when the vegetation got senesced, in the near infrared, reflectance tended to decrease while the breakdown of leaf pigments caused a rise in red reflectance (Sanger, 1971).

In the near infrared region (0.7-1.3  $\mu\text{m}$ ) single green leaf typically reflected about 40 per cent or more of the incident radiation as compared to only about 10 per cent in the visible wave lengths (0.4-0.7  $\mu\text{m}$ ) (Sinclair *et al.*, 1971). Thomas *et al.* (1971) also confirmed this by reporting that in the near infrared wavelength, reflectance from individual green leaf gradually had been found to increase with decreasing leaf moisture content. Patel *et al.* (1982) reported that a strong absorption took place by plant pigments like chlorophyll in the wavelength region of red (0.35-0.50  $\mu\text{m}$ ) and reflectance in the near infrared region (0.7-1.3 $\mu\text{m}$ ). Hinzman *et al.* (1986) reported that the crop deficient in nitrogen showed greater reflectance in the visible and middle infrared wavelengths and lower reflectance in the near infrared wavelength than those with adequate or high nitrogen fertility.

Hamdi *et al.* (1991) reported that green, red and infrared reflectance were closely related to the agronomic and physiological properties of cotton such as plant height, crop cover percentage, green leaf biomass and chlorophyll content. Further it was stated that green/red ratio seemed to be ineffective for vegetation discrimination. Thenkabail *et al.* (2000) found out a strong relationship between cotton crop characteristics *viz.*, wet biomass, LAI, plant height and yield and specific narrow bands in the longer wavelength portion of the red region (0.65 - 0.7nm).

## **2.2. Remote sensing applications**

Remote sensing studies aim to identify growing crops, measure the area that each crop covers, determine the physiological vigour of the plants, detect plant stresses and to predict potential crop yields. To accomplish this, various factors involved in identifying the crop and the spectrum reflected from the target plants must be known.

### **2.2.1. Crop identification**

Gausman *et al.* (1971) reported that reflectance of cotton crop increased as number of leaf layers increased within a plant canopy until a stable reflectance value was reached, which was one of the most promising for crop discrimination.

Williams *et al.* (1987) identified muckland vegetables with 90 per cent accuracy and upland vegetables with 75 per cent accuracy from Thematic

Mapper Data over New York. Hickman *et al.* (1991) reported the possibilities of detecting and mapping of moderate and severe herbicide injuries.

Sundara Sharma and Das (1994) generated spectral vegetative index profile which was used to identify the flowering period parameters *viz.*, flowering time, duration and intensity, besides differentiating the oil seed crops.

Patnaik and Dadhwal (1995) reported from their studies that the dominant *kharif* crops like cotton, groundnut, maize and pigeon pea could be discriminated through remote sensing data. Apart from cultivated crops, various natural vegetation classes were also identified. Panigrahy *et al.* (1995) reported that from multi-date satellite data, mixed cropping pattern and its management practices could be accurately assessed.

The data acquired in the months of August, September and October coinciding with peak LAI would be suitable to identify the crops grown in lowland condition (Patel *et al.*, 1995a). Patel *et al.* (1995b) identified the developmental stages of both determinate and indeterminate types of red gram by using spectral and vegetation indices.

Ninety six percent accuracy was achieved by Sehgal and Dubey (1997) in identifying dryland sorghum crop by using multi-date wide field sensor data. Krishnan *et al.* (1998) were able to discriminate *kharif* rice varieties through reflectance studies. Ben Dor and Levin (2000) reported that

hyperspectral data could be used even without simultaneous ground data to distinguish two cotton plots having different soil water status.

### **2.2.2. Crop acreage estimation**

A reliable methodology to obtain pre-harvest forecast with high accuracy would be useful for food security planning. A pre-requisite for such forecasting at State level and National level is the estimation of area under each crop with much accuracy.

Mac Donald and Hall (1980) used satellite measurements of radiation reflected from crop canopies to identify crop type and also estimated the crop acreage. Munshi (1982) determined the wheat crop statistics for India from Landsat Data by employing visual interpretation. A historical account of developments of digital analysis procedure of crop acreage estimation was reported by MacDonold (1984). Potdar *et al.* (1987) exploited the property of Normalised Difference Vegetation Index (NDVI) for detection of canopies with poor vegetative cover for acreage estimation of sorghum crop.

Panigrahy *et al.* (1991) reported that low-resolution with high repeativity data like NOAA-AVHRR could be used to obtain a quick estimate of acreage at State level. Sharma *et al.* (1991) reported that flowering stage would be ideal to collect remote sensing data for crop classification and area estimation. Rajeev Sharma *et al.* (1993) reported that remotely sensed data could be used in acreage estimation and also to assess the crop growth

condition and these observations were found to agree with the ground reality information.

Sujay *et al.* (1994) estimated cotton acreage by using LISS II Data and this was closer to that one obtained from the base map (maximum likelihood classifier and minimum distance to mean methods).

Oza *et al.* (1996) suggested that with proper data selection, it was possible to give National wheat acreage estimation with reasonable accuracy.

The area under crops which had higher year to year variation could be estimated from in-season stratified data (Sankhla *et al.* 1997). It was suggested by Sanjay Dutta *et al.* (1998) that among single dates, data acquired in February was better for wheat crop classification while multi temporal data increased the accuracy upto 94 per cent.

### **2.2.3. Crop condition assessment**

#### **2.2.3.1. Crop growth and stage**

Badhwar and Henderson (1981) concluded that spectral data were used as an input for crop development model to predict the developmental stage of corn with an accuracy of 96.4 per cent. Richardson *et al.* (1982) reported that the vegetation indices worked out from spectral data were of use to monitor seasonal development of sorghum crop.

Ahlich and Bauer (1983) found a strong relationship between spectral response and per cent soil cover, LAI, biomass and plant water content which demonstrated the potential of multispectral remote sensing to monitor crop growth and its condition. Daughtry *et al.* (1983) showed conceptually to use the remote sensing data to obtain an estimate of the solar radiation intercepted by canopies and then to dry matter accumulation. Herdisky *et al.* (1983) reported that spectral radiance measurements accurately detected the differential growth responses of marsh plant *Spartina alterniflora* to the addition of fresh water and sewage effluent and was confirmed by them by destructive harvesting and estimation.

Asrar *et al.* (1985) estimated the above ground phytomass value of wheat from spectral measurements and found a strong correlation between observed and estimated above ground phytomass. Major *et al.* (1986) reported the ability of canopy reflectance to provide accurate and non-destructive estimate of LAI for growth analysis. However, it was further cautioned, that the complex association between leaf area and biomass showed that a single measurement of canopy reflectance could not be used to estimate biomass or final grain yield.

Tara Sharma and Navalgund (1989) estimated the growth stages of wheat from agrometeorological model using spectral reflectance data as an input. It was concluded by Wiegand and Richardson (1990) that spectral component analysis did provide additional analytical tool for characterising and assessing crop development, growth and yield.

Daughtry *et al.* (1992) indicated that remotely sensed spectral measurements contributed valuable information concerning energy / phytomass accumulation in plant canopies. However, this approach required consideration on the influence of stress events such as drought, nutrient limitations and occurrence of diseases. Mass (1998) indicated that cotton canopy ground cover might be accurately estimated from reflectance in the red and near infrared wavebands using simple equation derived from linear mixture modeling. And further stated that since this methodology relied on information that are obtained solely through remote sensing, it would be particularly useful in application where other field information such as plant size, row spacing and orientation are unavailable.

#### **2.2.3.2. Leaf area index**

Field measurement of green leaf area index was tedious and time consuming, and it was sample dependent and subjected to sampling bias. An overall LAI was especially difficult to estimate for non-uniform crop stands. Remote sensing technique had potential for non-destructive estimation of crop growth parameter such as LAI. This technique required less labour and time, and could be applied to larger geographical area than direct field measurement.

Blair and Baumgardner (1977) reported that reflectance measurements in the visible and near infrared regions of electromagnetic spectrum were indicators of the amount of vegetation present.

Hatfield *et al.* (1983) compared several spectral reflectance transformations and confirmed that LAI of wheat could be estimated best from a ratio of near infrared (NIR) to red (R) reflectance. Aase and Tanaka (1984) based on the relationship between green leaf dry matter and IR/R ratio suggested the possibility that reflectance measurements might substitute the tedious and labour involved in leaf drymatter or leaf area measurements. Combination of NIR and Red reflectance was defined as Normalised Difference Vegetation Index (NDVI), and it was used by Asrar *et al.* (1984) to predict the LAI of wheat.

King *et al.* (1986) reported that reflectance measurements had the potential advantage to estimate herbage mass and LAI of rye grass.

Nagaraja Rao *et al.* (1987) observed significant correlation between LAI and ratio of IR/R reflectance of maize crop. Redelf *et al.* (1987) postulated from their study involving seven row crops that the relationship between greenness and LAI was general to several crops and not crop specific.

Price (1992) observed a direct relationship between reflectance and well defined vegetation parameters from which LAI was estimated. Subba Rao and Sastri (1992) reported that vegetative index could be used to predict LAI in mustard crop under stressed and non-stressed conditions.

Patel *et al.* (1995b) used the spectral vegetation indices like NDVI and IR/R ratio to predict the LAI and found that highly significant result was

obtained to define the variation up to 90 per cent. Ram Niwas and Sastri (1995) showed that LAI could be estimated by using regression equations from spectral indices. Qi *et al.* (1995) reported that estimated LAI values agreed well with field observations and there was a potential for multi-temporal remote sensing data for applying on an operational basis.

### **2.2.3.3. Leaf chlorophyll content**

The reflectance spectra of vegetation in the visible region of the spectrum were the manifestation of the light absorption. The pigments making the greatest contribution to light absorption in the region were those which were intimately involved in photosynthesis namely Chlorophyll a, b and carotinoids.

Benedict and Swindler (1961) found an inverse relation between reflectance and chlorophyll concentration. Knippling (1970) reported that spectral reflectance in the red range was inversely related to the *in situ* chlorophyll density while spectral reflectance in the NIR range was directly related to the green leaf density. Sinclair *et al.* (1971) reported that the reflectance increased with senescing of leaves and reduction in chlorophyll content. For most of the crops, chlorophyll was the most important independent factor affecting reflectance. The canopy reflectance at 550 nm was a good indicator of chlorophyll and carotinoids concentration for different crops (Thomas and Gausman, 1977).

Nageswara Rao (1984) reported that whenever there was a stress, the leaf pigment system was more readily affected accompanied by changes in the internal leaf structure ultimately led to overall changes in the spectral response.

Chappelle *et al.* (1992) estimated pigment concentration (Chlorophyll a and b) by using reflectance spectra and obtained a good agreement with the concentration analysed through chemical process. Curran *et al.* (1992) observed statistically significant correlation between reflectance and the concentration of chlorophyll and other biochemicals like starch, sugar, protein, amaranthine and water.

#### **2.2.3.4. Plant nitrogen content**

Nitrogen is one among the main limiting factors in crop production. An improvement in the ability to measure plant nutrient content could lead to an upgrading of yield forecast. Current results from research indicate the feasibility of using aircraft or satellite for routine monitoring of crops. Before this is being done ground based information is warranted to demonstrate the reliability of such remotely sensed data.

Reflectance spectra of nitrogen deficient leaves were similar to those of normal leaves, but percentage reflecting power differed depending on the severity of nitrogen deficiency (Myer, 1970). Thomas and Oerther (1972) found that the change in nitrogen concentration of sweet pepper from five per cent to four per cent was detectable through reflectance measurements which

otherwise might not be detected visually. Stanhill *et al.* (1972) made observation in wheat and concluded that the major cause of altered spectral response from nitrogen deficient wheat was due to differences in total biomass.

Spectral measurements of corn canopies varying in applied nitrogen fertilizer level were studied. The results indicated that changes in canopies due to nitrogen treatment resulted in detectable reflectance variations which demonstrated the potential for detecting crop stress by use of multi-spectral remote sensing (Walburg *et al.*, 1982). Richardson *et al.* (1983) used R and NIR measurement to compute vegetation indices to correlate nitrogen content of *Alicia* grass.

Ajai *et al.* (1984) reported much lower values of IR/R reflectance ratio and the ND vegetation indices for nitrogen deficient wheat crop as compared to that of nitrogen fertilized crop over the complete growth cycle. In rice, a decrease in the peak of the temporal and spectral profile with reduced level of nitrogen supply was reported by Panigrahy *et al.* (1986).

Different temporal and spectral responses were observed by Mahey *et al.* (1990) for fertilized and nutrient deficit plots of maize, and found that that spectral parameters could be used for detecting nutrient stress and possibly for other crops also. Mani *et al.* (1991) concluded that nutrient stress of sorghum could be monitored through remotely sensed spectral reflectance studies. Zhurmar and Yanovaskaya (1992) confirmed the effectiveness of the

use of remote sensing methods to determine the nitrogen content of potato crop. Relatively strong correlation was observed by Blackmer *et al.* (1994) between light reflectance and leaf nitrogen content of maize which indicated the possibility of assessing crop nitrogen requirement and status.

Blackmer *et al.* (1996) detected nitrogen status of corn using reflected short wave radiation and stated that reflected radiation around 550 nm and 710 nm provided the best detection of nitrogen deficiency. Ma *et al.* (1996) suggested that light reflectance measurements predicted grain yield and might provide in-season indication of nitrogen deficiency. Yehoshna Saranga *et al.* (1998) reported that the near infrared analysis method could safely be used for on the spot decision making in respect of fertilizer nitrogen application to cotton. This information could be used to prevent excessive nitrogen application for the benefit of farmer's revenue and the environment.

#### **2.2.4. Crop yield estimation**

Pre-harvest estimates of crop yields are important in planning procurement, distribution, import and export of agricultural commodities. Present methods of forecasting yield are inadequate. From remote sensing data, it is possible to make a quick assessment and to provide timely and accurate information for very large areas.

Idso *et al.* (1977) summarised from their studies that canopy albedo measurements appeared adequate to delineate the critical periods of crop growth, making the technique potentially adaptable to predict crop yields.

Aase and Siddoway (1981) observed strong relationship between normalized vegetation index (as determined from late tillering until the beginning of flowering and end of season) and total wheat dry matter. This clearly established the potential of remote sensing for predicting total dry matter. Badhwar and Thomspson (1983) reported that knowledge of emergence date of spring grain from satellite data could provide an ability to run crop development and yield prediction model at field level.

The relationship between canopy spectral data and degree of senescence would be of potential use to assess the crop yield (Nageswara Rao *et al.* 1985). Saha and Ajai (1989) indicted that remotely sensed canopy temperature based Crop Water Stress Index (CWSI) and Stress Degree Days (SDD) could be used to predict the wheat grain and biological yields. Rudorf and Batista (1990) reported that agro-meteorological spectral models to estimate sugarcane yield were comparable with conventional method of estimation, which took more time.

The wheat yield of Punjab was precisely estimated by Medhavy *et al.* (1995) using NDVI derived from satellite data and historical yield trend. Randhir Singh and Ibrahim (1996) reported that reliable forecast of wheat yield with standard error less than five per cent could be done by using spectral data collected after two or three months sowing. Ray *et al.* (1999) estimated the lint yield of cotton for Surendrenagar district of Gujarat from remotely sensed spectral profile which differed by around 13 per cent from ground estimate.

### 2.3. Applications in other fields

Everitt *et al.* (1987) used remotely sensed Ariel photography to quantify weed and brush infestations of range land. Kuldeep Singh *et al.* (1989) studied the distribution of micronutrients in relation to landform from multi-temporal and multi-spectral imageries and reported that distribution of micronutrients in various pedons did not follow any typical pattern either with depth or with land forms.

Rajeev Sharma *et al.* (1993) estimated the acreage and condition of tea plantations in Nilgiris. Also identified the distribution pattern of various vigour class of tea plantations. Hegde *et al.* (1994) demonstrated the feasibility of using remotely sensed data for identifying arecanut plantation and showed the potential for expanding the area under spices in arecanut garden.

Saline and sodic soils could be discriminated from non-saline soils through reflectance studies (Kalra and Joshi 1994). Pramila Raina (1994) showed that using remotely sensed data, degraded lands could be mapped and categorised from slight to severe. Premalatha and Nageswara Rao (1994) observed that remote sensing data would provide timely information on farm operations like ploughing, row direction and soil moisture.

Sugumaran *et al.* (1994) revealed the potentiality of using Indian Remote Sensing Satellite (IRS) data for categorisation of social forestry plantation based on the plantation types which was a pre-requisite for social

forestry management. Sudhakar *et al.* (1994) concluded from their study that remote sensing technique could be used to broadly categorise the forest, their crown density classes with aerial extent and location. Daughtry *et al.* (1995) concluded that reflectance technique did provide a method to discriminate crop residues from many agricultural soils and could be used to quantify crop residue cover. Dubey *et al.* (1996) indicated that the healthy and diseased plants of banana, grapes, brinjal and tomato crops could be better distinguished through their vegetation indices than their simple reflectance values in red and NIR region.

Benchalli and Prajapathi (1998) showed the possibility of using satellite data to assess the growing stock from time to time for effective management of the resources and monitor the changes in the biomass. Krishna Prasad *et al.* (1999) suggested the possibility of monitoring forest fire, using Defense Meteorological Satellite Programme (DMSP) and Operational Linescan System (OLS), over Central Himalayan region of India where extensive fire event had been reported during May/June month.

From the review of literature it is evident that remote sensing applications could be used for discrimination of cultivated crops from their natural environment.

Through spectral reflectance studies and working various vegetation indices, crop growth parameters and nutrient content of crop and moisture stress could be estimated.

Based on the condition of the crop growth and area estimation, yield forecasting for many crops is possible.

However, the following research gaps have been identified. And therefore maximum emphasis has been given in the present investigation to address the under mentioned problems.

- ◆ Spectral profile of cotton under varying agronomic management practices has not been looked into very seriously.
- ◆ Identification of genetically differing cultivars of cotton has not been attempted.
- ◆ Spectral estimation of plant nutrient concentration especially nitrogen, at peak growth stage is lacking.
- ◆ Early detection of plant related problems from spectral reflectance especially nutrient deficiency could suggest mid term correction measures. This area has not been studied.
- ◆ The possibility of forecasting seed cotton yield from spectral signatures at peak growth stage has not been attempted.

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## Materials and Methods

### *Chapter III*

## **MATERIALS AND METHODS**

The information on agricultural resources which have a direct impact on food production are being collected conventionally through ground based methods of survey and inventory. This types of collection requires more time and the reliability of information vary with organisations. Such information also are sparse, inadequate, lacking standard requirement and are highly subjective. In such situation, the modern scientific survey technique like remote sensing would be of much use.

Crop identification, area assessment and crop condition evaluation are the main concerns of remote sensing. Before gaining confidence for satellite based crop monitoring over large area, ground truth information are highly warranted.

Hence, an investigation on the development of ground truth information on the effect of cultivars, planting patterns and nitrogen levels for cotton through ground based remote sensing was under taken for three years from 1992-'93 to 1994-'95 at the farm attached to the Tamil Nadu Agricultural University, Coimbatore. The details of the materials used and methods adopted for the experiments are explained in this chapter.

### **3.1 Materials**

#### **3.1.1 Location**

Three experiments were conducted at the farm of Agricultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore

which is located at 11°N latitude and 77°E longitude. The mean altitude is 426.72 m above mean sea level. Coimbatore is in the Western agro-climatic sub-zone of Tamil Nadu. Field experiments were conducted as follows at this location.

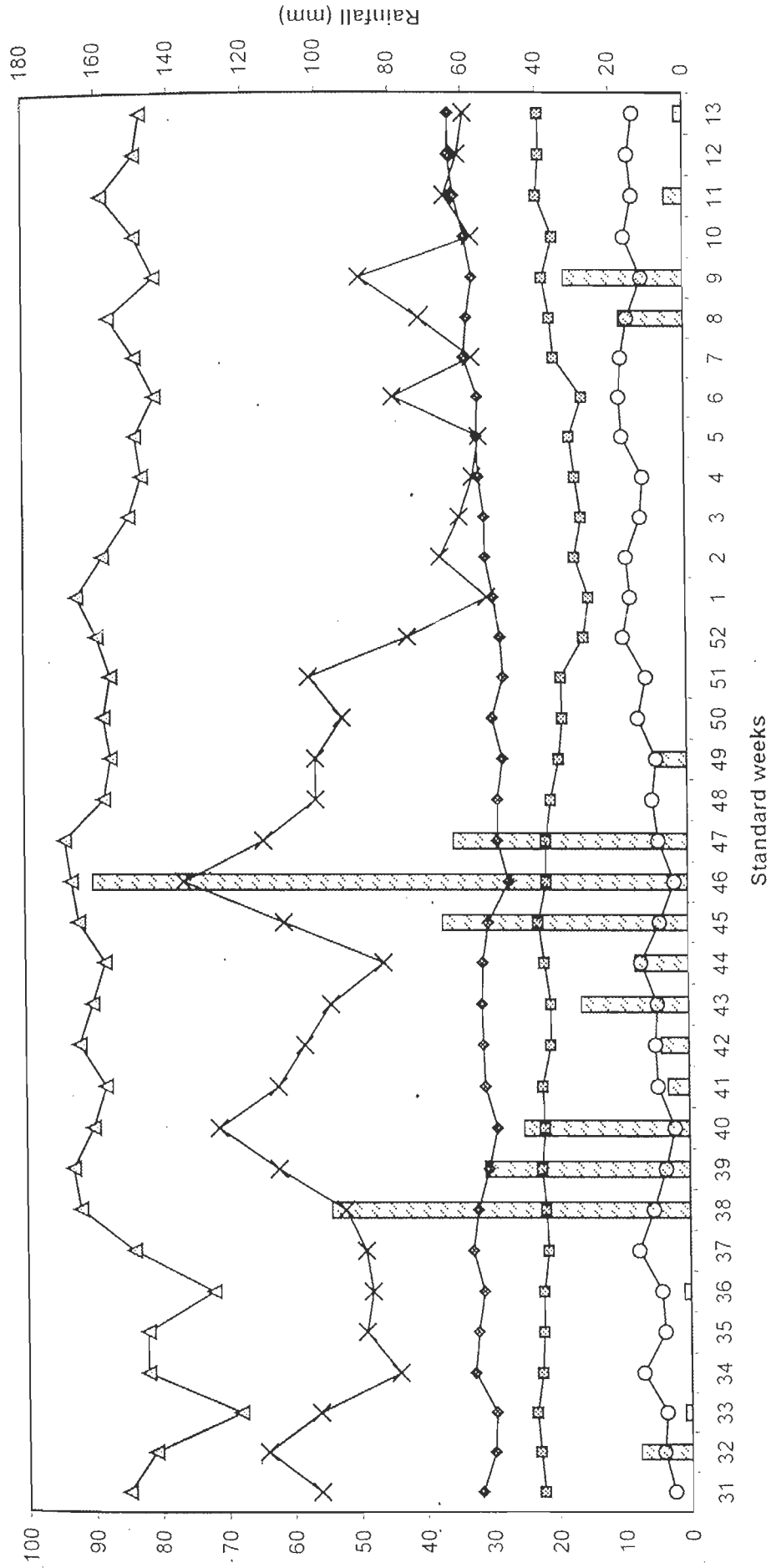
Expt. No.	Year	Month
I	1992-'93	September to February
II	1993-'94	August to February
III	1994-'95	August to February

### 3.1.2 Weather and climate

The mean annual rainfall is 640 mm (average of 30 years) distributed in 47 rainy days. The mean maximum and mean minimum temperatures are 30.6 and 20.9°C respectively.

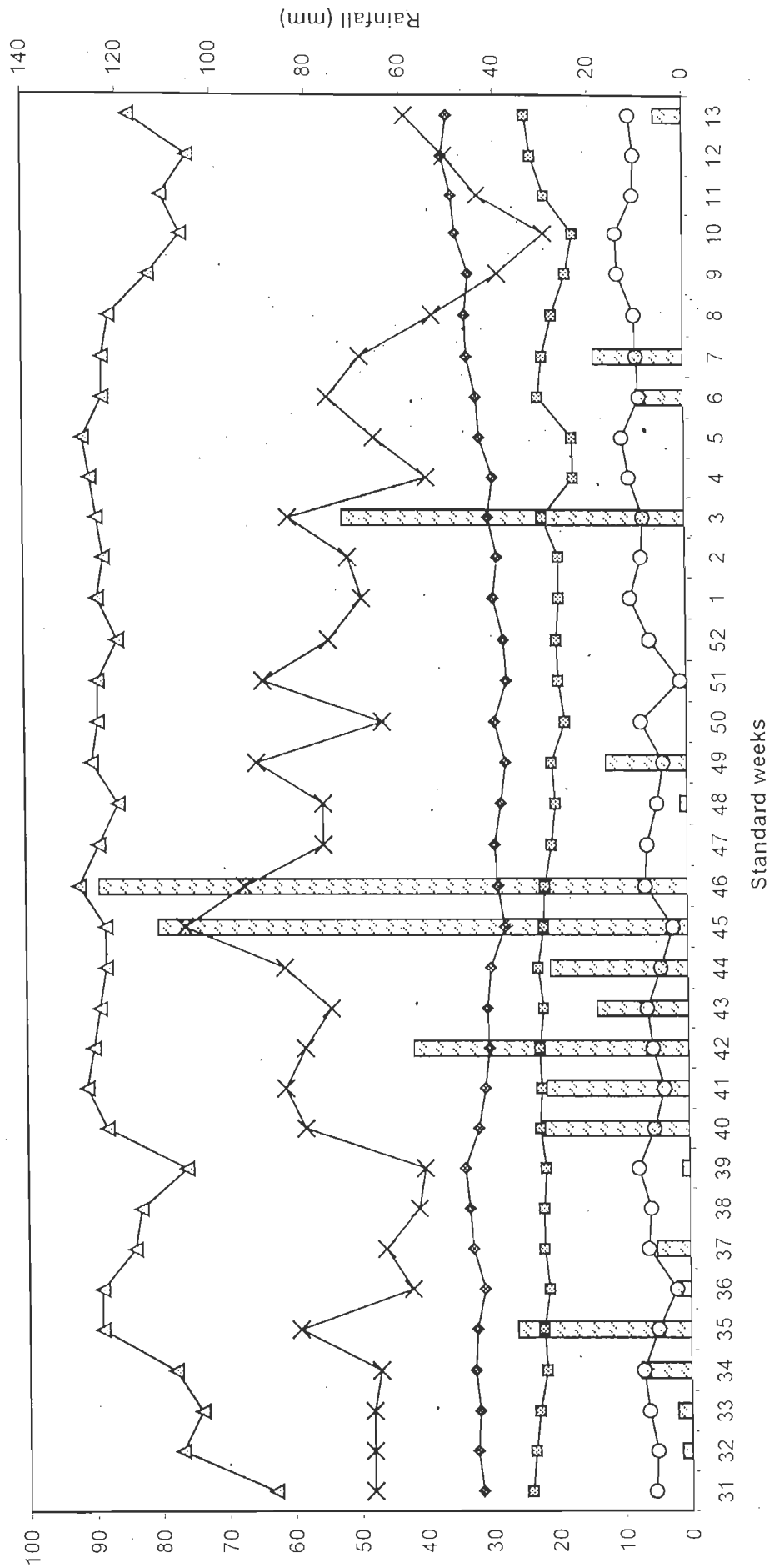
The weather elements *viz.*, maximum temperature (°C) minimum temperature (°C), relative humidity (%) (0722 hrs and 1422 hrs), solar radiation (Cal/cm<sup>2</sup>/day), bright sunshine (hours day<sup>-1</sup>), wind velocity (kmph), rainfall (mm) and evaporation (mm) prevailed during the experimental periods were collected from the 'A' class agro-meteorological observatory of Department of Agricultural Meteorology, Tamil Nadu Agricultural University, Coimbatore and presented in Tables (Annexure Ia, Ib and Ib) and Fig. 1a, 1b and 1c.

Fig.1a. Weather prevailed during crop growth period of cotton (Expt.I) (Aug.'92-April '93)



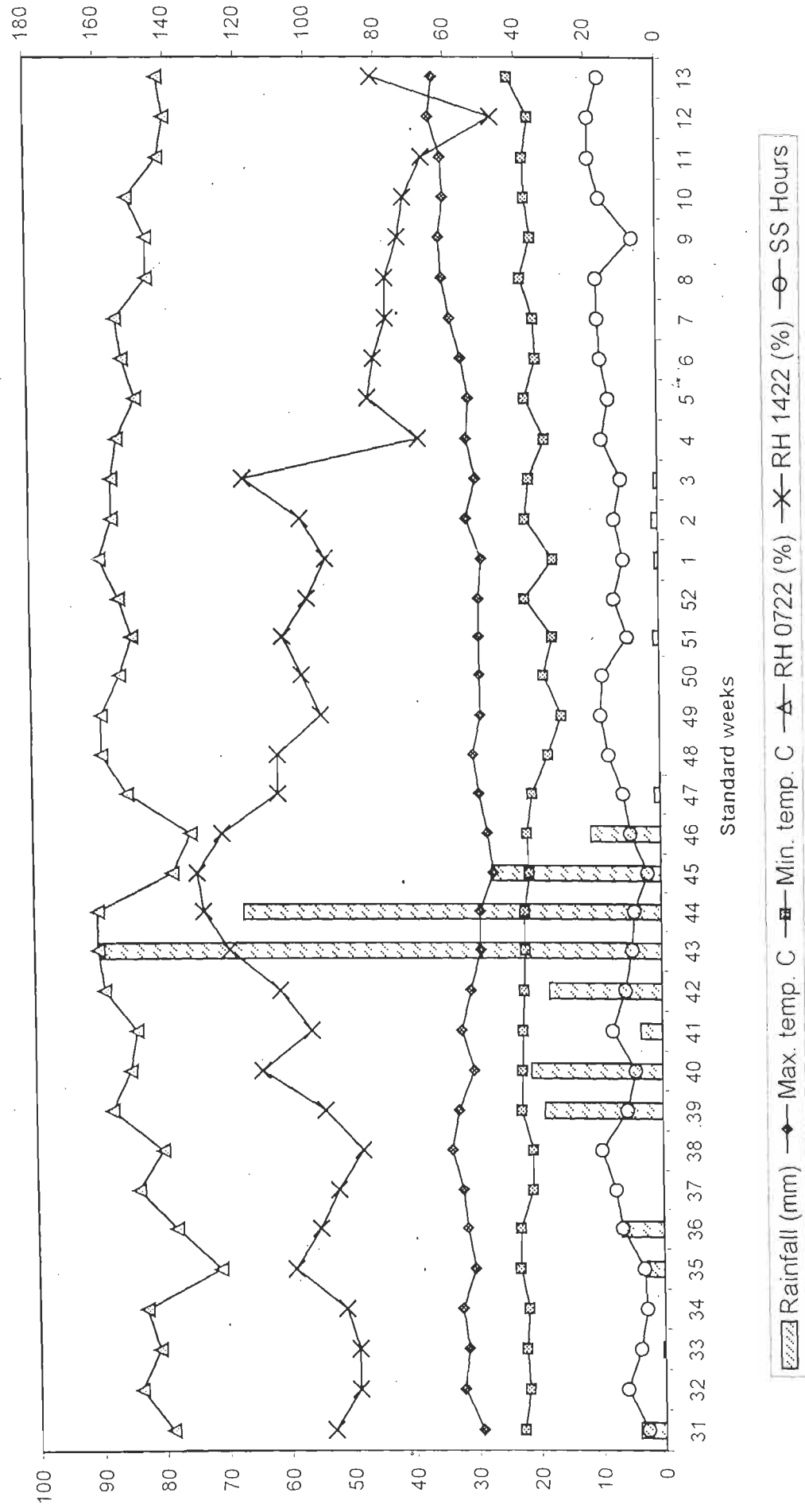
Rainfall (mm) 
  Max. temp. C 
  Min. temp. C 
  RH 0722 (%) 
  RH 1422 (%) 
  SS Hours

Fig.1b. Weather prevailed during crop growth period of cotton  
(Expt.II) (Aug.'93-April '94)



Rainfall (mm) 
  Max. temp. C 
  Min. temp. C 
  RH 0722 (%) 
  RH 1422 (%) 
  SS Hours

Fig.1c. Weather prevailed during crop growth period of cotton (Expt.III) (Aug.'94-April '95)



Standard weeks

Rainfall (mm) 
  Max. temp. C 
  Min. temp. C 
  RH 0722 (%) 
  RH 1422 (%) 
  SS Hours

### 3.1.3 Experimental site

The experiments I and II were conducted in field No.68 while experiment III was conducted in field No.37 of the Eastern Block of the Department of the Agronomy. The soils of both the experimental area are clay loam in texture. The physico-chemical properties of the soils are presented in Table 1.

**Table 1. Physico-chemical properties of the experimental soils**

Properties	Field No.68 Expt. I & II		Field No.37 Expt. III
<b>A. Mechanical analysis (Piper, 1950)</b>			
Clay (%)	30.80		30.93
Silt (%)	17.80		24.68
Fine sand (%)	29.80		21.84
Coarse sand (%)	21.50		22.43
Texture	Clay loam		Clay loam
<b>B. Chemical analysis</b>			
Organic carbon (%) (Walkley and Black, 1934)	0.57		0.41
	<b>I year</b>	<b>II Year</b>	
Available Nitrogen (kg ha <sup>-1</sup> ) (Subbiah and Asijah, 1956)	157 (low)	160 (low)	179 (low)
Available P <sub>2</sub> O <sub>5</sub> (kg ha <sup>-1</sup> ) (Olsen <i>et al.</i> 1954)	12 (medium)	13 (medium)	16 (medium)
Available K <sub>2</sub> O (kg ha <sup>-1</sup> ) (Stanford and English, 1945)	321 (high)	317 (high)	485 (high)
pH (1:2 water suspension)	8.1		7.7
EC dSm <sup>-1</sup> (1:2 water extract)	0.3		0.42

### 3.1.4 Crops and variety

Cotton plays a dominant role in India's agrarian scenario and industrial economy. Cotton accounts for around 70 percent of total fibre consumption in the textile sector, which accounts for 20 percent of India's industrial production and 38 percent of exports. The area under cotton is the largest with 7.86 m.ha. in the world. In Tamil Nadu, 2.1 lakh ha. is under cotton. So, it becomes imperative to take up research on cotton at Coimbatore, since Coimbatore represents the winter Cambodia cotton tract of Tamil Nadu.

A major factor behind the increased production since 1970 is the development of cotton hybrids and their commercial cultivation on a large scale. In all, cotton hybrids occupy 40 percent of the total cotton area and contribute more than 45 percent of the total production with improved fibre quality. (Kairon 1997). Hence, cotton hybrid was selected for this experiment.

Cotton is a wide spaced crop and this allows scope for introduction of an intercrop. If advanced agro-techniques like paired row planting is recommended still there is larger scope for the introduction of an intercrop with complementary effect between base and intercrop.

#### 3.1.4.1. Experiment I and II

Two ruling genotypes of cotton *viz.*, TCHB 213 (inter specific hybrid) and MCU11 (variety) were grown as main crop and green gram (Co4) was

grown as intercrop in between cotton rows. The characteristics features of cotton variety hybrid and green gram are given in Table 2 and 3.

#### **3.1.4.2. Experiment III**

Results of two years experiment revealed that planting pattern and nitrogen could be discriminated through spectral reflectance from 45 DAS. To study further on N levels the experimental design was altered by deleting planting pattern and intercrop and included an additional level of nitrogen (200 per cent of recommendation).

### **3.2. Methods**

#### **Design and layout**

##### **3.2.1. Experimental design**

Experiments I and II were conducted in split plot design replicated thrice (Fig 2a and 2b) during and 1992-'93 and 1993-'94 and the experiment III was laid out in FRBD with four replications during 1994-'95 (Fig 2c).

