Effect of nitrogen management through organic and inorganic sources in sole and intercropped Bt cotton– wheat system

By

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Effect of nitrogen management through organic and inorganic sources in sole and intercropped Bt cotton– wheat system

सम्मिलत एवं एकल बीटी कपास-गेहूं प्रणाली में कार्बनिक एवं अकार्बनिक स्रोतों के उपयोग के माध्यम से नाइट्रोजन प्रबंध संबंधी क्रियाओं का प्रभाव

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CERTIFICATE

This is to certify that the thesis entitled **"Effect of nitrogen management through organic and inorganic sources in sole and intercropped Bt cotton– wheat system"** submitted to the Post-Graduate School, Indian Agricultural Research Institute, New Delhi, in partial fulfilment of the requirements for the degree of **Doctor of Philosophy in Agronomy**, embodies the results of *bona fide* research work carried out by **Mr. Raman Jeet Singh** under my guidance and supervision. No part of the thesis has been submitted for any other degree or diploma.

All the assistance and help received during the course of the investigation have been duly acknowledged by him.

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(Raman Jeet singh)

CONTENTS

LIST OF TABLES

LIST OF TABLES (contd….)

LIST OF TABLES (contd….)

LIST OF TABLES (contd….)

LIST OF TABLES (contd….)

LIST OF FIGURES

1

INTRODUCTION

Cotton (*Gossypium hirsutum* L.) – the king of fiber crops and a crop of prosperity, is an industrial commodity of world wide performance. Cotton is an important cash crop of India, and the most important foreign exchange earner through export of raw cotton, garments and cotton seed byproducts in the form of edible oils and oilcakes. It occupies about 9.0 million hectares during 2007 (FAOSTAT, 2007). The existing cotton genotypes are prone to infestation by a variety of insect-pests especially bollworms. Between independence and the year 2000, the cotton cultivars have been changed from varieties to hybrids and the suitable agronomy of these hybrids has been developed. The transgenic cotton era has dawned in our country with the approval accorded by GEAC (Genetic Engineering Approval Committee), Govt. of India for the commercial cultivation of *Bt* cotton hybrids in the southern and central zones from 2002 crop season onwards. *Cry 1 Ac* gene of *Bacillus thruriengensis* (a soil borne bacterium), which has the capacity to produce proteins (endotoxins) toxic to lepidopteron pests in general, has been introduced in cotton, conferring inbuilt resistance (Perlak *et al*., 1990). These *Bt* cottons not only give higher yields, but also higher net income over traditional cottons due to reduced plant protection costs. Till now more than 20 hybrids have been approved for commercial cultivation by Genetic Engineering Approval Committee (GEAC). In 2005, transgenic cottons have been estimated to be cultivated over 1.3 million hectares as per the annual review report of the US based International Service for the Acquisition of Agri-Biotech Application (ISAAA).Though the *Bt* cottons were released four years back, now the companies (Monsanto- Mahyco) are coming up with Bollgard – II with two altered genes (*Cry 1 Ac* + *Cry 2 Ab*) that were found to provide increased bollworm (*Helicoverpa zea*) control. Looking to the prospects of large area coming under *Bt* cotton cultivation in the next few years, it is essential to study the fertilizer requirement and the agronomic efficiency of the crop in order to develop appropriate production packages. However, there is no comprehensive information on Bollgard – I itself regarding the field performance, which is highly varying under different environments, and the agronomic management for the same is still to be worked out.

Among all the approaches of increasing the agricultural productivity, intercropping is one of the highly promising possibility. Intercropping system involves growing of two or more crops simultaneously with distinct row arrangement for complementary use of natural resources and enhancing the productivity. Cotton is sown at a wider row spacing, hence provides space for cultivation of short duration intercrop like groundnut. This practice stabilizes the productivity besides enhancing the total returns (Patil *et al.,* 1996).

Among the agronomic packages of any crop, nutrient management is the most important factor deciding the crop performance and maintaining soil fertility. Of the three macronutrients, nitrogen, phosphorus and potassium, nitrogen is applied in the largest quantity both in cotton and wheat raised in rotation. The nitrogen requirement and utilization by cotton is more complex than other major field crop due to its indeterminate growth habit. Although the use of chemical fertilizers is the fastest way of counteracting the pace of nutrient depletion. However, technical, economical, logistical and environmental considerations, calls for practicing integrated nitrogen management (INM). The integration of mineral fertilizers and organic manures such as FYM has proved viable alternative for cotton-wheat system across the globe. High prices and low supply of nitrogenous fertilizers necessitates organic manure to substitute inorganic nitrogen for greater stability and sustainability in the crop production. The fertilizer applied to preceding cotton crop might leave some residual effect and thus modifies nitrogen requirement of wheat crop (Kairon *et al.,* 1996). The N removal by cotton alone is reported to be as high as 80-170 kg/ha. This high N input to the cropping system involving high costs for economical yields has led to the renewed interest in the use of FYM and increased involvement of legumes in the cropping systems. The use of FYM and introduction of legumes as intercrops such as groundnut in *Bt* cotton during *kharif* and their effects on N economy in cotton-wheat cropping system needs to be addressed.

Wheat is the second most important cereal after rice and an important component of food security in the country. Development of short duration early maturing varieties of *Bt* cotton and expansion of irrigation facilities have led to cultivation of these crop in sequence. Accordingly, cotton-wheat cropping system now occupies an important place in agricultural economy of north India, covering 1.7 million hectares in the states of Punjab, Haryana and Rajasthan. Development of *Bt* cotton in recent years has proved to be a boon for cotton-wheat cropping system due to their earliness in maturity making it possible for timely sowing of wheat.