##### **3.2.1.1. Treatments**

#### **Experiment I and II**

#### **Main plots**

##### **1. Cultivars**

TCHB 213 (C1)

MCU 11 (C2)

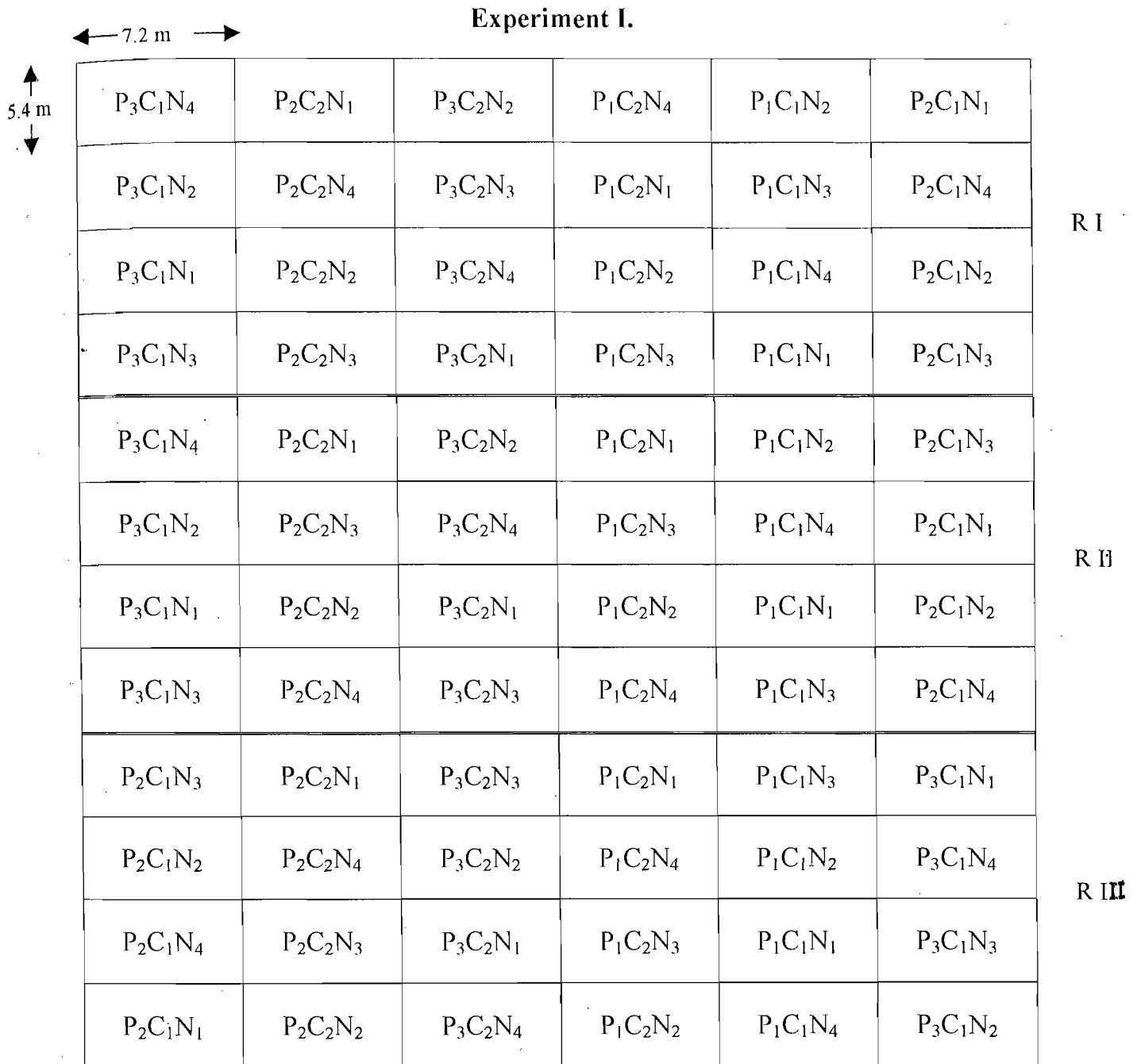
Table 2. Characteristics of cotton genotypes

S. No.	Characters	MCU 11 (variety)	TCHB 213 (Hybrid)
1.	Year of release	1988	1990
2.	Place of release	Cotton, Breeding Station, Coimbatore	Cotton, Breeding Station, Coimbatore
3.	Species	<i>G. hirsutum</i>	Interspecific cross of <i>G. hirsutum</i> x <i>G. barbadense</i>
4.	Parentage	MCU 5 x Egyptian <i>hirsutum</i>	TCH 218 x TCB 209
5.	Duration (days)	165	165
6.	Days to 50 per cent flowering	55-60	55-65
7.	Mean yield of kapas (kg ha <sup>-1</sup> )	2200	2500
8.	Optimum sowing time	August 15-31	August 15-31
9.	Harvest	Dec. - Jan.	Dec. - Feb.
10.	Quality		
	Mean fibre length (mm)	27.7	32.8
	Ginning (%)	34.6	32.0
	Highest standard count	50 <sup>s</sup> to 60 <sup>s</sup>	80 <sup>s</sup>
11.	Plant height (cm)	90-100	160-180
12.	Bolls nature	Medium, ovoid	Medium to big, conical
13.	100 seed weight (g)	9	12

**Table 3. Characteristics of Co 4 greengram**

<b>Characters</b>	
Parentage	Mutant of Co 1
Duration (days)	85
Days to 50 per cent flowering	40-45
Grain yield (kg ha <sup>-1</sup> )	
Rainfed	910
Irrigated	1550
Plant height (cm)	80
Stem colour	Green stem
Branches	3-4
Pod colour	
Tender	Green
Matured	Black
Grain colour	Dull green
100 grain weight (g)	4.1

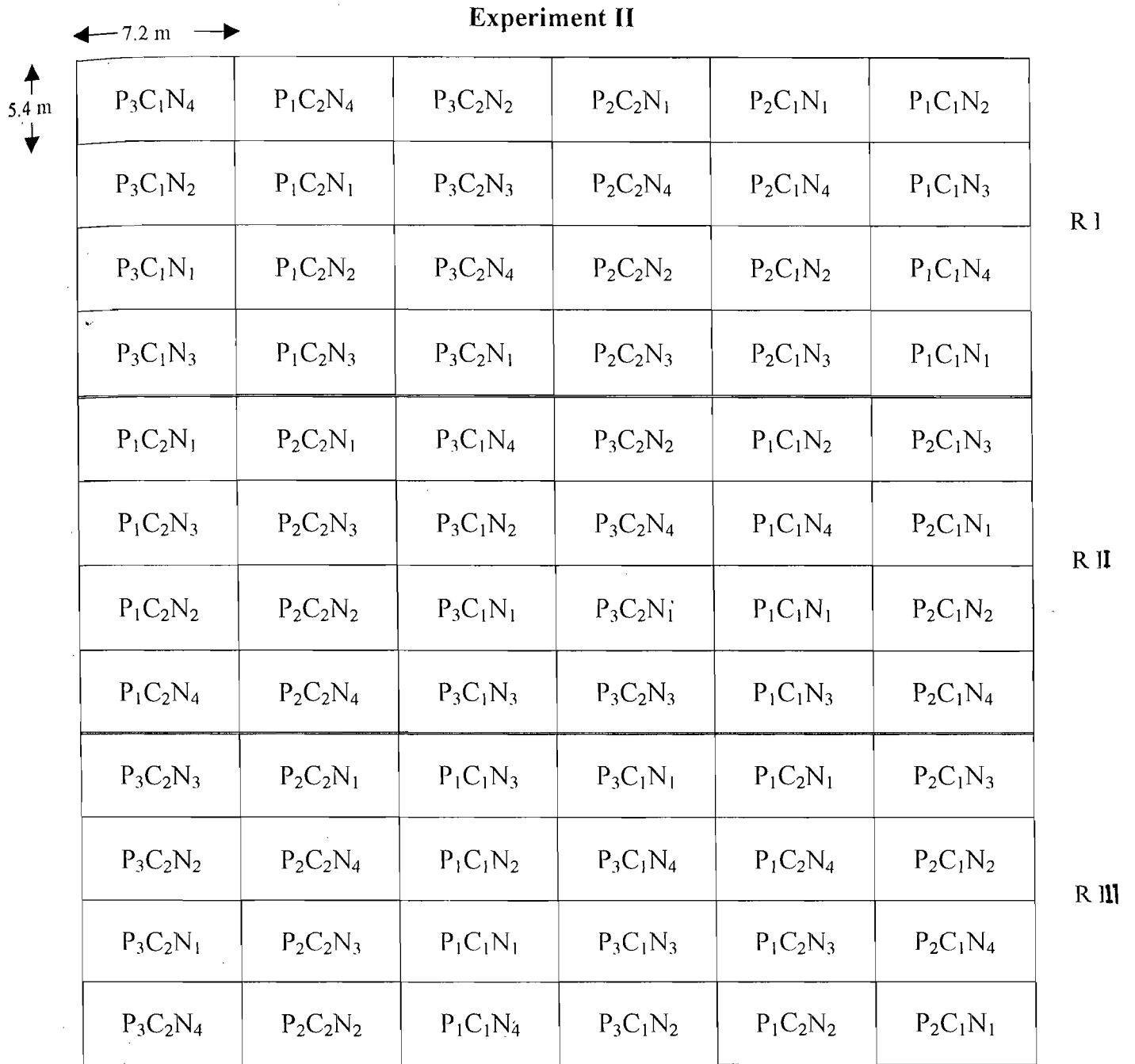
Fig.2a. Layout plan of 1992-'93



P = Planting patterns  
 C = Cultivars  
 N = Nitrogen levels



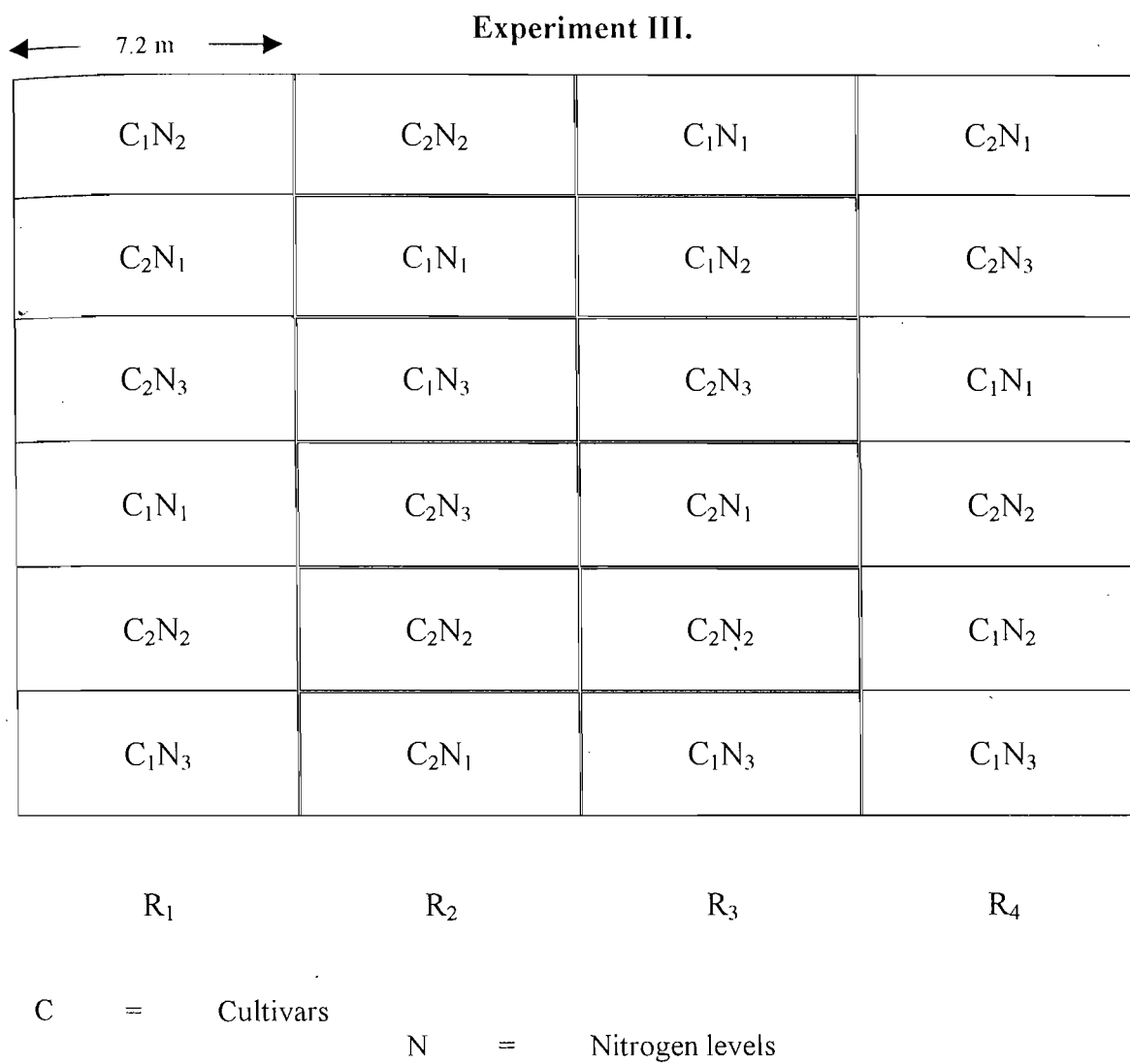
Fig.2b. Layout plan of 1993-'94



P = Planting patterns  
 C = Cultivars  
 N = Nitrogen levels



Fig.2c. Layout plan of 1994-'95



## 2. Planting patterns

### a. Normal row planting (P1)

75 x 45 cm for MCU 11

120 x 60 cm for TCHB 213

### b. Paired row planting (P2)

60/90 x 45 cm for MCU 11

90/150 x 60 cm for TCHB 213.

### c. Paired row with intercrop Greengram Co 4 (30 x 10 cm) (P3)

## Sub-plots

N levels

1. Control (No nitrogen) ( $N_1$ )
2. 50 per cent of recommended nitrogen ( $N_2$ )
3. 100 per cent of recommended nitrogen ( $N_3$ )
4. 150 per cent of recommended nitrogen ( $N_4$ )

## Recommended N : $P_2O_5$ : $K_2O$

80:40:40 kg ha<sup>-1</sup> for MCU 11

120:60:60 kg ha<sup>-1</sup> for TCHB 213

Gross plot size : 7.2 x 5.4 m

Net plot area : 4.8 x 4.8 m

### 3.2.2. Experiment III (1994-'95)

The experiment was conducted in Factorial Randomized Block Design (FRBD) with four replications after short listing based on the results of experiments I and II.

### 3.2.2.1. Treatments

#### a) Cultivars

1. TCHB 213 (C<sub>1</sub>)
2. MCU 11 (C<sub>2</sub>)

#### b) N levels

1. 100 per cent of recommended nitrogen (N<sub>1</sub>)
2. 150 per cent of recommended nitrogen (N<sub>2</sub>)
3. 200 per cent of recommended nitrogen (N<sub>3</sub>)

### Recommended N : P<sub>2</sub>O<sub>5</sub> : K<sub>2</sub>O

80:40:40 kg ha<sup>-1</sup> for MCU 11

120:60:60 kg ha<sup>-1</sup> for TCHB 213

Gross plot size : 7.2 x 5.4 m

Net plot size : 4.8 x 4.8 m

Spacing : TCHB 213 120 x 60 cm.

MCU 11 75 x 45 cm

## 3.3. Cultural operations

### 3.3.1. Land preparation

#### 3.3.1.1. Experiment I and II (1992-'93 and 1993-'94)

The land was ploughed with tractor drawn mould board plough followed by harrowing, clods crushing and levelling. The field was thrown

into ridges and furrows at 120 cm and 75 cm apart as per treatments. Then, the layout was altered manually to suit paired row planting of cotton with and without intercrop according to randomization of treatments.

#### **3.3.1.2. Experiment III (1994-'95)**

The land was ploughed with tractor drawn mould board plough followed by harrowing, clods crushing and levelling. The field was thrown into ridges and furrows at 120 cm and 75 cm apart as per treatments and later they were rectified with manual labour.

#### **3.3.2. Seeds and sowing**

##### **3.3.2.1. Experiment I and II (1992-'93 and 1993-'94)**

Seeds of cotton having germination of 90 per cent were acid delinted first by adopting standard method and treated with fungicide, (carbendazim) @ 2g kg<sup>-1</sup> of seeds. The treated seeds were sown on the side of ridges by adopting a spacing of 120 x 60 cm for TCHB 213 and 75 x 45 cm for MCU 11. In paired row planting the spacing followed for TCHB 213 was 90/150 x 60 cm and for MCU 11 it was 60/90 x 45 cm. The intercrop green gram (Co 4) was sown in the interspace between two rows of cotton in normal row planting and between two pairs in paired row planting by adopting a spacing of 30 x 10 cm. To ensure plant population, two seeds per hill were hand dibbled.

##### **3.3.2.2. Experiment III (1994-'95)**

Seeds of cotton having germination of 90 per cent were acid delinted first by adopting standard procedure and treated with fungicide,

(carbendazim) @ 2 g kg<sup>-1</sup> of seeds. The treated seeds were sown on the side of the ridges by adopting a spacing of 120 x 60 cm for TCHB 213 and 75 x 45 cm for MCU 11. To ensure population, two seeds were sown per hill.

### **3.4. Management practices**

#### **3.4.1. Manures and fertilizers**

##### **3.4.1.1. Manure**

Well decomposed farm yard manure was applied @ 12.5 t.ha<sup>-1</sup> for all the three experiments during the last ploughing and incorporated well into the soil.

##### **3.4.1.2. Fertilizers**

Nitrogen, phosphorus and potassium were applied in the form of urea (46% N), single super phosphate (16% P<sub>2</sub>O<sub>5</sub>) and muriate of potash (60% K<sub>2</sub>O).

###### **3.4.1.2.1. Nitrogen (All experiments)**

Four levels of nitrogen viz., 0, 50, 100 and 150 per cent of recommendation were followed for the first two experiments (1992-'93 and 1993-'94) and 100, 150 and 200 per cent of recommendation were followed for the third experiment (1994-'95). It was applied in two equal splits for MCU 11 (basal and at 45 DAS) and in three splits for TCHB 213 (basal at 45 DAS and 65 DAS).

###### **3.4.1.2.2. Phosphorus (All Experiments)**

The entire quantity was applied as basal.

#### **3.4.1.2.3. Potassium (All Experiments)**

The entire quantity was applied as basal.

### **3.5. After cultivation**

#### **3.5.1. Irrigation (All experiments)**

Irrigation was given immediately after sowing. On third day after sowing, life saving irrigation was extended. Subsequent irrigations were given following the recommendation of Crop Production Guide (CPG) taking into account the amount of rainfall received.

#### **3.5.2. Weed control(All experiments)**

Pre-emergence herbicide, fluchloralin was mixed with sand and applied @ 1 kg a.i. ha<sup>-1</sup> on third day after sowing (DAS) before life saving irrigation. First hand weeding was done on 25 DAS followed by earthing up on 45 DAS.

#### **3.5.3. Plant protection (All experiments)**

Leaf hoppers, boll worms and aphids were observed in experimental fields. Need based plant protection measures were undertaken against pests and as a prophylactic measure, Dithane-M.45 was sprayed against the possible disease occurrence.

### **3.6. Harvest**

Seed cotton was harvested through five pickings at 10 days interval as detailed below :

Expt. No.	Dates of sowing	Dates of picking				
		I	II	III	IV	V
I	3.9.'92	5.1.'93	15.1.'93	25.1.'93	4.2.'93	14.2.'93
II	17.8.'93	17.12.'93	27.12.'93	6.1.'94	16.1.'94	26.1.'94
III	12.8.'94	15.12.'94	25.12.'94	4.1.'95	14.1.'95	24.1.'95

### 3.7. Spectral measurements

Spectral reflectance of cotton canopy from different treatments was measured by using a multiband ground truth radiometer (Plate 1). The reflectance was measured in four bands viz., 0.45 - 0.52  $\mu\text{m}$  (Blue), 0.52 - 0.59  $\mu\text{m}$  (Green), 0.62 - 0.68  $\mu\text{m}$  (Red) and 0.77 - 0.86  $\mu\text{m}$  (Near Infra Red). The ground truth radiometer was held vertically one meter above the top of the cotton canopy to measure the reflectance. Simultaneously reflectance from 1 sq.m.  $\text{BaSO}_4$  (Barium sulphate) plate was taken as control. The reflectance from  $\text{BaSO}_4$  plate was taken as standard i.e. 100 per cent and based on this, the reflectance from cotton canopy was computed into percentage of reflectance.

The reflectance reading was taken between 10:00 am and 1:00 pm to avoid interference from sun rays angle. To avoid the reflectance from soil in between plant rows the canopy cover over soil surface should be more than 25 per cent (Leamer *et al.*, 1978). The reflectance percentage of experimental field soil was also taken separately to be used for vegetation index computation. The reflectance percentage was analyzed statistically and also used to work out

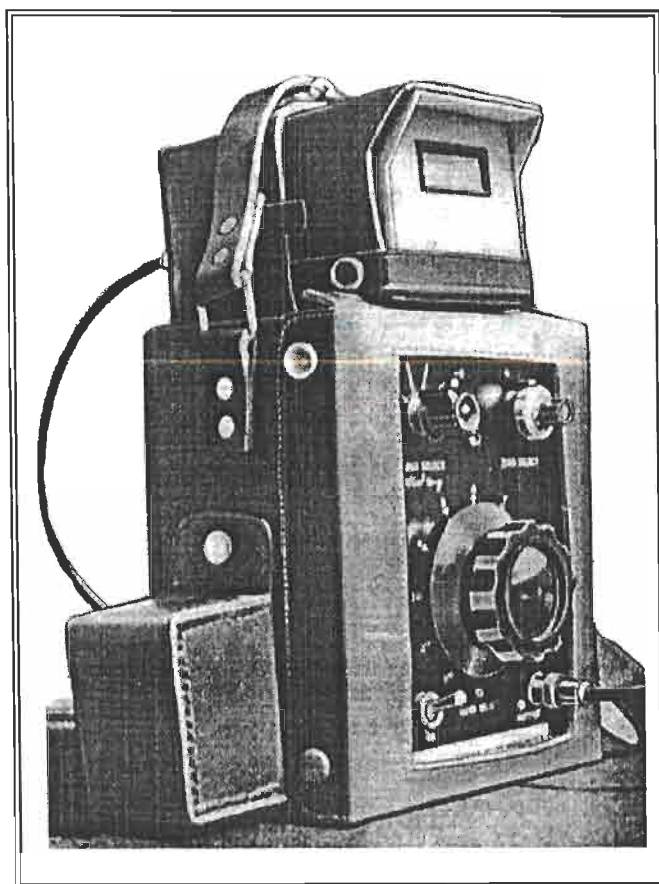


Plate 1. Multi-band ground truth radiometer

various vegetation indices. The spectral measurements were taken from 45 DAS on wards upto 90 DAS at fortnightly interval.

### 3.8. Vegetation indices

Vegetation indices are combination of spectral reflectance measured in different bands. Two general classes of vegetation indices have been developed and they are only ratios and orthogonal transformations. These vegetation indices are used to discriminate vegetation amounts and their condition. These vegetation indices are:

1. Reflectance ratio
  - (a) IR - R (Pearson *et al.*, 1976)
  - (b) IR/R (Curran and Milton, 1983)
  
2. Normalized difference (ND) (Rouse *et al.*, 1973)
 

(or)

Vegetation index (VI)

$$\frac{\text{IR} - \text{R}}{\text{IR} + \text{R}}$$

3. Transformed vegetation index (TVI) (Rouse *et al.*, 1973)

$$\sqrt{\left[ \frac{\text{IR} - \text{R}}{\text{IR} + \text{R}} \right] + 0.5}$$

4. Perpendicular vegetation index (PVI) (Richardson and Wiegand, 1977)

$$\sqrt{[R_{\text{soil}} - R_{\text{veg}}]^2 + [IR_{\text{soil}} - IR_{\text{veg}}]^2}$$

where,

R = canopy reflectance in red band (0.62 - 0.68  $\mu\text{m}$ )

IR = canopy reflectance in infrared band (0.77 - 0.86  $\mu\text{m}$ )

R soil & R veg = reflectance from bare soil and vegetation respectively in red bands.

IR soil & IR veg = reflectance from bare soil and vegetation respectively in infrared band.

The vegetation indices were worked out from spectral reflectance from 45 DAS onwards upto 90 DAS (four stages) at 15 days interval.

### **3.9. Bio-metric observations**

#### **3.9.1. Growth components (All experiments)**

Five cotton plants in each treatment were selected at random from the net plot area and tagged and the following observations were made and mean was arrived at. These observations were made simultaneously with spectral reflectance measurements from 45 DAS onwards upto 90 DAS at fortnightly intervals.

##### **3.9.1.1. Plant height (cm)**

The plant height was measured from cotyledonary node located at the base of the plant to the fully opened leaf at the top (Madhavi Latha, 1988).

### 3.9.1.2. Leaf area index (LAI)

Plant samples for each treatment were taken at random from the rows left for the purpose to calculate the leaf area. All the leaves were stripped off and fed to leaf area meter (LICOR-3100/HI) to get the leaf area in cm<sup>2</sup>. The LAI was computed by dividing the leaf area of the plants by the land area occupied.

### 3.9.1.3. Dry matter production (DMP)

Five plants at random from the rows left for the purpose were cut at ground level (Madhavi Latha, 1988) for estimating the DMP. The plant samples were first air dried and later oven dried at 80°C to obtain constant weight. Their weights were recorded on moisture free basis and computed and expressed as kg ha<sup>-1</sup>. These samples were later used for chemical analysis.

### 3.9.1.4. Ground cover

The ground area covered by cotton canopy was measured by Meter-stick method as suggested by Adams and Arkin (1977). One meter scale was placed on soil surface parallel with and against the plant row. The shaded area on the meter scale was measured and totaled to the nearest centimeter. Then the stick was moved 5 cm away from the row for the next measurement. The measurement was repeated at 5 cm increments until the distance between plant rows had traversed (21 position for rows 100 cm apart). The ground coverage was calculated as follows

$$\text{Ground-cover (\%)} = \frac{\text{Total shade (cm) for 21 position}}{100 \times 21} \times 100$$

Canopy cover measurement was taken between cotton rows with or without inter crop.

The ground cover was measured during second (1993-'94) and third year (1994-'95) of experiments only.

### **3.9.2. Yield components**

#### **3.9.2.1. Number of bolls per plant**

Total number of bolls from each picking from the selected plants were added and reported per plant after arriving mean.

#### **3.9.2.2. Yield**

The seed cotton obtained from the net plot area of each treatment at each picking were weighed and pooled and expressed in  $\text{kg ha}^{-1}$ .

### **3.9.3. Physiological parameters**

#### **3.9.3.1. Leaf water content**

Twenty five leaf samples were taken at random and fresh weight was recorded immediately. After air drying, the samples were dried in hot air oven at  $75^{\circ}\text{C}$  till a constant weight was obtained. The difference between fresh and dry weight was considered as moisture content and was expressed in percentage.

$$\text{Leaf water content} = \frac{\text{Fresh weight} - \text{Dry weight}}{\text{Fresh weight}} \times 100$$

### **3.9.3.2. Leaf angle**

The leaf angle between main stem/branch and leaf petiole was measured by using a protractor. Then, the plant sample was taken in a polythene bag and brought to lab without loss of moisture and turgor. The plant samples were placed on a tracing sheet and angle between main stem/branch and leaf petiole was traced. This was measured with protractor and expressed in degrees.

Leaf angle was measured for second (1993-'94) and third year (1994-'95) of experimentation only.

### **3.9.3.3. Leaf thickness**

Leaf thickness was measured from 20 leaf samples for each treatment by dividing leaf weight by leaf area as suggested by Al-Abbas *et al.* (1974). Leaf samples taken for leaf area index were used for this measurement also.

Leaf thickness was measured for second (1993-'94) and third year (1994-'95) of experimentation only.

### **3.9.3.4. Chlorophyll content**

The chlorophyll content was assessed by measuring the absorption spectrum of leaf extracts for the wave length range of 400-700 nm with peak point at 645 and 663 nm. using spectrophotometer model D.C. 64. The pigment composition was computed by following the formula as suggested by Yoshida *et al.* (1971) and expressed as mg g<sup>-1</sup> of fresh leaf.

**Chlorophyll a.**

$$\frac{(12.7 \times \text{O.D at } 663) - (2.69 \times \text{O.D at } 645) \times \text{volume}}{1000 \times \text{wt. of sample}}$$

**Chlorophyll b.**

$$\frac{(22.9 \times \text{O.D at } 645) - (4.68 \times \text{O.D at } 663) \times \text{volume}}{1000 \times \text{wt. of sample}}$$

Total Chlorophyll = Chlorophyll a + Chlorophyll b

**3.10. Chemical analysis****3.10.1. Plant analysis****Nitrogen**

The plant samples collected for estimating DMP were used for chemical analysis. The dried samples were ground thoroughly in a Willy mill and analysed for percentage of nitrogen by using the microkjeldhal method as suggested by Yoshida *et al.* (1971). The nitrogen content in terms of percentage was estimated from 45 DAS at fortnightly interval upto 90 DAS coinciding with spectral measurements.

**3.11. Statistical analysis**

The experimental data on different characters of cotton were statistically analyzed for split plot design for experiment I and II and factorial randomised block design for experiment III following the procedure of Panse and Sukhatme (1967). Wherever the treatments were significant, the critical differences were worked out at five percent level.

### 3.12. Allometric relation

Non-destructive estimation of plant growth and physiological parameters and final seed cotton yield were attempted by exploiting allometric relation between spectral reflectance and plant parameters. The allometric relation is of the form.

$$A = \alpha [SR]^\beta$$

where A = plant parameters LAI, DMP, total chlorophyll content, plant nitrogen concentration, canopy ground coverage and seed cotton yield.

SR = Spectral reflectance in red and infra-red bands and vegetation indices calculated from the red and infra-red band at 75 DAS.

$\alpha, \beta$  = The parameters to be estimated.

The allometric relation was estimated by Ordinary Least Square (OLS) method.

To validate the estimated relation, Chi-square test was performed and cumulated residual was compared for n-1 degrees of freedom.

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Results

## *Chapter IV*

# RESULTS

The results of the field experiments conducted at Tamil Nadu Agricultural University Farm, Coimbatore during 1992 - '95 to study the spectral reflectance from planting patterns, cultivars and levels of applied nitrogen in irrigated winter cotton through remote sensing technique are presented in this chapter.

In the first (1992-'93) and second (1993-'94) year, the experiments were conducted with three factors *viz.*, planting patterns [normal row (P<sub>1</sub>); paired row (P<sub>2</sub>) and paired row with greengram intercrop (P<sub>3</sub>)], cultivars [TCHB 213 (C<sub>1</sub>) and MCU 11 (C<sub>2</sub>)] and levels of nitrogen [0, 50, 100 and 150 per cent of recommended level]. The results of first and second year experiments are presented in part one.

During third year (1994-'95), the experiment was conducted with two factors *viz.*, cultivars [TCHB 213 (C<sub>1</sub>) and MCU 11 (C<sub>2</sub>)] and levels of nitrogen [100, 150 and 200 per cent of recommended level]. The results of the third year experiment are presented in part two.

The interactions at 75 days of growth have been discussed in detail, since this stage was identified as the best for spectral reflectance studies.

### **4.1. Part I (First and Second years)**

#### **4.1.1. Growth and physiological parameters**

##### **4.1.1.1. Plant height (cm)**

The data recorded on plant height at various growth stages (45, 60, 75 and 90 DAS) during the study periods are presented in Table 4.

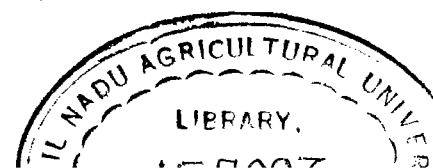
Table 4. Effect of treatments on mean plant height (cm) of cotton during 1992 - '93 and 1993 - '94

	1992-'93				1993-'94			
	45 DAS	60 DAS	75 DAS	90 DAS	45 DAS	60 DAS	75 DAS	90 DAS
P <sub>1</sub>	31.21a	54.01a	64.12a	65.03a	33.09a	39.57a	52.51a	63.36a
P <sub>2</sub>	29.26b	51.21b	60.25b	61.07b	31.53b	35.27b	48.86b	59.23b
P <sub>3</sub>	28.27c	49.63b	61.15b	59.05c	29.09c	34.22c	46.10c	52.56c
SEd	0.34	0.77	1.08	0.31	0.57	0.34	0.26	0.13
CD	0.76	1.71	2.40	0.69	1.28	0.77	0.57	0.30
C <sub>1</sub>	31.15a	54.97a	63.93a	66.17a	34.02a	39.12a	53.25a	65.34a
C <sub>2</sub>	28.46b	51.27b	59.74b	57.26b	28.45b	33.60b	45.06b	51.43b
SEd	0.28	0.63	0.88	0.25	0.47	0.28	0.21	0.11
CD	0.62	1.32	1.96	0.56	1.04	0.63	0.47	0.24
N <sub>1</sub>	25.34d	44.81d	48.41d	49.85d	21.73d	25.09d	34.66d	38.33d
N <sub>2</sub>	28.84c	49.58c	61.32c	58.08c	30.54c	33.57c	45.24c	55.77c
N <sub>3</sub>	30.97b	53.20b	67.22b	65.29b	33.91b	39.74b	54.77b	64.25b
N <sub>4</sub>	34.06a	58.88a	70.40a	73.65a	38.77a	47.04a	61.95a	75.19a
SEd	0.25	0.45	0.66	0.26	0.47	0.27	0.21	0.23
CD	0.51	0.92	1.33	0.53	0.96	0.55	0.42	0.46
PxC ; SEd	0.48	1.08	1.52	0.44	0.81	0.49	0.36	0.19
CD	NS	NS	NS	0.98	NS	1.10	0.81	0.42
PxN ; SEd	0.51	1.02	1.46	0.50	0.91	0.53	0.40	0.37
CD	1.08	NS	NS	1.05	NS	1.53	0.85	0.75
CxN ; SEd	0.41	0.84	1.19	0.41	0.74	0.44	0.33	0.30
CD	NS	NS	2.55	0.86	NS	0.92	0.69	0.62

NS - Not significant

CD - (P=0.05)

The mean having the same alphabet are not significantly different at 5 % level.



Plant growth had increased with the advancement in stages in both the years of study.

Among the three planting patterns evaluated, normal row planting ( $P_1$ ) had produced taller plants in all the stages in both the years of study. Next to  $P_1$ , the statistical ranking was for paired row ( $P_2$ ) followed by paired row with greengram intercrop ( $P_3$ ). During first year, the plant heights recorded under  $P_2$  and  $P_3$  treatments were at statistical par at 60 (51.21 and 49.63) and 75 DAS (60.25 and 61.15).

Between the two cultivars, TCHB 213 ( $C_1$ ) had grown taller (66.17 and 65.34 cm in first and second year respectively) than the other ( $C_2$ ) cultivar MCU 11 (57.26 and 51.43 cm). This was observed in both the years at all the stages of crop growth.

The levels of nitrogen in both the years had altered plant height significantly in all the stages. The plant height had increased with increase in nitrogen level from absolute control (0) to 150 per cent of recommended level in both the years of investigation.

Interaction between planting patterns and cultivars, planting patterns and nitrogen levels and between cultivars and nitrogen levels became significant in certain stages of growth, of which, interactions at 75 DAS between cultivars and nitrogen levels are presented in Table 5.

**Table 5.** Interaction effect between cultivars and nitrogen levels at 75 DAS on mean cotton plant height (cm) of cotton during 1992 - '93 and 1993 - '94

1992 - '93

	N <sub>1</sub>	N <sub>2</sub>	N <sub>3</sub>	N <sub>4</sub>	Mean
C <sub>1</sub>	50.55	64.58	68.52	72.09	63.93
C <sub>2</sub>	46.27	58.06	65.92	68.72	59.74
Mean	48.41	61.32	67.22	70.40	

	SEd	CD (P=0.05)
N at C	0.93	1.88
C at N	1.19	2.55

1993 - '94

	N <sub>1</sub>	N <sub>2</sub>	N <sub>3</sub>	N <sub>4</sub>	Mean
C <sub>1</sub>	36.17	50.12	59.65	67.12	53.26
C <sub>2</sub>	33.16	40.36	49.90	56.82	45.06
Mean	34.66	45.24	54.78	61.97	

	SEd	CD (P=0.05)
N at C	0.29	0.59
C at N	0.33	0.69

The plant height got increased with increasing levels of applied nitrogen in both the cultivars of the two years study periods. The rate of increase in plant height was higher between 0 to 50 per cent (21 to 38 per cent) of recommended level than from 50 to 100 (6 to 21 per cent) and 100 to 150 per cent (4 to 13 per cent). Application of 150 per cent of recommended level of nitrogen to TCHB 213 had given taller plants (72.09 and 67.12 cm respectively for the two years study period).

#### **4.1.1.2. Leaf Area Index (LAI)**

The data collected for LAI of cotton for the first two years of study period are presented in Table 6.

The LAI had increased with increase in ageing of cotton in both the years of study.

Among the three planting patterns studied, normal row planting ( $P_1$ ) had recorded significantly higher LAI (3.98 and 4.07 at 90 DAS during first and second years respectively) over paired row ( $P_2$ ) (3.90 and 4.01) and paired row with greengram intercrop ( $P_3$ ) (3.85 and 4.02). At 45 DAS during first year and at 90 DAS during second year, the treatments  $P_2$  and  $P_3$  were at statistical par.

Between the two cultivars, TCHB 213 ( $C_1$ ) had recorded higher LAI (4.03 and 4.23 at 90 DAS) as compared to MCU 11 ( $C_2$ ) (3.79 and 3.84) during both the years of study at all the growth stages.

Table 6. Effect of treatments on mean LAI of cotton during 1992 - '93 and 1993 - '94

	1992-'93				1993-'94			
	45 DAS	60 DAS	75 DAS	90 DAS	45 DAS	60 DAS	75 DAS	90 DAS
P <sub>1</sub>	1.31a	2.90a	3.40a	3.98a	1.27a	2.99a	3.45a	4.07a
P <sub>2</sub>	1.23b	2.73b	3.26b	3.90b	1.22b	2.85b	3.39b	4.01b
P <sub>3</sub>	1.20b	2.63c	3.06c	3.85c	1.19c	2.80c	3.33c	4.02b
SEd	0.02	0.005	0.01	0.015	0.003	0.006	0.005	0.03
CD	0.05	0.01	0.03	0.01	0.007	0.014	0.01	0.06
C <sub>1</sub>	1.29a	2.90a	3.40a	4.03a	1.30a	3.07a	3.70a	4.23a
C <sub>2</sub>	1.20b	2.60b	3.08b	3.79b	1.16b	2.70b	3.08b	3.84b
SEd	0.02	0.004	0.012	0.004	0.002	0.005	0.004	0.02
CD	0.04	0.01	0.03	0.01	0.005	0.011	0.009	0.05
N <sub>1</sub>	1.10d	2.19d	2.33d	2.60d	1.11d	2.27d	2.42d	2.71d
N <sub>2</sub>	1.20c	2.64c	3.19c	3.87c	1.17c	2.67c	3.31c	3.99c
N <sub>3</sub>	1.30b	2.91b	3.53b	4.30b	1.26b	3.13b	3.75b	4.40b
N <sub>4</sub>	1.38a	3.25a	3.90a	4.88a	1.36a	3.47a	4.09a	5.04a
SEd	0.01	0.008	0.008	0.005	0.005	0.009	0.007	0.01
CD	0.02	0.015	0.02	0.01	0.009	0.017	0.014	0.02
PxC ; SEd	0.03	0.007	0.02	0.006	0.004	0.009	0.007	0.04
CD	NS	0.15	0.04	0.015	0.009	NS	0.015	NS
PxN ; SEd	0.03	0.01	0.02	0.009	0.008	0.014	0.012	0.03
CD	0.06	0.03	0.04	0.018	0.015	0.03	0.024	NS
CxN ; SEd	0.02	0.01	0.015	0.007	0.006	0.01	0.009	0.03
CD	NS	0.02	0.03	0.015	0.013	0.024	0.020	0.06

NS - Not significant

CD - (P=0.05)

The mean having the same alphabet are not significantly different at 5 % level.