With the above background in mind, an experiment entitled "**Effect of nitrogen management through organic and inorganic sources in sole and intercropped *Bt* cotton-wheat system"** was undertaken during 2006-07 and 2007-08 at I.A.R.I., New Delhi to develop an INM package for sustaining *Bt* cotton– wheat cropping system with the following objectives:

Objectives

1. To evaluate the performance of cotton based intercropping system involving groundnut with and without FYM
2. To quantify the residual effect of FYM and legume (groundnut) as intercrop in cotton on N requirement of succeeding wheat crop
3. To assess the N requirement of cotton-wheat cropping system
4. To work out the economics of N fertilization in cotton-wheat cropping system

2

REVIEW OF LITERATURE

Nitrogen is one of the vital nutrients required for the growth and development of crop plants. It is an integral component of many plant compounds such as amino acids, which are building block of proteins. As N is a mobile element, its deficiency during the early and mid season results in the chlorosis of older leaves. Nitrogen deficiency reduces the plant height, shortens the fruiting branches and increases boll shed (Hodges, 1995). Plants contain 1 to 5% N by weight (Tisdale *et al*, 1993). Nitrogen nutrition influenced leaf development, leaf photosynthetic potential and chlorophyll content, which ultimately affects fruit production and retention (Gerik *et al*., 1994).

Indian soils are generally low in nitrogen status. The current drive for maintaining and increasing food production is seriously handicapped due to sub optimal use of costly nitrogenous fertilizers. It is the most widely distributed element in nature. It occurs in the atmosphere, lithosphere and hydrosphere. The soil accounts for only a very small amount of lithospheric nitrogen, and of this soil nitrogen, a very minute amount is directly available to plants.

The review of literature on important aspects pertaining to present study is being presented in this chapter. An attempt has been made to cite as much as literature possible on the effects of N management through organic and inorganic sources in sole and intercropped cotton-wheat system, but due to paucity of adequate experimental evidences, the similar work on other crops has also been included, wherever felt necessary.

2.1 Effect of cropping system

2.1.1 Cotton

Cotton is usually grown at a wider inter-row spacing and possesses initial slow growth rate for about 60-75 days. This offers a good scope for intercropping of short duration crops (Masunde *et al*., 1986). Numerous experiments have been conducted in both rainfed and irrigated agriculture with cotton based intercropping systems.

Legumes are found to be most promising intercrop in most of the systems. It is a conventional practice to include legumes in the crop mixtures and crop rotations for enriching the soil besides meeting the grain and fodder requirements. The legumes benefit the associated and succeeding non legumes (CIAT, 1974 and IARI, 1976, Palaniappan, 1980 and Yadav, 1981).

2.1.1.1 Effect on plant growth parameters

Robinson (1973) recorded highest dry matter production in cotton intercropped with legume as compared to pure cotton. However, Nagre (1979) and Rao (1982) observed no difference in plant height and dry matter production of cotton due to intercropping with legume. Similarly, Masunde *et al*. (1986) observed no significant differences in leaf area indeed and dry matter production due to intercropping of cotton with blackgram and greengram. Balasubramaniyan (1987) recorded reduced plant height, leaf area index and dry matter of cotton when intercropped with blackgram.

2.1.1.2 Effect on yield attributes and yield

Waterworth (1994) suggested that a crop such as cotton, which tolerates a wide range of population density and develops leaf canopy at a later stage, may be ideally suited to intercropping. Maitra *et al*. (2001) reported that seed cotton yield of sole cotton was similar to that of intercropped treatments. Palchamy *et al*. (1990) observed a complimentary effect by recording higher yield of cotton when intercropped with legume (groundnut) which could be attributed to legume effect on cotton and improved physical conditions of the soil. Koradi *et al*. (1991) also observed significantly higher seed cotton yield when intercropped with groundnut. Dayal and Kale (1976) recorded more sympodia and bolls plant^{-1} in cotton + greengram intercropping system, which ultimately led to increased yields. Masunde *et al*. (1986) reported larger boll size, more squares and bolls in cotton intercropped with legume. Rao and Sadaphal (1983) obtained higher seed cotton yield when a legume crop (greengram) was grown as an intercrop with cotton. Similar increase in yield of cotton when intercropped with legume was reported by many workers (Prasad, 1988, Balasubramaniyan *et al*., 1994, Ramamoorthy *et al*, 1994, Tomar *et al*., 1994 and Krishnasamy *et al*, 1995).

2.1.1.3 Effect on nutrient uptake

Robinson (1973) reported that cotton with legume intercropping recorded a significant increase in N content of cotton plant as compared to sole cotton owing to better N fixation by legumes. However, P and K content of the plants were not influenced by intercrops. Thangamuthu (1979) indicated intercropping blackgram with cotton enhanced the N uptake. Satar *et al*. (1983) observed higher nitrogen uptake during the early and later stages of cotton in intercropped situation.

Birajdar *et al*. (1987) noticed that uptake of nitrogen, phosphorus and potassium by cotton was relatively poor when intercropped with sorghum and pigeonpea as compared with blackgram.

2.1.1.4 Effect on fibre quality

Blaise *et al*. (2005) reported improved fibre quality of cotton grown with pigeonpea. Mukherji and Verma (1994), however, reported that there was no difference in ancillary characters and technological qualities of cotton due to intercropping with legumes. Chellamuthu and Purusothaman (1980) observed higher values of lint index and seed index in sole cotton than cotton intercropped with legumes. Similarly, Mukerji *et al*. (1987) observed higher values of seed index and ginning percentage in sole than cotton intercropped with onion or greengram.

Several workers reported that the fibre quality character of ginning percentage, seed index, lint index, fibre fineness, maturity coefficient and fibre strength were not affected by intercrops like blackgram and greengram (Singh and Dargan, 1965, Robinson, 1973, Shanmugasundram, 1976, Sorghavasan, 1979 and Balasubramanian, 1987).