The LAI increased with increase in levels of nitrogen from zero to 150 per cent of recommended level in both the years. The increase in LAI between zero to 50 per cent of recommended nitrogen was of greater magnitude (7 to 48 per cent) as compared increase in LAI either between 50 to 100 or 100 to 150 per cent (6 to 15 per cent).

Significant interaction existed between planting patterns and cultivars (P x C), between planting patterns and nitrogen levels (P x N) and between cultivars and nitrogen levels (C x N) in both the years except at 45 DAS for P x C and C x N in the first year and P x C (60 and 90 DAS) and P x N (90 DAS) in the second year of the study (Tables 7, 8 and 9). In the interaction between planting patterns and cultivars, higher LAI of 3.64 and 3.76 during first and second year were recorded by TCHB 213 under normal planting pattern as compared to MCU 11. In the interaction between planting patterns and nitrogen levels, there was significant difference between nitrogen levels in the three planting patterns. During both the years the highest LAI of 4.07 and 4.20 were recorded under higher levels of recommended nitrogen. During both the years TCHB 213 (C<sub>1</sub>) had recorded significantly higher LAI under higher level of nitrogen (4.05 and 4.35).

#### **4.1.1.3. Dry matter production (DMP)(kg ha<sup>-1</sup>)**

The data recorded on DMP of cotton are presented in Table. 10

The three planting patterns were independently significant from each other in both the years except at 45 DAS in the first year. Normal planting pattern (P<sub>1</sub>) had recorded higher DMP (3273 and 3206 kg ha<sup>-1</sup> at 90 DAS respectively for first and second years) over P<sub>2</sub> and P<sub>3</sub> in all the growth



Table 8. Interaction effect between planting patterns and nitrogen levels at 75 DAS on mean LAI of cotton during 1992 - '93 and 1993 - '94

1992 - '93

	P <sub>1</sub>	P <sub>2</sub>	P <sub>3</sub>	Mean
N <sub>1</sub>	2.44	2.32	2.25	2.34
N <sub>2</sub>	3.39	3.27	2.89	3.18
N <sub>3</sub>	3.69	3.55	3.34	3.53
N <sub>4</sub>	4.07	3.89	3.74	3.90
Mean	3.40	3.26	3.06	

	SEd	CD (P=0.05)
P at N	0.02	0.04
N at P	0.01	0.03

1993 - '94

	P <sub>1</sub>	P <sub>2</sub>	P <sub>3</sub>	Mean
N <sub>1</sub>	2.46	2.42	2.37	2.42
N <sub>2</sub>	3.36	3.29	3.28	3.31
N <sub>3</sub>	3.79	3.75	3.70	3.75
N <sub>4</sub>	4.20	4.10	3.95	4.08
Mean	3.45	3.39	3.33	

	SEd	CD (P=0.05)
P at N	0.01	0.02
N at P	0.01	0.02

**Table 9. Interaction effect between cultivars and nitrogen levels at 75 DAS on mean cotton LAI of cotton during 1992 - '93 and 1993 - '94**

1992 - '93					
	N <sub>1</sub>	N <sub>2</sub>	N <sub>3</sub>	N <sub>4</sub>	Mean
C <sub>1</sub>	2.46	3.36	3.71	4.05	3.40
C <sub>2</sub>	2.21	3.02	3.35	3.74	3.08
<b>Mean</b>	2.34	3.19	3.53	3.90	

	SEd	CD (P=0.05)
N at C	0.015	0.03
C at N	0.01	0.02

1993 - '94					
	N <sub>1</sub>	N <sub>2</sub>	N <sub>3</sub>	N <sub>4</sub>	Mean
C <sub>1</sub>	2.68	3.71	4.08	4.35	3.70
C <sub>2</sub>	2.16	2.91	3.41	3.82	3.08
<b>Mean</b>	2.42	3.31	3.75	4.09	

	SEd	CD (P=0.05)
N at C	0.01	0.02
C at N	0.01	0.02

Table 10. Effect of treatments on mean DMP (kg ha<sup>-1</sup>) of cotton during 1992 - '93 and 1993 - '94

	1992-'93				1993-'94			
	45 DAS	60 DAS	75 DAS	90 DAS	45 DAS	60 DAS	75 DAS	90 DAS
P <sub>1</sub>	607	1413a	2420a	3273a	635a	1491a	2490a	3206a
P <sub>2</sub>	585	1334b	2327b	3139b	604b	1424b	2369b	3120b
P <sub>3</sub>	572	1275b	2219c	3087c	593c	1325 c	2233c	3031c
SEd	27.62	34.08	2892	18.67	4.41	29.38	5.94	15.47
CD	NS	75.93	64.42	41.60	9.83	65.47	13.23	34.47
C <sub>1</sub>	619a	1482a	2567a	3418a	641a	1552a	2599a	3315a
C <sub>2</sub>	556b	1199b	2078b	2915b	580b	1275b	2129b	2924b
SEd	22.55	27.82	23.61	15.24	3.60	23.99	4.85	12.63
CD	50.24	61.99	52.60	33.96	8.03	53.45	10.80	28.14
N <sub>1</sub>	407d	879d	955d	1038d	430d	875d	975d	1027d
N <sub>2</sub>	602c	1294c	2359c	3420c	620c	1383c	2417c	3299c
N <sub>3</sub>	646b	1484b	2807b	3880b	670b	1551b	2847b	3912b
N <sub>4</sub>	695a	1706a	3168a	4327a	722a	1844a	3218a	4240a
SEd	2.26	5.36	14.44	22.97	2.69	14.09	5.24	8.99
CD	4.59	7.57	29.29	46.59	5.45	28.58	10.63	18.24
PxC ; SEd	39.05	48.19	40.89	26.40	6.24	41.55	8.40	21.88
CD	NS	NS	NS	58.83	NS	NS	18.71	48.74
PxN ; SEd	27.82	35.92	36.13	39.19	5.98	36.20	9.86	20.52
CD	61.91	79.32	77.90	81.26	12.78	78.18	20.70	43.96
CxN ; SEd	22.72	29.33	29.50	32.00	4.88	29.55	8.05	16.76
CD	50.55	64.76	63.61	66.35	10.43	63.83	16.91	35.89

NS - Not significant

CD - (P=0.05)

The mean having the same alphabet are not significantly different at 5 % level.

stages. Paired row with greengram intercrop ( $P_3$ ) had recorded the least DMP throughout the study period.

Between the two cultivars evaluated, TCHB 213 ( $C_1$ ) had recorded significantly higher DMP (3418 and 3315 kg ha<sup>-1</sup> at 90 DAS) throughout the crop growth in both the years of study. The difference in DMP between  $C_1$  and  $C_2$  increased upto 75 DAS of crop growth and subsequently decreased gradually.

Levels of applied nitrogen differed significantly among themselves in all the growth stages of both first and second year of experimentation. The highest level of recommended nitrogen (150 per cent) had registered higher DMP (4327 and 4240 kg ha<sup>-1</sup>) than other levels evaluated.

Interaction was observed. The interaction was significant between P x C at 90 DAS of first year and at 75 and 90 DAS of second year. The interaction between P x N and between C x N was significant at all the stages of first and second year of experimentation.

The data on interaction between planting patterns and nitrogen levels and cultivars and nitrogen levels are presented in Tables 11 and 12.

The three planting patterns were significantly different from each other in all the four levels of nitrogen evaluated during both the years except at absolute control of first year where  $P_1$  and  $P_2$  were at statistical par and differed significantly from  $P_3$ . The highest DMP (3327 and 3375 kg ha<sup>-1</sup> at 75 DAS) was recorded under normal row planting under higher level of nitrogen.

**Table 11. Interaction effect between planting patterns and nitrogen levels at 75 DAS on mean DMP (kg ha<sup>-1</sup>) of cotton during 1992 - '93 and 1993 - '94**

1992 - '93

	P <sub>1</sub>	P <sub>2</sub>	P <sub>3</sub>	Mean
N <sub>1</sub>	965	987	912	955
N <sub>2</sub>	2454	2386	2287	2359
N <sub>3</sub>	2934	2770	2717	2807
N <sub>4</sub>	3327	3217	2961	3168
Mean	2420	2327	2219	

	SEd	CD (P=0.05)
P at N	36.13	77.90
N at P	25.02	50.73

1993 - '94

	P <sub>1</sub>	P <sub>2</sub>	P <sub>3</sub>	Mean
N <sub>1</sub>	1006	986	932	975
N <sub>2</sub>	2559	2394	2296	2416
N <sub>3</sub>	3019	2826	2696	2847
N <sub>4</sub>	3375	3270	3009	3218
Mean	2490	2369	2233	

	SEd	CD (P=0.05)
P at N	9.86	20.70
N at P	9.08	18.42

**Table 12. Interaction effect between cultivars and nitrogen levels at 75 DAS on mean DMP ( $\text{kg ha}^{-1}$ ) of cotton during 1992 - '93 and 1993 - '94**

1992 - '93					
	N <sub>1</sub>	N <sub>2</sub>	N <sub>3</sub>	N <sub>4</sub>	Mean
C <sub>1</sub>	1024	2623	3155	3464	2567
C <sub>2</sub>	885	2095	2459	2872	2078
Mean	955	2359	2807	3168	

	SEd	CD (P=0.05)
N at C	29.50	63.61
C at N	20.43	41.42

1993 - '94					
	N <sub>1</sub>	N <sub>2</sub>	N <sub>3</sub>	N <sub>4</sub>	Mean
C <sub>1</sub>	1029	2699	3191	3476	2599
C <sub>2</sub>	920	2134	2503	2960	2129
Mean	975	2417	2847	3218	

	SEd	CD (P=0.05)
N at C	8.05	16.91
C at N	7.42	15.04

In the interaction between cultivars and nitrogen levels, TCHB 213 ( $C_1$ ) had recorded significantly higher DMP (3464 and 3476 kg ha<sup>-1</sup>) under 150 per cent of recommendation.

#### 4.1.1.4. Ground cover (%)

The data on ground cover by cotton canopy during second year of experiment are presented in Table 13. During first year of experiment, the data were not recorded.

The three planting patterns were independently significant from each other in all the growth stages in respect of ground cover. Among the planting patterns evaluated, paired row with greengram intercrop ( $P_3$ ) had covered the ground to a maximum at 45 (82.20%), 60 (85.78%) and 75 (88.63%) DAS and the least (52.44%) at 90 DAS wherein normal row planting had higher ground coverage (60.75%). Paired row planting ( $P_2$ ) had the lowest ground cover at 45, 60 and 75 DAS, and it was moderate at 90 DAS. Maximum ground cover of 60.75 per cent was recorded at 90 DAS under normal row planting ( $P_1$ ).

Between the two cultivars, TCHB 213 ( $C_1$ ) had covered the ground effectively (59.61 per cent at 90 DAS) over MCU 11 ( $C_2$ ) (54.08 per cent at 90 DAS) in all the growth stages. The two cultivars were significantly different from each other.

The levels recommended of nitrogen studied had pronounced significant difference in respect of ground coverage throughout the growth

Table 13. Effect of treatments on mean canopy ground coverage (%) of cotton during 1993 - '94

	1993-'94			
	45 DAS	60 DAS	75 DAS	90 DAS
P <sub>1</sub>	37.09b	45.23b	54.62b	60.75a
P <sub>2</sub>	28.74c	39.47c	49.07c	57.36b
P <sub>3</sub>	82.20a	85.78a	88.63a	52.44c
SEd	0.92	0.92	1.02	0.71
CD	2.05	2.05	2.27	1.59
C <sub>1</sub>	51.30a	59.67a	66.91a	59.61a
C <sub>2</sub>	47.38b	53.98b	61.31b	54.08b
SEd	0.75	0.75	0.83	0.58
CD	1.67	1.68	1.85	1.30
N <sub>1</sub>	41.76d	46.77d	51.62d	38.58d
N <sub>2</sub>	48.05c	53.92c	61.38c	55.60c
N <sub>3</sub>	52.52b	60.45b	68.90b	63.55b
N <sub>4</sub>	55.04a	66.16a	74.54a	69.66a
SEd	0.43	0.45	0.53	0.40
CD	0.88	0.92	1.08	0.81
PxC ; SEd	1.30	1.30	1.44	1.01
CD	2.90	2.91	3.21	2.25
PxN ; SEd	1.13	1.14	1.30	0.93
CD	2.44	2.47	2.79	2.00
CxN ; SEd	0.92	0.93	1.06	0.76
CD	1.99	2.02	2.28	1.63

CD - (P=0.05)

The mean having the same alphabet are not significantly different at 5 % level.

highest level (150 per cent of recommendation) of nitrogen had recorded maximum ground cover (69.66 per cent at 90 DAS) throughout.

Interaction was significant for different growth stages. The data on interaction between P x C, P x N and between C x N are given in Table 14.

The cultivar TCHB 213 (C<sub>1</sub>) under paired row with greengram intercrop (P<sub>3</sub>) had produced more ground cover (90.78 per cent) followed by normal row planting (57.78 per cent). In Interaction between planting patterns and nitrogen levels at 75 DAS, paired row planting with inter crops (P<sub>3</sub>) at 150 per cent of recommended level had covered the ground to a maximum level of 95.82 per cent.

The cultivar TCHB 213 (C<sub>1</sub>) had interacted positively with nitrogen levels and produced more ground cover at 150 per cent of recommended level (77.41 per cent) than MCU-11 (C<sub>2</sub>) (71.67 per cent).

Both cultivars had covered the ground to a greater extent under paired row planting with greengram intercrop.

#### **4.1.1.5. Plant nitrogen content (%)**

The data on plant nitrogen content recorded at various growth stages during first and second years of investigation are presented in Table 15.

The plant nitrogen content continued to increase with the increase in crop growth.

**Table 14. Interaction effect between planting patterns, cultivars and nitrogen levels on mean canopy ground cover (%) of cotton at 75 DAS during 1993 - '94**

**P x C**

	P <sub>1</sub>	P <sub>2</sub>	P <sub>3</sub>	Mean
C <sub>1</sub>	57.78	52.16	90.78	66.91
C <sub>2</sub>	51.46	45.99	86.49	61.31
Mean	54.62	49.07	88.63	

**SEd**

1.44

**CD (P=0.05)**

3.21

**P x N**

	N <sub>1</sub>	N <sub>2</sub>	N <sub>3</sub>	N <sub>4</sub>	Mean
P <sub>1</sub>	39.65	52.55	60.38	65.91	54.62
P <sub>2</sub>	33.40	45.97	55.03	61.90	49.09
P <sub>3</sub>	31.80	85.62	91.30	95.82	88.63
Mean	51.62	61.38	68.90	74.54	

**SEd**

**P at N**

1.30

**CD (P=0.05)**

2.79

**N at P**

0.93

1.88

**C x N**

	N <sub>1</sub>	N <sub>2</sub>	N <sub>3</sub>	N <sub>4</sub>	Mean
C <sub>1</sub>	53.92	64.83	71.46	77.41	66.91
C <sub>2</sub>	49.32	57.92	66.34	71.67	61.31
Mean	51.62	61.38	68.90	74.54	

**SEd**

**N at C**

0.76

**CD (P=0.05)**

1.53

**C at N**

1.06

2.28

**Table 15. Effect of treatments on mean plant nitrogen content (%) of cotton during 1992 - '93 and 1993 - '94**

	1992-'93				1993-'94			
	45 DAS	60 DAS	75 DAS	90 DAS	45 DAS	60 DAS	75 DAS	90 DAS
P <sub>1</sub>	1.12	1.16	1.22	1.28	1.11	1.19	1.40	1.61
P <sub>2</sub>	1.08	1.13	1.23	1.28	1.09	1.18	1.36	1.57
P <sub>3</sub>	1.07	1.14	1.22	1.25	1.09	1.17	1.33	1.53
SEd	0.04	0.02	0.01	0.01	0.016	0.01	0.04	0.06
CD	NS	NS	NS	NS	NS	NS	NS	NS
C <sub>1</sub>	1.12a	1.19a	1.24a	1.31a	1.18a	1.21a	1.41a	1.66a
C <sub>2</sub>	1.06b	1.10b	1.20b	1.24b	1.02b	1.15b	1.31b	1.48b
SEd	0.01	0.01	0.01	0.01	0.013	0.01	0.01	0.007
CD	0.02	0.03	0.03	0.03	0.029	0.02	0.02	0.02
N <sub>1</sub>	0.97d	1.03d	1.08d	1.15d	0.91d	1.06d	1.07d	1.03d
N <sub>2</sub>	1.06c	1.13c	1.21c	1.25c	1.06c	1.16c	1.29c	1.57c
N <sub>3</sub>	1.13b	1.19b	1.27b	1.31b	1.16b	1.22b	1.40b	1.76b
N <sub>4</sub>	1.20a	1.24a	1.32a	1.37a	1.25a	1.28a	1.68a	1.92a
SEd	0.02	0.01	0.01	0.01	0.01	0.013	0.01	0.01
CD	0.03	0.02	0.02	0.02	0.03	0.03	0.03	0.03
PxC ; SEd	0.01	0.03	0.02	0.02	0.02	0.02	0.02	0.01
CD	NS	NS	NS	NS	NS	NS	NS	NS
PxN ; SEd	0.02	0.02	0.02	0.02	0.03	0.02	0.03	0.02
CD	NS	NS	NS	NS	NS	NS	NS	NS
CxN ; SEd	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
CD	0.04	0.04	0.03	0.04	0.05	0.04	0.04	0.04

NS - Not significant

CD - (P=0.05)

The mean having the same alphabet are not significantly different at 5 % level.

Among the three planting patterns studied, there was no significant difference among them in respect of plant nitrogen content in the first and second years of study.

The two cultivars differed significantly for plant nitrogen content in both the years at 45, 60, 75 and at 90 DAS.

The cultivar TCHB 213 (C<sub>1</sub>) had registered more nitrogen content (1.31 and 1.66 per cent at 90 DAS in respect of first and second years) than MCU 11 (C<sub>2</sub>). It was true for all the growth stages of both the years.

Increased levels of applied nitrogen had positively enhanced the plant nitrogen content. In all the growth stages, 150 per cent of recommended level had recorded the highest level of nitrogen content (1.37 and 1.92 per cent at 90 DAS in the first and second years respectively) in cotton plants.

The interactions between planting patterns and cultivars and between planting patterns and nitrogen levels were not significant at any of the stages both in the first and second years of the study. The interaction between cultivars and nitrogen levels was significant in all the stages during first and second year.

The data on interaction between cultivars and nitrogen levels at 75 DAS are presented in Table 16.

Table 16. Interaction effect between cultivars and nitrogen levels at 75 DAS on mean plant nitrogen content (%) of cotton during 1992 - '93 and 1993 - '94

1992 - '93

	N <sub>1</sub>	N <sub>2</sub>	N <sub>3</sub>	N <sub>4</sub>	Mean
C <sub>1</sub>	1.09	1.23	1.29	1.34	1.24
C <sub>2</sub>	1.07	1.19	1.25	1.30	1.20
Mean	1.08	1.21	1.27	1.32	

	<b>SEd</b>	<b>CD (P=0.05)</b>
N at C	0.01	0.02
C at N	0.02	0.03

1993 - '94

	N <sub>1</sub>	N <sub>2</sub>	N <sub>3</sub>	N <sub>4</sub>	Mean
C <sub>1</sub>	1.10	1.36	1.45	1.74	1.41
C <sub>2</sub>	1.04	1.22	1.36	1.62	1.31
Mean	1.07	1.29	1.41	1.68	

	<b>SEd</b>	<b>CD (P=0.05)</b>
N at C	0.02	0.04
C at N	0.02	0.04

During both first and second years TCHB 213 ( $C_1$ ) under 150 per cent of recommended level had recorded higher plant nitrogen content over other levels tested.

#### **4.1.1.6. Chlorophyll a, b and total contents in plants ( $\text{mg g}^{-1}$ )**

The data recorded on chlorophyll a, b and total contents of first and second years are presented in Tables 17,18 and 19.

The chlorophyll content (a, b and total) continued to increase with crop age.

The three planting patterns did not differ significantly in respect of chlorophyll contents (a, b and total).

The two cultivars were significantly different for chlorophyll contents (a, b and total). TCHB 213 ( $C_1$ ) had recorded higher chlorophyll content (2.17 and 2.22 of "a", 1.17 and 1.20 "b" and 3.38 and 3.44  $\text{mg g}^{-1}$  of "total" chlorophyll at 90 DAS of a during first and second year respectively) in all the growth stages.

The levels of nitrogen studied were significantly different from each other except at 90 DAS for chlorophyll "a" during both the years. The contents got increased with increase in levels of applied nitrogen. The highest level of nitrogen (150 per cent) had registered higher content of chlorophyll "a" (2.72 and 2.76)  $\text{mg g}^{-1}$  "b" (1.44 and 1.32  $\text{mg g}^{-1}$ ) and total (4.20 and 4.07  $\text{mg g}^{-1}$ ) at 90 DAS.

Table 17. Effect of treatments on mean chlorophyll "a" content (mg g<sup>-1</sup>) of cotton during 1992 - '93 and 1993 - '94

	1992-'93				1993-'94			
	45 DAS	60 DAS	75 DAS	90 DAS	45 DAS	60 DAS	75 DAS	90 DAS
P <sub>1</sub>	1.64	1.76	1.92	2.07	1.71	1.77	1.95	2.11
P <sub>2</sub>	1.56	1.68	1.88	2.10	1.69	1.72	1.86	2.07
P <sub>3</sub>	1.50	1.66	1.84	2.03	1.67	1.70	1.86	2.05
SEd	0.02	0.03	0.04	0.07	0.04	0.04	0.06	0.05
CD	NS	NS	NS	NS	NS	NS	NS	NS
C <sub>1</sub>	1.68a	1.85a	2.05a	2.17a	1.74a	1.90a	2.11a	2.22a
C <sub>2</sub>	1.46b	1.55b	1.71b	1.97b	1.51b	1.63b	1.72b	1.99b
SEd	0.02	0.02	0.03	0.06	0.03	0.02	0.05	0.05
CD	0.4	0.05	0.07	0.13	0.07	0.05	0.11	0.62
N <sub>1</sub>	0.96d	1.06d	1.05d	1.05c	0.97d	1.10d	1.06d	1.17c
N <sub>2</sub>	1.36c	1.53c	1.67c	1.87b	1.39c	1.59c	1.77c	1.90b
N <sub>3</sub>	1.73b	1.92b	2.23b	2.63a	1.80b	1.87b	2.32b	2.68a
N <sub>4</sub>	2.22a	2.30a	2.56a	2.72a	2.25a	2.34a	2.50a	2.76a
SEd	0.02	0.03	0.03	0.08	0.03	0.04	0.06	0.05
CD	0.04	0.06	0.05	0.16	0.07	0.09	0.12	0.11
PxC ; SEd	0.03	0.04	0.05	0.10	0.04	0.03	0.04	0.05
CD	NS	NS	NS	NS	NS	NS	NS	NS
PxN ; SEd	0.04	0.05	0.05	0.13	0.05	0.06	0.07	0.11
CD	NS	NS	NS	NS	NS	NS	NS	NS
CxN ; SEd	0.03	0.04	0.04	0.11	0.02	0.03	0.02	0.02
CD	0.06	0.09	0.09	0.24	0.04	0.07	0.04	0.05

NS - Not significant

CD - (P=0.05)

The mean having the same alphabet are not significantly different at 5 % level.

Table 18. Effect of treatments on mean chlorophyll 'b' content ( $\text{mg g}^{-1}$ ) of cotton during 1992 - '93 and 1993 - '94

	1992-'93				1993-'94			
	45 DAS	60 DAS	75 DAS	90 DAS	45 DAS	60 DAS	75 DAS	90 DAS
P <sub>1</sub>	0.84	0.92	1.03	1.17	0.87	1.00	1.07	1.20
P <sub>2</sub>	0.78	0.93	1.01	1.13	0.81	1.02	1.09	1.23
P <sub>3</sub>	0.78	0.94	0.99	1.11	0.80	1.04	1.10	1.24
SEd	0.04	0.01	0.03	0.01	0.05	0.04	0.03	0.04
CD	NS	NS	NS	NS	NS	NS	NS	NS
C <sub>1</sub>	0.83a	0.96a	1.03a	1.17a	0.91a	1.07a	1.09a	1.20a
C <sub>2</sub>	0.77b	0.90b	0.99b	1.09b	0.84b	0.91b	0.98b	1.01b
SEd	0.01	0.01	0.01	0.009	0.002	0.01	0.02	0.07
CD	0.02	0.02	0.02	0.02	0.005	0.02	0.04	0.14
N <sub>1</sub>	0.48d	0.56d	0.67d	0.73d	0.51d	0.57d	0.77d	0.80d
N <sub>2</sub>	0.76c	0.89c	1.05c	1.15c	0.74c	0.81c	1.061c	1.14c
N <sub>3</sub>	0.93b	1.09b	1.11b	1.22b	0.98b	1.01b	1.09b	1.21b
N <sub>4</sub>	1.03a	1.17a	1.21a	1.44a	1.05a	1.11a	1.20a	1.32a
SEd	0.01	0.01	0.006	0.007	0.01	0.04	0.006	0.04
CD	0.03	0.02	0.013	0.014	0.02	0.08	0.012	0.08
PxC ; SEd	0.02	0.02	0.03	0.02	0.03	0.04	0.05	0.06
CD	NS	NS	NS	NS	NS	NS	NS	NS
PxN ; SEd	0.02	0.02	0.02	0.02	0.003	0.04	0.02	0.03
CD	NS	NS	NS	NS	NS	NS	NS	NS
CxN ; SEd	0.02	0.02	0.01	0.01	0.01	0.03	0.02	0.02
CD	NS	0.04	0.03	0.03	0.02	0.06	0.04	0.04

NS - Not significant

CD - (P=0.05)

The mean having the same alphabet are not significantly different at 5 % level.

Table 19. Effect of treatments on mean total chlorophyll content ( $\text{mg g}^{-1}$ ) of cotton during 1992 - '93 and 1993 - '94

	1992-'93				1993-'94			
	45 DAS	60 DAS	75 DAS	90 DAS	45 DAS	60 DAS	75 DAS	90 DAS
P <sub>1</sub>	2.48	2.60	2.86	3.33	2.57	2.78	3.03	3.34
P <sub>2</sub>	2.36	2.68	2.90	3.19	2.49	2.82	2.96	3.31
P <sub>3</sub>	2.29	2.62	2.80	3.11	2.46	2.74	2.94	3.29
SEd	0.08	0.05	0.07	0.09	0.06	0.04	0.06	0.08
CD	NS	NS	NS	NS	NS	NS	NS	NS
C <sub>1</sub>	2.53a	2.77a	3.03a	3.38a	2.67a	2.99a	3.21a	3.44a
C <sub>2</sub>	2.23b	2.49b	2.66b	3.03b	2.32b	2.43b	2.81b	3.01b
SEd	0.02	0.04	0.05	0.06	0.03	0.02	0.04	0.06
CD	0.05	0.09	0.11	0.13	0.07	0.05	0.09	0.13
N <sub>1</sub>	1.47d	1.60d	1.71d	1.74d	1.43d	1.64d	1.88d	1.96d
N <sub>2</sub>	2.12c	2.41c	2.71c	3.03c	2.12c	2.41c	2.89c	3.02c
N <sub>3</sub>	2.67b	3.01b	3.27b	3.85b	2.87b	2.90b	3.44b	3.89b
N <sub>4</sub>	3.26a	3.51a	3.87a	4.20a	3.32a	3.46a	3.81a	4.07a
SEd	0.03	0.06	0.08	0.07	0.04	0.06	0.08	0.05
CD	0.06	0.11	0.19	0.14	0.09	0.13	0.17	0.11
PxC ; SEd	0.04	0.07	0.06	0.09	0.04	0.07	0.06	0.04
CD	NS	NS	NS	NS	NS	NS	NS	NS
PxN ; SEd	0.05	0.09	0.07	0.13	0.06	0.04	0.05	0.12
CD	NS	NS	NS	NS	NS	NS	NS	NS
CxN ; SEd	0.04	0.06	0.07	0.10	0.03	0.05	0.07	0.10
CD	0.09	0.12	0.14	0.22	0.07	0.11	0.15	0.21

NS - Not significant

CD - (P=0.05)

The mean having the same alphabet are not significantly different at 5 % level.

The interactions between P x C and between P x N were non significant for all the growth stages in respect of chlorophyll a, b and total contents, while interaction between cultivars and nitrogen levels was significant for chlorophyll "a", "b" and total during both the years except at 45 DAS of first year for chlorophyll "b" (Table 20 and 21).

The cultivar interacted positively with nitrogen levels and TCHB 213 (C<sub>1</sub>) recorded higher contents of chlorophyll a (2.74) b (1.24) and total (3.96) under 150 per cent of recommended level in the first year. Similar trend was observed in the second year also.

#### 4.1.1.7. Leaf thickness (mg cm<sup>-2</sup>)

The data on leaf thickness recorded during second year are presented in Table 22.

Since this parameter for observation was included only during the second year of experiment as per advisory committee recommendation, observation was not included during first year.

There was no significant difference in leaf thickness among the three planting patterns studied. In general the leaf thickness got decreased between 45 and 60 DAS and there after increase in thickness was observed.

Between the two cultivars, TCHB 213 (C<sub>1</sub>) had recorded thicker leaf (6.03) than MCU 11 (C<sub>2</sub>) (4.78). In TCHB 213 (C<sub>1</sub>), the leaf thickness was increasing from 45 DAS to 90 DAS while in MCU 11 (C<sub>2</sub>) the leaf thickness got decreased from 45 DAS to 60 DAS and again started increasing.

Table 20. Interaction effect between cultivars and nitrogen levels at 75 DAS on mean chlorophyll (a, b and total) content  $\text{mg g}^{-1}$  of cotton during 1992 - '93

Chlorophyll a					
	N <sub>1</sub>	N <sub>2</sub>	N <sub>3</sub>	N <sub>4</sub>	Mean
C <sub>1</sub>	1.07	1.92	2.48	2.74	2.05
C <sub>2</sub>	1.03	1.42	1.99	2.37	1.70
Mean	1.05	1.67	2.24	2.56	

	<b>SEd</b>	<b>CD (P=0.05)</b>
C at N	0.04	0.09
N at C	0.04	0.08

Chlorophyll b					
	N <sub>1</sub>	N <sub>2</sub>	N <sub>3</sub>	N <sub>4</sub>	Mean
C <sub>1</sub>	0.70	1.06	1.12	1.24	1.03
C <sub>2</sub>	0.65	1.03	1.09	1.18	0.99
Mean	0.68	1.05	1.11	1.21	

	<b>SEd</b>	<b>CD (P=0.05)</b>
C at N	0.01	0.03
N at C	0.01	0.02

Chlorophyll total					
	N <sub>1</sub>	N <sub>2</sub>	N <sub>3</sub>	N <sub>4</sub>	Mean
C <sub>1</sub>	1.76	2.90	3.50	3.96	3.03
C <sub>2</sub>	1.68	2.52	3.03	3.42	2.66
Mean	1.72	2.71	3.22	3.69	

	<b>SEd</b>	<b>CD (P=0.05)</b>
C at N	0.07	0.14
N at C	0.06	0.12

**Table 21. Interaction effect between cultivars and nitrogen levels at 75 DAS on mean chlorophyll (a, b and total) content  $\text{mg g}^{-1}$  of cotton during 1993-'94**

<b>Chlorophyll a</b>					
	<b>N<sub>1</sub></b>	<b>N<sub>2</sub></b>	<b>N<sub>3</sub></b>	<b>N<sub>4</sub></b>	<b>Mean</b>
<b>C<sub>1</sub></b>	1.10	2.01	2.53	2.75	2.10
<b>C<sub>2</sub></b>	1.01	1.53	2.07	2.25	1.71
<b>Mean</b>	1.06	1.77	2.30	2.50	

	<b>SEd</b>	<b>CD (P=0.05)</b>
<b>C at N</b>	0.02	0.04
<b>N at C</b>	0.03	0.07

<b>Chlorophyll b</b>					
	<b>N<sub>1</sub></b>	<b>N<sub>2</sub></b>	<b>N<sub>3</sub></b>	<b>N<sub>4</sub></b>	<b>Mean</b>
<b>C<sub>1</sub></b>	0.85	1.12	1.13	1.26	1.09
<b>C<sub>2</sub></b>	0.69	1.01	1.06	1.25	1.00
<b>Mean</b>	0.77	1.06	1.09	1.21	

	<b>SEd</b>	<b>CD (P=0.05)</b>
<b>C at N</b>	0.02	0.04
<b>N at C</b>	0.01	0.02

<b>Total Chlorophyll</b>					
	<b>N<sub>1</sub></b>	<b>N<sub>2</sub></b>	<b>N<sub>3</sub></b>	<b>N<sub>4</sub></b>	<b>Mean</b>
<b>C<sub>1</sub></b>	1.99	3.19	3.72	4.08	3.22
<b>C<sub>2</sub></b>	1.76	2.60	3.19	3.47	2.80
<b>Mean</b>	1.88	2.89	3.45	3.80	

	<b>SEd</b>	<b>CD (P=0.05)</b>
<b>C at N</b>	0.07	0.15
<b>N at C</b>	0.06	0.12

Table 22. Effect of treatments on mean leaf thickness ( $\text{mg cm}^{-2}$ ) of cotton during 1993 - '94

	1993-'94			
	45 DAS	60 DAS	75 DAS	90 DAS
P <sub>1</sub>	5.14	4.95	5.19	5.53
P <sub>2</sub>	5.20	4.89	5.22	5.25
P <sub>3</sub>	4.85	4.65	5.09	5.49
SEd	0.88	1.18	0.76	0.91
CD	NS	NS	NS	NS
C <sub>1</sub>	5.49 <sup>a</sup>	5.58 <sup>a</sup>	5.67 <sup>a</sup>	6.03 <sup>a</sup>
C <sub>2</sub>	4.82 <sup>b</sup>	4.29 <sup>b</sup>	4.46 <sup>b</sup>	4.78 <sup>b</sup>
SEd	0.31	0.58	0.56	0.58
CD	0.66	1.23	1.20	1.22
N <sub>1</sub>	4.41 <sup>d</sup>	4.29 <sup>d</sup>	4.30 <sup>d</sup>	4.58 <sup>d</sup>
N <sub>2</sub>	4.95 <sup>c</sup>	4.70 <sup>c</sup>	4.84 <sup>c</sup>	5.08 <sup>c</sup>
N <sub>3</sub>	5.35 <sup>b</sup>	5.15 <sup>b</sup>	5.32 <sup>b</sup>	5.73 <sup>b</sup>
N <sub>4</sub>	5.91 <sup>a</sup>	5.60 <sup>a</sup>	5.80 <sup>a</sup>	6.21 <sup>a</sup>
SEd	0.26	0.20	0.23	0.21
CD	0.53	0.40	0.49	0.46
PxC ; SEd	1.24	1.67	1.08	1.29
CD	NS	NS	NS	NS
PxN ; SEd	1.15	1.22	0.86	0.98
CD	NS	NS	NS	NS
CxN ; SEd	0.94	1.0	0.70	0.80
CD	NS	NS	NS	NS

NS - Not significant

CD - (P=0.05)

The mean having the same alphabet are not significantly different at 5 % level.

The four levels of nitrogen were independent in showing significance in this parameter. There was variation in leaf thickness between growth stages. However, the leaf thickness increased with increased levels of applied nitrogen.

Interactions were absent.

#### 4.1.1.8 Leaf angle (°)

The data on leaf angle recorded during second year of experiment are presented in Table 23.

This parameter for observation was included only during the second year of experiment and hence there was no record made on leaf angle in the first year of the study.

The leaf angle varied between stages. The leaves of normal planting pattern ( $P_1$ ) were inclined more nearer to horizontal ( $42.94^\circ$ ) as compared to paired rows  $P_2$  ( $36.30^\circ$ ) and  $P_3$  ( $33.10^\circ$ ) at 90 DAS. The leaf angles of cotton in paired row ( $P_2$ ) and paired row with greengram intercrop ( $P_3$ ) were on par.

The two cultivars were significantly different in respect of leaf angles. The leaves of TCHB 213 ( $C_1$ ) were more tilted towards horizontal ( $39.56^\circ$ ) than MCU 11 ( $C_2$ ) ( $35.34^\circ$ ).

The levels of applied nitrogen had significantly altered the leaf angle in all the growth stages of evaluation. The angle of leaves had increased with increase in nitrogen levels and also with advancement of crop growth. The

**Table 23. Effect of treatments on mean leaf angle (°) of cotton during 1993 - '94**

	1993-'94			
	45 DAS	60 DAS	75 DAS	90 DAS
<b>P<sub>1</sub></b>	37.50a	55.56a	43.79a	42.94a
<b>P<sub>2</sub></b>	36.04ab	36.64b	39.03b	36.30b
<b>P<sub>3</sub></b>	33.85b	36.19b	36.75b	33.10b
<b>SEd</b>	1.18	1.45	1.71	1.96
<b>CD</b>	2.63	3.20	3.81	4.12
<b>C<sub>1</sub></b>	40.93a	54.40a	42.73a	39.56a
<b>C<sub>2</sub></b>	30.67b	31.19b	33.64b	35.34b
<b>SEd</b>	0.96	1.02	1.39	1.42
<b>CD</b>	2.1	2.21	3.11	3.02
<b>N<sub>1</sub></b>	28.41d	28.74d	29.95d	30.72d
<b>N<sub>2</sub></b>	32.53c	33.55c	34.48c	35.24c
<b>N<sub>3</sub></b>	38.44b	40.33b	41.76b	42.39b
<b>N<sub>4</sub></b>	43.81a	44.57a	46.57a	46.95a
<b>SEd</b>	0.34	0.64	0.85	0.92
<b>CD</b>	0.71	1.34	1.72	1.87
<b>PxC ; SEd</b>	1.67	2.67	2.42	4.19
<b>CD</b>	3.51	5.6	5.39	8.7
<b>PxN ; SEd</b>	1.25	2.42	2.13	3.27
<b>CD</b>	2.60	5.3	4.60	6.80
<b>CxN ; SEd</b>	1.05	2.20	1.74	2.67
<b>CD</b>	2.41	4.6	3.75	5.60

CD - (P=0.05)

The mean having the same alphabet are not significantly different at 5 % level.

leaves were comparatively more horizontal at higher level of nitrogen ( $46.95^{\circ}$  at 90 DAS) than lower levels.