2.1.1.5 Effect on economics

Koradi *et al*. (1991) reported that the highest net income was realized with alternate rows of cotton and groundnut, where cotton received the recommended NPK and the associated groundnut only 25% of the recommended rate. Ramananjaneyulu and Reddy (2002) reported higher net return and B:C ratio when cotton was intercropped with soybean and groundnut over sole cotton. Maitra *et al*. (2001) concluded that the average additional product per ha of land was more when cotton was intercropped with greengram and groundnut. Palchamy *et al*. (1991) noticed that groundnut along with direct seeded summer cotton could be grown as 2-tier intercropping by adjusting crop geometry for higher net return.

2.1.2 Groundnut as intercrop

Intercropping implies growing of two or more crops in separate rows, at the same time on the same piece of land (Andrews and Kassam, 1975). It was widely recognized that intercropping (sowing two or more than two crops in distinct but proximate rows) designed on principle of scientific base in crop production, holds a great promise in increasing the land productivity (Saxena *et al*., 1975 and Willey, 1979). Intercropping is recognized as a high potential system which can boost up production per unit area per unit time at low energy input levels.

Intercropping system is a man made non-equilibrium crop consuming where non competitive and less competitive association of diverse crops can be exploited (Harper, 1963). The advantages in intercropping would be more when the growth pattern of the component crops differ both in time and space for complimentary utilization of resources like water (Kassam, 1973), light (Baker and Yusuf, 1976) and nutrients (Kassam and Stockinger, 1971).

The cotton grows slowly for the first two and half months, and picks up growth thereafter, making it possible to accommodate an early maturing and short growing crop in between two rows. The groundnut compared to cotton grows faster and develops extensive canopy cover during the first two months. Thus, it utilizes growth resource more efficiently in earlier stages (Reddy and Willey, 1980). In the subsequent stages when cotton growth picks up, groundnut showed better growth, in spite of the competition from cotton. This is because of the fact that groundnut grows well under reduced light intensities (Rao and Willey, 1980).

2.1.2.1 Effect on plant growth parameters

Results of various studies indicated that intercropping of groundnut did not interfere with the normal growth of the component crop (Giri *et al*., 1980). Further, Katti *et al*. (1999) reported that total dry matter production plant^{-1} in groundnut was higher with sole cropping at all the growth stages. Karle *et al*. (1989) reported that leaf area plant^{-1} of groundnut was higher in sole stands than intercropped with component crops like pigeonpea and soybean. Shading effect of tall growing crops on groundnut in intercropping systems has also been reported. Narwal and Malik (1986) noticed reduced groundnut growth when intercropped with sunflower. They also reported a significant decline in branches plant^{-1}, being more pronounced with advancement of crop age probably due to more shading and moisture deficit at later stages.

2.1.2.2 Effect on yield attributes and yield

Channal (1983) noticed that yield attributing characters viz., pods plant^{-1}, kernel pod^{-1} and harvest index of groundnut remained unaffected by intercropping with cotton. Subramaniyan and Kalaiselvan (2005) working with additive series of cotton + groundnut observed that cotton competed with groundnut for resources, and the shading effect of cotton on groundnut crop resulted in decreased pod yield of groundnut and also prolonged its duration. Similar results were also noticed by Cattan and Fluery (1998). Waterworth (1994) observed that yields of intercropped groundnut were about half of the sole crop. The more compact and low growth habit of the groundnut failed to compensate the yield at reduced plant density when grown in competition with cotton.

2.1.2.3 Effect on nutrient uptake

Resources with regard to plant nutrients present in soil or added to it as manure were utilized to the full extent in mixed stand than raising of component crops in sole stand (Aiyer, 1949). In most cropping systems, where groundnut was raised as an intercrop, both the component crops were found to require higher amounts of nutrients than groundnut raised alone, and the fertilizer applied to base crop did not meet the nutrient requirement of the groundnut crop (Dwivedi, 1981). The pod yield of groundnut is often positively correlated with total N content and uptake (Sagare and Bhalkar, 1986 and Maliwal *et al*., 1988).

2.1.2.4 Intercropping indices

Waterworth (1994) observed land equivalent ratio of 1.4 from cotton + groundnut system. Maitra *et al*. (2001) found that the total productivity in terms of seed cotton equivalent increased when cotton was intercropped with greengram and groundnut, irrespective of row ratio. They also reported higher values of area-time equivalency ratio (ATER) and relative crowding coefficient (RCC) indicating cotton being a dominant crop over the intercrops. The values of aggressivity were positive for cotton and negative for intercrops indicating dominance of cotton in the intercropping systems. Sarkar *et al*. (1995) also reported similar results.

2.2 Effect of fertility levels

2.2.1 Cotton

The soil is a most precious natural resource. The fertility of the soil is depleting day by day due to exhaustive cropping systems. The high yielding varieties of many crops are being developed, which lead to heavy nutrient removal from soil (Prasad *et al*., 1989). The fertility of the soil needs to be maintained through organic manures, crop residues and application of chemical fertilizers. Soil, climate, nature of fertilizers and organic materials added have a direct bearing on the rate of organic matter decomposition. Where similar practices are continued over a period of time, the organic matter level of the soil will come to the equilibrium. In view of this, sustenance of soil fertility is important through balanced and integrated plant nutrient use for sustainable agriculture and maintenance of soil health.

The main conventional organic source for manuring is the farm yard manure (FYM). Its role is multidimensional ranging from building up of organic matter, improving soil aggregation, soil permeability and related physical properties to long lasting supply of several macro and micronutrients besides improving the cation exchange capacity of soil (Olsen *et al*., 1970, Krishnamoorthy and Ravikumar, 1973 and Gupta *et al*., 1983).