There was interaction between factors studied. The interaction between P x C, P x N and C x N at 75 DAS are given in Table 24.

In interaction between P x C, the results revealed that planting patterns P<sub>1</sub> and P<sub>2</sub> under TCHB 213, and P<sub>2</sub> and P<sub>3</sub> under MCU 11 were at statistical par. But the two cultivars were significantly different in all the planting patterns. The leaf angle was higher ( $48.56^{\circ}$ ) in TCHB 213 under normal planting pattern.

In interaction between P x N, the planting patterns P<sub>1</sub> and P<sub>2</sub> were on par under zero to 100 per cent of recommended level of nitrogen but significantly different from P<sub>3</sub>. At 150 per cent level, the three planting patterns were significantly different from each other. Wide angled leaf ( $54.34^{\circ}$ ) was produced in normal planting pattern (P<sub>1</sub>) at 150 per cent level of nitrogen.

In interaction between C x N, both cultivars and nitrogen levels were significantly different. Cultivar TCHB 213 had produced wide angled leaves ( $52.25^{\circ}$ ) under 150 per cent level of nitrogen than MCU 11 (C<sub>2</sub>) ( $40.89^{\circ}$ ) at same level of nitrogen application.

#### **4.1.1.9. Leaf water content (%)**

The data recorded on leaf water content of cotton plants are presented in Table 25.

Table 24. Interaction effect between planting patterns cultivars and nitrogen levels at 75 DAS on mean leaf angle ( $^{\circ}$ ) of cotton during 1993 - '94

**P x C**

	P <sub>1</sub>	P <sub>2</sub>	P <sub>3</sub>	Mean
C <sub>1</sub>	48.56	44.46	35.18	42.73
C <sub>2</sub>	39.02	33.59	38.31	33.64
Mean	43.79	39.03	36.75	

SEd

2.42

CD (P=0.05)

5.39

**P x N**

	N <sub>1</sub>	N <sub>2</sub>	N <sub>3</sub>	N <sub>4</sub>	Mean
P <sub>1</sub>	34.03	39.29	47.50	54.34	43.79
P <sub>2</sub>	30.86	35.06	43.32	46.88	39.03
P <sub>3</sub>	24.96	29.08	34.45	38.50	36.74
Mean	29.95	34.48	41.76	46.57	

SEd

2.13

CD (P=0.05)

4.60

P at N

N at P

1.47

2.98

**C x N**

	N <sub>1</sub>	N <sub>2</sub>	N <sub>3</sub>	N <sub>4</sub>	Mean
C <sub>1</sub>	33.19	37.86	47.64	52.25	42.74
C <sub>2</sub>	26.70	31.09	35.87	40.89	33.64
Mean	29.95	34.48	41.76	46.57	

SEd

1.74

CD (P=0.05)

3.75

N at C

C at N

1.20

2.43

**Table 25. Effect of treatments on mean leaf water content (%) of cotton during 1992 - '93 and 1993 - '94**

	1992-'93				1993-'94			
	45 DAS	60 DAS	75 DAS	90 DAS	45 DAS	60 DAS	75 DAS	90 DAS
P <sub>1</sub>	71.42	75.89	75.95	78.04	71.78	69.19	75.95	79.20
P <sub>2</sub>	72.21	76.36	76.71	77.81	72.93	71.78	75.77	79.77
P <sub>3</sub>	71.19	76.45	76.54	79.86	72.73	70.86	76.54	80.87
SEd	0.82	1.20	1.27	1.11	0.79	2.51	1.29	1.40
CD	NS	NS	NS	NS	NS	NS	NS	NS
C <sub>1</sub>	72.70	77.86	77.87	82.19	72.70	74.81	77.60	79.15
C <sub>2</sub>	70.51	74.14	74.92	75.28	70.75	72.40	74.57	75.28
SEd	0.67	0.98	1.04	0.90	0.64	1.10	1.05	1.64
CD	1.49	2.06	2.30	2.01	1.43	2.31	2.22	3.41
N <sub>1</sub>	71.15	73.04	74.45	75.15	64.17	67.90	72.41	74.00
N <sub>2</sub>	71.45	74.90	75.84	77.90	71.88	72.40	74.40	75.80
N <sub>3</sub>	71.49	76.74	77.25	80.65	71.91	74.15	76.45	78.64
N <sub>4</sub>	72.33	78.57	78.84	83.15	72.35	76.03	78.56	80.60
SEd	0.89	0.82	0.66	0.95	0.78	0.82	0.93	0.70
CD	NS	1.73	1.37	2.06	NS	1.73	1.9	1.67
PxC ; SEd	1.16	1.70	1.79	1.57	1.11	3.55	1.82	1.75
CD	NS	NS	NS	NS	NS	NS	NS	NS
PxN ; SEd	1.57	3.47	1.71	2.13	1.41	3.64	1.19	1.82
CD	NS	NS	NS	NS	NS	NS	NS	NS
CxN ; SEd	1.29	2.84	1.40	1.74	1.15	3.29	1.56	1.69
CD	NS	NS	NS	NS	NS	NS	NS	NS

NS - Not significant

CD - (P=0.05)

The mean having the same alphabet are not significantly different at 5 % level.

The leaf water content continued to increase with ageing of crop.

Among the three planting patterns, the result was not significant in both the first and second years of experimentation.

The two cultivars were significantly different from each other in leaf water content. At all the growth stages, cultivar TCHB 213 (C<sub>1</sub>) contained more leaf water (82.19 and 79.15 per cent at 90 DAS) than the other cultivar MCU 11 (75.28 and 75.28 per cent) in both the years.

The four levels of recommended nitrogen application had exhibited significant difference at all the growth stages during both the years except 45 DAS of both first and second year. Increasing levels of nitrogen and advancement of crop growth stage had increased the water content of cotton leaves. At 90 DAS, the cotton leaves contained more amount of water (83.15 and 80.60 per cent in the first and second years respectively) under 150 per cent of nitrogen application than at lower levels.

Interactions were absent.

## **4.2. Part II**

Based on first and second years of experimentation, treatments were short listed and studied in the third year. Results of experiment conducted during third year (1994-'95) are presented below.

### **4.2.1. Crop growth and physiological parameters**

#### **4.2.1.1. Plant height (cm)**

The data collected on plant height in the third year experiment are presented in Table 26.

**Table 26. Effect of treatments on mean plant height (cm) of cotton during 1994 - '95**

	1994-'95			
	45 DAS	60 DAS	75 DAS	90 DAS
<b>C<sub>1</sub></b>	40.86 <sup>a</sup>	60.89 <sup>a</sup>	75.55 <sup>a</sup>	87.72 <sup>a</sup>
<b>C<sub>2</sub></b>	35.00 <sup>b</sup>	49.89 <sup>b</sup>	67.16 <sup>b</sup>	81.38 <sup>b</sup>
<b>SEd</b>	0.20	0.04	0.09	0.43
<b>CD</b>	0.42	0.08	0.19	0.91
<b>N<sub>1</sub></b>	33.12 <sup>c</sup>	50.84 <sup>c</sup>	65.06 <sup>c</sup>	77.51 <sup>c</sup>
<b>N<sub>2</sub></b>	39.02 <sup>b</sup>	55.87 <sup>b</sup>	71.78 <sup>b</sup>	84.74 <sup>b</sup>
<b>N<sub>3</sub></b>	45.54 <sup>a</sup>	59.46 <sup>a</sup>	77.22 <sup>a</sup>	91.40 <sup>a</sup>
<b>SEd</b>	0.24	0.05	0.11	0.53
<b>CD</b>	0.52	0.10	0.24	1.12
<b>C x N ; SEd</b>	0.34	0.07	0.16	0.74
<b>CD</b>	0.73	0.14	0.34	NS

NS = Not significant

CD - (P=0.05)

The mean having the same alphabet are not significantly different at 5 % level.

**Table 26a. Interaction effect between cultivars and nitrogen levels at 75 DAS on mean plant height (cm) of cotton during 1994 - '95**

	N <sub>1</sub>	N <sub>2</sub>	N <sub>3</sub>	Mean
<b>C<sub>1</sub></b>	69.94	76.35	80.36	75.55
<b>C<sub>2</sub></b>	60.19	67.21	74.08	67.16
<b>Mean</b>	65.06	71.78	77.22	

**SEd**

0.16

**CD (P=0.05)**

0.34

Between the two cultivars, TCHB 213 had recorded taller plants (87.72 cm) throughout the crop growth than MCU 11.

The levels of nitrogen application had increased the plant growth positively. Significant difference in plant height was observed upto 200 per cent of recommended level of nitrogen application. Taller plants (91.40 cm at 90 DAS) were observed under higher level of nitrogen over the lower levels.

Interaction was significant at all the growth stages except at 90 DAS. The data on interaction between cultivars and nitrogen levels are presented in Table 26a.

Both cultivars and nitrogen levels were significantly different from each other at the same level of other factor. TCHB 213 had grown taller (80.36 cm) under 200 per cent of recommended nitrogen level than other lower levels.

#### **4.2.1.2. Leaf Area Index (LAI)**

The data recorded on LAI of cotton during third year of study are presented in Table 27.

The LAI had increased with ageing of cotton plants.

Between the two cultivars, TCHB 213 (C<sub>1</sub>) had produced more LAI (4.98 at 90 DAS) than MCU 11 (C<sub>2</sub>) (4.54) throughout.

The levels of nitrogen had increased the LAI at a decreasing rate from 100 to 200 per cent of recommendation. The rate of increase in LAI between 45 and 60 DAS was around 150 per cent at all the three levels of nitrogen

**Table 27. Effect of treatments on mean LAI of cotton during 1994 - '95**

	1994-'95			
	45 DAS	60 DAS	75 DAS	90 DAS
<b>C<sub>1</sub></b>	1.40 <sup>a</sup>	3.68 <sup>a</sup>	4.36 <sup>a</sup>	4.98 <sup>a</sup>
<b>C<sub>2</sub></b>	1.28 <sup>b</sup>	3.18 <sup>b</sup>	3.64 <sup>b</sup>	4.54 <sup>b</sup>
<b>SEd</b>	0.03	0.012	0.018	0.017
<b>CD</b>	0.06	0.02	0.025	0.023
<b>N<sub>1</sub></b>	1.28 <sup>c</sup>	3.16 <sup>c</sup>	3.62 <sup>c</sup>	4.31 <sup>c</sup>
<b>N<sub>2</sub></b>	1.34 <sup>b</sup>	3.43 <sup>b</sup>	4.05 <sup>b</sup>	4.82 <sup>b</sup>
<b>N<sub>3</sub></b>	1.40 <sup>a</sup>	3.69 <sup>a</sup>	4.34 <sup>a</sup>	5.14 <sup>a</sup>
<b>SEd</b>	0.04	0.015	0.023	0.021
<b>CD</b>	0.08	0.021	0.031	0.029
<b>C x N ; SEd</b>	0.05	0.021	0.032	0.029
<b>CD</b>	NS	0.03	0.044	0.041

NS - Not significant

CD - (P=0.05)

The mean having the same alphabet are not significantly different at 5 % level.

**Table 27a. Interaction effect between cultivars and nitrogen levels at 75 DAS on mean LAI of cotton during 1994 - '95**

	<b>N<sub>1</sub></b>	<b>N<sub>2</sub></b>	<b>N<sub>3</sub></b>	<b>Mean</b>
<b>C<sub>1</sub></b>	4.03	4.44	4.62	4.36
<b>C<sub>2</sub></b>	3.21	3.66	4.06	3.64
<b>Mean</b>	3.62	4.05	4.34	

**SEd**  
0.032

**CD (P=0.05)**  
0.044

while the rate of increase in LAI between 60 and 75 and between 75 and 90 was less than 20 per cent. The highest LAI of 5.14 was recorded at 200 per cent of nitrogen level.

Interaction between cultivars and nitrogen level was significant at all the growth stages except at 45 DAS. The data on interaction between C x N at 75 DAS are presented in Table 27a.

TCHB 213 ( $C_1$ ) had, produced higher LAI (4.62) under 200 per cent nitrogen level, while it was 4.06 for the cultivar MCU 11 ( $C_2$ ).

#### **4.2.1.3. Dry matter production (DMP) ( $\text{kg ha}^{-1}$ )**

The data recorded on DMP of cotton during third year of experimentation are presented in Table 28.

Both the cultivars had recorded higher DMP with advancement of crop growth. At all the growth stages, TCHB 213 had produced more DMP ( $4792 \text{ kg ha}^{-1}$  at 90 DAS) than MCU 11 ( $C_2$ ) ( $3912 \text{ kg ha}^{-1}$ ).

The levels of nitrogen applied were significantly different from each other at all the growth stages. The DMP was higher at 200 per cent level ( $4661 \text{ kg ha}^{-1}$  at 90 DAS) than at lower levels. The rate of increase was decreasing from 100 to 200 per cent of nitrogen application.

The interaction was significant at 45 and 75 DAS only. The data on interaction obtained at 75 DAS are presented in Table 28a.

Table 28. Effect of treatments on mean DMP ( $\text{kg ha}^{-1}$ ) of cotton during 1994 - '95

	1994-'95			
	45 DAS	60 DAS	75 DAS	90 DAS
<b>C<sub>1</sub></b>	768 <sup>a</sup>	2044 <sup>a</sup>	3707 <sup>a</sup>	4792 <sup>a</sup>
<b>C<sub>2</sub></b>	697 <sup>b</sup>	1760 <sup>b</sup>	3001 <sup>b</sup>	3912 <sup>b</sup>
<b>SEd</b>	6.64	63.00	54.47	36.85
<b>CD</b>	9.18	87.10	75.31	50.95
<b>N<sub>1</sub></b>	690 <sup>c</sup>	1602 <sup>c</sup>	2867 <sup>c</sup>	4005 <sup>c</sup>
<b>N<sub>2</sub></b>	732 <sup>b</sup>	1939 <sup>b</sup>	3471 <sup>b</sup>	4391 <sup>b</sup>
<b>N<sub>3</sub></b>	775 <sup>a</sup>	2165 <sup>a</sup>	3723 <sup>a</sup>	4661 <sup>a</sup>
<b>SEd</b>	8.13	77.16	66.72	45.13
<b>CD</b>	11.24	106.67	92.23	62.39
<b>C x N ; SEd</b>	11.50	109.12	44.26	63.83
<b>CD</b>	15.96	NS	94.15	NS

NS - Not significant

CD - (P=0.05)

The mean having the same alphabet are not significantly different at 5 % level.

Table 28a. Interaction effect between cultivars and nitrogen levels at 75 DAS on mean DMP  $\text{kg ha}^{-1}$  of cotton during 1994 - '95

	N <sub>1</sub>	N <sub>2</sub>	N <sub>3</sub>	Mean
<b>C<sub>1</sub></b>	3296	3776	4048	3707
<b>C<sub>2</sub></b>	2439	3166	3397	3001
<b>Mean</b>	2868	3471	3723	

**SEd**  
44.26

**CD (P=0.05)**  
94.35

TCHB 213 ( $C_1$ ) had registered higher biomass ( $4048 \text{ kg ha}^{-1}$ ) under 200 per cent of nitrogen level than at lower levels and also than MCU 11 ( $C_2$ ) at the same level.

#### 4.2.1.4. Ground cover (%)

The data recorded on ground cover by the cotton canopy during third year of experiment are presented in Table 29.

Between the two cultivars studied, TCHB 213 ( $C_1$ ) was more efficient in covering the ground at all the growth stages than MCU 11 ( $C_2$ ). TCHB 213 ( $C_1$ ) had covered the ground surface upto 80.63 per cent at 90 DAS while MCU 11 had covered only 70.34 per cent at the same stage.

The three levels of nitrogen tested had produced significantly different ground cover at all the growth stages. Increasing levels of nitrogen had also enhanced the ground cover. Two hundred per cent of nitrogen level had produced higher ground cover throughout and was maximum at 90 DAS (81.38 per cent).

The interaction was significant at all the growth stages. The data on interaction at 75 DAS are given in Table 29a.

Both the cultivars were significantly different at all the three levels of nitrogen and all the levels of nitrogen were significantly different under both the cultivars in respect of covering the ground surface. TCHB 213 ( $C_1$ ) had

Table 29. Effect of treatments on mean canopy ground coverage (%) of cotton during 1994 - '95

	1994-'95			
	45 DAS	60 DAS	75 DAS	90 DAS
C <sub>1</sub>	43.86 <sup>a</sup>	56.08 <sup>a</sup>	69.16 <sup>a</sup>	80.63 <sup>a</sup>
C <sub>2</sub>	40.07 <sup>b</sup>	48.90 <sup>b</sup>	60.92 <sup>b</sup>	70.34 <sup>b</sup>
SEd	0.52	0.09	0.16	0.04
CD	1.12	0.20	0.34	0.08
N <sub>1</sub>	38.30 <sup>c</sup>	47.81 <sup>c</sup>	59.15 <sup>c</sup>	69.51 <sup>c</sup>
N <sub>2</sub>	42.84 <sup>b</sup>	53.41 <sup>b</sup>	65.64 <sup>b</sup>	75.57 <sup>b</sup>
N <sub>3</sub>	44.76 <sup>a</sup>	56.26 <sup>a</sup>	70.32 <sup>a</sup>	81.38 <sup>a</sup>
SEd	0.64	0.11	0.20	0.04
CD	1.37	0.24	0.42	0.09
C x N ; SEd	0.91	0.16	0.28	0.06
CD	2.67	0.34	0.83	0.13

NS - Not significant

CD - (P=0.05)

The mean having the same alphabet are not significantly different at 5 % level.

Table 29a. Interaction effect between cultivars and nitrogen levels at 75 DAS on mean canopy ground cover (%) of cotton during 1994 - '95

	N <sub>1</sub>	N <sub>2</sub>	N <sub>3</sub>	Mean
C <sub>1</sub>	63.10	69.97	74.41	69.16
C <sub>2</sub>	55.20	61.32	66.23	60.92
Mean	59.15	65.65	70.32	

SEd

0.28

CD (P=0.05)

0.83

produced higher ground coverage (74.41 per cent) under 200 per cent level of nitrogen application.

#### **4.2.1.5. Plant nitrogen content (%)**

The data recorded on plant nitrogen content of third year experiment are presented in Table 30.

Both the cultivars had significantly different nitrogen percentage at all the growth stages. Cultivar TCHB 213 ( $C_1$ ) had more nitrogen content (1.43 per cent at 90 DAS) than MCU 11 ( $C_2$ ) at the same stage (1.34 per cent).

The increasing levels of nitrogen had also increased the nitrogen content of cotton plants. The three levels were significantly different from each other at all the growth stages. The plant nitrogen content had increased at a decreasing rate from 100 to 200 per cent of nitrogen level. Maximum nitrogen content of 1.43 per cent was recorded at 90 DAS under higher (200 per cent) level of nitrogen application to cotton.

The interaction was significant at 45 and 75 DAS only. The data on interaction at 75 DAS between cultivars and nitrogen levels are presented in Table 30a.

The cultivar TCHB 213 had recorded higher level of nitrogen content (1.45 per cent) than MCU 11 (1.32 per cent) at the highest level (200 per cent of recommended level) of nitrogen application.

**Table 30. Effect of treatments on mean plant nitrogen content (%) of cotton during 1994 - '95**

	1994-'95			
	45 DAS	60 DAS	75 DAS	90 DAS
<b>C<sub>1</sub></b>	1.26 <sup>a</sup>	1.36 <sup>a</sup>	1.41 <sup>a</sup>	1.43 <sup>a</sup>
<b>C<sub>2</sub></b>	1.18 <sup>b</sup>	1.26 <sup>b</sup>	1.29 <sup>b</sup>	1.34 <sup>b</sup>
<b>SEd</b>	0.003	0.008	0.006	0.01
<b>CD</b>	0.004	0.01	0.008	0.013
<b>N<sub>1</sub></b>	1.16 <sup>c</sup>	1.24 <sup>c</sup>	1.31 <sup>c</sup>	1.34 <sup>c</sup>
<b>N<sub>2</sub></b>	1.22 <sup>b</sup>	1.30 <sup>b</sup>	1.35 <sup>b</sup>	1.39 <sup>b</sup>
<b>N<sub>3</sub></b>	1.28 <sup>a</sup>	1.35 <sup>a</sup>	1.39 <sup>a</sup>	1.43 <sup>a</sup>
<b>SEd</b>	0.004	0.01	0.007	0.011
<b>CD</b>	0.005	0.013	0.01	0.02
<b>C x N ; SEd</b>	0.005	0.014	0.005	0.02
<b>CD</b>	0.01	NS	0.01	NS

NS - Not significant

CD - (P=0.05)

The mean having the same alphabet are not significantly different at 5 % level.

**Table 30a. Interaction effect between cultivars and nitrogen levels at 75 DAS on mean plant nitrogen content (%) of cotton during 1994 - '95**

	N <sub>1</sub>	N <sub>2</sub>	N <sub>3</sub>	Mean
<b>C<sub>1</sub></b>	1.36	1.40	1.45	1.40
<b>C<sub>2</sub></b>	1.25	1.30	1.32	1.29
<b>Mean</b>	1.31	1.35	1.39	

**SEd**  
0.005

**CD (P=0.05)**  
0.01

#### 4.2.1.6. Chlorophyll "a", "b" and total content ( $\text{mg g}^{-1}$ )

The data recorded on chlorophyll a, b and total contents are presented in Tables 31, 32 and 33.

The chlorophyll contents (a, b and total) got increased with increase in crop age.

The two cultivars were significantly different from each other in respect chlorophyll (a, b and total) contents at all the growth stages. Cultivar TCHB 213 ( $C_1$ ) had recorded higher chlorophyll content throughout the experimentation. At 90 DAS, maximum amount of chlorophyll (a : 2.98; b : 1.40 and total :  $4.21 \text{ mg g}^{-1}$ ) was recorded in TCHB 213.

The levels of nitrogen application had also increased the chlorophyll contents positively. The three levels of nitrogen were significantly different from each other at all the growth stages except for chlorophyll a at 75 DAS and chlorophyll b at 60 DAS. At 90 DAS maximum content of chlorophyll (a : 3.01; b : 1.47 and total :  $4.49 \text{ mg g}^{-1}$ ) was recorded under 200 per cent of nitrogen application.

Interaction existed between cultivars and nitrogen levels in chlorophyll contents. At 75 DAS the interaction was significant in respect of chlorophyll b, but not with chlorophyll "a" and total.

The data on interaction between C x N in respect of chlorophyll b are presented in Table 32a.

Table 31. Effect of treatments on mean chlorophyll 'a' content ( $\text{mg g}^{-1}$ ) of cotton during 1994 - '95

	1994-'95			
	45 DAS	60 DAS	75 DAS	90 DAS
<b>C<sub>1</sub></b>	2.42 <sup>a</sup>	2.45 <sup>a</sup>	2.65 <sup>a</sup>	2.98 <sup>a</sup>
<b>C<sub>2</sub></b>	2.13 <sup>b</sup>	2.20 <sup>b</sup>	2.40 <sup>b</sup>	2.62 <sup>b</sup>
<b>SEd</b>	0.015	0.10	0.08	0.11
<b>CD</b>	0.02	0.14	0.11	0.16
<b>N<sub>1</sub></b>	1.92 <sup>c</sup>	2.04 <sup>c</sup>	2.33 <sup>b</sup>	2.62 <sup>c</sup>
<b>N<sub>2</sub></b>	2.31 <sup>b</sup>	2.36 <sup>b</sup>	2.57 <sup>a</sup>	2.78 <sup>b</sup>
<b>N<sub>3</sub></b>	2.60 <sup>a</sup>	2.59 <sup>a</sup>	2.67 <sup>a</sup>	3.01 <sup>a</sup>
<b>SEd</b>	0.019	0.12	0.10	0.14
<b>CD</b>	0.03	0.17	0.14	0.19
<b>C x N ; SEd</b>	0.03	0.18	0.14	0.20
<b>CD</b>	0.04	0.24	NS	NS

NS - Not significant

CD - (P=0.05)

The mean having the same alphabet are not significantly different at 5 % level.

Table 32. Effect of treatments on mean chlorophyll 'b' content ( $\text{mg g}^{-1}$ ) of cotton during 1994 - '95

	1994-'95			
	45 DAS	60 DAS	75 DAS	90 DAS
C <sub>1</sub>	1.08 <sup>a</sup>	1.21 <sup>a</sup>	1.29 <sup>a</sup>	1.40 <sup>a</sup>
C <sub>2</sub>	0.99 <sup>b</sup>	1.11 <sup>b</sup>	1.22 <sup>b</sup>	1.36 <sup>b</sup>
SEd	0.008	0.04	0.004	0.002
CD	0.012	0.05	0.01	0.003
N <sub>1</sub>	0.91 <sup>c</sup>	1.08 <sup>b</sup>	1.17 <sup>c</sup>	1.28 <sup>c</sup>
N <sub>2</sub>	1.03 <sup>b</sup>	1.18 <sup>a</sup>	1.26 <sup>b</sup>	1.40 <sup>b</sup>
N <sub>3</sub>	1.15 <sup>a</sup>	1.22 <sup>a</sup>	1.33 <sup>a</sup>	1.47 <sup>a</sup>
SEd	0.01	0.05	0.004	0.002
CD	0.014	0.06	0.01	0.003
C x N ; SEd	0.015	0.06	0.003	0.003
CD	0.02	NS	0.006	0.004

NS - Not significant

CD - (P=0.05)

The mean having the same alphabet are not significantly different at 5 % level.

Table 32a. Interaction effect between cultivars and nitrogen levels at 75 DAS of mean chlorophyll "b: content of cotton during 1994 - '95

	N <sub>1</sub>	N <sub>2</sub>	N <sub>3</sub>	Mean
C <sub>1</sub>	1.19	1.30	1.38	1.29
C <sub>2</sub>	1.16	1.21	1.28	1.22
Mean	1.18	1.26	1.33	

SEd  
0.003

CD (P=0.05)  
0.006

Table 33. Effect of treatments on mean total chlorophyll content ( $\text{mg g}^{-1}$ ) of cotton during 1994 - '95

	1994-'95			
	45 DAS	60 DAS	75 DAS	90 DAS
<b>C<sub>1</sub></b>	3.51 <sup>a</sup>	3.69 <sup>a</sup>	4.01 <sup>a</sup>	4.21 <sup>a</sup>
<b>C<sub>2</sub></b>	3.12 <sup>b</sup>	3.29 <sup>b</sup>	3.64 <sup>b</sup>	3.87 <sup>b</sup>
<b>SEd</b>	0.02	0.05	0.04	0.06
<b>CD</b>	0.05	0.11	0.09	0.13
<b>N<sub>1</sub></b>	2.81 <sup>c</sup>	3.15 <sup>c</sup>	3.52 <sup>c</sup>	3.84 <sup>c</sup>
<b>N<sub>2</sub></b>	3.36 <sup>b</sup>	3.57 <sup>b</sup>	3.84 <sup>b</sup>	4.14 <sup>b</sup>
<b>N<sub>3</sub></b>	3.79 <sup>a</sup>	3.84 <sup>a</sup>	3.94 <sup>a</sup>	4.49 <sup>a</sup>
<b>SEd</b>	0.008	0.07	0.01	0.06
<b>CD</b>	0.017	0.15	0.03	0.13
<b>C x N ; SEd</b>	0.04	0.07	0.12	0.06
<b>CD</b>	0.09	0.14	NS	NS

NS - Not significant

CD - (P=0.05)

The mean having the same alphabet are not significantly different at 5 % level.

Both the cultivars TCHB 213 (1.38) and MCU 11 (1.28) had recorded higher level of chlorophyll 'b' content under 200 per cent of nitrogen application, but were significantly different from each other.

#### **4.2.1.7. Leaf thickness (mg cm<sup>2</sup>)**

The data recorded on leaf thickness of cotton plants are presented in Table 34.

There was variation in leaf thickness between stages. A trend of reduction in leaf thickness from 45 DAS to 60 DAS was observed and thereafter started increasing.

Between the two cultivars studied, TCHB 213 (C<sub>1</sub>) had thicker leaves throughout than MCU 11 (C<sub>2</sub>). For TCHB 213 (C<sub>1</sub>) the leaves were thicker (6.55) at 90 DAS, while for MCU 11, at 90 DAS the leaf thickness was 5.13.

The levels of nitrogen application were significantly different from each other at all the growth stages. The leaf thickness decreased from 45 DAS to 75 DAS and then got increased. At all the stages, 200 per cent of nitrogen application had produced thicker leaves and at all the levels of nitrogen application higher leaf thickness was recorded at 45 DAS (5.52 - N<sub>1</sub>, 6.06 - N<sub>2</sub> and 6.27 - N<sub>3</sub>).

Interaction was absent.

#### **4.2.1.8. Leaf angle (°)**

The data recorded on angle between main stem and individual leaf, in degrees, are presented in Table 35.

Table 34. Effect of treatments on mean leaf thickness ( $\text{mg cm}^{-2}$ ) of cotton during 1994 - '95

	1994-'95			
	45 DAS	60 DAS	75 DAS	90 DAS
C <sub>1</sub>	6.21 <sup>a</sup>	5.80 <sup>a</sup>	5.87 <sup>a</sup>	6.55 <sup>a</sup>
C <sub>2</sub>	5.61 <sup>b</sup>	4.53 <sup>b</sup>	4.55 <sup>b</sup>	5.13 <sup>b</sup>
SEd	0.08	0.14	0.03	0.29
CD	0.16	0.29	0.07	0.62
N <sub>1</sub>	5.52 <sup>c</sup>	4.80 <sup>c</sup>	4.57 <sup>c</sup>	5.47 <sup>c</sup>
N <sub>2</sub>	6.06 <sup>b</sup>	5.23 <sup>b</sup>	5.05 <sup>b</sup>	5.89 <sup>b</sup>
N <sub>3</sub>	6.27 <sup>a</sup>	5.47 <sup>a</sup>	5.43 <sup>a</sup>	6.17 <sup>a</sup>
SEd	0.09	0.10	0.04	0.13
CD	0.20	0.22	0.09	0.27
C x N ; SEd	0.13	0.24	0.06	0.50
CD	NS	NS	NS	NS

NS - Not significant

CD - (P=0.05)

The mean having the same alphabet are not significantly different at 5 % level.

Table 35. Effect of treatments on mean leaf angle (°) of cotton during 1994 - '95

	1994-'95			
	45 DAS	60 DAS	75 DAS	90 DAS
<b>C<sub>1</sub></b>	51.19 <sup>a</sup>	50.60 <sup>a</sup>	52.08 <sup>a</sup>	52.81 <sup>a</sup>
<b>C<sub>2</sub></b>	43.26 <sup>b</sup>	37.36 <sup>b</sup>	40.61 <sup>b</sup>	42.56 <sup>b</sup>
<b>SEd</b>	0.47	0.51	0.40	0.27
<b>CD</b>	1.01	0.71	0.55	0.38
<b>N<sub>1</sub></b>	40.81 <sup>c</sup>	42.59 <sup>c</sup>	44.83 <sup>c</sup>	45.99 <sup>c</sup>
<b>N<sub>2</sub></b>	43.53 <sup>b</sup>	43.95 <sup>b</sup>	46.44 <sup>b</sup>	47.58 <sup>b</sup>
<b>N<sub>3</sub></b>	46.60 <sup>a</sup>	47.40 <sup>a</sup>	47.78 <sup>a</sup>	49.50 <sup>a</sup>
<b>SEd</b>	0.54	0.63	0.48	0.33
<b>CD</b>	1.13	0.87	0.67	0.46
<b>C x N ; SEd</b>	0.68	0.89	0.68	0.47
<b>CD</b>	NS	NS	NS	NS

NS - Not significant

CD - (P=0.05)

The mean having the same alphabet are not significantly different at 5 % level.

The leaf angle decreased between 45 and 60 DAS and then gradually started increasing.

Between the two cultivars, TCHB 213 ( $C_1$ ) had more horizontal leaves ( $52.81^\circ$  at 90 DAS) comparatively than the cultivar MCU 11 ( $42.56^\circ$ ). Throughout the growth period TCHB 213 ( $C_1$ ) had produced leaves tilted more towards horizontal position than MCU 11 ( $C_2$ ).

The levels of nitrogen application had influenced leaf angle and were significantly different from each other at all the growth stages of observation. The leaf angle gradually increased from 45 DAS onwards through 90 DAS. Two hundred per cent of nitrogen application (90 DAS) had produced more horizontal ( $49.50^\circ$ ) leaves than other lower levels studied.

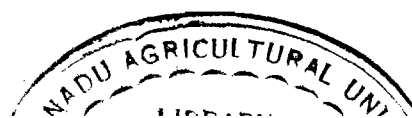
No interaction existed between cultivars and nitrogen levels throughout the crop growth stages observed.

#### **4.2.1.9. Leaf water content (%)**

The data recorded on leaf water content of cotton plants are presented in Table 36.

The leaf water content continued to increase with increase in crop age.

The two cultivars taken for study differed significantly from each other at all the growth stages. The cultivar TCHB 213 had more leaf water (82.45 per cent at 90 DAS) than the other cultivar MCU 11 (78.14 per cent) at the same age.



**Table 36. Effect of treatments on mean leaf water content (%) of cotton during 1994 - '95**

	1994-'95			
	45 DAS	60 DAS	75 DAS	90 DAS
<b>C<sub>1</sub></b>	73.40	75.46	79.82	82.45
<b>C<sub>2</sub></b>	71.10	73.15	76.40	78.14
<b>SEd</b>	0.91	0.97	1.22	1.47
<b>CD</b>	1.94	2.05	2.56	3.20
<b>N<sub>1</sub></b>	72.15	73.10	75.17	76.32
<b>N<sub>2</sub></b>	75.20	76.10	78.14	79.14
<b>N<sub>3</sub></b>	77.60	78.24	80.75	81.15
<b>SEd</b>	0.78	0.97	0.96	0.67
<b>CD</b>	1.67	2.01	2.03	1.40
<b>C x N ; SEd</b>	1.13	1.41	1.21	1.27
<b>CD</b>	NS	NS	NS	NS

NS - Not significant

CD - (P=0.05)

The mean having the same alphabet are not significantly different at 5 % level.

Applied levels of nitrogen had influenced leaf water content positively and significantly at all the growth stages of observation. Two hundred per cent of nitrogen application had increased the leaf water content to a maximum of 81.15 per cent at 90 DAS as compared to other levels at the same age.

Interaction was absent.

#### **4.3. Canopy spectral reflectance**

The spectral reflectance data collected during the three years of study, (1992-'93, 1993-'94 and 1994-'95 at 45, 60, 75 and 90 DAS) are presented in Tables 37, 38 and 39.

The spectral reflectance continued to increase with increase in crop growth stages in blue, green and infrared bands. Where as, in general, a reverse trend was observed in red band during all the three years under investigation.

In respect of planting pattern, eventhough the treatments were discriminated in blue band from 45 DAS onwards during both the first and second years of study the discrimination was varying.