Biswas and Mukherjee (1994) stated that addition of organic manure improved soil structure and soil fertility. Nutrients were released slowly and were available to the plant over a long period and only one-third of total nitrogen was available to the crop during first season.

2.2.1.1 Effect on plant growth parameters

Das *et al*. (2006) reported that the growth attributes of cotton viz., plant height, leaf area index, dry matter production, root dry weight and main stem nodes plant^{-1} were significantly improved by the organic and inorganic sources of N.

2.2.1.2 Effect on yield attributes and yield

Application of FYM favourably affected the yield attributes in cotton (Rathinakumari *et al*., 2004). Richard (1967) observed that higher seed cotton yield was maintained for eleven years by the application of FYM @ 20 t ha^{-1} and NPK based on the experiments conducted in Central African Republic over the same period, the yield increase due to continuous NPK fertilizer application being gradual. However, higher yields were obtained with combined application of NPK and FYM. Muthuvel *et al*. (1989) stated that application of 20 kg N ha^{-1} as FYM with 40 kg N ha^{-1} as urea gave higher seed cotton yield over control. Padole *et al*. (1998) reported the beneficial effect of combined application of organic and inorganic fertilizer over their single application. Askerov *et al.* (1992) reported that application of 50 kg N + 15 kg P_2O_5 and 10 t FYM ha^{-1} recorded higher seed cotton yield of 4.1 t ha^{-1} over inorganic fertilizers applied alone. Srinivasulu *et al*. (2004) reported that application of 10 t FYM ha^{-1} along with 50% RDF recorded higher seed cotton yield. Based on decade of experimentation, Veeraiah *et al*. (2004) observed a significant increase in seed cotton yield with 100% NPK + FYM @ 10 t ha^{-1}, followed by 150 kg NPK over control. The number of sympodia plant^{-1}, number of boll plant^{-1}, boll weight, seed index, lint index and yield were significantly higher in FYM applied plots as compared to non FYM applied plots (Ratnakumari *et al*., 2004). Hosmath *et al*. (2004) recorded significantly higher seed cotton yield with RDF + FYM as compared to RDF alone.

2.2.1.3 Effect on nutrient uptake

Singh (1995) observed more recovery of applied N with urea + FYM as compared to urea alone. He further noticed that increased yield and NPK uptake with FYM over urea might be due to better utilization of applied N fertilizers over a long period. Katkar *et al*. (2002) noted that recommended dose of inorganic fertilizers recorded higher dry matter accumulation, and consequently the uptake of NPK followed by 50% RDF + 5 t ha^{-1} FYM. Das *et al*. (2006) reported the largest removal of

NPK with integrated application of 30 kg N ha^{-1} and FYM @ 12 t ha^{-1} along with *Azotobacter*.

2.2.1.4 Effect on fibre quality

Mukerji and Verma (1994) reported that fibre length, fibre weight, maturity coefficient and bundle strength were not influenced by nitrogen application. Simlote *et al*. (1967) reported that halo-length and ginning percentage were not affected by nitrogen levels and its source. Khippal and Nehra (1995) noticed that uniformity ratio, ginning percentage, lint index and maturity coefficient were not improved with the application of N.

2.2.1.5 Effect on economics

Katkar *et al*. (2002) found higher gross monetary return of Rs 17,455 by application of 50% RDF + 50% through organic manure (FYM) over application of inorganic fertilizers alone due to higher seed cotton yield in this treatment.

2.2.2 Groundnut

Chaithanya *et al*. (2003) reported that application of FYM @ 8 t ha^{-1} significantly increased dry matter production at all the crop growth stages of groundnut. The favourable effect of FYM on growth attributes has also been reported by several workers (Raju and Verma, 1984, Singh *et al*., 1990 and Sharma and Singh, 1971).

The findings of Kambale *et al*. (2002) revealed that application of 50% RDF + 5 t FYM + 10 t soybean straw/ha recorded significantly higher pod yield of groundnut over rest of the treatments. The magnitude of increase in dry pods and kernel yield being 15 and 16%, respectively over RDF (20 kg N + 50 kg P_2O_5 ha^{-1}). Yield attributes viz., shelling percentage; 1,000-kernel weight and fully mature kernel percentage were also influenced significantly due to different treatments. Subramaniyam *et al*. (2000) and Kumaran and Solaimalai (2000) reported significant increase in growth and yield of groundnut due to application of FYM.

Mehta *et al*. (1996) reported significant increase in protein content and yield of groundnut with the application of FYM @ 10 t ha^{-1} over no FYM. Mehta *et al*. (1996) reported that the treatment involving FYM @ 10 t ha^{-1} recorded higher N, P and K uptake over control. The organic acids products from organic substances may partly be responsible for quick release of nutrients which resulted into greater uptake of nutrients.

Kambale *et al*. (2002) reported that the treatment consisting of 50% RDF + 5 t FYM + 10 t soybean straw recorded higher net returns (Rs 16,171/ha) and B:C ratio (2.18) as compared to other treatments. Similarly, Mehta *et al*. (1996) reported higher net returns (Rs 2926/ha) with FYM @ 10 t ha^{-1} as compared to no FYM (Rs 2660/ha).

2.3 Residual effect on wheat

2.3.1 Cropping system

Preceding crops certainly influence the growth of the crop grown in recurrent succession on the same piece of land. The influence is mainly experienced in respect of nutrients. That is why choice of crop in any cropping sequence is of paramount importance both from point of view of productivity and maintenance of soil fertility.