In green band, the treatments were non-significant at 45 DAS and were discriminated significantly from 60 DAS onwards during first year, while during second year, significant discrimination was observed from 45 DAS onwards. However, in the two years period at 60 and 90 DAS, paired

Table 37. Effect of treatments on spectral reflectance (%) of cotton during 1992 - '93

Stages	45 DAS						60 DAS						75 DAS						90 DAS					
	B	G	R	IR	B	G	B	G	R	IR	B	G	B	G	R	IR	B	G	B	G	R	IR		
Main : P <sub>1</sub>	5.87 <sup>c</sup>	6.60	14.33 <sup>a</sup>	30.96 <sup>b</sup>	11.16 <sup>b</sup>	13.26 <sup>b</sup>	15.51 <sup>b</sup>	42.75 <sup>b</sup>	16.43 <sup>c</sup>	17.41 <sup>b</sup>	10.3 <sup>b</sup>	48.56 <sup>b</sup>	21.43 <sup>b</sup>	22.95 <sup>c</sup>	6.14 <sup>c</sup>	59.40 <sup>b</sup>								
P <sub>2</sub>	6.81 <sup>a</sup>	6.68	13.23 <sup>b</sup>	30.87 <sup>c</sup>	10.32 <sup>c</sup>	12.64 <sup>c</sup>	18.53 <sup>a</sup>	39.62 <sup>c</sup>	16.81 <sup>b</sup>	18.47 <sup>a</sup>	11.64 <sup>a</sup>	46.97 <sup>c</sup>	23.81 <sup>a</sup>	24.55 <sup>b</sup>	9.49 <sup>a</sup>	57.81 <sup>c</sup>								
P <sub>3</sub>	6.21 <sup>b</sup>	6.71	10.83 <sup>c</sup>	32.29 <sup>a</sup>	12.46 <sup>a</sup>	14.23 <sup>a</sup>	15.14 <sup>c</sup>	44.99 <sup>a</sup>	17.18 <sup>a</sup>	18.52 <sup>a</sup>	10.27 <sup>c</sup>	49.59 <sup>a</sup>	22.35 <sup>c</sup>	25.15 <sup>a</sup>	7.35 <sup>b</sup>	60.72 <sup>a</sup>								
SEd	0.01	0.08	0.004	0.01	0.19	0.21	0.13	0.31	0.07	0.17	0.02	0.01	0.11	0.19	0.06	0.01								
CD	0.02	NS	0.009	0.02	0.42	0.47	0.03	0.69	0.17	0.38	0.04	0.02	0.24	0.43	0.14	0.03								
C <sub>1</sub>	6.89 <sup>a</sup>	7.58 <sup>a</sup>	15.18 <sup>a</sup>	33.86 <sup>a</sup>	12.49 <sup>a</sup>	14.69 <sup>a</sup>	17.86 <sup>a</sup>	45.36 <sup>a</sup>	17.90 <sup>a</sup>	18.89 <sup>a</sup>	12.51 <sup>a</sup>	52.10 <sup>a</sup>	24.30 <sup>a</sup>	25.60 <sup>a</sup>	8.87 <sup>a</sup>	65.24 <sup>a</sup>								
C <sub>2</sub>	5.70 <sup>b</sup>	5.74 <sup>b</sup>	10.41 <sup>b</sup>	28.89 <sup>b</sup>	10.14 <sup>b</sup>	12.06 <sup>b</sup>	14.93 <sup>b</sup>	39.55 <sup>b</sup>	15.72 <sup>b</sup>	17.37 <sup>b</sup>	8.96 <sup>b</sup>	44.64 <sup>b</sup>	22.76 <sup>b</sup>	22.83 <sup>b</sup>	6.94 <sup>b</sup>	53.38 <sup>b</sup>								
SEd	0.006	0.06	0.003	0.01	0.16	0.17	0.01	0.25	0.06	0.14	0.01	0.01	0.09	0.16	0.05	0.01								
CD	0.013	0.14	0.01	0.02	0.35	0.38	0.02	0.57	0.14	0.31	0.03	0.02	0.19	0.35	0.11	0.03								
Sub : N <sub>1</sub>	5.32 <sup>d</sup>	5.92 <sup>d</sup>	14.64 <sup>a</sup>	28.80 <sup>d</sup>	10.38 <sup>d</sup>	11.91 <sup>d</sup>	18.63 <sup>a</sup>	40.05 <sup>d</sup>	15.28 <sup>d</sup>	16.86 <sup>d</sup>	11.98 <sup>a</sup>	43.83 <sup>d</sup>	19.41 <sup>d</sup>	21.33 <sup>d</sup>	9.71 <sup>a</sup>	53.77 <sup>d</sup>								
N <sub>2</sub>	5.92 <sup>c</sup>	6.12 <sup>c</sup>	13.41 <sup>b</sup>	29.77 <sup>c</sup>	10.90 <sup>c</sup>	13.07 <sup>c</sup>	16.82 <sup>b</sup>	42.08 <sup>c</sup>	16.33 <sup>c</sup>	17.93 <sup>c</sup>	11.10 <sup>b</sup>	46.59 <sup>c</sup>	20.47 <sup>c</sup>	23.00 <sup>c</sup>	7.91 <sup>b</sup>	57.42 <sup>c</sup>								
N <sub>3</sub>	6.82 <sup>b</sup>	7.13 <sup>b</sup>	12.26 <sup>c</sup>	32.16 <sup>b</sup>	11.63 <sup>b</sup>	13.94 <sup>b</sup>	15.67 <sup>c</sup>	43.07 <sup>b</sup>	17.25 <sup>b</sup>	18.98 <sup>b</sup>	10.36 <sup>c</sup>	49.80 <sup>b</sup>	21.26 <sup>b</sup>	25.05 <sup>b</sup>	7.07 <sup>c</sup>	61.07 <sup>b</sup>								
N <sub>4</sub>	7.12 <sup>a</sup>	7.49 <sup>a</sup>	10.87 <sup>d</sup>	34.76 <sup>a</sup>	12.36 <sup>a</sup>	14.58 <sup>a</sup>	14.47 <sup>d</sup>	44.61 <sup>a</sup>	18.38 <sup>a</sup>	19.85 <sup>a</sup>	9.50 <sup>d</sup>	53.28 <sup>a</sup>	22.00 <sup>a</sup>	27.49 <sup>a</sup>	5.75 <sup>d</sup>	64.98 <sup>a</sup>								
SEd	0.013	0.08	0.01	0.01	0.06	0.24	0.01	0.10	0.09	0.42	0.02	0.01	0.11	0.22	0.07	0.02								
CD	0.025	0.16	0.02	0.03	0.12	0.49	0.03	0.20	0.18	0.85	0.04	0.03	0.22	0.45	0.14	0.03								
PxN : SEd	0.01	0.11	0.01	0.02	0.27	0.30	0.02	0.44	0.11	0.24	0.03	0.01	0.15	0.27	0.09	0.02								
CD	0.02	0.24	0.01	0.04	0.60	0.66	0.04	0.98	NS	0.54	0.06	0.03	NS	NS	0.20	0.04								
PxN : SEd	0.02	0.14	0.01	0.02	0.21	0.42	0.03	0.34	0.16	0.65	0.03	0.02	0.19	0.39	0.12	0.12								
CD	0.04	0.30	0.02	0.05	0.46	NS	0.05	0.75	NS	NS	0.07	0.05	NS	NS	0.25	0.26								
CxN : SEd	0.017	0.12	0.01	0.02	0.17	0.34	0.02	0.28	0.13	0.53	0.03	0.02	0.16	0.32	0.10	0.02								
CD	0.034	0.24	0.02	0.04	NS	0.71	0.04	0.62	0.26	NS	0.06	0.04	0.33	0.66	0.20	0.05								

CD (P = 0.05)

NS = Not significant

B = Blue; G = Green; R = Red; IR = Infrared red

Table 38. Effect of treatments on spectral reflectance (%) of cotton during 1993 - '94

Stages	45 DAS						60 DAS						75 DAS						90 DAS						
	B	G	R	IR	B	G	R	IR	B	G	R	IR	B	G	R	IR	B	G	R	IR	B	G	R	IR	
Main : P <sub>1</sub>	6.17 <sup>b</sup>	7.04 <sup>a</sup>	18.91 <sup>a</sup>	34.16 <sup>b</sup>	11.58 <sup>b</sup>	13.43 <sup>b</sup>	16.38 <sup>b</sup>	42.77 <sup>b</sup>	16.88 <sup>b</sup>	18.52 <sup>a</sup>	13.75 <sup>b</sup>	50.74 <sup>b</sup>	23.92 <sup>a</sup>	24.69 <sup>b</sup>	10.10 <sup>c</sup>	57.83 <sup>b</sup>									
P <sub>2</sub>	5.38 <sup>c</sup>	6.20 <sup>b</sup>	17.73 <sup>b</sup>	31.73 <sup>c</sup>	10.61 <sup>c</sup>	12.46 <sup>c</sup>	18.53 <sup>a</sup>	39.55 <sup>c</sup>	15.40 <sup>c</sup>	16.61 <sup>b</sup>	15.85 <sup>a</sup>	46.72 <sup>c</sup>	21.84 <sup>c</sup>	23.48 <sup>c</sup>	13.46 <sup>a</sup>	54.44 <sup>c</sup>									
P <sub>3</sub>	6.26 <sup>a</sup>	7.24 <sup>a</sup>	13.72 <sup>c</sup>	34.67 <sup>a</sup>	12.51 <sup>a</sup>	14.25 <sup>a</sup>	15.21 <sup>c</sup>	44.6 <sup>a</sup>	17.28 <sup>a</sup>	18.71 <sup>a</sup>	13.11 <sup>c</sup>	51.98 <sup>a</sup>	22.97 <sup>b</sup>	25.30 <sup>a</sup>	11.30 <sup>b</sup>	60.66 <sup>a</sup>									
SEd	0.006	0.07	0.05	0.09	0.06	0.08	0.18	0.15	0.07	0.11	0.17	0.04	0.20	0.04	0.11	0.06									
CD	0.01	0.14	0.11	0.20	0.13	0.18	0.41	0.34	0.15	0.24	0.38	0.10	0.45	0.10	0.24	0.14									
C <sub>1</sub>	6.28 <sup>a</sup>	6.97 <sup>a</sup>	17.49 <sup>a</sup>	35.55 <sup>a</sup>	10.82 <sup>a</sup>	14.68 <sup>a</sup>	19.89 <sup>a</sup>	45.32 <sup>a</sup>	15.92 <sup>a</sup>	19.37 <sup>a</sup>	14.93 <sup>a</sup>	52.46 <sup>a</sup>	24.57 <sup>a</sup>	25.70 <sup>a</sup>	14.89 <sup>a</sup>	61.25 <sup>a</sup>									
C <sub>2</sub>	6.10 <sup>b</sup>	6.68 <sup>b</sup>	14.09 <sup>b</sup>	31.49 <sup>b</sup>	10.31 <sup>b</sup>	12.08 <sup>b</sup>	14.85 <sup>b</sup>	39.28 <sup>b</sup>	15.12 <sup>b</sup>	18.52 <sup>b</sup>	13.72 <sup>b</sup>	47.17 <sup>b</sup>	21.24 <sup>b</sup>	25.28 <sup>b</sup>	1.34 <sup>b</sup>	54.04 <sup>b</sup>									
SEd	0.005	0.05	0.04	0.07	0.05	0.06	0.15	0.13	0.06	0.10	0.14	0.04	0.16	0.03	0.09	0.05									
CD	0.01	0.12	0.09	0.16	0.11	0.14	0.33	0.28	0.13	0.20	0.31	0.08	0.37	0.08	0.20	0.11									
Sub : N <sub>1</sub>	5.84 <sup>d</sup>	6.44 <sup>d</sup>	18.85 <sup>a</sup>	29.94 <sup>d</sup>	10.62 <sup>d</sup>	11.93 <sup>d</sup>	18.89 <sup>a</sup>	39.83 <sup>d</sup>	14.95 <sup>d</sup>	16.43 <sup>d</sup>	15.76 <sup>a</sup>	46.93 <sup>d</sup>	20.23 <sup>d</sup>	22.53 <sup>d</sup>	13.84 <sup>a</sup>	51.78 <sup>d</sup>									
N <sub>2</sub>	5.78 <sup>c</sup>	6.56 <sup>c</sup>	17.08 <sup>b</sup>	32.07 <sup>c</sup>	10.93 <sup>c</sup>	12.09 <sup>c</sup>	16.86 <sup>b</sup>	41.94 <sup>c</sup>	15.92 <sup>c</sup>	17.18 <sup>c</sup>	14.69 <sup>b</sup>	48.62 <sup>c</sup>	21.83 <sup>c</sup>	24.03 <sup>c</sup>	12.3 <sup>b</sup>	55.71 <sup>c</sup>									
N <sub>3</sub>	6.04 <sup>b</sup>	6.83 <sup>b</sup>	16.50 <sup>c</sup>	34.64 <sup>b</sup>	11.68 <sup>b</sup>	12.88 <sup>b</sup>	15.64 <sup>c</sup>	42.76 <sup>b</sup>	17.94 <sup>b</sup>	18.54 <sup>b</sup>	13.61 <sup>c</sup>	50.53 <sup>b</sup>	23.39 <sup>b</sup>	24.26 <sup>b</sup>	11.00 <sup>c</sup>	59.27 <sup>b</sup>									
N <sub>4</sub>	6.10 <sup>a</sup>	7.48 <sup>a</sup>	14.60 <sup>d</sup>	37.43 <sup>a</sup>	12.03 <sup>a</sup>	13.82 <sup>a</sup>	14.61 <sup>d</sup>	44.68 <sup>a</sup>	18.37 <sup>a</sup>	19.62 <sup>a</sup>	13.14 <sup>d</sup>	53.18 <sup>a</sup>	26.17 <sup>a</sup>	25.93 <sup>a</sup>	9.8 <sup>d</sup>	63.82 <sup>a</sup>									
SEd	0.008	0.05	0.06	0.084	0.07	0.05	0.12	0.15	0.09	0.12	0.08	0.04	0.27	0.06	0.12	0.08									
CD	0.02	0.10	0.13	0.17	0.14	0.10	0.31	0.30	0.19	0.26	0.17	0.09	0.55	0.14	0.24	0.17									
PxC : SEd	0.008	0.09	0.07	0.13	0.08	0.11	0.26	0.22	0.09	0.15	0.24	0.06	0.28	0.06	0.15	0.09									
CD	0.02	0.21	0.16	0.28	0.18	0.25	0.57	0.49	NS	0.34	0.54	0.14	NS	0.13	0.34	0.19									
PxN : SEd	0.01	0.10	0.11	0.15	0.12	0.11	0.35	0.27	0.15	0.20	0.21	0.08	0.46	0.10	0.21	0.14									
CD	0.03	0.20	0.23	0.32	NS	NS	0.73	0.56	NS	NS	0.46	0.17	0.94	NS	0.43	0.28									
CxN : SEd	0.01	0.08	0.09	0.13	0.10	0.09	0.29	0.22	0.12	0.17	0.17	0.06	0.37	0.08	0.17	0.11									
CD	0.02	0.17	0.19	0.26	0.20	0.19	0.60	0.46	0.25	0.35	0.37	0.14	0.77	0.17	0.35	0.23									

CD (P = 0.05)

NS = Not significant

B = Blue; G = Green; R = Red; IR = Infrared red

Table 39. Effect of treatments on spectral reflectance (%) of cotton during 1994 - '95

Stages	45 DAS				60 DAS				75 DAS				90 DAS			
	B	G	R	IR	B	G	R	IR	B	G	R	IR	B	G	R	IR
Band																
C <sub>1</sub>	6.91 <sup>a</sup>	7.39 <sup>a</sup>	18.93 <sup>a</sup>	38.35 <sup>a</sup>	14.01 <sup>a</sup>	15.68 <sup>a</sup>	15.11 <sup>a</sup>	49.85 <sup>a</sup>	16.45 <sup>a</sup>	19.72 <sup>a</sup>	16.33 <sup>a</sup>	66.53 <sup>a</sup>	23.41 <sup>a</sup>	24.21 <sup>a</sup>	10.95 <sup>a</sup>	69.44 <sup>a</sup>
C <sub>2</sub>	6.80 <sup>b</sup>	7.69 <sup>b</sup>	17.38 <sup>b</sup>	31.34 <sup>b</sup>	13.46 <sup>b</sup>	15.40 <sup>b</sup>	12.91 <sup>b</sup>	47.06 <sup>b</sup>	16.86 <sup>b</sup>	19.30 <sup>b</sup>	11.82 <sup>b</sup>	52.40 <sup>b</sup>	22.54 <sup>b</sup>	21.94 <sup>b</sup>	9.44 <sup>b</sup>	60.21 <sup>b</sup>
SEd	0.04	0.06	0.20	0.25	0.05	0.04	0.015	0.17	0.03	0.07	0.20	0.52	0.18	0.25	0.09	0.47
CD	0.10	0.13	0.43	0.53	0.11	0.08	0.33	0.31	0.1	0.15	0.42	1.10	0.39	0.54	0.18	1.07
N <sub>1</sub>	6.37 <sup>c</sup>	7.38 <sup>c</sup>	19.46 <sup>a</sup>	30.78 <sup>c</sup>	12.86 <sup>c</sup>	13.74 <sup>c</sup>	15.80 <sup>a</sup>	45.92 <sup>c</sup>	15.28 <sup>b</sup>	18.09 <sup>c</sup>	15.99 <sup>a</sup>	57.79 <sup>c</sup>	20.81 <sup>c</sup>	20.95 <sup>c</sup>	11.70 <sup>a</sup>	60.53 <sup>c</sup>
N <sub>2</sub>	6.57 <sup>b</sup>	6.78 <sup>b</sup>	18.44 <sup>b</sup>	35.67 <sup>b</sup>	13.50 <sup>b</sup>	14.13 <sup>b</sup>	14.83 <sup>b</sup>	48.66 <sup>b</sup>	16.86 <sup>a</sup>	19.16 <sup>b</sup>	14.06 <sup>b</sup>	59.64 <sup>b</sup>	21.84 <sup>b</sup>	23.00 <sup>b</sup>	9.64 <sup>b</sup>	66.24 <sup>b</sup>
N <sub>3</sub>	6.74 <sup>a</sup>	8.16 <sup>a</sup>	16.56 <sup>c</sup>	36.68 <sup>a</sup>	14.06 <sup>a</sup>	15.24 <sup>a</sup>	12.60 <sup>c</sup>	52.99 <sup>a</sup>	17.63 <sup>a</sup>	20.09 <sup>a</sup>	12.48 <sup>c</sup>	66.97 <sup>a</sup>	23.28 <sup>a</sup>	25.28 <sup>a</sup>	8.34	72.24 <sup>a</sup>
SEd	0.05	0.81	0.25	0.20	0.07	0.04	0.19	0.21	0.52	0.38	0.24	0.43	0.23	0.31	0.11	0.32
CD	0.12	NS	0.52	0.45	0.16	0.10	0.40	0.44	1.12	0.90	0.52	0.85	0.48	0.66	0.22	0.93
PxC																
SEd	0.10	1.14	0.35	0.43	0.09	0.06	0.26	0.29	0.74	0.46	0.34	0.89	0.32	0.44	0.15	0.91
CD	NS	NS	NS	0.91	NS	0.13	NS	NS	NS	NS	NS	NS	0.68	0.93	0.32	NS

CD (P = 0.05)  
 NS = Not significant  
 B = Blue; G = Green; R = Red; IR = Infrared red

row with greengram intercrop ( $P_3$ ) was discriminated effectively as compared to normal ( $P_1$ ) and paired row alone ( $P_2$ ).

The three planting patterns were discriminated in red and infrared bands from 45 DAS onwards in both the years of investigation. In contrast to blue and green bands, the treatments were discriminated consistently during both the years of study in red and infrared bands.

In red band, the planting pattern, paired row with greengram intercrop ( $P_3$ ) had recorded low reflectance during 45, 60 and 75 DAS and higher reflectance at 90 DAS compared to other two planting patterns. Whereas, normal row planting ( $P_1$ ) had recorded low reflectance at 90 DAS. The planting pattern paired row pattern alone ( $P_2$ ) had recorded higher reflectance in red band from 60 DAS onwards only.

Similarly in the infrared band, the reflectance was low in treatment  $P_2$  (paired row planting alone) and high in  $P_3$  (paired row planting with greengram intercrop) in all the four stages (45, 60, 75 and 90 DAS) of observation made during both the years. Normal row planting ( $P_1$ ) had recorded an intermediary value throughout between  $P_2$  and  $P_3$  treatments.

The comprehensive analysis indicated that the planting patterns could be discriminated from 45 DAS onwards in all the bands except green. The blue and green bands were inconsistent in discriminating the planting pattern treatments while red and infrared band were consistently discriminated the planting patterns.

The discrimination was stronger in terms of absolute values at 45 DAS in red and infra-red bands.

The two cotton cultivars *viz.*, TCHB 213 and MCU 11 were discriminated in all the four bands *viz.*, blue, green, red and infrared in all the three years at all the four growth stages (45, 60, 75 and 90 DAS).

Between the two cultivars, TCHB 213 (C<sub>1</sub>) had recorded higher reflectance value than MCU 11 (C<sub>2</sub>) consistently in all the four bands, at all the four stages of the three years of study.

Among the four bands, the discrimination was stronger, in terms of absolute difference between treatments as compared to critical difference (CD) in red and infrared bands at 75 DAS.

The reflectance value continued to increase with increase in levels of nitrogen applied in blue, green and infrared band, whereas reflectance decreased with increase in nitrogen levels in red band.

Four levels of nitrogen *viz.*, 0, 50, 100 and 150 per cent of recommended level could be discriminated in all the four bands (blue, green, red and infrared) and in all the stages (45, 60, 70 and 90 DAS) during both first and second year. Similarly, in the third year, the three levels of nitrogen studied *viz.*, 100, 150 and 200 per cent of recommended level were also discriminated in the four bands at all the stages of crop growth except at 75 DAS in blue band where 150 and 200 per cent of applied nitrogen were on par.

Based on the absolute value obtained from the study, it is inferred that the levels of applied nitrogen were discriminated on 45 DAS of crop growth itself in all the four bands. However, the discrimination was more precise during 75 DAS in red and infrared bands.

The interactions between planting patterns and cultivars and between planting patterns and nitrogen levels and between cultivars and nitrogen levels were significant in both first and second years of study at 45 DAS in respect of all the bands. In the other three stages (60, 75 and 90 DAS) during first and second years interactions were significant only for red and infrared bands.

The interaction effect between cultivars and levels of nitrogen application was absent during the third year experiment.

At 75 DAS, when the discrimination was stronger compared to other stages of observation, the interaction existed in red band between planting patterns, cultivars and nitrogen levels and the data are presented for 1992-'93 and 1993-'94 in Tables 40, 41 and 42.

In the interaction between planting patterns and cultivars (Table 40), the two cultivars were significantly different from each other at all the three planting patterns. In both the cultivars, normal planting pattern ( $P_1$ ) was significantly different from  $P_2$  and  $P_3$  which were at statistical par in both first and second years. TCHB 213 ( $C_1$ ) under normal planting pattern ( $P_1$ )

**Table 40.** Interaction effect between planting patterns and cultivars at 75 DAS on mean spectral reflectance (%) of cotton in red band during 1992 - '93 and 1993 - '94

1992 - '93				
	P <sub>1</sub>	P <sub>2</sub>	P <sub>3</sub>	Mean
C <sub>1</sub>	14.08	11.73	11.72	12.51
C <sub>2</sub>	9.19	8.88	8.82	8.50
Mean	11.64	10.01	10.28	

	<b>SEd</b>	<b>CD (P=0.05)</b>
<b>P at C</b>	0.03	0.06

1993 - '94				
	P <sub>1</sub>	P <sub>2</sub>	P <sub>3</sub>	Mean
C <sub>1</sub>	17.13	14.58	16.09	14.93
C <sub>2</sub>	14.50	12.92	12.42	13.72
Mean	15.97	13.85	13.20	

	<b>SEd</b>	<b>CD (P=0.05)</b>
	0.24	0.54

Table 41. Interaction effect between planting patterns and nitrogen levels at 75 DAS on mean spectral reflectance (%) of cotton in red band during 1992 - '93 and 1993 - '94

1992 - '93

	N <sub>1</sub>	N <sub>2</sub>	N <sub>3</sub>	N <sub>4</sub>	Mean
P <sub>1</sub>	13.00	11.88	11.19	10.47	11.64
P <sub>2</sub>	11.48	10.79	9.93	9.00	10.30
P <sub>3</sub>	11.47	10.73	9.95	9.04	10.29
Mean	11.98	11.13	10.36	9.50	

	<b>SEd</b>	<b>CD (P=0.05)</b>
<b>P at N</b>	0.03	0.07
<b>N at P</b>	0.03	0.07

1993 - '94

	N <sub>1</sub>	N <sub>2</sub>	N <sub>3</sub>	N <sub>4</sub>	Mean
P <sub>1</sub>	16.86	15.92	15.38	11.83	15.75
P <sub>2</sub>	15.16	14.39	12.50	12.12	13.54
P <sub>3</sub>	15.35	13.93	11.91	11.31	13.13
Mean	15.79	11.75	13.24	13.01	

	<b>SEd</b>	<b>CD (P=0.05)</b>
<b>P at N</b>	0.21	0.46
<b>N at P</b>	0.39	0.82

**Table 42.** Interaction effect between cultivars and nitrogen levels at 75 DAS on mean spectral reflectance (%) of cotton in red band during 1992 - '93 and 1993 - '94

1992 - '93					
	N <sub>1</sub>	N <sub>2</sub>	N <sub>3</sub>	N <sub>4</sub>	Mean
C <sub>1</sub>	14.05	12.92	11.99	11.07	12.51
C <sub>2</sub>	9.92	9.28	8.72	7.94	8.97
Mean	11.98	11.10	10.34	9.51	

	SEd	CD (P=0.05)
C at N	0.03	0.06
N at C	0.03	0.06

1993 - '94					
	N <sub>1</sub>	N <sub>2</sub>	N <sub>3</sub>	N <sub>4</sub>	Mean
C <sub>1</sub>	16.51	15.38	14.34	13.49s	14.93
C <sub>2</sub>	15.01	14.00	13.08	12.79	13.72
Mean	15.76	14.69	13.71	13.14	

	SEd	CD (P=0.05)
C at N	0.17	0.37
N at C	0.12	0.24

had reflected more (14.08 and 17.13 per cent) than MCU 11 (C<sub>2</sub>) in 1992-'93 and 1993-'94.

In the interaction between planting patterns and nitrogen levels (Table 41), the levels of nitrogen application were significantly different from each other at each planting pattern. Whereas, planting patterns P<sub>2</sub> and P<sub>3</sub> were at statistical par and significantly lower than P<sub>1</sub> at all the levels of nitrogen application. The reflectance got reduced with increasing nitrogen levels in red band. More reflectance (16.86 per cent) was recorded in normal planting pattern (P<sub>1</sub>) under absolute control of nitrogen during 1993-'94.

The discrimination between cultivars and nitrogen levels (Table 42) was consistent in both the years of study. At the same level of nitrogen between the two cultivars (TCHB 213 and MCU 11), TCHB 213 had recorded higher reflectance than MCU 11. The difference in reflectance between the two cultivars at the same level of nitrogen and also the difference between levels of nutrient at same level of cultivars, decreased with increase in nitrogen level from zero to 150 per cent of recommended level.

The data on interaction between cultivars, planting patterns and nitrogen levels on spectral reflectance in infrared band at 75 DAS are presented in Tables 43, 44 and 45.

In the interaction between planting patterns and cultivars (Table 43), TCHB 213 had reflected more light than MCU 11 in all the three patterns of planting during both the years. In planting pattern P<sub>3</sub>, TCHB 213 had

**Table 43.** Interaction effect between planting patterns and cultivars at 75 DAS on mean spectral reflectance (%) of cotton in infrared band during 1992 - '93 and 1993 - '94

1992 - '93				
	P <sub>1</sub>	P <sub>2</sub>	P <sub>3</sub>	Mean
C <sub>1</sub>	52.45	50.69	53.15	52.09
C <sub>2</sub>	45.48	42.42	46.03	44.64
Mean	48.97	46.56	49.59	

SEd                      CD (P=0.05)  
0.011                      0.03

1993 - '94				
	P <sub>1</sub>	P <sub>2</sub>	P <sub>3</sub>	Mean
C <sub>1</sub>	52.07	49.85	55.47	52.46
C <sub>2</sub>	46.02	43.59	51.89	47.17
Mean	49.05	46.72	53.68	

SEd                      CD (P=0.05)  
0.06                      0.14

**Table 44.** Interaction between planting patterns and nitrogen levels at 75 DAS on spectral reflectance (%) in infrared bands during 1992-'93 and 1993-'94

1992 - '93					
	N <sub>1</sub>	N <sub>2</sub>	N <sub>3</sub>	N <sub>4</sub>	Mean
<b>P<sub>1</sub></b>	44.37	46.98	50.54	53.97	48.97
<b>P<sub>2</sub></b>	41.99	44.80	47.80	51.64	46.56
<b>P<sub>3</sub></b>	45.12	47.98	51.06	54.21	49.59
<b>Mean</b>	43.83	46.59	49.80	53.27	

	<b>SEd</b>	<b>CD (P=0.05)</b>
<b>P at N</b>	0.02	0.05
<b>N at P</b>	0.02	0.05

1993 - '94					
	N <sub>1</sub>	N <sub>2</sub>	N <sub>3</sub>	N <sub>4</sub>	Mean
<b>P<sub>1</sub></b>	47.47	49.49	51.72	54.29	46.72
<b>P<sub>2</sub></b>	43.47	45.92	47.21	50.28	50.74
<b>P<sub>3</sub></b>	49.84	50.45	52.66	54.98	51.98
<b>Mean</b>	46.93	48.62	50.53	53.18	

	<b>SEd</b>	<b>CD (P=0.05)</b>
<b>P at N</b>	0.08	0.17
<b>N at P</b>	0.08	0.16

Table 45. Interaction effect between cultivars and nitrogen levels at 75 DAS on mean spectral reflectance (%) of cotton in infrared band during 1992 - '93 and 1993 - '94

## 1992 - '93

	N <sub>1</sub>	N <sub>2</sub>	N <sub>3</sub>	N <sub>4</sub>	Mean
C <sub>1</sub>	47.01	50.07	53.96	57.34	52.10
C <sub>2</sub>	40.65	43.10	45.63	49.21	44.65
Mean	43.83	45.59	49.80	53.28	

SEd

CD (P=0.05)

C at N

0.02

0.04

N at C

0.02

0.04

## 1993 - '94

	N <sub>1</sub>	N <sub>2</sub>	N <sub>3</sub>	N <sub>4</sub>	Mean
C <sub>1</sub>	49.62	51.34	53.35	56.54	52.71
C <sub>2</sub>	44.24	45.90	47.71	50.83	47.17
Mean	46.93	48.62	50.53	53.69	

SEd

CD (P=0.05)

C at N

0.06

0.14

N at C

0.06

0.13

reflected more (53.15 and 55.47 per cent) than under other planting patterns during 1992-'93 and 1993-'94.

In the interaction between planting patterns and nitrogen levels (Table 44) both the factors were significantly different from each other at the same level of other factor. The highest reflectance (54.21 and 54.98 per cent) was recorded in paired row with greengram intercrops ( $P_3$ ) at higher level of nitrogen application during 1992-'93 and 1993-'94.

In the interaction between cultivars and nitrogen levels (Table 45) both the cultivars were significantly different from each other at the all levels of nitrogen application. The levels of nitrogen application were also significantly different from each other in both the cultivars. TCHB 213 had reflected more (57.34 and 56.54 per cent) at higher level of nitrogen application than MCU 11 during 1992-'93 and 1993-'94.

#### 4.4. Vegetation indices

The data on vegetation indices *viz.*, ratios (IR-R and IR/R) and orthogonal transformations (vegetation index (VI), transformed vegetation index (TVI) and perpendicular vegetation index (PVI) worked out from the spectral reflectance of the three years study are presented in Tables 46, 47 and 48.

The values of all the vegetation indices continued to increase with the increase in age of the cotton crop.

Table 46. Effect of treatments on the vegetation indices of cotton during 1992 - '93

Stage	45 DAS				60 DAS				75 DAS				90 DAS							
	IR-R	IR/R	VI	TVI	PVI	IR-R	IR/R	VI	TVI	PVI	IR-R	IR/R	VI	TVI	PVI	IR-R	IR/R	VI	TVI	PVI
Main	16.97 <sup>a</sup>	2.26 <sup>a</sup>	0.39 <sup>a</sup>	0.94 <sup>a</sup>	9.78 <sup>a</sup>	27.19 <sup>b</sup>	3.16 <sup>a</sup>	0.46 <sup>b</sup>	0.98 <sup>b</sup>	20.51 <sup>b</sup>	38.16 <sup>b</sup>	4.98 <sup>b</sup>	0.65 <sup>b</sup>	1.07 <sup>b</sup>	27.22 <sup>b</sup>	49.16 <sup>a</sup>	7.21 <sup>a</sup>	0.75 <sup>a</sup>	1.12 <sup>a</sup>	36.33 <sup>a</sup>
P <sub>1</sub>	17.84 <sup>b</sup>	2.41 <sup>b</sup>	0.39 <sup>a</sup>	0.95 <sup>a</sup>	9.35 <sup>a</sup>	21.10 <sup>a</sup>	2.99 <sup>b</sup>	0.37 <sup>a</sup>	0.93 <sup>a</sup>	17.78 <sup>a</sup>	34.54 <sup>a</sup>	4.23 <sup>a</sup>	0.60 <sup>a</sup>	1.05 <sup>a</sup>	24.71 <sup>a</sup>	52.30 <sup>b</sup>	8.19 <sup>b</sup>	0.78 <sup>b</sup>	1.13 <sup>b</sup>	38.29 <sup>b</sup>
P <sub>2</sub>	21.55 <sup>c</sup>	3.15 <sup>c</sup>	0.47 <sup>b</sup>	1.00 <sup>b</sup>	11.36 <sup>b</sup>	29.88 <sup>c</sup>	3.65 <sup>c</sup>	0.50 <sup>c</sup>	1.00 <sup>c</sup>	22.89 <sup>c</sup>	38.90 <sup>c</sup>	5.68 <sup>c</sup>	0.66 <sup>c</sup>	1.08 <sup>c</sup>	28.11 <sup>c</sup>	53.33 <sup>c</sup>	8.42 <sup>c</sup>	0.78 <sup>b</sup>	1.13 <sup>b</sup>	39.21 <sup>b</sup>
SEd	0.33	0.04	0.03	0.01	0.39	0.32	0.06	0.01	0.003	0.57	0.20	0.14	0.004	0.002	0.28	0.11	0.10	0.003	0.001	0.54
CD	0.73	0.09	0.07	0.02	0.87	0.71	0.12	0.02	0.007	1.05	0.47	0.32	0.008	0.004	0.62	0.25	0.22	0.01	0.003	1.22
C <sub>1</sub>	18.65	2.33 <sup>a</sup>	0.38 <sup>a</sup>	0.94 <sup>a</sup>	11.79 <sup>b</sup>	27.48 <sup>b</sup>	2.62 <sup>a</sup>	0.43 <sup>a</sup>	0.96 <sup>a</sup>	23.21 <sup>b</sup>	39.21 <sup>b</sup>	4.34 <sup>a</sup>	0.61 <sup>a</sup>	1.05 <sup>a</sup>	30.10 <sup>b</sup>	56.84 <sup>b</sup>	7.98	0.77	1.13	43.42 <sup>b</sup>
C <sub>2</sub>	18.79	2.88 <sup>b</sup>	0.46 <sup>b</sup>	0.99 <sup>b</sup>	8.53 <sup>a</sup>	24.63 <sup>a</sup>	2.73 <sup>b</sup>	0.45 <sup>b</sup>	0.98 <sup>b</sup>	17.58 <sup>a</sup>	35.05 <sup>a</sup>	5.19 <sup>b</sup>	0.67 <sup>b</sup>	1.08 <sup>b</sup>	23.23 <sup>a</sup>	46.35 <sup>a</sup>	7.89	0.77	1.13	32.47 <sup>a</sup>
SEd	0.27	0.03	0.02	0.01	0.32	0.26	0.05	0.005	0.002	0.39	0.98	0.12	0.003	0.001	0.23	0.09	0.08	0.002	0.001	0.45
CD	NS	0.07	0.05	0.01	0.71	0.58	0.10	0.01	0.01	0.86	2.18	0.26	0.007	0.003	0.51	0.21	NS	NS	NS	0.99
Sub	14.28 <sup>a</sup>	2.02 <sup>a</sup>	0.33 <sup>a</sup>	0.91 <sup>a</sup>	7.45 <sup>a</sup>	21.42 <sup>a</sup>	2.17 <sup>a</sup>	0.36 <sup>a</sup>	0.94	17.89 <sup>a</sup>	32.75 <sup>a</sup>	3.80 <sup>a</sup>	0.57 <sup>a</sup>	1.04 <sup>a</sup>	21.98 <sup>a</sup>	45.00 <sup>a</sup>	6.18 <sup>a</sup>	0.72 <sup>a</sup>	1.10 <sup>a</sup>	33.26 <sup>a</sup>
N <sub>1</sub>	16.36 <sup>b</sup>	2.30 <sup>b</sup>	0.39 <sup>a</sup>	0.94 <sup>b</sup>	8.38 <sup>b</sup>	25.31 <sup>b</sup>	2.57 <sup>b</sup>	0.43 <sup>b</sup>	1.03	20.03 <sup>b</sup>	36.92 <sup>ab</sup>	4.38 <sup>b</sup>	0.62 <sup>b</sup>	1.06 <sup>b</sup>	25.13 <sup>b</sup>	49.36 <sup>b</sup>	7.28 <sup>b</sup>	0.76 <sup>b</sup>	1.12 <sup>b</sup>	35.76 <sup>b</sup>
N <sub>2</sub>	20.35 <sup>c</sup>	2.75 <sup>c</sup>	0.48 <sup>b</sup>	0.98 <sup>c</sup>	11.30 <sup>c</sup>	27.41 <sup>c</sup>	2.82 <sup>c</sup>	0.46 <sup>c</sup>	0.99	21.32 <sup>c</sup>	40.63 <sup>b</sup>	4.99 <sup>c</sup>	0.66 <sup>c</sup>	1.08 <sup>c</sup>	28.03 <sup>c</sup>	53.81 <sup>c</sup>	8.51 <sup>c</sup>	0.79 <sup>c</sup>	1.14 <sup>c</sup>	39.57 <sup>c</sup>
N <sub>3</sub>	23.89 <sup>d</sup>	3.36 <sup>d</sup>	0.48 <sup>b</sup>	1.01 <sup>d</sup>	13.52 <sup>d</sup>	30.09 <sup>d</sup>	3.16 <sup>d</sup>	0.51 <sup>d</sup>	0.93	22.34 <sup>d</sup>	38.22 <sup>b</sup>	5.88 <sup>d</sup>	0.70 <sup>d</sup>	1.10 <sup>d</sup>	31.58 <sup>d</sup>	58.21 <sup>d</sup>	9.79 <sup>d</sup>	0.81 <sup>d</sup>	1.15 <sup>d</sup>	43.20 <sup>d</sup>
SEd	0.36	0.03	0.03	0.01	0.29	0.11	0.03	0.05	0.07	0.38	2.26	0.09	0.002	0.001	0.28	0.11	0.12	0.002	0.001	0.86
CD	0.74	0.05	0.06	0.02	0.58	0.22	0.06	0.01	NS	0.77	4.58	0.19	0.004	0.002	0.56	0.22	0.25	0.004	0.003	1.74
PxC	0.46	0.06	0.04	0.01	0.56	0.45	0.08	0.01	0.004	0.67	1.70	0.20	0.01	0.002	0.39	0.16	0.14	0.003	0.002	0.77
SEd	1.03	NS	NS	0.02	NS	1.00	0.18	0.02	0.01	NS	NS	NS	0.012	0.005	0.88	0.36	NS	NS	NS	1.72
CD	0.64	0.06	0.06	0.01	0.58	0.36	0.07	0.01	0.10	0.74	3.59	0.20	0.003	0.002	0.50	0.20	0.21	0.004	0.003	1.40
CxN	1.33	0.12	NS	0.03	1.23	0.78	0.15	0.02	NS	1.56	NS	NS	0.01	0.005	1.05	0.42	NS	NS	NS	NS
SEd	0.52	0.05	0.05	0.01	0.48	0.29	0.06	0.01	0.08	0.60	2.93	0.16	0.004	0.002	0.41	0.16	0.17	0.003	0.002	1.14
CD	1.08	0.10	NS	NS	1.01	0.64	0.12	0.02	NS	1.27	NS	NS	0.01	0.004	0.85	0.34	0.36	0.01	0.004	NS

CD (P = 0.05)

NS = Not significant

VI = Vegetation Index;

TVI = Transformed Vegetation Index;