Wheat grown in sequence with legumes generally gives higher yields and greater uptake of nutrients (Tiwari *et al*., 1980). Wild (1972) observed that groundnut benefited the succeeding cereal to the extent of 60 kg N ha^{-1}. Higher yield of succeeding crop in legume cereal rotation were due to availability of nitrogen contributed by the legume (Giri and De, 1979). Das (1977) reported that legumes either in monoculture or in intercropping systems had greater influence in increasing grain yield of succeeding wheat crop as compared to cereals.

2.3.2 Fertility levels

The manures and fertilizers applied to preceding crop might have some residual effect, which may consequently modify the nutrient requirement of succeeding crop. Prakash and Prasad (2000) reported greater residual effect of FYM on succeeding wheat. The highest net return in cotton-wheat system was registered with FYM alone @ 10 t ha^{-1}, followed by 100 kg N ha^{-1}. Das *et al*. (2004) observed that integrated nutrient management involving both organic and inorganic sources resulted in higher productivity and sustainability of the cotton-wheat system. The fertilizer applied to preceding cotton crop might leave some residual effect and may thus change nutrient requirement of wheat crop (Kairon *et al*., 1996).

2.4 Direct effect of nitrogen on wheat

Sharma *et al*. (2000) reported significant increase in dry matter production and grain yield of wheat with nitrogen application up to 120 kg ha^{-1} (40.09 q ha^{-1}) being 32% higher than control.

Kumpawat and Rathore (1998) observed that application of N to wheat up to 120 kg ha^{-1} significantly increased the dry matter accumulation, N content and N uptake. Numerous other workers also reported the increased dry matter production and grain yield of wheat with nitrogen up to 120 kg ha^{-1} (Kataria *et al*., 1999 and Jain, 1999).

Gonita and Joshi (2000) noticed that application of nitrogen increased the wheat yield significantly and maximum grain yield was recorded with 120 kg N ha^{-1}. However, harvest index decreased with increasing rate of nitrogen. Under late sown conditions, maximum value of yield attributes and yield of wheat was recorded up to 100 kg N ha^{-1} at Hisar (Khola *et al*., 1959).

Significant increase in N, P and K uptake by grain and straw of wheat was observed in silty clay loam soil up to 120 kg N ha^{-1} (Singh *et al*., 1989).

2.5 Soil fertility status

The soil quality determines the sustainability and productivity of agro ecosystems. The excessive use of mineral fertilizers in intensive agriculture has reduced the soil organic matter in most of the Indian soils leading to an increase of erosion risk and fertility losses. Therefore, one of the most important ways of soil regeneration involves the addition of organic materials to conserve organic matter and maintain or enhance soil fertility.

Katkar *et al*. (2002) observed that available nitrogen in soil increased in all the treatments having organic manure alone or in combination with inorganic fertilizer. The increase in available N due to organic materials application could also be attributed to the greater multiplication of soil microbes which could convert organically bound N to inorganic form. They also recorded increase in available P and K contents due to decomposition of organic matter. Similar results were also reported by Das *et al*. (2006).

Singh *et al*. (2004) observed significant increase in organic carbon content of the soil by annual application of 10 t FYM ha^{-1} along with recommended chemical fertilizers over chemical fertilizers alone. They also found that introduction of soybean as an intercrop in cotton effectively increased the organic carbon content compared to sole cotton. The available soil N in intercropped plots recorded similar values to that of sole crop despite a higher uptake, indicating a more efficient utilization of applied and fixed N by soybean in the intercropping system.

2.6 Soil enzyme activities

Organic and inorganic fertilizer amendments are used primarily to increase nutrient availability to plants, but they can also affect soil microorganisms, changes in microbial activity and composition can in turn influence plant growth, by increased nutrient turn over or by increasing disease incidence or disease suppression. Organic matter addition often leads to a rapid increase of soil CO_2 evolution (Ajwa and Tabatabai, 1994) and increases the activity of various enzymes (Crecchio *et al*., 2001). An increase in enzyme activity was also observed after addition of either NPK fertilizer or FYM in a long term study (Kandeler *et al*., 1999). Dinesh *et al*. (2004) observed that leguminous cover crop enhanced microbial activity and enzyme synthesis and accumulation due to increased C turn over and nutrient availability. Malero *et al*. (2007) found higher dehydrogenase activity with addition of organic matter to soil than under inorganic fertilization. Changes of microbial population or the small proportion of active microbial biomass during the conversion period could explain the lack of correlation between intercellular activity (dehydrogenate) and microbial biomass.

2.7 Nitrogen use efficiency

Efficiency is defined as the amount of product produced per unit of resource used. This means nutritional efficiency is the amount of dry matter produced per unit of nutrient applied or absorbed. Soomro *et al*. (1999) reported about 82% apparent nitrogen recovery by the whole cotton plant in control plot treatment, while in flooding treatment it was 77%. Silvertooth *et al*. (2001) found that all treatments of fertility levels averaged approximately 80% total fertilizer N recovery in cotton, of the fertilizer N that was recovered, approximately 40% was taken up by the plants and 50% recovered in the soil, primarily in the top 60 cm of the soil profile. Fritschi *et al*. (2004) reported total recovery of ^{15}N fertilizer in plant and soil averaged 89% (76-98%), across all the treatments applied to Pima cotton.

3

MATERIALS AND METHODS

Field experiment entitled **"Effect of nitrogen management through organic and inorganic sources in sole and intercropped *Bt* cotton– wheat system"** was conducted during *kharif* and *rabi* seasons of 2006-07 and 2007-08 for making a comparative assessment of cropping systems, fertility levels and nitrogen doses applied to wheat on the productivity of *Bt* cotton-wheat cropping system. This chapter deals in brief the experimental details of materials used, the observations taken and techniques employed during the course of investigation.