PVI = Perpendicular Vegetation Index

Table 47. Effect of treatments on vegetation indices of cotton during 1993 - '94

Stage	45 DAS				60 DAS				75 DAS				90 DAS							
	IR-R	IR/R	VI	PVI	IR-R	IR/R	VI	PVI	IR-R	IR/R	VI	PVI	IR-R	IR/R	VI	PVI	IR-R	IR/R	VI	PVI
Main	15.35 <sup>b</sup>	1.83 <sup>a</sup>	0.28 <sup>a</sup>	0.88 <sup>a</sup>	12.61 <sup>b</sup>	2.79 <sup>b</sup>	0.47 <sup>b</sup>	0.98 <sup>b</sup>	20.44 <sup>b</sup>	36.91 <sup>b</sup>	3.71 <sup>b</sup>	0.57 <sup>b</sup>	1.03 <sup>b</sup>	47.64 <sup>b</sup>	5.91 <sup>c</sup>	28.51 <sup>b</sup>	1.10 <sup>b</sup>	35.93 <sup>b</sup>		
P <sub>1</sub>	14.00 <sup>a</sup>	1.83 <sup>a</sup>	0.28 <sup>a</sup>	0.88 <sup>a</sup>	10.16 <sup>c</sup>	2.18 <sup>a</sup>	0.36 <sup>a</sup>	0.93 <sup>a</sup>	17.67 <sup>a</sup>	29.78 <sup>a</sup>	2.80 <sup>a</sup>	0.47 <sup>a</sup>	0.98 <sup>a</sup>	40.99 <sup>a</sup>	4.20 <sup>a</sup>	24.88 <sup>a</sup>	1.05 <sup>a</sup>	32.16 <sup>a</sup>		
P <sub>2</sub>	20.83 <sup>c</sup>	2.61 <sup>b</sup>	0.43 <sup>b</sup>	0.96 <sup>b</sup>	12.45 <sup>b</sup>	3.00 <sup>c</sup>	0.49 <sup>c</sup>	1.00 <sup>c</sup>	22.37 <sup>c</sup>	39.63 <sup>c</sup>	4.43 <sup>c</sup>	0.62 <sup>c</sup>	1.06 <sup>c</sup>	49.35 <sup>c</sup>	5.47 <sup>b</sup>	29.82 <sup>c</sup>	1.09 <sup>b</sup>	38.52 <sup>c</sup>		
SED	0.14	0.05	0.003	0.002	0.21	0.04	0.004	0.002	0.21	0.20	0.07	0.005	0.002	0.12	0.08	0.37	0.004	0.13		
CD	0.32	0.11	0.007	0.01	0.48	0.09	0.009	0.01	0.48	0.45	0.16	0.01	0.005	0.27	0.19	0.82	0.01	0.28		
C <sub>1</sub>	18.05 <sup>b</sup>	2.11	0.34 <sup>b</sup>	0.92 <sup>b</sup>	13.71 <sup>b</sup>	2.74 <sup>b</sup>	0.43 <sup>a</sup>	0.97 <sup>a</sup>	23.30 <sup>b</sup>	37.45 <sup>b</sup>	3.56 <sup>a</sup>	0.55	1.03 <sup>b</sup>	49.31 <sup>b</sup>	5.39 <sup>b</sup>	30.44 <sup>b</sup>	1.08	39.10 <sup>b</sup>		
C <sub>2</sub>	15.40 <sup>a</sup>	2.07	0.32 <sup>a</sup>	0.90 <sup>b</sup>	9.77 <sup>a</sup>	2.43 <sup>a</sup>	0.45 <sup>b</sup>	0.98 <sup>b</sup>	17.03 <sup>a</sup>	33.43 <sup>a</sup>	3.73 <sup>b</sup>	0.55	1.02 <sup>a</sup>	42.68 <sup>a</sup>	5.00 <sup>a</sup>	25.03 <sup>a</sup>	1.07	31.97 <sup>a</sup>		
SED	0.18	0.04	0.002	0.002	0.17	0.14	0.003	0.002	0.18	0.17	0.06	0.004	0.002	0.10	0.07	0.30	0.003	0.10		
CD	0.26	NS	0.005	0.004	0.39	0.31	0.07	0.004	0.39	0.37	0.13	NS	0.004	0.22	0.15	0.67	NS	0.23		
Sub	11.39 <sup>a</sup>	1.64 <sup>a</sup>	0.23 <sup>a</sup>	0.85 <sup>a</sup>	8.77 <sup>a</sup>	2.15 <sup>a</sup>	0.36 <sup>a</sup>	0.93 <sup>a</sup>	17.93 <sup>a</sup>	31.16 <sup>a</sup>	3.01 <sup>a</sup>	0.50 <sup>a</sup>	1.00 <sup>a</sup>	38.42 <sup>a</sup>	3.94 <sup>a</sup>	24.64 <sup>a</sup>	1.05 <sup>a</sup>	29.53 <sup>a</sup>		
N <sub>1</sub>	14.47 <sup>b</sup>	1.87 <sup>b</sup>	0.29 <sup>b</sup>	0.89 <sup>b</sup>	10.23 <sup>b</sup>	2.55 <sup>b</sup>	0.43 <sup>b</sup>	0.96 <sup>b</sup>	19.83 <sup>b</sup>	33.90 <sup>b</sup>	3.37 <sup>b</sup>	0.53 <sup>b</sup>	1.02 <sup>b</sup>	43.37 <sup>b</sup>	4.60 <sup>b</sup>	26.28 <sup>b</sup>	1.07 <sup>b</sup>	33.68 <sup>b</sup>		
N <sub>2</sub>	18.08 <sup>c</sup>	2.16 <sup>c</sup>	0.35 <sup>c</sup>	0.92 <sup>c</sup>	12.60 <sup>c</sup>	2.80 <sup>c</sup>	0.46 <sup>c</sup>	0.98 <sup>c</sup>	20.58 <sup>c</sup>	36.82 <sup>c</sup>	3.87 <sup>c</sup>	0.58 <sup>c</sup>	1.04 <sup>c</sup>	48.29 <sup>c</sup>	5.57 <sup>c</sup>	28.88 <sup>c</sup>	1.09 <sup>c</sup>	37.20 <sup>c</sup>		
N <sub>4</sub>	22.96 <sup>d</sup>	2.67 <sup>d</sup>	0.44 <sup>d</sup>	0.97 <sup>d</sup>	15.36 <sup>d</sup>	3.12 <sup>d</sup>	0.51 <sup>d</sup>	1.00 <sup>d</sup>	22.30 <sup>d</sup>	39.87 <sup>d</sup>	4.32 <sup>d</sup>	0.60 <sup>d</sup>	1.05 <sup>c</sup>	53.90 <sup>d</sup>	6.67 <sup>d</sup>	31.14 <sup>d</sup>	1.11 <sup>s</sup>	41.73 <sup>d</sup>		
SED	0.13	0.031	0.002	0.002	0.16	0.15	0.002	0.001	0.16	0.25	0.07	0.006	0.003	0.12	0.08	0.40	0.004	0.12		
CD	0.27	0.06	0.005	0.004	0.32	0.31	0.05	0.003	0.33	0.51	0.15	0.01	0.01	0.24	0.17	0.80	0.01	0.24		
Px C																				
SED	0.20	0.07	0.004	0.003	0.30	0.24	0.005	0.003	0.30	0.29	0.10	0.01	0.003	0.17	0.12	0.52	0.01	0.18		
CD	0.45	NS	0.010	0.007	0.67	0.55	0.12	0.007	0.68	0.64	0.23	0.02	0.01	0.38	0.26	1.16	0.01	0.40		
Px N																				
SED	0.25	0.07	0.01	0.003	0.32	0.29	0.005	0.003	0.32	0.43	0.13	0.01	0.01	0.21	0.15	0.70	0.01	0.21		
CD	0.51	0.14	0.01	0.007	0.68	0.61	0.10	0.006	0.68	0.89	0.28	0.02	0.01	0.45	0.31	NS	0.12	NS		
Cx N																				
SED	0.20	0.06	0.004	0.003	0.26	0.23	0.004	0.002	0.26	0.35	0.11	0.01	0.004	0.18	0.12	0.58	0.01	0.18		
CD	0.42	0.12	0.01	0.006	0.55	0.49	0.10	0.005	0.56	NS	0.23	NS	NS	0.37	0.26	NS	0.01	0.37		

CD (P = 0.05)

NS = Not significant

VI = Vegetation Index;

TVI = Transformed Vegetation Index;

PVI = Perpendicular Vegetation Index

Table 48. Effect of treatments on vegetation indices of cotton during 1994 - '95

Stage	45 DAS						60 DAS						75 DAS						90 DAS						
	IR-R	IR/R	VI	TVI	PVI	IR-R	IR/R	VI	TVI	PVI	IR-R	IR/R	VI	TVI	PVI	IR-R	IR/R	VI	TVI	PVI	IR-R	IR/R	VI	TVI	PVI
C <sub>1</sub>	19.25 <sup>b</sup>	2.03 <sup>b</sup>	0.34 <sup>b</sup>	0.91 <sup>b</sup>	16.32 <sup>b</sup>	1.01 <sup>c</sup>	1.01 <sup>c</sup>	0.53 <sup>a</sup>	1.01 <sup>a</sup>	27.11 <sup>b</sup>	49.74 <sup>b</sup>	4.07 <sup>a</sup>	0.60 <sup>a</sup>	1.05 <sup>a</sup>	43.77 <sup>b</sup>	62.12 <sup>b</sup>	7.43 <sup>b</sup>	0.75 <sup>b</sup>	1.12 <sup>b</sup>	50.09 <sup>b</sup>	54.47 <sup>a</sup>	6.75 <sup>a</sup>	0.74 <sup>a</sup>	1.11 <sup>a</sup>	42.21 <sup>a</sup>
C <sub>2</sub>	13.96 <sup>a</sup>	1.81 <sup>a</sup>	0.29 <sup>a</sup>	0.89 <sup>a</sup>	9.26 <sup>a</sup>	1.02 <sup>b</sup>	1.02 <sup>b</sup>	0.54 <sup>b</sup>	1.02 <sup>b</sup>	25.13 <sup>a</sup>	40.94 <sup>c</sup>	4.52 <sup>b</sup>	0.63 <sup>b</sup>	1.07 <sup>b</sup>	30.57 <sup>a</sup>	54.47 <sup>a</sup>	6.75 <sup>a</sup>	0.74 <sup>a</sup>	1.11 <sup>a</sup>	42.21 <sup>a</sup>	54.47 <sup>a</sup>	6.75 <sup>a</sup>	0.74 <sup>a</sup>	1.11 <sup>a</sup>	42.21 <sup>a</sup>
SED	0.37	0.03	0.006	0.004	0.26	0.002	0.002	0.002	0.002	0.47	0.32	0.07	0.01	0.003	0.25	0.32	0.10	0.002	0.002	0.31	0.32	0.10	0.002	0.002	0.31
CD	0.80	0.06	0.01	0.01	0.55	0.004	0.005	0.005	0.004	1.01	0.68	0.14	0.01	0.006	0.54	0.69	0.21	0.01	0.003	0.66	0.69	0.21	0.01	0.003	0.66
N <sub>1</sub>	15.31 <sup>a</sup>	1.79 <sup>a</sup>	0.28 <sup>a</sup>	0.89 <sup>a</sup>	13.13	1.00 <sup>a</sup>	1.00 <sup>a</sup>	0.50 <sup>a</sup>	1.00 <sup>a</sup>	24.19 <sup>a</sup>	41.78 <sup>a</sup>	3.73 <sup>a</sup>	0.58 <sup>a</sup>	1.04 <sup>a</sup>	34.87 <sup>a</sup>	51.83 <sup>a</sup>	5.43 <sup>a</sup>	0.69 <sup>a</sup>	1.09 <sup>a</sup>	41.32 <sup>a</sup>	51.83 <sup>a</sup>	5.43 <sup>a</sup>	0.69 <sup>a</sup>	1.09 <sup>a</sup>	41.32 <sup>a</sup>
N <sub>2</sub>	16.33 <sup>b</sup>	1.89 <sup>b</sup>	0.316 <sup>b</sup>	0.90 <sup>a</sup>	12.86	1.02 <sup>b</sup>	1.02 <sup>b</sup>	0.54 <sup>b</sup>	1.02 <sup>b</sup>	26.30 <sup>b</sup>	45.52 <sup>b</sup>	4.26 <sup>b</sup>	0.62 <sup>b</sup>	1.06 <sup>b</sup>	37.38 <sup>b</sup>	59.60 <sup>b</sup>	7.20 <sup>b</sup>	0.76 <sup>b</sup>	1.12 <sup>b</sup>	47.21 <sup>b</sup>	59.60 <sup>b</sup>	7.20 <sup>b</sup>	0.76 <sup>b</sup>	1.12 <sup>b</sup>	47.21 <sup>b</sup>
N <sub>3</sub>	18.12 <sup>c</sup>	2.09 <sup>c</sup>	0.35 <sup>c</sup>	0.92 <sup>b</sup>	12.39	1.03 <sup>c</sup>	1.03 <sup>c</sup>	0.57 <sup>c</sup>	1.03 <sup>c</sup>	27.87 <sup>c</sup>	48.73 <sup>c</sup>	4.89 <sup>c</sup>	0.66 <sup>c</sup>	1.08 <sup>c</sup>	39.27 <sup>c</sup>	63.46 <sup>c</sup>	8.65 <sup>c</sup>	0.79 <sup>c</sup>	1.14 <sup>c</sup>	49.92 <sup>c</sup>	63.46 <sup>c</sup>	8.65 <sup>c</sup>	0.79 <sup>c</sup>	1.14 <sup>c</sup>	49.92 <sup>c</sup>
SED	0.46	0.03	0.01	0.005	0.31	0.002	0.003	0.003	0.002	0.58	0.39	0.08	0.01	0.003	0.31	0.40	0.12	0.003	0.002	0.38	0.40	0.12	0.003	0.002	0.38
CD	0.98	0.07	0.02	0.011	NS	0.005	0.006	0.006	0.005	1.24	0.83	0.17	0.01	0.01	0.66	0.84	0.26	0.006	0.004	0.81	0.84	0.26	0.006	0.004	0.81
CxN																									
SED	0.65	0.05	0.01	0.01	0.44	0.003	0.004	0.004	0.003	0.83	0.55	0.11	0.01	0.01	0.44	0.56	0.17	0.004	0.003	0.54	0.56	0.17	0.004	0.003	0.54
CD	1.38	0.10	0.03	0.02	0.94	NS	NS	NS	NS	NS	NS	0.24	NS	0.01	NS	NS	0.37	NS	NS	NS	NS	0.37	NS	NS	NS

CD (P = 0.05)

NS = Not significant

VI = Vegetation Index;

TVI = Transformed Vegetation Index;

PVI = Perpendicular Vegetation Index

Planting pattern treatments were discriminated from 45 DAS onwards till 90 DAS only under ratio (IR-R during both first and second years). At 60 and 75 DAS the three planting patterns were discriminated in all the five vegetation indices in both first and second years. At 90 DAS of second year, the planting patterns were discriminated in vegetation index (VI) and perpendicular vegetation index (PVI) apart from ratios (IR-R and IR/R).

Among the three planting patterns, paired row with greengram intercrop ( $P_3$ ) had recorded higher value in all the vegetation indices followed by normal row planting ( $P_1$ ) and paired row alone ( $P_2$ ).

Comparing the various vegetation indices in terms of absolute values, IR - R was more precise in discriminating the planting patterns followed by vegetation index (VI) at 60 DAS than at 75 DAS.

The two cotton cultivars were discriminated from each other from 45 DAS onwards through 90 DAS, but there was variation among vegetation indices in discriminating the cultivars.

At 45 DAS, perpendicular vegetation index (PVI) alone had discriminated the cultivars in which TCHB 213 ( $C_1$ ) had recorded higher values than MCU 11 ( $C_2$ ). The other vegetation indices (IR-R IR/R, VI and TVI) were varying in discriminating the cultivars.

At 60 and 75 DAS, the cultivars were discriminated in all the vegetation indices, wherein TCHB 213 ( $C_1$ ) had recorded higher values in IR - R and PVI and lower values in IR/R, VI and TVI than MCU 11 ( $C_2$ ).

At 90 DAS, the cultivars were discriminated in IR-R and PVI alone in all the three years of study. IR/R, VI and TVI during first year and TVI during second year were non significant. In contrast to 60 and 75 DAS, at 90 DAS the cultivar TCHB 213 (C<sub>1</sub>) had recorded higher values in all the vegetation indices than MCU 11 (C<sub>2</sub>).

In short, the cultivars could be discriminated from 45 DAS onwards. IR-R had discriminated the cutlivars from 60 DAS onwards and at early stage (45 DAS) PVI had discriminated the cultivars

The four nitrogen levels during first and second year and three levels during third year were discriminated from 45 DAS onwards through 90 DAS. In all the years, the values of vegetation indices increased with increase in nitrogen levels.

At 45 DAS during first year in vegetation index (VI) the nitrogen levels 0 and 50 and 100 and 150 per cent were at statistical par. In the same stage during third year, PVI was non-significant. All the treatments were significantly different in all the vegetation indices only during second year of experiment.

AT 60 DAS except TVI in first year, all the nitrogen levels were significantly different in all the vegetation indices during the three year periods of study. AT 75 DAS of first year study, the nitrogen levels 0 and 50, 50, 100 and 150 per cent of recommended level were at statistical par in IR -

R alone whereas in other vegetation (IR/R, VI, TVI and PVI) indices all the treatments were significantly different in all the three years.

AT 90 DAS, all the four levels of nitrogen during first and second years and three levels during third year were significantly different from each other for all the vegetation indices studied.

In summary, the nitrogen levels could be discriminated by employing vegetation indices from 45 DAS of crop growth. It is inferred from absolute value that all the vegetation indices calculated at 75 DAS were more stronger in differentiating the treatments.

The interaction between planting patterns and cultivars, between planting patterns and nitrogen levels and between cultivars and nitrogen levels were significant from 45 DAS onwards. But the interactions varied between year to year and there was no consistency in delivering any concrete information

#### **4.5. Spectral characters Vs agronomic variables (Three years combined)**

The spectral reflectance at 75 DAS in red and infrared bands and the vegetation indices (IR-R, IR/R, VI, TVI and PVI) derived from the spectral reflectance were correlated with agronomic and physiological parameters recorded at 75 DAS. The results are presented in Table 49.

Table 49. Correlation between agronomic, physiological parameters of cotton and spectral reflectance in red and infrared bands at 75 DAS

Parameters	Red		Infrared	
	r value	F value	r value	F value
LAI	-0.2455	-1.19 <sup>NS</sup>	0.6601	4.1213**
Chlorophyll a	-0.3245	-1.609 <sup>NS</sup>	0.6467	3.54**
Chlorophyll b	-0.3176	-1.570 <sup>NS</sup>	0.4899	2.635**
Total Chlorophyll	-0.2874	-1.407 <sup>NS</sup>	0.574	3.29**
Plant N	-0.3045	-1.499 <sup>NS</sup>	0.6541	3.62**
Ground cover	-0.7154	-3.6867**	0.6417	3.38**
Leaf thickness	-0.0207	-0.809 <sup>NS</sup>	0.247	1.21 <sup>NS</sup>
Leaf Angle	-0.0212	-1.49 <sup>NS</sup>	0.5337	2.996**
DMP	-0.0902	-1.56 <sup>NS</sup>	0.6109	3.19**

\*\* Significant at 1% level

\* Significant at 5% level

NS Not significant

Spectral reflectance in red band had a negative relation with agronomic and physiological parameters and were non-significant except canopy ground cover which had significant negative correlation even at one percent probability level. Whereas infrared band had positive and significant correlation with the agronomic and physiological parameters except leaf thickness which had non-significant correlation value.

It was inferred from the absolute values that in infrared band, LAI had stronger relation or more contribution towards reflection followed by plant nitrogen content, chlorophyll a, ground cover, total chlorophyll and DMP.

#### **4.5.1. Estimation of agronomic and physiological parameters**

To estimate the agronomic and physiological parameters from spectral reflectance based on observed values of present investigation at 75 DAS, an allometry study was made.

The allometric relation is in the form of

$$A = \alpha[\text{SR}]^\beta$$

Where A is agronomic and physiological parameters *viz.*, LAI, DMP, total chlorophyll, plant nitrogen content, and ground coverage.

SR is spectral reflectance in red and infrared bands and the vegetation indices derived.

$\alpha$ ,  $\beta$  are the parameters to be estimated.

The relationship between spectral reflectance, vegetation indices and plant growth and physiological parameters *viz.*, LAI, DMP, total chlorophyll content, plant nitrogen content and canopy ground coverage are given in Tables 50 through 54.

To test the significance of the computed allometric relationship "Chi-square" test was carried out.

Red band had negative relation with plant growth characters whereas infrared band had positive relation.

The allometric relation with all the growth parameters was highly significant except for DMP indicating that the agronomic and physiological parameters could be estimated from spectral reflectance and derived indices. In DMP the variation between observed and estimated value was more than the permitted value (Chi-square test).

#### **4.1.2. Yield components (1992-'93 and 1993-'94)**

##### **4.1.2.1. Number of bolls per plant**

The data recorded on boll numbers per plant during first and second year of experiment are presented in Table 55.

The three planting patterns were significantly different in producing bolls per plant. Normal row planting ( $P_1$ ) had produced more number of bolls (23.45 and 27.54) per plant in both the years of study followed by  $P_2$  (21.82, and 25.95) and  $P_3$  (19.72 and 23.28).

Table 50. Allometric relation between spectral characters and LAI of cotton

SR	TCHB 213					MCU 11				
	$\alpha_1$	$\beta_1$	r	$\chi^2$		$\alpha_1$	$\beta_1$	r	$\chi^2$	
Red	64.1800	-1.1520	-0.775	3.64		27.4950	-0.9280	-0.6793	4.64	
IR	0.0065	1.5640	0.914	1.64		0.0083	1.5270	0.8607	2.23	
IR-R	0.1313	0.8883	0.9577	0.91		0.1100	0.9358	0.8751	1.35	
IR/R	1.1983	0.7171	0.8701	2.38		1.1107	0.6754	0.8190	2.60	
VI	7.1796	1.2908	0.9715	0.62		11.4310	2.1113	0.6191	6.94	
TVI	2.7977	5.0602	0.9556	0.93		2.2434	5.6481	0.8826	1.94	
PVI	0.1595	0.8881	0.9385	4.03		0.2299	0.8065	0.9045	1.53	

$\chi^2$  table value for n-1 degrees of freedom 23.685

$$LAI = \alpha_1 (SR)^{\beta_1}$$

Table 51. Allometric relation between spectral characters and DMP ( $\text{kg ha}^{-1}$ ) of cotton

SR	TCHB 213					MCU 11				
	$\alpha_2$	$\beta_2$	r	$\chi^2$		$\alpha_2$	$\beta_2$	r	$\chi^2$	
Red	479327.25	-2.041	-0.8546	*		104147.61	-1.6274	-0.7647	*	
IR	0.0595	2.67	0.9713	-		0.0992	2.5853	0.936	-	
IR-R	11.8361	1.4748	0.9894	-		9.9060	1.5224	0.9667	-	
IR/R	428.99	1.2472	0.9417	-		389.09	1.1595	0.9027	-	
VI	8870.69	2.1029	0.9849	-		7766.47	2.3934	0.9349	-	
TVI	1901.07	8.3895	0.9859	-		1407.76	9.1702	0.9337	-	
PVI	15.4435	1.4910	0.9805	-		31.42	1.3253	0.9545	-	

\* Since the calculated  $\chi^2$  value were significant than the table value it is not been given

Table 52. Allometric relation between spectral characters and total chlorophyll content ( $\text{mg g}^{-1}$ ) of cotton

SR	TCHB 213					MCU 11				
	$\alpha_3$	$\beta_3$	r	$\chi^2$		$\alpha_3$	$\beta_3$	r	$\chi^2$	
Red	9.415	-0.377	-0.8680	0.17		7.1628	-0.3300	-0.7010	0.43	
IR	0.5610	0.4627	0.9473	0.07		0.3892	0.5500	0.9742	0.05	
IR-R	1.3980	0.2571	0.9452	0.07		1.0314	0.3262	0.9568	0.09	
IR/R	2.5801	0.2276	0.9468	0.07		2.2518	0.2508	0.9029	0.16	
VI	4.4496	0.3710	0.9290	0.08		4.4792	0.6070	0.9220	0.23	
TVI	3.3918	1.4885	0.9463	0.07		2.9175	2.2265	0.9214	0.20	
PVI	1.4899	0.2548	0.9414	0.08		1.4113	0.2646	0.9246	0.29	

$\chi^2$  table value for n-1 degrees of freedom 16.919

Total Chlorophyll Content =  $\alpha_3$  (SR)  $\beta_3$

Table 53. Allometric relation between spectral characters and plant nitrogen content (%) of cotton

SR	TCHB 213				MCU 11			
	$\alpha_4$	$\beta_4$	r	$\chi^2$	$\alpha_4$	$\beta_4$	r	$\chi^2$
Red	3.2190	-0.3250	-0.6460	0.38	2.3032	-0.24	-0.5570	0.34
IR	0.3147	0.3730	0.6437	0.39	0.3532	0.3365	0.5990	0.33
IR-R	0.6663	0.2032	0.6464	0.38	0.6240	0.2100	0.6400	0.3
IR/R	1.0699	0.1866	0.6683	0.37	1.0800	0.1600	0.6200	0.34
VI	1.6585	0.2898	0.6437	0.38	1.5500	0.3400	0.6500	0.3
TVI	1.3401	1.1826	0.6591	0.39	1.2200	1.2800	0.6400	0.31
PVI	0.6885	0.2065	0.6441	0.40	0.7400	0.1800	0.6200	0.32

$\chi^2$  table value for n-1 degrees of freedom 23.685

Plant nitrogen (%) content =  $\alpha_4$  (SR)  $\beta_4$

Table 54. Allometric relation between spectral characters and canopy ground cover (%) of cotton

SR	TCHB 213					MCU 11				
	$\alpha_5$	$\beta_5$	r	$\chi^2$		$\alpha_5$	$\beta_5$	r	$\chi^2$	
Red	467.02	-0.780	-8.95	7.81		430.5957	-0.8261	-0.9574	2.56	
IR	1.1970	0.9818	0.9764	2.01		0.7640	1.1050	0.9760	1.53	
IR-R	9.6431	0.5060	0.9711	2.36		8.2000	0.54	0.97	1.87	
IR/R	31.5465	0.4730	0.9718	2.33		30.44	0.38	0.90	5.73	
VI	92.4390	0.6891	0.9575	3.27		87.69	0.82	0.95	2.52	
TVI	55.6001	2.8681	0.9696	2.46		48.65	3.28	0.97	1.86	
PVI	9.3519	0.5437	0.9707	2.47		9.43	0.55	0.96	2.16	

$\chi^2$  table value for n-1 degrees of freedom 16.919

Cotton canopy ground cover (%) =  $\alpha_5 + \beta_5$

**Table 55. Effect of treatments on mean boll numbers per plant of cotton during 1992 - '93 and 1993 - '94**

Treatments	1992-'93	1993-'94
P <sub>1</sub>	23.45a	27.54a
P <sub>2</sub>	21.82b	25.95b
P <sub>3</sub>	19.72c	23.28c
SEd	0.94	0.60
CD	2.09	1.35
C <sub>1</sub>	31.77a	38.54a
C <sub>2</sub>	14.55b	16.66b
SEd	0.77	0.49
CD	1.71	1.10
N <sub>1</sub>	7.45d	9.60d
N <sub>2</sub>	16.71c	20.26c
N <sub>3</sub>	25.09b	29.01
N <sub>4</sub>	37.39a	46.16a
SEd	0.63	0.56
CD	1.29	1.14
PxC ; SEd	1.33	0.85
CD	NS	NS
PxN ; SEd	1.34	1.04
CD	2.84	2.17
CxN ; SEd	1.09	0.85
CD	2.32	1.78

NS - Not significant

CD - (P=0.05)

The mean having the same alphabet are not significantly different at 5 % level.

Between the two cultivars, TCHB 213 had produced more number of bolls per plant (31.77 and 38.54) than MCU 11 (14.55 and 16.66) in first and second year of study.

The levels of nitrogen had positive influence on producing bolls per plant. All the four levels were significantly different in bearing bolls per plant. Maximum number of bolls per plant (37.39 and 46.16) were produced at 150 per cent of recommended nitrogen application in both the first and second years of experimentation.

Interaction was observed between planting patterns and nitrogen levels and between cultivars and nitrogen levels. The data on interaction are presented in Tables 56 and 57.

In the interaction between planting patterns and nitrogen levels, the three planting patterns were at statistical par at zero (absolute control) level of nitrogen during both the years. At 150 per cent level of nitrogen application, all the three planting patterns were significantly different from each other, while  $P_2$  and  $P_3$  were at statistical par at 50 and 100 per cent of nitrogen application during both the years. Normal planting pattern ( $P_1$ ) had produced more number of bolls (40.99 and 47.68) during first and second years, at higher level of nitrogen application (150 per cent of recommended nitrogen) than  $P_2$  and  $P_3$ .

In the interaction between cultivars and nitrogen levels in both the first and second years TCHB 213 ( $C_1$ ) had produced higher number of bolls. (51.92 and 66.17) per plants under 150 per cent of recommended level.

**Table 56. Interaction effect between planting patterns and nitrogen levels on mean boll numbers per plant during 1992 - '93 and 1993 - '94**

1992 - '93

	N <sub>1</sub>	N <sub>2</sub>	N <sub>3</sub>	N <sub>4</sub>	Mean
P <sub>1</sub>	7.43	18.05	27.31	40.99	23.45
P <sub>2</sub>	8.04	16.97	24.92	37.35	21.82
P <sub>3</sub>	6.89	15.10	23.05	33.83	19.72
<b>Mean</b>	7.45	16.71	25.09	37.39	

	<b>SEd</b>	<b>CD (P=0.05)</b>
<b>P at N</b>	1.34	2.84
<b>N at P</b>	1.10	2.23

1993 - '94

	N <sub>1</sub>	N <sub>2</sub>	N <sub>3</sub>	N <sub>4</sub>	Mean
P <sub>1</sub>	9.84	22.19	30.52	47.68	27.55
P <sub>2</sub>	9.92	18.97	29.28	45.62	25.95
P <sub>3</sub>	9.05	19.62	27.23	45.22	23.28
<b>Mean</b>	9.6	20.26	29.01	46.17	

	<b>SEd</b>	<b>CD (P=0.05)</b>
<b>P at N</b>	1.04	2.17
<b>N at P</b>	1.17	2.45

Table 57. Interaction effect between cultivars and nitrogen levels on mean boll numbers per plant during 1992 - '93 and 1993 - '94

1992 - '93					
	N <sub>1</sub>	N <sub>2</sub>	N <sub>3</sub>	N <sub>4</sub>	Mean
C <sub>1</sub>	8.53	22.37	32.26	51.92	31.77
C <sub>2</sub>	6.37	11.05	17.92	22.86	14.55
Mean	7.45	16.71	25.09	37.39	

	SEd	CD (P=0.05)
C at N	1.09	2.32
N at C	0.89	1.82

1993 - '94					
	N <sub>1</sub>	N <sub>2</sub>	N <sub>3</sub>	N <sub>4</sub>	Mean
C <sub>1</sub>	10.72	27.69	38.86	66.17	38.54
C <sub>2</sub>	9.49	12.83	19.16	26.14	16.66
Mean	9.65	20.26	29.01	46.16	

	SEd	CD (P=0.05)
C at N	0.85	1.78
N at C	0.79	1.62

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

The seed cotton yield data recorded during first and second year of experimentation are presented in Table 58

The grain yield of greengram intercrop are presented in Annexure II.

The three planting patterns had differed significantly for seed cotton yield in both first and second years of study. Normal planting pattern had produced maximum seed cotton yield (1550 and 1724 kg ha<sup>-1</sup> during first and second year respectively). Whereas paired row with greengram intercrop had produced comparatively lowest yield during both the years (1310 and 1460 kg ha<sup>-1</sup>).

Between the two cultivars, TCHB 213 was superior in yielding (1574 and 1775 kg ha<sup>-1</sup>) than MCU 11 (1241 and 1364 kg ha<sup>-1</sup>).

Higher levels of nitrogen had increased the seed cotton yield positively and significantly. Maximum yield (2401 and 2825 kg ha<sup>-1</sup>) was produced under 150 per cent of recommended level as compared to absolute control (501 and 543 kg ha<sup>-1</sup> in the first and second years of study).

Interaction existed between planting patterns and nitrogen levels and also between cultivars and nitrogen levels and the data are presented in Tables 59 and 60.

In the interaction between planting patterns and nitrogen levels, all the three planting patterns were at statistical par at absolute control of nitrogen (no nitrogen). Whereas, at 50, 100 and 150 per cent level of nitrogen

**Table 58. Effect of treatments on means seed cotton ( $\text{kg ha}^{-1}$ ) yield of cotton during 1992 - '93 and 1993 - '94**

Treatments	1992-'93	1993-'94
P <sub>1</sub>	1550a	1724a
P <sub>2</sub>	1362b	1526b
P <sub>3</sub>	1310c	1460c
SEd	22.07	29.43
CD	49.19	61.80
C <sub>1</sub>	1574a	1775a
C <sub>2</sub>	1241b	1364b
SEd	18.02	11834
CD	40.16	240.03
N <sub>1</sub>	501d	543d
N <sub>2</sub>	1092c	1179c
N <sub>3</sub>	1635b	1729b
N <sub>4</sub>	2401a	2825a
SEd	27.95	118.34
CD	56.70	240.03
PxC ; SEd	31.22	148.95
CD	NS	NS
PxN ; SEd	47.39	51.24
CD	98.17	107.60
CxN ; SEd	38.69	42.15
CD	80.15	92.73

NS - Not significant

CD - (P=0.05)

The mean having the same alphabet are not significantly different at 5 % level.

**Table 59. Interaction effect between planting patterns and nitrogen levels on mean seed cotton yield (kg ha<sup>-1</sup>) during 1992 - '93 and 1993 - '94**

1992 - '93					
	N <sub>1</sub>	N <sub>2</sub>	N <sub>3</sub>	N <sub>4</sub>	Mean
P <sub>1</sub>	532	1220	1780	2669	1550
P <sub>2</sub>	538	1066	1588	2257	1362
P <sub>3</sub>	435	994	1531	2286	1310
Mean	501	1093	1653	2404	

	SEd	CD (P=0.05)
P at N	47.39	98.17
N at P	48.42	98.20

1993 - '94					
	N <sub>1</sub>	N <sub>2</sub>	N <sub>3</sub>	N <sub>4</sub>	Mean
P <sub>1</sub>	582	1328	1984	3002	1724
P <sub>2</sub>	558	1150	1646	2748	1526
P <sub>3</sub>	490	1061	1559	2731	1460
Mean	543	1180	1730	2827	

	SEd	CD (P=0.05)
P at N	51.24	107.60
N at P	53.41	112.61

Table 60. Interaction effect between cultivars and nitrogen levels on mean seed cotton yield ( $\text{kg ha}^{-1}$ ) during 1992 - '93 and 1993 - '94

1992 - '93

	N <sub>1</sub>	N <sub>2</sub>	N <sub>3</sub>	N <sub>4</sub>	Mean
C <sub>1</sub>	520	1209	1729	2839	1574
C <sub>2</sub>	483	974	1542	1963	1240
Mean	501	1091	1635	2401	

	SEd	CD (P=0.05)
C at N	38.69	80.15
N at C	39.53	80.18

1993 - '94

	N <sub>1</sub>	N <sub>2</sub>	N <sub>3</sub>	N <sub>4</sub>	Mean
C <sub>1</sub>	609	1343	1990	3158	1775
C <sub>2</sub>	478	1015	1469	2492	1364
Mean	543	1179	1729	2825	

	SEd	CD (P=0.05)
C at N	42.15	92.73
N at C	67.35	141.44

application, normal planting pattern ( $P_1$ ) had produced significantly higher seed cotton yield than  $P_2$  and  $P_3$  which were at statistical par at the same level. Maximum seed cotton yield (2669 and 3002 kg ha<sup>-1</sup>) was recorded in normal planting pattern at 150 per cent level of nitrogen application followed by  $P_2$  (2257 and 2748) kg ha<sup>-1</sup> and  $P_3$  (2286 and 2731 in the first and second year respectively).

In the interaction between cultivars and nitrogen levels, TCHB 213 had yielded more (2839 and 3158 kg ha<sup>-1</sup>) at higher level of nitrogen application during both the first and second year.

#### **4.2.2. Yield component (1994-'95)**

##### **4.2.2.1. Number of bolls per plant**

The data recorded on boll numbers per plant are presented in Table 61.

The two cultivars differed significantly in bearing bolls per plant. The cultivars TCHB 213 ( $C_1$ ) had produced more bolls (55.64) per plant as compared to MCU 11 (20.70 per plant).

The levels of nitrogen application influenced the boll numbers per plant. One hundred and fifty and 200 per cent of recommended nitrogen application were at statistical par in respect of boll numbers per plant but were significantly differed from 100 per cent of nitrogen application.

Interaction existed between cultivars and levels of nitrogen application and the data are presented in Table 61a.

**Table 61. Effect of treatments on mean boll numbers per plant during 1994 - '95**

Treatments	1994-'95
C <sub>1</sub>	55.64 <sup>a</sup>
C <sub>2</sub>	20.70 <sup>b</sup>
SEd	0.33
CD	0.71
N <sub>1</sub>	30.46 <sup>b</sup>
N <sub>2</sub>	41.64 <sup>a</sup>
N <sub>3</sub>	42.40 <sup>a</sup>
SEd	0.41
CD	0.87
C x N ; SEd	0.58
CD	1.23

CD - (P=0.05)

The mean having the same alphabet are not significantly different at 5 % level.

**Table 61a. Interaction effect between cultivars and nitrogen levels on mean boll numbers per plant during 1994 - '95**

	N <sub>1</sub>	N <sub>2</sub>	N <sub>3</sub>	Mean
C <sub>1</sub>	41.06	62.32	63.52	55.64
C <sub>2</sub>	19.87	20.96	21.28	20.70
Mean	30.47	46.64	42.40	

SEd

0.58

CD (P=0.05)

1.23

The two cultivars had produced significantly different boll numbers per plant at all the three levels of nitrogen application. The two levels of nitrogen applications *viz.*, 150 and 200 per cent of recommended nitrogen were at statistical par in producing higher number of bolls per plant. This was true for both the cultivars.

#### 4.2.2.2. Seed cotton yield

The data recorded on seed cotton yield are presented in Table 62.

The two cultivars were significantly different in yielding seed cotton. TCHB 213 was superior in yielding (3055 kg ha<sup>-1</sup>) as compared to MCU 11 (1824 kg ha<sup>-1</sup>).

Though increasing levels of nitrogen application had increased the seed cotton yield, 150 and 200 per cent of nitrogen application were at statistical par but significantly different from 100 per cent of nitrogen application. Maximum yield was recorded at 200 per cent application (2684 kg ha<sup>-1</sup>) followed by 150 (2639 kg ha<sup>-1</sup>) and 100 per cent nitrogen application (1995 kg ha<sup>-1</sup>).

Interaction was observed between cultivars and nitrogen levels and the data are presented in Table 62a.

The two nitrogen levels *viz.*, 150 and 200 per cent were at statistical par but significantly higher than 100 per cent level under both the cultivars. The two cultivars were significantly different from each other in yielding seed cotton at all the three levels of nitrogen application.

Table 62. Effect of treatments of mean seed cotton yield ( $\text{kg ha}^{-1}$ ) during 1994 - '95

Treatments	1994-'95
C <sub>1</sub>	3055 <sup>a</sup>
C <sub>2</sub>	1824 <sup>b</sup>
SEd	20.79
CD	44.31
N <sub>1</sub>	1995 <sup>b</sup>
N <sub>2</sub>	2639 <sup>a</sup>
N <sub>3</sub>	2684 <sup>a</sup>
SEd	25.46
CD	54.27
C x N ; SEd	36.01
CD	76.75

CD - (P=0.05)

The mean having the same alphabet are not significantly different at 5 % level.

Table 62a. Interaction effect between cultivars and nitrogen levels on mean seed cotton yield during 1994 - '95

	N <sub>1</sub>	N <sub>2</sub>	N <sub>3</sub>	Mean
C <sub>1</sub>	2249	3425	3491	3055
C <sub>2</sub>	1740	1853	1877	1823
Mean	1995	2639	2684	

SEd  
36.01

CD (P=0.05)  
76.75

#### 4.6. Spectral characters Vs Seed cotton yield (Three years combined)

The spectral reflectance at 75 DAS in red and infrared bands and the vegetation indices derived from the spectral reflectance were correlated with the final seed cotton yield. The results are presented in Table 63.

Between the two bands red had a negative and non-significant correlation with final yield while infrared band had positive and significant correlation.

Among the vegetation indices IR-R, IR/R and PVI had a positive and significant relation with seed cotton yield. While VI and TVI had negative and non-significant correlation with final yield of cotton.

#### 4.7. Yield forecasting

To forecast the final yield from spectral reflectance and vegetation indices allometric models were established and the models are presented in Table 64.

The allometric models worked out were validated using the three years yield data and Chi-square test was done for significance.

The model is in the form of

$$Y = \alpha[\text{SR}]^\beta$$

Where Y = seed cotton yield kg ha<sup>-1</sup>

SR = spectral reflectance and vegetation indices.

$\alpha$  and  $\beta$  = parameters to be worked out.

**Table 63. Correlation between spectral reflectance, vegetation indices and seed cotton yield at 75 DAS**

SR & VI	'r' value	'F' value
Red	-0.3010	-1.48 <sup>NS</sup>
Infrared	0.638	3.89**
IR - R	0.640	3.90**
IR/R	0.4630	2.45*
VI	-0.078	-0.366 <sup>NS</sup>
TVI	-0.076	-0.357 <sup>NS</sup>
PVI	0.511	2.79*

\*\* Significant at 1% level

\* Significant at 5% level

NS Not significant

**Table 64. Allometric models for seed cotton yield forecasting**

SR	TCHB 213					MCU 11				
	$\alpha$	$\beta$	r	$\chi^2$		$\alpha$	$\beta$	r	$\chi^2$	
Red	700.72	0.4155	0.6840	*		113.35	0.1649	0.6360	*	
IR	95.62	0.7689	0.7775	-		217.88	0.5317	0.6217	-	
IR-R	68.28	0.9210	0.7876	-		369.10	0.4266	0.3492	-	
IR/R	4543.38	-0.5512	-0.4347	-		2464.89	-27.02	-0.6645	-	
VI	1305.35	-0.9457	-0.4116	-		1281.06	-0.5428	-0.6337	-	
TVI	2585.09	-4.2336	-0.4647	-		1848.06	-1.90	-0.6512	-	
PVI	395.08	0.4770	0.7837	-		632.62	0.3051	0.5859	-	

\* Since the calculated  $\chi^2$  value were significant than the table value it is not been given

Table 65. Relative deviation(%) in yield prediction from spectral reflectance and vegetation indices

SR and VI	MCU 11		TCHB 213	
	-	+	-	+
Red	5.5	10.0	8.0	11.00
IR	7.8	9.9	5.7	9.9
IR-R	12.9	8.9	5.0	8.3
IR/R	7.0	8.0	11.3	9.6
VI	6.8	8.4	11.8	9.1
TVI	6.0	7.8	11.9	9.1
PVI	9.0	10.0	5.5	7.49

The model to forecast the final yield, was not valid, as the calculated Chi square value exceeded the table value.

The Relative Difference (RD) of estimated yield from that of observed yield was worked out using the formula.

$$RD = 100 \times \frac{\text{Estimated value} - \text{Observed value}}{\text{Estimated value}}$$

The relative deviation in predicting the yield from spectral reflectance and vegetation indices for the two cultivars are presented Table 65.

The relative deviation varied from 5 per cent to 13 per cent. Comparing the reflectance in red and infrared bands with that of derived vegetation indices, the relative deviation is comparatively less, in predicting the final yield for spectral reflectance *viz.*, Red and Infra-red. Between the two bands, infrared band was more precise than red band.

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Discussion

*Chapter V*  
**DISCUSSION**

The results of the field experiments conducted at Tamil Nadu Agricultural University farm, Coimbatore for three years from 1992 to 1995 during 1992-'95 to study the spectral reflectance from planting patterns, cultivars and levels of recommended nitrogen in irrigated winter cotton through remote sensing technique are discussed in this chapter.

The spectral reflectance measurements were initiated in the present investigation from 45 DAS, since, this was the stage at which the ground cover had crossed 25 per cent (Table 13). Below 25 per cent of soil cover, the open ground soil effect would vitiate the spectral reflectance. This was earlier indicated by Leamer *et al.* (1978) in wheat.

The spectral measurements were taken for study upto 90 DAS of cotton crop, since the maximum growth and development take place only upto this stage. Halevy (1976) observed 75 per cent of dry matter accumulation in cotton between 72 to 112 days from emergence. It was also confirmed by Honora J. Francis *et al.* (1979) later. Apart from growth and development, nutrient requirement and accumulation of cotton fell between 75 and 90 days of crop growth. Peak uptake and accumulation of nitrogen in cotton at 90 DAS was observed and reported by Chandrasekaran and Sankaran (1983).

The spectral reflectance was more stronger for discriminating the treatments at 75 DAS. Hence, that stage of crop growth (75 DAS) was adjudged for discussing in detail.

### 5.1.1. Plant growth characters

The normal row planting pattern was superior in respect of plant growth characters like plant height, LAI and DMP as compared to paired row planting with and without intercrop green gram. This might be due to the absence of inter and intra species competition for plant growth factors *viz.*, space, nutrient, water, light, etc. Similar finding was reported by Krishnasamy *et al.* (1995a) who brought out significant variation due to crop geometry and intercropping on the growth of cotton. Increased plant height might have produced more number of leaves. This would have caused more LAI under normal row planting than paired row planting. The cumulative effect of both taller plants and more LAI had increased the DMP of normal row planting. Between the paired rows with and without intercrop green gram, because of the absence of inter species competition, paired row without intercrop had produced taller plants upto 90 DAS next to normal row planting.

Between the two cultivars, TCHB 213 was superior to MCU 11 in respect of all the growth characters, eventually because of its wide genetic difference and its vigour of heterosis. Increased rate of leaf area development, especially in interspecific hybrid, was found to be the reason for more LAI and DMP by Muramoto *et al.* (1965) and Marani and Avieli (1973).

Increasing levels of recommended nitrogen application had marked influence on the growth components of cotton crop *viz.*, plant height, LAI and DMP. The height of cotton plant was positively correlated with increasing levels of nitrogen application since cotton belongs to indeterminate crop group. Increase in plant height could be attributed to higher and prolonged availability of nitrogen as compared to absolute control. The response of cotton to higher level of nitrogen might have also increased the plant height (Yan and Zhu, 1986). Linear increase in plant height with increased rate of nitrogen was reported by Aravindababu (1980), Janardhan Singh and Warsi (1985), Nehru *et al.* (1982) and Jain and Katti (1983).

Increasing plant height tended the plant to produce more LAI (Satao *et al.*, 1984 and Madhavi Latha 1988) and DMP (Thirumurugan *et al.*, 1984 and Vireshwar Singh and Verma 1988). In the present study, increase in plant growth (Height, LAI and DMP) was in decreasing rate. The reason being, the response will decrease at increasing level and will not be proportional to the amount added, since the parabolic function operates for every input studied for crops in general.

The response for plant height, LAI and DMP was upto 200 per cent of recommended dose of nitrogen ( $160 \text{ kg ha}^{-1}$  for MCU-11 and  $240 \text{ kg ha}^{-1}$  for TCHB 213). Halevy *et al.* (1987) reported linear increase in DMP from 60-180  $\text{kg ha}^{-1}$  and found further increase in nitrogen to  $240 \text{ kg ha}^{-1}$  decreased the DMP in respect of varieties. In the present investigation, in respect of hybrid cotton, the response of nitrogen was relatively higher (TCHB 213).

Interaction was significant between planting patterns, cultivars and nitrogen levels. The cultivar TCHB 213 being a hybrid produced taller plants, more LAI and DMP under normal planting pattern, when supplied with higher level of nitrogen ( $240 \text{ kg ha}^{-1}$  for TCHB 213 and  $160 \text{ kg ha}^{-1}$  for MCU 11) than recommended ( $120$  and  $80 \text{ kg ha}^{-1}$ ).

### 5.1.2. Ground cover

The proportion of ground covered by vegetation is more important than the developmental stages of the crop growth not only for spectral measurements but also for evapotranspiration. In this present study, paired rows with green gram as inter crop had maximum ground cover upto 75 DAS and was minimum at 90 DAS. This was because of the presence of intercrop. When the intercrop was harvested on 80 DAS, the ground was cleared off from part of vegetation and hence the minimum was observed as compared to paired rows without inter crop greengram. at 90 DAS. The intercrop, greengram, competed for below and above ground growth factors and reduced the growth of cotton crop. The growth of cotton at initial stage was slow and hence the growth of intercrop surpassed the growth of cotton and competed strongly for space, nutrient, water and solar radiation. The reduction in cotton growth at initial stage was also reported by Balasubramanian (1987) and Jagannathan *et al.* (1994). This could be ascribed to reduction in ground cover to a minimum level. At 90 DAS, the normal row planting, which grew without any competition, had higher ground cover than paired rows.

TCHB 213, a hybrid, endowed with the vigour of heterosis produced abundant growth compared to MCU 11, (variety) and covered the ground area more efficiently.

Increasing levels of nitrogen had a positive effect on plant height, LAI and DMP in the present investigation. This had resulted in production of more canopy which might have covered the ground area more efficiently.

In the interaction between planting patterns and cultivars and between planting patterns and nitrogen levels at 75 DAS, because of the presence of intercrops, more ground area was covered under paired rows with green gram as intercrop when high level of nitrogen was introduced. Whereas in the interaction between cultivars and nitrogen level, TCHB 213 had more plant growth as a result of higher nitrogen and covered the ground more efficiently.

### **5.1.3. Nitrogen content and chlorophyll concentration**

The three planting patterns were at par statistically in respect of nitrogen content in cotton plants. The geometry of planting did not affect the nitrogen concentration of cotton plant. Nitrogen being a structural constituent of chlorophyll molecule and there was no difference in chlorophyll concentration among the three planting patterns evaluated.

The two cotton cultivars differed significantly interms of its nitrogen concentration. Hybrids are more efficient in taking up nitrogen compared to

varieties (Patel 1977, Bhat and Nathan 1979, Thangaraj 1981). TCHB 213, being a hybrid, it had more concentration of nitrogen. Nitrogen, being a structural constituent of chlorophyll was positively associated with chlorophyll content. Increase in chlorophyll content with increase in nitrogen was earlier reported by Kalarani (1991). This might be the reason for higher chlorophyll concentration in TCHB 213. The result was in confirmation with results of Rakhmankulov (1976) and Thakaraj (1981).

Increasing levels of nitrogen had increased the nitrogen uptake and resulted in higher concentration of nitrogen in the plants. This was because of higher soil application which led to longer availability. Because of deeper root system, cotton was able to forage nitrogen even from deeper layers if it was lost. Linear increase in nitrogen uptake with increased nitrogen rates was reported by Gopalasamy (1982) and Malik and Misra (1984). This increased uptake and higher concentration might have increased the chlorophyll concentration. The same view was expressed by Fujimora and Kadowaski (1960), Thomas (1970) and Thomas and Oerther (1972).

#### **5.1.4. Leaf thickness**

Leaf thickness, otherwise the specific leaf weight, is an important feature of storage of photosynthates and nutrient concentration and its subsequent translocation to the development of seed. Leaf thickness had a direct and positive relation with DMP (Veerawirdth 1974). Genotypes of cotton having thicker leaves possessed higher chlorophyll content and were relatively more thermostable. This trait was desirable under arid tropical

environment and could profitably be used for breeding for higher biomass production (Bhardwaj and Singh 1988).

The three planting patterns did not differ for the leaf thickness. This might be due to non-significant influence of geometry or planting on leaf thickness. The thickness was reduced between 45 and 60 DAS and then started increasing. This might be due to faster expansion of leaf area (denominator value for assessing leaf thickness) during this period (Halevy, 1976) as a result of cell division and its multiplication. This might have caused reduction in leaf thickness.

The cultivar TCHB 213 had thicker leaves than MCU 11, possibly due to its genetic character. Thangaraj (1981) studied the physiology of heterosis in inter-specific hybrid cotton and reported that the specific leaf weight (leaf thickness) of hybrid was higher as compared to its parental lines (varieties). Thickness of leaf is an indicator of richness of nutrient content. High yielding genotypes were significantly superior to low yielders in terms of nutrient concentration and chlorophyll content (Krishnamoorthy *et al.*, 1974). The leaf thickness of these two cultivars was decreasing from 45 to 60 DAS and started increasing afterwards. The reason ascribed to this performance was speedy growth and development of cotton leaves during that period.

The increasing levels of nitrogen from zero to 150 per cent (during second year) and from 100 to 200 per cent of recommended nitrogen level (during third year) increased the leaf thickness. During second year leaf

thickness reduced from 45 to 60 DAS and then gradually increased while during third year, the reduction in leaf thickness continued upto 75 DAS and subsequently started increasing. This was due to the fact that higher level of nitrogen, during third year over second year, increased the leaf area expansion faster upto 75 DAS. So, the reduction in leaf thickness was noticed upto 75 DAS.

Increasing nitrogen level had increased the nitrogen concentration and chlorophyll concentration which were the indicators of leaf health in terms of leaf thickness.

#### **5.1.5. Leaf angle**

The leaf angle distribution of a plant canopy determines the amount of solar radiation intercepted, absorbed and reflected. The vertical arrangement of leaves in an erectophile canopy generally scattered more radiation into lower leaf layers than the more horizontal arrangement of a planophile (Pinter *et al.*, 1985, Jackson and Pinter 1986). The ground coverage was more complete in planophile canopy than erectophile at the same level of LAI. Hence, the spectral properties were influenced by leaf angle distribution (Goel and Strebel 1984).

The leaf angle varied between planting patterns. The leaves of cotton planted in normal row were tilted more towards horizontal than in paired rows. This might be due to the reduction in row spacing under paired rows which could have caused the variation in leaf angle to harness solar energy.

The growth of cultivar TCHB 213 was of comparatively open type as a result of longer internodal length while MCU 11 was of bushy type. This would have made large angle between main stem and leaves.

Increasing levels of nitrogen had promoted the crop growth in terms of plant height and LAI. This increase in growth and development might have increased the leaf angle and tilted more towards horizontal position.

Interaction existed only during second year. It was evident from the data that in normal row planting, the leaves were more open and tilted towards horizontal position. Increasing levels of nitrogen application beyond the recommended level (100 per cent) offset the competition between plants and produced significantly different leaf angles. Cultivar TCHB 213 responded to higher level of nitrogen and resulted in leaf production with large angle comparatively.

#### **5.1.6. Leaf water content**

The three planting patterns did not differ in respect of leaf water content. This might be due to non-significant influence of planting geometry on water uptake. The present finding was in line with the observations made by Wahab (1978), Willy, (1979) Rangasamy *et al.* (1983) and Balasubramanian (1987). Moreover, the experiment was conducted under irrigated condition where there was no constraint for soil moisture availability.

The cultivars differed significantly for their leaf water content. This might be due to large leaf area, faster growth and its genetic make up to have more leaf water potential.

The increasing levels of nitrogen might have also produced more root volume as compared to lower levels, which absorbed more water from deeper layer and thereby more leaf water content. The positive correlation between root volume and leaf water content was also reported by Doss *et al.* 1964 and Cohan 1985.

## **5.2. Canopy spectral reflectance**

Solar radiation is the source of energy for photosynthesis. Of the total incidental solar radiation, a portion is absorbed, transmitted and a portion is reflected back. The reflecting property is unique and no two objects reflect similarly. However, the spectral reflectance of a plant canopy is altered by the management, cultural, inherited genetic properties and plant stresses. Moreover, the reflectance and absorbance of solar radiation differ with regions of electromagnetic spectrum. This forms the basis for identification of crops, area under crops deficiency of nutrients and plant stresses.

The canopy spectral reflectance had increased with increase in crop age. As the crop grew, the reflectance got increased in blue, green and infrared bands, while it was reverse in red band, irrespective of treatments (Fig. 3). The spectral character (reflectance) of a plant canopy is an integrated and cumulative effect of plant growth and its development. Leaf pigments

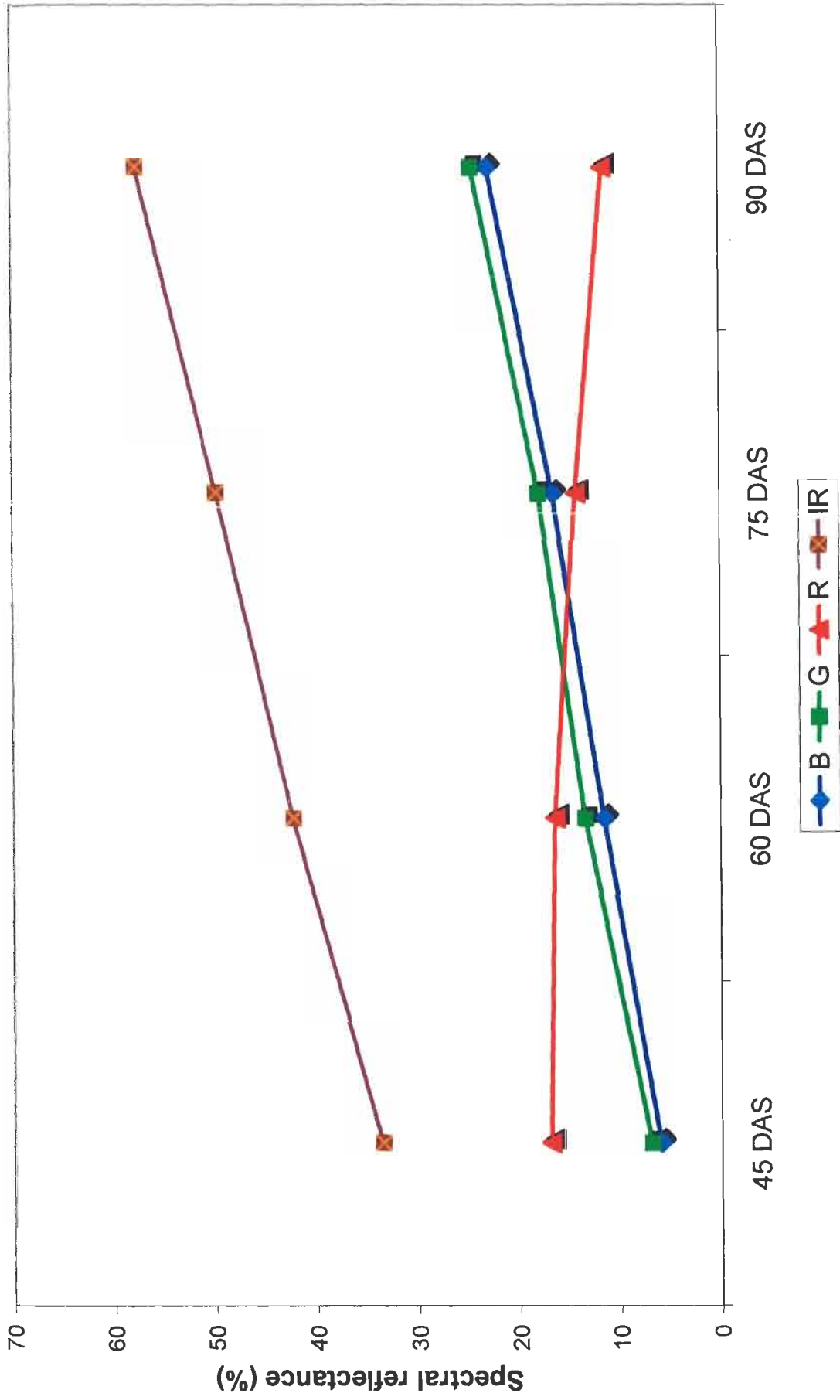


Fig.3. Spectral reflectance (%) of cotton crop during growth stages

absorb much of the radiation in the red portion of the spectrum and as a result, reflectance is relatively small. In contrast, reflectance in blue, green and infrared was much greater. So reflected light varied as a function of the amount of green foliage present (King *et al.*, 1986).

Increasing plant height, LAI, DMP, chlorophyll contents nitrogen concentration, leaf thickness, leaf water content and leaf angle with increase in crop growth stages would have increased the reflectance in blue, green and infrared regions. For the same reason, the absorption increased in red region with reduced reflectance.

The three planting patterns were discriminated from each other from 45 DAS onwards. This was ascribed to the significant difference in plant growth characters *viz.*, plant height, LAI, DMP, ground cover and leaf angle, as observed under the three planting patterns.

All the plant growth parameters influencing spectral reflectance were higher under normal row planting. But the reflectance in general, was higher under paired rows with greengram as intercrop (Fig. 4). This was because of the reason that the proportion of the ground covered by plant species was more important than developmental stages of crop alone in determining spectral responses of crop canopy. This was in confirmation with the results of Leamer *et al.* (1978) who conducted study on wheat at USDA, Weslaco.

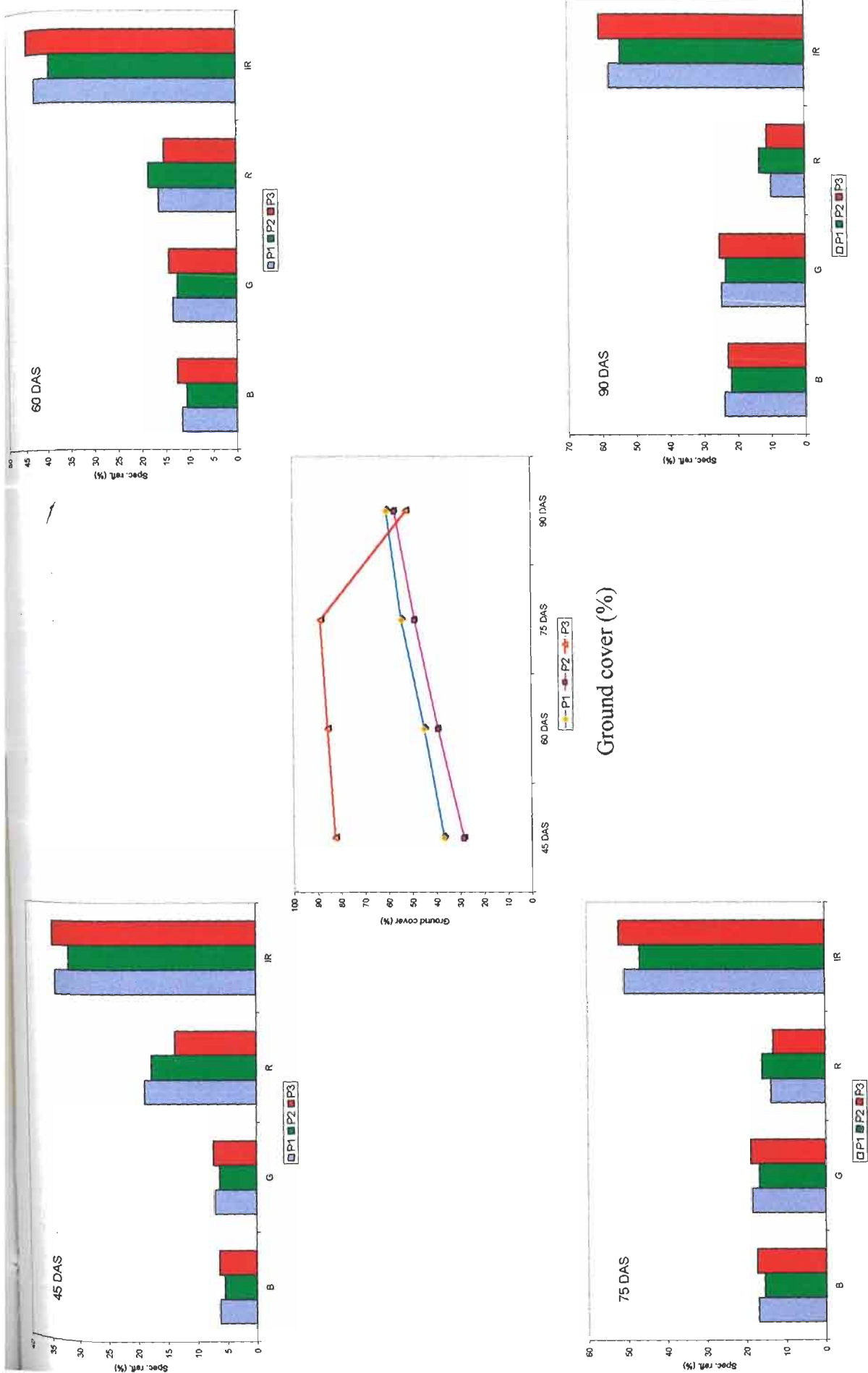


Fig.4. Ground cover and spectral reflectance (%) of cotton under different planting patterns

Once the intercrops were harvested, the reflectance decreased in infrared band and there was increase in red band. This was due to exposure of ground area between cotton pairs.

Though blue and green bands were able to discriminate the planting patterns, it was not consistent in all the four growth stages of observation of two years of experimentation, since these (bands) regions of electromagnetic spectrum were largely influenced by the atmosphere (Clevers, 1992), while red and infrared regions were not affected by the atmospheric conditions. The reflectance in red and infrared bands had been found to be very useful for the study of crop growth patterns by Dubey *et al.* (1992) and for rice varietal discrimination by Krishnan *et al.* (1998).

The two cultivars were distinctly differentiated from each other at all the growth stages (Fig. 5) and in all the three years of experimentation. Between the two cultivars, TCHB 213 was superior in recording higher biometric and physiological parametric values, which evidently increased the reflectance value, as compared to MCU 11. This might be the reason for the significant discrimination of these two cultivars studied throughout.

The levels of nitrogen were distinguished from each other during all the three years of experimentation and at all the growth stages in all the four bands.

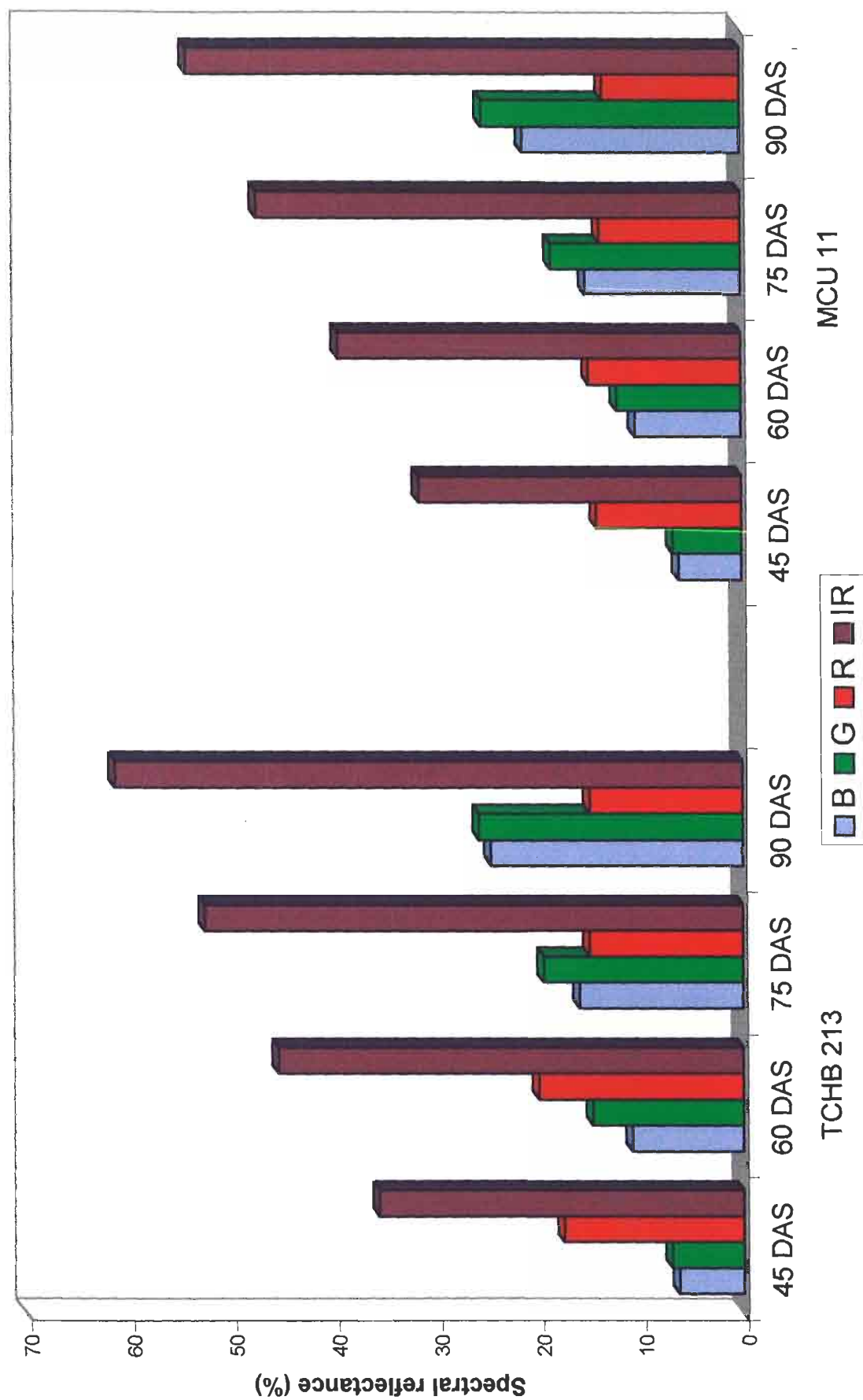


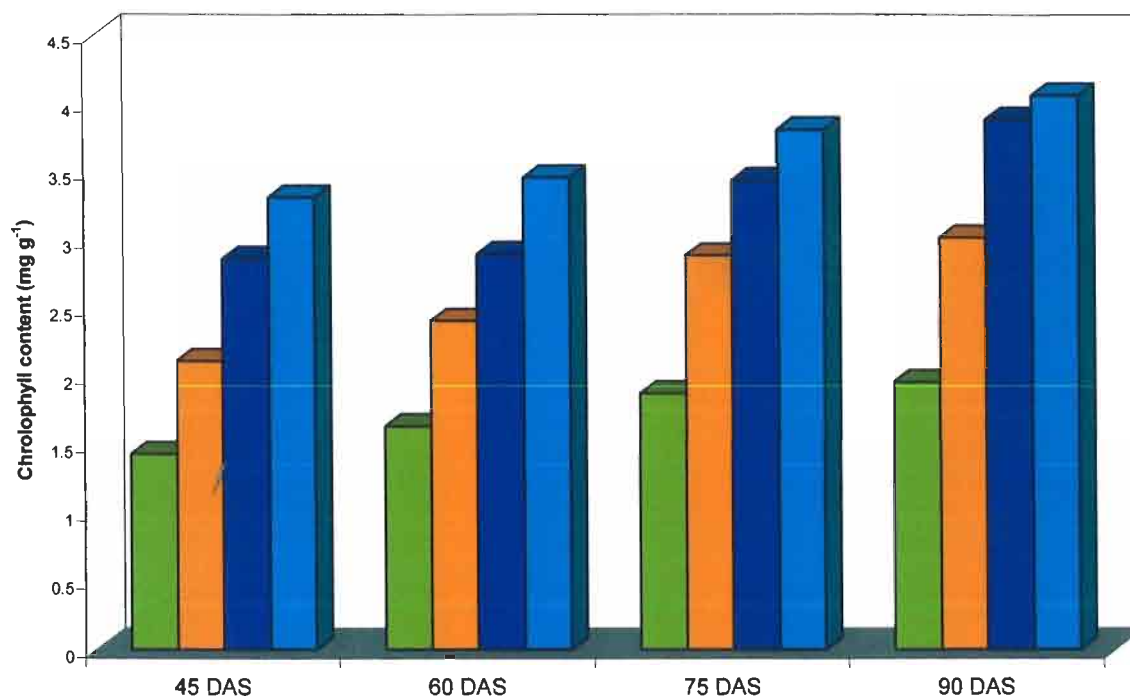
Fig.5. Spectral reflectance (%) of cotton cultivars

Significant correlation existed between nitrogen levels and vegetative growth (Jat *et al.*, 1976 and Singh *et al.*, 1990). Nitrogen fertilization caused increase in LAI, DMP, soil cover, chlorophyll content and plant nitrogen concentration apart from changes in leaf thickness, leaf water content and leaf angle. Difference in these parameters was caused by variations in nitrogen levels studied (Daughtry *et al.*, 1980), which was seen in the reflectance spectra.

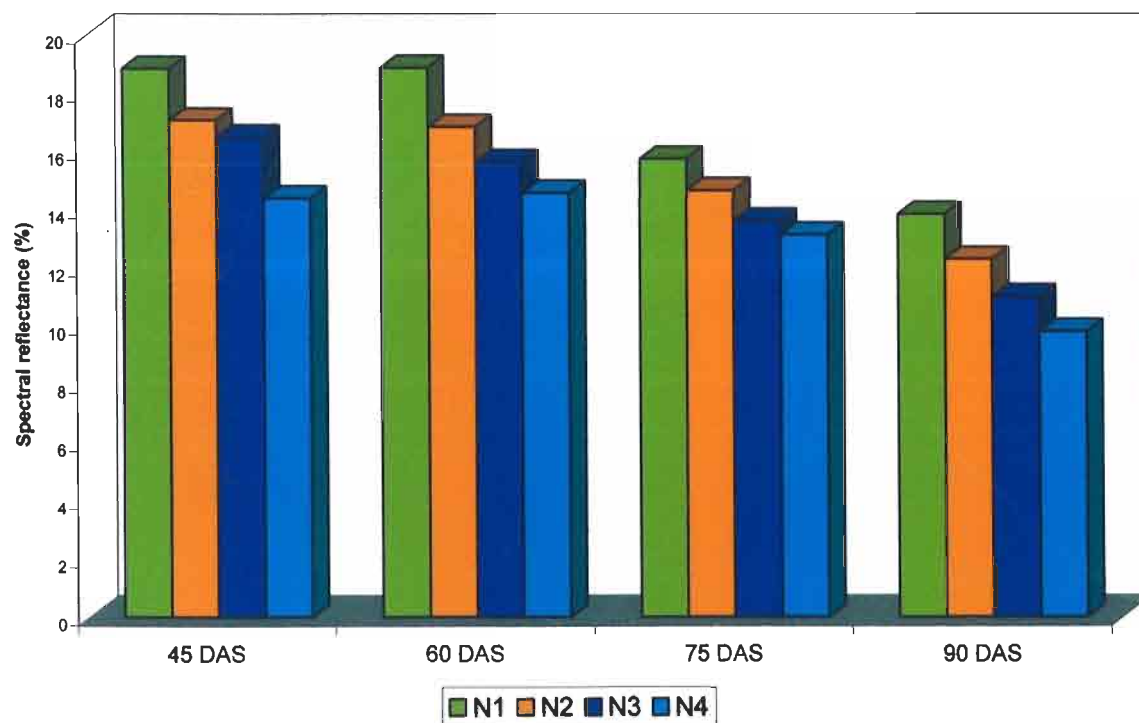
Light absorption in red region depended primarily on chlorophyll concentration. Increasing nitrogen apparently increased the concentration of chlorophyll and thereby increased the absorbance in the red regions (Fig. 6). While reflectance in the infrared region of the spectrum primarily depended on the water content and internal structure of the leaves. The increase in leaf thickness of cotton was ascribed to the increase in spongy parenchyma and vacuoles which caused higher reflectance in infrared region (Thomas *et al.*, 1966) (Fig. 7).

As a cumulative and integrated effect of all the plant growth factors and physiological parameters under by increased nitrogen levels, significantly increased the spectral reflectance and got discriminated from each level.