3.1 Experimental site

The experiment was conducted in Main Block 3A at the Research Farm of Division of Agronomy, Indian Agricultural Research Institute, New Delhi. The field had an even topography and good drainage system.

3.2 Climate and weather

New Delhi is situated at 28°35'N latitude and 77°12'E longitude at an altitude of about 228.61 m above mean sea level. It has a semi-arid and sub-tropical climate with hot dry summers and severe cold winters. The mean maximum temperature in June, which is the hottest month of the year, ranges from 40° to 45°C, while the mean minimum temperature in the coldest month of January is as low as 1.9°C. Sand storms and ground frost are commonly associated with summer and winter seasons, respectively. The mean annual rainfall is about 650 mm, of which nearly 80 per cent is received during the monsoon period from July to September and the rest during the period between October and May. The mean daily U.S. Weather Bureau Class 'A' open pan evaporation value reaches as high as 10.9 mm in the month of June and as low as 1.5 mm in the month of January. The annual pan evaporation is about 850 mm. The mean wind velocity varies from 3.5 km hr^{-1} during October to 7.6 km hr^{-1} during April. Mean relative humidity attains the maximum value (85 to 90% or even more) during the south-west monsoon and the minimum (30 to 45%) during the summer months.

The meteorological data for the period of experimentation (i.e. June 2006 to April 2008) recorded at the meteorological observatory of IARI, New Delhi are presented in Appendices X and XI and depicted graphically in Fig. 3.1 and 3.2. The total rainfall was 629.5 mm in 2006-07 and 489.0 mm in 2007-08. Out of the total rainfall, 505.8 mm during *kharif* 2006 and 457.0 mm during *kharif* 2007 was received. Mean monthly relative humidity in 2006-07 and 2007-08 ranged from 47.1 to 95.0%, and 31.0 to 95.0%, respectively during the period of experimentation.

3.3 Soil characteristics

The soil of IARI farm belongs to order Inceptisol, Mahauli series having sandy loam texture in upper 30 cm layer and loam below that. Water table remained below 3.5 m deep from ground surface during crop growth period. A composite representative soil sample was collected from the experimental field prior to experimentation and analysed (Table 3.2). The soil was sandy loam in texture, poor in organic carbon, available N and medium in available P.

3.4 Cropping history of the experimental field

The cropping history of experimental fields for four years prior to the present experiment has been given in Table 3.1.

Table 3.1. Cropping history of the experimental fields

	Crop season	
	Kharif	*Rabi*
Year 2006		
2002-03	Pigeonpea + blackgram	Wheat
2003-04	Pigeonpea + groundnut	Chickpea
2004-05	Sorghum (fodder)	Chickpea
2005-06	Pigeonpea	Wheat
2006-07*	*Bt* cotton/groundnut	Wheat
Year 2007		
2003-04	Pigeonpea + blackgram	Wheat
2004-05	Pigeonpea + groundnut	Chickpea
2005-06	Greengram + cowpea	Lentil
2006-07	Pigeonpea	Wheat
2007-08*	*Bt* cotton/groundnut	Wheat

* Present experiment

3.5 Experimental details

3.5.1 Experimental design

The *kharif* experiment was laid out in randomized block design, and the *rabi* experiment in split-plot design with cropping systems and fertility levels in the main plots and nitrogen applied to succeeding wheat in the sub-plots. An additional main plot with sole groundnut receiving recommended fertilizer dose was kept for assessment of intercropping indices and wheat crop was sown in sub-plots. The plan of layout of the experiment is shown in Fig. 3.3.

3.5.2 Treatment details

Main plot treatments

A. cropping system	**Symbol**
i. Sole cotton	C_1
ii. Cotton + groundnut (1:3)	C_3
B. Fertility level	
i. Control (no application of N)	F_0
ii.100 % RDN	F_1
iii.75% RDN + 25 % FYM	F_2
iv.50% RDN + 50 % FYM	F_3
C. An additional main plot with sole groundnut receiving recommended fertilizer dose	C_2

Sub-plot treatments

N applied to wheat (kg ha^{-1})	**Symbol**
1. 0	N_0
2. 50	N_1
3. 100	N_2
4. 150	N_3

3.5.3 The recommended dose of nitrogen @ 150 kg ha^{-1} to cotton

3.5.4 **Replication** : Three

3.5.5 **Total number of plots in *kharif*:** 2 x 4 + 1 = 9 x 3 = 27

in *rabi* : 27 x 4 = 108

3.5.6 Plot size

Cotton/groundnut

A. Gross plot : 6.0 m x 18.0 m (five rows)

B. Net plot : 1.2 m x 16.0 m (one row)

Wheat

A. Gross plot : 6.0 m x 4.0 m

B. Net plot : 4.6 m x 3.0 m

3.5.7 Variety

Cotton	:	RCH-134 *Bt*
Groundnut	:	Punjab Groundnut - 1
Wheat	:	Pusa Gold

3.6 Description of materials used

3.6. 1 Cotton (cv. RCH-134 Bt)

This variety is a semi dwarf, early maturing variety with boll weight of 4-5 g, staple length of 27-28 mm, ginning percentage of 34 %, high yields and suitable for irrigated areas of north India.

3.6.2 Groundnut (Punjab Groundnut – 1)

It is a spreading variety recommended for north Indian condition. It yields about 1.4-1.6 t/ha and matures in 130 days with 69 per cent shelling out turn and 49 per cent oil content**.**

3.6.3 Wheat (Pusa Gold)

Pusa Gold (WR- 544) was developed at IARI, New Delhi and released for commercial cultivation in 2003. This variety is thermo tolerant, resistant to brown rust, suitable for late and very late sown conditions and is recommended for adjoining areas of Delhi, north western and north eastern plain zones. This variety matures in 95-100 days. It has round, hard, amber and lustrous grains with test weight of 40 g. The average yield is 3.73 t/ha**.**

3.7 Field operations

The schedule of the field operations carried out during the period of experimentation is presented in Table 3.3.

3.7.1 Land preparation

3.7.1.1 Before cotton

In order to ensure good germination, a pre-sowing irrigation was given to the field prior to sowing of cotton. The field, when came to condition, was tilled, using a tractor drawn disc plough followed by harrowing and planking to have a uniform and firm seed bed of fine tilth. Plots were demarcated according to layout plan.

3.7.1.2 Before wheat

The cotton crop was irrigated about a week before its cutting sticks. The field was ploughed immediately after the cutting of cotton sticks with the help of a tractor drawn mould board plough running in one direction only so that the soil was not displaced. These operations were followed by double discing and planking to conserve soil moisture.

3.7.2 Fertilizer application

3.7.2.1 Cotton

Well decomposed Farm Yard Manure (FYM) was applied and mixed with the soil in advance, two days before of sowing, based on treatment recommendation. As per treatment in cotton, half the nitrogen as urea was applied as basal dose, and remaining half was top dressed at square initiation stage. Irrespective of the treatment a uniform dose of 60 kg P_2O_5 ha^{-1} in the form of single super phosphate (SSP) was applied as basal dose. Single superphosphate was placed 3-5 cm below the seed with the help of metallic tube attached to plough (i.e. pora). No potassium fertilizer was applied.

3.7.2.2 Wheat

N was supplied through urea as per treatments. The nitrogen was applied in two splits, half at sowing and the remaining half at first irrigation at 21 days coinciding with crown root initiation (CRI) stage. Phosphorus was applied through single superphosphate as a basal dose, placed 3-5 cm below the seed with the help of metallic tube attached to plough (i.e. *pora*).

3.7.3 Seeds and sowing

The sowing of cotton (RCH-134) was done by dibbling method with row spacing of 120 cm and plant to plant spacing of 60 cm. In groundnut (Punjab Groundnut-1), the seed rate used was 100 kg/ha i.e. additive series of intercropping system was followed. After sowing, light planking was done immediately to cover the seeds. In intercropped cotton plots, three rows of groundnut were planted in between two rows of cotton. In *rabi*, wheat (Pusa Gold) was sown by seed drill in rows spaced at 22.5 cm using a seed rate of 125 kg ha^{-1}.

3.8 Thinning and gap filling

In cotton, extra plants in the rows were thinned to maintain an intra-row spacing of 60 cm on 20th day after sowing. The filling of gaps was also accomplished both in cotton and wheat immediately after the completion of germination in order to maintain optimum plant population.

3.9 Interculture operations

The weeds were controlled by pre-emergence spray of pendimethalin (1.0 kg ha^{-1}) in cotton and post-emergence spray of isoproturon (1.0 kg ha^{-1}) in wheat. However, herbicide application in both the crops was also supplemented with one hand weeding 30 DAS in cotton and 45 DAS in wheat.

3.10 Irrigation

A complete schedule of irrigation indicating the number and time of irrigation for each crop is given in Table 3.3. The *rabi* crop of wheat was entirely supported by irrigation water. Irrigation to cotton was provided to supplement the rainfall.

3.11 Plant protection measures

Cotton crop was infested with red cotton bug and white fly. In order to control these insects, two sprayings of monocrotophos @ 0.04% were given. No plant protection measures were adopted in wheat crop.

3.12 Picking and threshing

The cotton crop was picked twice at full boll burst stage manually. Seed cotton was cleaned and weighed from each net plot for expressing yield in t ha^{-1}. The weight of stalk in cotton and straw in wheat was recorded separately and expressed as t ha^{-1}. Wheat was harvested manually and threshed by mechanically operated thresher.

3.13 Biometric observations

In cotton, groundnut and wheat, second row on either side of plot was used for destructive sampling.

3.13.1 *Bt* cotton

3.13.1.1 Plant height

Plant height of five randomly selected and tagged plants in each plot was measured from the base to the tip of the plant at 60, 90, 120 and 150 DAS during both the seasons.

3.13. 1.2 Leaf area index (LAI)

Leaf area of two randomly selected plants were measured with the help of leaf area meter (Model LI-3100, USA) at 60, 90, 120 and 150 DAS. Plants were cut at the soil surface, leaves were separated from the plants, covered with polythene bag and were brought to the laboratory. Leaf area was measured immediately after bringing them in the laboratory. Leaf area index was computed with the following formula:

$$\text{LAI} = \frac{\text{Total leaf area plant}^{-1}(\text{cm}^2)}{\text{Ground area covered by the plant (cm}^2)}$$

3.13. 1.3 Dry matter (DM) accumulation plant $^{-1}$

The plants used for measuring leaf area were also used for determining DM. Sun dried samples were transferred into a thermostatic drying oven and were dried at 65°C to obtain a constant dry weight.

3.13. 1.4 Dry matter partitioning

Dry matter partitioning in different parts of the plant was measured at various time intervals during both the years. Two randomly selected plants were segmented into leaf, stem and reproductive parts and then the plant parts were kept separately in paper bags for sun drying. Sun dried samples were transferred into a thermostatic drying oven and were dried at 65°C (36 to 48 hours) to obtain a constant dry weight.

3.13. 1.5 Main-stem nodes plant $^{-1}$

Number of main stem nodes were counted from 5 randomly selected plants in each plot during picking stage in both the seasons and was averaged to get the main-stem nodes plant^{-1}.