The interaction effects were significant. In the interaction between planting patterns and cultivars, TCHB 213 under normal row planting had reflected more solar radiation in both red and infrared bands and this might be due to the absence of both inter and intra-species competition. Influence of

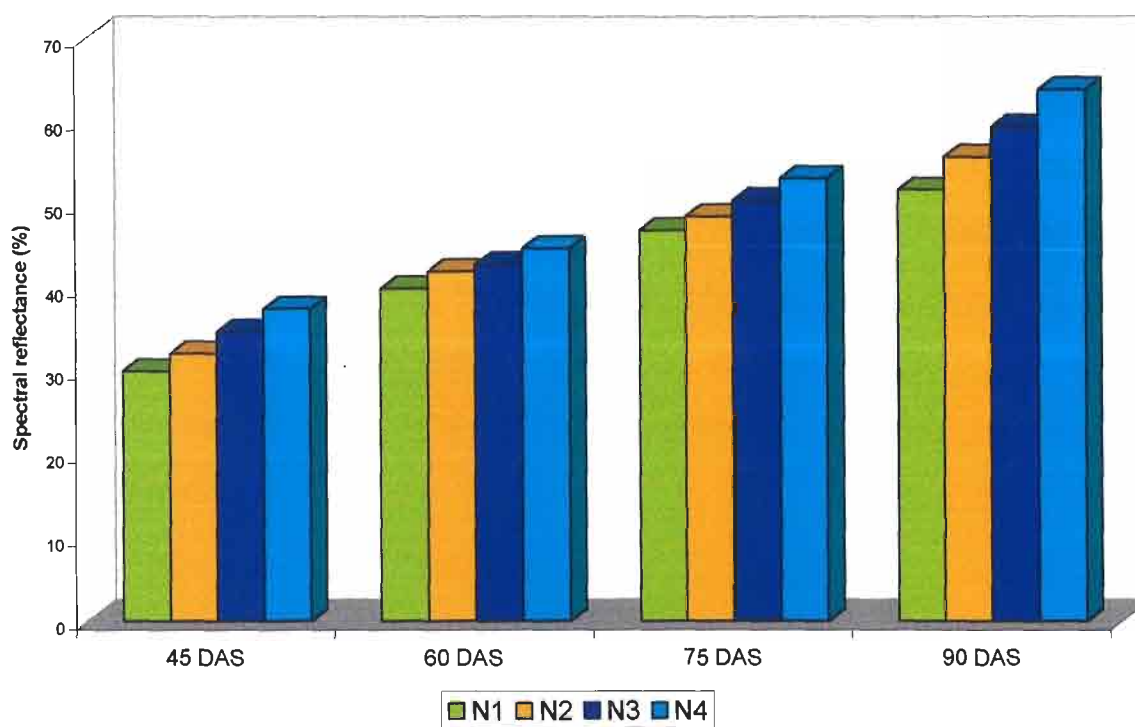
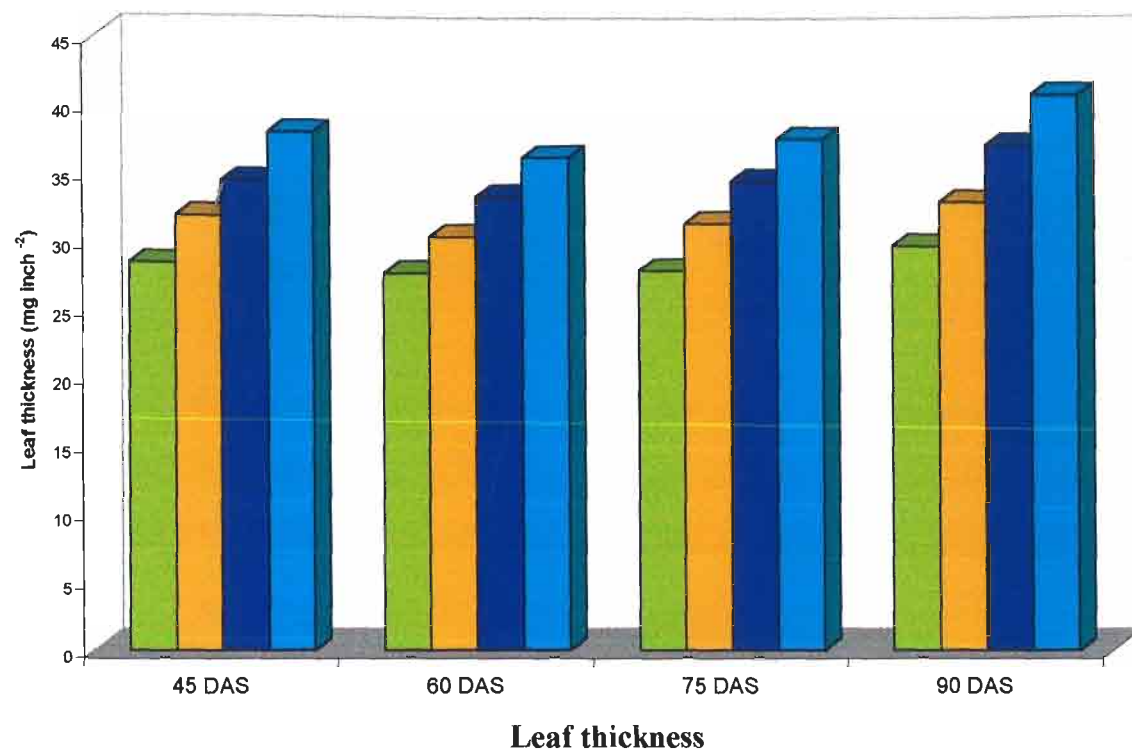


**Chlorophyll content**



**Spectral reflectance in red band**

**Fig.6. Chlorophyll content and spectral reflectance of cotton in red band**



Spectral reflectance in infrared band

Fig.7. Leaf thickness and spectral reflectance of cotton in infrared band

intercropping and nitrogen supply on spectral reflectance was reported by Sutradhar *et al.* (1990). They reported that under normal row planting in conjunction with higher level of nitrogen and chlorophyll concentration, there was more reflectance in infrared region.

In the interaction between cultivars and nitrogen levels, TCHB 213 absorbed more nitrogen under higher dose of 200 per cent of recommended level ( $240 \text{ kg N ha}^{-1}$ ) and reflected more radiation energy. This type of result was reported from  $240 \text{ kg ha}^{-1}$  of nitrogen application by Stanhill *et al.* (1972).

The spectral discrimination of the treatments were found to be stronger at 75 DAS of crop growth. Because this was the time at which cotton crop grew faster and produced more biomass (Halevy, 1976). Moreover, at earlier growth stage, the spectral response of crop canopy was strongly dominated by soil background. At later stages of crop growth, the spectral reflectance was adversely affected by crop senescence. The spectral sensitivity causing parameters such as LAI, biomass and chlorophyll got decreased at later stages of cotton. Hence, the best period for assessing these canopy variables was around 75 days of cotton crop growth as observed in the present investigation.

### 5.3. Vegetation indices

Vegetation indices are combinations of remotely sensed visible (red) and near - infrared spectral reflectance measurements. The variations present in the relationship between spectral reflectance and crop characters

caused by soil background or atmosphere apart from crop characteristics are taken care of in the vegetation indices. These vegetation indices are diagnostic results of canopy size LAI, chlorophyll concentration as well as per cent of ground cover (Tucker, 1979; Colwell, 1974).

The vegetation indices values increased with increase in crop stages because of increasing spectral reflectance in infrared band and reduction in red band.

The variations caused by planting geometry and nitrogen levels on plant canopy got reflected on the spectral reflectance in both red and infrared bands. This was the reason for the significant difference in values of vegetation indices recorded by the three planting patterns, two cultivars and different nitrogen levels evaluated.

Among the five vegetation indices, IR-R was more precise than others because of the reason that the reflectance of red and infrared light appeared primarily from the outer layer of the leaves in the plant canopy. Under irrigated condition cotton canopy structure and reflectance would be consistent (Mass, 1998). This feature favoured the red and infrared ratio for discriminating the treatments.

At early stages of crop growth, Perpendicular Vegetation Indices (PVI) was able to discriminate the treatments well, as compared to other vegetation indices. This was due to dominant influence of background soil reflectance

associated with other vegetation indices. But, in PVI calculation, the soil effect was nullified and only reflectance from vegetation in red and infrared bands was considered. The PVI was also used for vegetation discrimination at early stages of crop growth by Curran (1983) and Jackson *et al.* (1983). The other indices viz., vegetation index and transformed vegetation index were able to discriminate at 60 and 75 DAS when the reflectance was not influenced either by background soil or by crop senescence.

The vegetation indices were stronger in discriminating the treatments at 75 DAS, obviously due to occurrence of differing spectral reflectance at that stage.

#### **5.4. Spectral reflectance Vs agronomic variables**

Spectral reflectance in red band had negative correlation with agronomic parameters and was non-significant, except ground cover which was significant. While, infrared band had a positive and significant correlation with agronomic and physiological variables.

In the red region, vegetation absorbed more radiation and showed relatively low reflectance. As the leaf area and biomass increased, there was a progressive and characteristic reduction in the reflectance of the chlorophyll absorption region of red. In the infrared region, the opposite event occurred. Hence, negative correlation existed in red region and positive correlation occurred in infrared region.

Ground cover alone had significant correlation with red band. In this red region, the absorption would be around 80 per cent and reflectance and transmittance would be 10 per cent or less (Clevers, 1992) and that too from upper leaves alone. The large contrast in reflectance between vegetation and bare soil in the red region gave a significant vegetative correlation.

Among the agronomic and physiological parameters, LAI was more strongly correlated with infrared reflectance followed by plant nitrogen concentration. In the infrared region, the reflectance was from lower layer of vegetation apart from upper surface and there was little absorption in this region (Clevers, 1992). Increasing LAI had increased the reflectance and correlated more strongly and positively.

Between the two bands, red region had weak correlation with agronomic and physiological variables unlike infrared region.

### **5.5. Vegetation indices Vs agronomic and physiological variables**

Among the five vegetation indices, Perpendicular Vegetation Index (PVI) wherein the background effect of soil was set aside, had strong correlation with both agronomic and physiological variables compared to other indices. The infrared and red ratio (IR/R) was also equally satisfactory in terms of correlation with crop variables. Vegetation Index (VI) and transformed vegetation index had comparatively weak correlation as compared to IR-R; IR/R and PVI. The PVI was used for crop growth and developmental studies, as indicated by Curran (1983) and Jackson *et al.*

(1983). However, in order to apply the PVI, the reflectance of the bare soil of the experimental site has to be recorded.

The ratios (IR-R and IR/R) and other orthogonal transformation except PVI, the reflectance was not only affected by green foliage but also by the differences in reflectance from bare soil and from dead foliage fallen on the ground. Therefore, for a canopy, the relationship between ratios (IR-R and IR/R), VI, TVI and crop variables was a function of soil background disturbances. But in PVI, the background disturbances were subtracted and hence PVI had strong correlation with crop variables.

#### **5.6. Estimation of agronomic and physiological parameters**

Important crop variables which are indicative of crop condition were estimated from spectral reflectance and vegetation indices, using allometric relationship between crop variables and their spectral reflecting property.

The spectral reflectance of an object is based on its composition and internal contents. No two different objects would have similar reflectance, which is unique like human thumb impression. Indirectly, the spectral reflectance is a function of growth variables. Based on this principle, the allometric relation was worked out. Allometric model was also used by Chellamuthu *et al.* (1998) to study the root length and shoot length of *Prosopis juliflora* and Ramesh *et al.* (2000) to study the relation between soybean growth parameters.

### **5.6.1. Leaf area index**

The spectral reflectance and vegetation indices had satisfactory allometric relationship with LAI. Compared to red band the allometric relation was more stronger in infrared band due to strong correlation between LAI and infrared reflectance. The vegetation indices were also found to possess good agreement to estimate the LAI. The estimation of LAI was more precise in using vegetation index with least Chi-square value. The vegetation index was also used by Goel (1987), Goward *et al.* (1991), Baret and Guyot (1991) and Goward and Huemmrich (1992).

### **5.6.2. Dry matter production**

The allometric relation could not estimate the dry matter production as the Chi-square validation was significant. The dry matter estimation from spectral reflectance was an indirect method and merely based on LAI (Clevers, 1992). Moreover, the DMP estimation was from a few selected sample plants and computed per hectare. This might be the reason for poor relation arrived at between spectral reflectance and DMP.

### **5.6.3. Total chlorophyll content**

The total chlorophyll concentration could be estimated from spectral reflectance and vegetation indices. As the chlorophyll concentration was the main bio-chemical constituent, it absorbed more light in red region and reflected almost entire amount of solar radiation falling in the infrared region. Both spectral reflectance and vegetation indices were useful in estimating the chlorophyll content. Estimation of chlorophyll content from

spectral reflectance was used by Card *et al.* (1988), Curran (1989) and Curran *et al.* (1992).

#### **5.6.4. Plant nitrogen content**

Plant nitrogen concentration could best be estimated from spectral reflectance and vegetation indices. The plant nitrogen concentration manifested the spectral reflectance through other parameters like chlorophyll content and LAI rather than by itself (Vesk *et al.*, 1966). The reduction in leaf nitrogen concentration, even by one per cent, could not be detected visually by the gradual change in leaf colour but can be differentiated by spectral reflectance measurements (Thomas and Oerthor, 1972). This made it possible to estimate the plant nitrogen content.

#### **5.6.5. Ground cover**

In spectral measurement studies of crop canopy, the extent of ground cover would be more important than the stage of the crop (Leamer *et al.*, 1978). As the soil coverage by canopy increased, the reflectance was from crop canopy alone and hence it had stronger relation with both spectral reflectance and vegetation indices.

### **5.7. Yield components**

#### **5.7.1. Number of bolls per plant**

The method of planting had influenced the number of bolls produced per plant. The competition existed between cotton plants and between cotton and green gram (inter) might have reduced the boll production under paired

row planting. Decrease in boll number due to paired row system of planting was also reported by Krishnasamy *et al.* 1995(b) and Christopher Lourduraj and Chinasami (1996).

TCHB 213 being a hybrid had produced more boll number surpassing a variety is not uncommon in biological sciences especially in agriculture sciences.

The increased expression of growth attributes at higher level of applied nitrogen partitioned more dry matter to the reproductive development. Jackson and Gerik (1990) reported the dependence of boll number on leaf area and DMP in cotton, which were the functions dictated by applied nitrogen.

In the present investigation, increasing levels of nitrogen increased plant growth and its vigour and led to production of more number of bolls per plant. Increased boll numbers per plant due to increasing levels of nitrogen was also reported by Chamy *et al.* (1977), Jagannathan and Iruthayaraj (1980), Thirumurugan *et al.* (1984), Sawan (1986) and Madhavi Latha (1988).

During first and second years the response in terms of boll number per plant was upto 150 per cent of recommended level (120 kg ha<sup>-1</sup> for MCU 11 and 180 kg ha<sup>-1</sup> for TCHB 213). But there was no response for boll production when nitrogen application was increased further. Similar response to nitrogen upto 160 kg ha<sup>-1</sup> was reported by Madhavi Latha (1988) and Thirumurugan *et al.* (1984) in cotton hybrids.

Interaction existed between cultivars and nitrogen levels. TCHB 213 was superior in boll production and the response was only upto 150 per cent of recommended nitrogen ( $180 \text{ kg nitrogen ha}^{-1}$ )

### 5.7.2. Seed cotton yield

The three planting patterns influenced the seed cotton yield. Cotton sown in normal row system had produced more yield as compared to paired rows. The reason being reduction in yield attribute under paired row system of planting. (Balasubramanian *et al.* 1994). By pairing cotton rows with reduced inter row space caused intra-species competition. When an intercrop was introduced, inter species competition was also added. Reduction in seed cotton yield due to introduction of inter crop corroborates the results reported by Krishnasamy *et al.* (1995c).

The increased seed cotton yield obtained in TCHB 213 was because of the increased boll numbers. Though the population of TCHB 213 was lesser ( $13,889 \text{ plants ha}^{-1}$ ) compared to MCU 11 ( $29,630 \text{ plants ha}^{-1}$ ) it had more number of bolls per plant (Table 55 and 61).

Increased levels of nitrogen upto 150 per cent of recommended level  $\text{ha}^{-1}$  had increased the seed cotton yield. Though 200 per cent of recommended level of nitrogen produced numerically higher seed cotton yield in the third year, the increase was non significant. This confirmed the results of Deshpande *et al.* (1989), Brar *et al.* (1992), Chandrasekaran and Sankaran (1983) and Mukarji and Verma (1994).

### 5.7.3. Spectral reflectance Vs Seed cotton yield

The final seed cotton yield was correlated well with infrared reflectance and ratios of red to infrared apart from PVI calculated at 75 DAS. This might be due to the active growth of crop at that stage (Halevy 1976). The reflectance in the infrared region was from the entire canopy (Clevers, 1992) which was a function of LAI, nitrogen concentration and ground cover. These were the parameters which decided the seed cotton yield. Hence, the reflectance in the infrared region had correlated strongly with final seed cotton yield.

As the growth parameters, that decided the yield attributes and yield, increased the differences in reflectance between red and infrared band widened and increased. This might be the reason for a positive and significant correlation between ratios (IR-R and IR/R), and final yield. The reason ascribed for a positive and significant correlation of PVI with final yield was the removal of adverse disturbance from the soil background.

### 5.8. Yield forecasting

Yield forecasting of cotton was made from the spectral reflectance and vegetation indices at 75 DAS, the optimum stage for spectral measurement studies.

Allometric models were used for this prediction. The validation by Chi-square test exposed the ineffectiveness of this model to predict the final seed cotton yield in the present investigation.

The spectral measurements were taken from experimental area alone but the yield was calculated per hectare basis from net plot area. This might be the reason for non-validation of this model to predict the final yield.

However, the relative deviation of estimated yield from observed yield fell within a reasonable range of (-) 6 to (+) 13 per cent for MCU 11 and for TCHB 213, it ranged from (-) 5 to (+) 12 per cent. Similar results for wheat yield prediction was reported by Medhavy *et al.* (1995).

The spectral reflectances in red and infrared bands were more precise than the combination of these bands. This might be due to loss of sensitivity of these bands when combined together. This loss of sensitivity might happen between red and infrared bands when LAI was at peak (Clevers, 1992).

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## Summary and Conclusion

*Chapter VI*  
**SUMMARY AND CONCLUSION**

Three field experiments were conducted at Tamil Nadu Agricultural University Farm, Coimbatore during 1992-'95 to study the spectral reflectance from planting patterns, cultivars and levels of applied nitrogen in irrigated winter cotton through remote sensing technique.

During the first and second years, the experiments were laid out in split plot design. Three planting patterns *viz.*, normal row planting, paired row planting and paired row planting with green gram as intercrop and two cultivars *viz.*, TCHB 213 and MCU 11 were taken as main plot treatments. In the sub plots four levels of nitrogen *viz.*, 0, 50 (60 and 40 kg ha<sup>-1</sup>) 100 (120 and 80 kg ha<sup>-1</sup>) and 150 (180 and 120 kg ha<sup>-1</sup> for TCHB 213 and MCU 11 respectively) per cent of recommended levels of nitrogen were applied.

Third year experiment was conducted in factorial randomised block design with two cultivars *viz.*, TCHB 213 and MCU 11 as one factor and three levels of nitrogen *viz.*, 100 (120 and 80 kg ha<sup>-1</sup>), 150 (180 and 120 kg ha<sup>-1</sup>) and 200 (240 and 160 kg ha<sup>-1</sup> for TCHB 213 and MCU 11 respectively) per cent of recommended nitrogen as the other factor.

From the first two years of experimentation, it was found that the planting patterns and nitrogen levels were discriminated from each other from 45 DAS on wards.

Spectral reflectance measurements were taken using a multi-band ground truth radio meter in visible [blue (0.45 - 0.52  $\mu\text{m}$ ), green (0.52 - 0.59  $\mu\text{m}$ ) and red (0.62 - 0.68  $\mu\text{m}$ )] and near infrared region (0.77 - 0.86  $\mu\text{m}$ ). Simultaneously all the agronomic and physiological parameters were recorded.

The canopy ground cover crossed 25 per cent only at 45 DAS. The peak growth rate and nutrient uptake and concentration were recorded upto 90 DAS of cotton crop growth. Hence, the observations were made from 45 DAS to 90 DAS at fortnightly interval (45, 60, 75 and 90 DAS). Among these four stages spectral reflectance discrimination was stronger, in terms of absolute difference between treatments as compared to critical difference (CD) at 75 DAS. Hence, 75 DAS of cotton was adjudged as optimum stage for spectral reflectance studies.

Plant growth factors *viz.*, plant height, LAI and DMP were higher under normal row planting. In paired rows with greengram inter crop, the growth factors were the least. TCHB 213 was superior in recording growth factors than MCU 11. Response of growth factors to nitrogen application was upto 200 per cent (240 and 160  $\text{kg ha}^{-1}$  for TCHB 213 and MCU 11 respectively) of recommendation.

The ground cover was maximum under paired rows with green gram intercrop upto 75 DAS due to the presence of intercrop. TCHB 213 had obtained more growth and covered ground to higher level.

Nitrogen and chlorophyll contents were not affected by the planting geometry. Cultivar TCHB 213 contained more nitrogen and hence more chlorophyll than MCU 11. Increasing levels of nitrogen application had increased the plant nitrogen concentration.

Leaf water content and leaf thickness were not affected by the patterns of planting but were significantly influenced by nitrogen levels and cultivars. TCHB 213 under higher nitrogen levels had more leaf water and leaf thickness.

Leaf angle had varied among planting patterns. Plants under normal row planting had leaves tilted more towards horizontal position while in paired rows the leaves were relatively erect. TCHB 213 had open and large angled leaves than MCU 11. Increasing nitrogen levels had produced leaves inclined towards horizontal

Boll production was influenced by planting pattern. Normal row plants produced more number of bolls per plant followed by paired row and paired rows with greengram intercrop. TCHB 213 produced more bolls than MCU 11. The response to nitrogen applications for boll production was only upto 150 per cent (180 and 120 kg ha<sup>-1</sup> for TCHB 213 and MCU 11 respectively) of recommended nitrogen. The 200 per cent of recommended nitrogen (240 and 160 kg ha<sup>-1</sup> for TCHB 213 and MCU 11 respectively) was at statistical par with 150 per cent.

Seed cotton yield differed significantly. Normal row planting method produced significantly higher seed cotton yield than the other two methods of

planting. Paired rows with greengram intercrop had least seed cotton yield. TCHB 213 produced significantly higher yield than MCU11. Significant increase in seed cotton yield was observed for nitrogen upto 150 per cent of nitrogen (180 and 120 kg ha<sup>-1</sup> for TCHB 213 and MCU 11 respectively) recommendation, beyond which no significant increase was recorded.

Spectral reflectance increased with increase in crop growth in reflective bands (blue, green and infrared) while it got decreased in red band (absorption band).

Planting patterns, cultivars and nitrogen levels could be discriminated from spectral reflectance from 45 DAS onwards. The discrimination was stronger, in terms of absolute value, at 75 DAS.

Blue and green bands were inconsistent in discriminating the treatments, while red and infrared bands were consistent and more stronger in discriminating the treatments.

The cultural practices like methods of planting, cultivars and nitrogen application levels could be discriminated from vegetation indices also.

At earlier stage of crop growth, when ground cover was the least, PVI would be more suitable to discriminate the crop growth and its development. When ground cover was more at later stages of crop growth IR-R would be useful to discriminate the crop growth and condition.

Red band had a negative correlation with growth parameters while, infrared had positive correlation. Ground cover alone had significant and

comparatively more stronger correlation in red band than infrared band. In the infrared reflectance LAI contributed more than any other growth variable studied.

Ground cover could be estimated from red band and LAI can be estimated from infrared and reflectance.

Infrared reflectance, ratios of red and infrared reflectance and perpendicular vegetation index correlated well with final seed cotton yield.

Agronomic and physiological parameters could be estimated precisely from reflectance in red and infrared bands and the vegetation indices.

DMP could not be estimated from spectral reflectance.

The forecasted yield of cotton from spectral reflectance and vegetation indices varied from (-) 5 to (+) 13 per cent. In forecasting the yield, spectral reflectance were more precise than the vegetation indices.

Based on the findings the future research may be attempted in the following lines.

Further satellite studies may be attempted with red and infrared bands alone.

Estimation of growth parameters and yield prediction may be attempted from satellite based observations based on present investigation.

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\* Originals not seen

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Annexures

Annexure - I (a)

Weather prevailed during crop growth period of cotton during 1992-'93 (August '92 - April '93)

Std. Wk.	Mean max. temp (°C)	Mean min. temp (°C)	Mean RH 0722 hrs (%)	Mean RH 1422 hrs (%)	RF (mm)	Mean S.S. hrs	Mean Evp (mm)	Mean WV (KMPH)	Mean S.R. cal/cm <sup>2</sup> /day
31	31.7	22.3	85	56	-	2.6	5.7	15.3	188.1
32	29.7	22.8	81	64	13.8	4.1	5.0	14.6	170.4
33	29.5	23.3	68	56	1.8	3.7	6.8	31.1	188.7
34	32.6	22.4	82	44	-	7.1	7.0	15.3	230.6
35	32.1	22.2	82	49	-	3.9	6.9	14.9	240.7
36	31.2	22.1	72	48	1.8	4.3	8.1	22.7	213.3
37	32.8	21.4	84	49	-	7.7	7.0	10.8	231.9
38	32.0	21.7	92	52	97.4	5.4	4.6	5.6	189.4
39	30.3	22.3	93	62	55.5	3.6	2.7	4.4	121.0
40	29.0	21.8	90	71	44.9	2.2	4.3	4.9	156.5
41	30.8	22.1	88	62	5.7	4.7	4.0	5.1	186.9
42	31.0	20.8	92	58	7.5	5.0	3.7	3.9	190.6
43	31.2	20.7	90	54	29.0	4.7	3.5	3.0	177.9
44	31.0	21.7	88	46	14.5	7.1	4.2	4.2	205.3
45	30.1	22.6	92	61	66.8	4.3	3.0	4.1	165.3
46	27.0	21.3	93	76	161.7	2.0	1.9	8.6	103.2
47	28.7	21.3	94	64	63.6	4.4	2.0	3.5	159.2

## Annexure la Contd..

48	28.6	20.6	88	56	-	5.3	3.6	6.2	184.5
49	27.8	19.3	87	56	8.1	4.6	2.9	7.6	159.8
50	29.3	18.7	88	52	-	7.3	3.4	4.2	191.0
51	27.6	18.9	87	57	-	6.1	3.5	7.1	169.8
52	28.0	15.4	89	42	-	9.5	4.4	6.7	227.1
1	29.1	14.6	92	30	-	8.3	5.1	7.5	223.5
2	30.2	16.7	88	37	-	8.9	4.6	6.1	219.3
3	30.3	15.6	84	34	-	6.7	4.3	5.2	201.3
4	31.1	16.5	82	32	-	6.3	4.9	6.4	229.4
5	31.3	17.3	83	31	-	9.4	6.0	9.4	229.4
6	31.2	15.4	80	44	-	9.8	5.4	6.6	231.7
7	33.2	19.6	83	32	-	9.5	5.5	5.2	222.9
8	32.7	20.2	87	40	17.5	8.5	4.7	5.8	218.6
9	31.9	21.3	80	49	32.5	6.3	4.7	5.6	200.6
10	33.0	19.7	83	32	-	8.9	5.9	6.9	243.3
11	34.6	22.1	88	36	5	7.7	5.3	4.3	222.3
12	35.5	21.7	83	34	-	8.3	5.9	4.6	231.5
13	35.4	21.8	82	33	2.2	7.5	5.9	4.8	213.6

**Annexure I (b)**

**Weather prevailed during crop growth period of cotton during 1993-'94 (August '93 to April '94)**

Std. Wk.	Mean max. temp (°C)	Mean min. temp (°C)	Mean RH 0722 hrs (%)	Mean RH 1422 hrs (%)	RF (mm)	Mean S.S. hrs	Mean Evp (mm)	Mean WV (KMPH)	Mean S.R. cal/cm <sup>2</sup> /day
31	31.6	24.1	63	48	-	5.5	8.6	29.4	344
32	32.3	23.6	77	48	2	5.2	6.9	16.8	365.3
33	32.0	22.9	74	48	3	6.4	7.4	23.5	411.0
34	32.6	21.8	78	47	10.6	7.2	7.9	16.2	395.2
35	32.3	22.2	89	59	36.6	4.9	3.9	6.9	356.2
36	31.1	21.3	89	42	3.0	2.1	4.9	8.0	361.3
37	32.8	22.0	84	46	7	6.3	4.5	7.4	397.4
38	33.3	22.0	83	41	-	5.9	5.9	8.6	420.0
39	33.9	21.7	76	40	1.6	7.7	7.3	10.9	435.1
40	31.8	22.5	88	58	30.8	5.3	4.9	5.3	306.4
41	30.8	22.3	91	61	30	3.7	3.8	3.5	339.7
42	30.1	22.5	90	58	58.3	5.4	2.2	5.0	328.2
43	30.4	21.9	89	54	19.3	6.2	3.1	3.1	352.4
44	29.8	22.7	88	61	29.1	4.1	4.2	7.1	362.4
45	27.6	21.8	88	76	112.1	2.3	1.9	8.2	222.6
46	28.7	21.5	92	67	124.6	6.4	2.3	2.5	395.9

## Annexure 1b Contd ...

47	29.1	20.5	89	55	-	6.1	3.3	3.2	379.1
48	28.1	19.8	86	55	1.5	4.5	3.1	4.5	370.9
49	27.4	20.4	90	65	17.1	3.6	3.2	3.3	300.1
50	29.0	18.3	89	46	-	6.9	3.7	3.1	427.6
51	27.1	19.3	89	64	-	0.9	2.9	3.5	235.0
52	27.5	19.5	86	54	-	5.5	3.2	3.5	319.8
1	29.1	19.1	89	49	-	8.3	4.1	4.1	417.8
2	28.4	19.1	88	51	0.2	6.6	3.8	3.3	417.4
3	29.7	21.5	89	60	72.5	6.3	3.2	3.9	395.0
4	29.0	16.8	90	39	-	8.3	4.3	4.8	467.3
5	30.9	16.9	91	47	-	9.4	4.7	3.2	473.6
6	31.4	22.0	88	54	10.0	6.7	4.4	4.2	392.2
7	32.8	21.4	88	49	19.0	7.1	4.1	4.1	473.6
8	33.0	19.8	87	38	-	7.4	5.3	3.7	439.4
9	32.5	17.7	81	28	-	9.9	6.7	6.2	400.6
10	34.4	16.6	76	21	-	10.1	7.3	6.2	483.7
11	35.0	20.9	79	31	-	7.5	7.2	7.5	437.8
12	36.4	22.9	75	36	-	7.4	6.4	7.2	424.8
13	35.6	23.8	84	42	6	8.1	6.5	6.8	431.0

## Annexure 1b Contd ...

47	29.1	20.5	89	55	-	6.1	3.3	3.2	379.1
48	28.1	19.8	86	55	1.5	4.5	3.1	4.5	370.9
49	27.4	20.4	90	65	17.1	3.6	3.2	3.3	300.1
50	29.0	18.3	89	46	-	6.9	3.7	3.1	427.6
51	27.1	19.3	89	64	-	0.9	2.9	3.5	235.0
52	27.5	19.5	86	54	-	5.5	3.2	3.5	319.8
1	29.1	19.1	89	49	-	8.3	4.1	4.1	417.8
2	28.4	19.1	88	51	0.2	6.6	3.8	3.3	417.4
3	29.7	21.5	89	60	72.5	6.3	3.2	3.9	395.0
4	29.0	16.8	90	39	-	8.3	4.3	4.8	467.3
5	30.9	16.9	91	47	-	9.4	4.7	3.2	473.6
6	31.4	22.0	88	54	10.0	6.7	4.4	4.2	392.2
7	32.8	21.4	88	49	19.0	7.1	4.1	4.1	473.6
8	33.0	19.8	87	38	-	7.4	5.3	3.7	439.4
9	32.5	17.7	81	28	-	9.9	6.7	6.2	400.6
10	34.4	16.6	76	21	-	10.1	7.3	6.2	483.7
11	35.0	20.9	79	31	-	7.5	7.2	7.5	437.8
12	36.4	22.9	75	36	-	7.4	6.4	7.2	424.8
13	35.6	23.8	84	42	6	8.1	6.5	6.8	431.0

Annexure I (c)

Weather prevailed during crop growth period of cotton during 1994-'95 (August '94 to April '95)

Std. Wk.	Mean max. temp (°C)	Mean min. temp (°C)	Mean RH 0722 hrs (%)	Mean RH 1422 hrs (%)	RF (mm)	Mean S.S. hrs	Mean Eyp (mm)	Mean WV (KMPH)	Mean S.R cal/cm <sup>2</sup> /da
31	29.3	22.7	79	53	7.5	2.8	5.2	16.9	282.3
32	32.2	21.8	84	49	-	6.1	6.0	9.8	391.1
33	31.5	22.2	81	49	0.8	3.9	5.8	11.7	334.1
34	32.4	21.8	83	51	-	2.8	5.3	12.4	325.2
35	30.3	23.1	71	59	5.0	3.2	5.5	26.4	347.8
36	31.4	22.9	78	55	12.2	6.6	6.7	17.6	390.4
37	32.1	20.9	84	52	-	7.6	6.0	8.4	422.1
38	33.8	20.8	80	48	-	9.8	7.1	13.3	440.4
39	32.6	22.6	88	54	33.9	5.7	4.4	5.2	361.5
40	30.1	22.4	85	64	37.8	4.3	4.4	6.7	345.0
41	32.1	22.3	84	56	6.1	7.9	4.5	7.1	428.2
42	30.5	22.0	89	61	32.3	5.8	3.8	5.6	359.4
43	28.9	21.8	90	69	161.3	4.7	2.0	8.2	295.1
44	28.9	21.8	90	73	119.9	4.3	2.4	3.4	340.7
45	26.7	21.0	78	74	48.7	2.1	2.4	7.5	294.5
46	27.6	21.3	75	70	20.0	4.8	2.9	3.0	353.2
47	28.9	20.4	85	61	1.6	5.9	3.8	6.0	396.4

Annexure I (c)

Weather prevailed during crop growth period of cotton during 1994-'95 (August '94 to April '95)

Std. Wk.	Mean max. temp (°C)	Mean min. temp (°C)	Mean RH 0722 hrs (%)	Mean RH 1422 hrs (%)	RF (mm)	Mean S.S. hrs	Mean Evp (mm)	Mean WV (KMPH)	Mean S.R. cal/cm <sup>2</sup> /day
31	29.3	22.7	79	53	7.5	2.8	5.2	16.9	282.3
32	32.2	21.8	84	49	-	6.1	6.0	9.8	391.1
33	31.5	22.2	81	49	0.8	3.9	5.8	11.7	334.1
34	32.4	21.8	83	51	-	2.8	5.3	12.4	325.2
35	30.3	23.1	71	59	5.0	3.2	5.5	26.4	347.8
36	31.4	22.9	78	55	12.2	6.6	6.7	17.6	390.4
37	32.1	20.9	84	52	-	7.6	6.0	8.4	422.1
38	33.8	20.8	80	48	-	9.8	7.1	13.3	440.4
39	32.6	22.6	88	54	33.9	5.7	4.4	5.2	361.5
40	30.1	22.4	85	64	37.8	4.3	4.4	6.7	345.0
41	32.1	22.3	84	56	6.1	7.9	4.5	7.1	428.2
42	30.5	22.0	89	61	32.3	5.8	3.8	5.6	359.4
43	28.9	21.8	90	69	161.3	4.7	2.0	8.2	295.1
44	28.9	21.8	90	73	119.9	4.3	2.4	3.4	340.7
45	26.7	21.0	78	74	48.7	2.1	2.4	7.5	294.5
46	27.6	21.3	75	70	20.0	4.8	2.9	3.0	353.2
47	28.9	20.4	85	61	1.6	5.9	3.8	6.0	396.4

## Annexure 1c Contd..

48	29.8	17.8	89	61	-	8.2	3.3	3.4	433.3
49	28.6	15.6	89	54	-	9.4	3.4	4.4	505.8
50	28.7	18.5	86	57	-	9.1	3.6	5.2	467.5
51	28.7	16.9	84	60	1.6	5.0	3.4	8.5	325.2
52	28.7	21.3	86	56	-	7.1	3.7	7.2	412.6
1	28.2	16.8	89	53	1.0	5.6	3.4	5.6	368.4
2	30.5	21.1	87	57	1.8	7.0	2.3	4.7	399.0
3	29.0	20.5	87	66	1.0	5.8	4.2	9.2	331.0
4	30.4	17.9	86	38	-	8.8	4.6	7.0	469.6
5	30.0	21.0	83	46	-	7.7	5.1	7.3	393.4
6	31.1	19.2	85	45	-	8.9	4.8	8.3	443.7
7	32.8	19.5	86	43	-	9.3	5.3	5.5	464.1
8	34.0	21.5	81	43	-	9.5	5.9	6.1	472.6
9	34.4	19.8	81	41	-	3.7	6.7	6.1	450.8
10	33.7	20.7	84	40	-	8.9	6.5	7.0	433.0
11	34.0	21.0	79	37	-	10.6	7.1	7.2	480.0
12	35.9	20.1	78	26	-	10.6	8.7	7.9	479.6
13	35.2	23.2	79	45	-	9.0	6.4	6.9	436.8



## Annexure II

### Mean yield kg ha<sup>-1</sup> of greengram (Co 4)

N levels	TCHB 213		MCU 11	
	1992-'93	1993-'94	1992-'93	1993-'94
N <sub>1</sub>	357	502	277	410
N <sub>2</sub>	502	585	427	583
N <sub>3</sub>	735	897	652	738
N <sub>4</sub>	995	1150	863	

Statistically not analysed

#### Result

Green gram yield was higher during second year of study (1993-'94). When greengram was grown along with TCHB 213 comparatively higher grain yield was obtained.

# PLATE 1



**Plate 2. General view of the experimental field**