3.13. 1.6 Root dry weight

Roots of three plants from each plot were carefully dug out after final picking. After washing the roots in running water, the stem portion was removed. These roots were first sun dried and then oven dried at 65°C up a constant dry weight. Finally, the roots were weighed and dry weight root $^{-1}$ was calculated.

3.13.1.7 Bolls plant $^{-1}$

Number of boll plant^{-1} were counted from five tagged plants in each plot and was averaged to get the number of boll plant^{-1}.

3.13.1.8 Boll weight

Seed cotton from 20 randomly selected open bolls in each plot were picked, weighed and averaged to get the weight boll^{-1}.

3.13.1.9 Seed cotton yield

Seed cotton yield from two pickings were weighed separately and were added to get plot^{-1} seed cotton yield. Seed cotton yield was expressed in t ha^{-1}.

3.13.1.10 Total dry matter production (TDM) or biological yield

After the final picking, the plants were cut close to the soil surface. Sun dried weight of the stalks from each plot was recorded. The TDM plot^{-1} was worked out by adding the seed cotton yield plot^{-1} to this dry weight.

3.13.1.11 Ginning percentage (GP)

All the seed cotton picked from individual plot was mixed and a composite sample weighing 200 g was taken for ginning. The samples were ginned and weight of lint was recorded. The ginning percentage was computed by using the formula.

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

3.13.1.12 Seed index

Seed index was measured by weighing 100 randomly selected ginned seeds.

3.13.1.13 Lint index

Line index was computed by the formula:

$$\text{Lint index} = \frac{\text{Seed index x GP}}{100 - \text{GP}}$$

3.13.1.14 Maturity coefficient

This is the ratio of the mature, half mature and immature fibre in a sample of lint. This was determined with the help of micronaire instrument by air flow method. A quantity of 3.24 gram of lint was fed to the instrument and compressed air was allowed to pass through the sample with and without spacer. The difference between the two readings referred against a standard table, gave the coefficient directly.

3.13.1.15 Fibre fineness

Fibre fineness is a measure of the fibre weight in Mg unit^{-1} length of the fibre. This was determined by air flow method with the help of a micronaire.

3.13.1.16 Bundle strength

Bundle strength is the ratio of the breaking strength of a bundle of fibre to its weight and it is expressed in Tenacity '0' gauge.

3.13.1.17 Fibre length

The mean length is the quantitative estimate, which theoretically signifies the arithmetic mean of the sample. Length was determined by 'Ball's sorter' where the weight ratio method was adopted and the mean length expressed in mm.

3.13.1.18 Bartlett's index

Earliness of cotton under various treatments was assessed by working out Bartlett's index on the basis of seed cotton obtained at different pickings using the following formula:

$$BI = \frac{P_1 + (P_1 + P_2) + (P_1 + P_2 + P_3) + (P_1 + P_2 + P_3 + \ldots\ldots\ldots Pn)}{(P_1 + P_2 + P_3 + \ldots\ldots\ldots\ldots Pn) \text{ x } n}$$

Where,

P_1 = Seed cotton weight in first picking

P_2 = Seed cotton weight in second picking

P_3 = Seed cotton weight in third picking

Pn = Seed cotton weight in nth picking

n = Total number of pickings

3.13.2 Groundnut

3.13.2.1 Growth attributes

Five plants of groundnut from each plot were selected at random and observations on growth attributes were recorded at 40 and 80 days after sowing and at harvest.

3.13.2.2 Plant height

Plant height was measured in centimeters from ground level to the apex of the main axis at 40 and 80 days after sowing and at harvest.

3.13.2.3 Leaf area index

The leaf area index was calculated 40 and 80 days after sowing and at harvest by using the formula given below:

$$\text{Leaf area index (LAI)} = \frac{\text{Total leaf area plant}^{-1}\ (\text{cm}^2)}{\text{Ground area occupied plant}^{-1}\ (\text{cm}^2)}$$

3.13.2.4 Number of branch plant^{-1}

Number of primary branch in all the five plants were recorded and the average number of branch plant^{-1} was worked out.

3.13.2.5 Dry matter production

The same five plants which were used for recording height and leaf area were used for calculating dry matter production. The root portion of the plants was separated and the remaining (shoot) portion was first air dried followed by oven drying at 65^{o}C for 24 hours and weighed. Dry matter production was expressed in g plant^{-1}.

3.13.2.6 Yield attributes and yield

3.13.2.6.1 Number of pod plant^{-1}

The pods from the five tagged plants were separated and filled pods were counted and expressed as number of pod plant^{-1}.

3.13.2.6.2 Number of kernel pod^{-1}

Twenty five pods of groundnut were randomly picked from the sampled plants and the total number of seed in them was counted and averaged to record number of kernel pod^{-1}.

3.13.2.6.3 Shelling percentage

A known weight (250 g) of sun-dried pods from each plot was collected and weight of kernel was recorded. Then, shelling percentage was calculated by the following expression.

$$\text{Shelling (\%)} = \frac{\text{Kernel weight}}{\text{Pod weight}} \times 100$$

3.13.2.6.4 1000-kernel weight (test weight)

1000-kernels randomly collected from each net plot were weighed for recording 1000-kernel weight.

3.13.2.6.5 Pod yield

The net plot was harvested, pods were separated and sun-dried (about 15% moisture) and pod yield was recorded and the yield ha^{-1} was worked out.

3.13.2.6.6 Kernel yield

From pod yield of groundnut, the weight of shell was deducted and expressed as kernel yield (t ha^{-1}).

3.13.2.6.7 Haulm yield

The sun-dried groundnut haulm from each plot was weighed and expressed in t ha^{-1}.

3.13.2.6.8 Biological yield

The weight of total produce harvested from each plot was recorded after sun-drying and expressed as biological yield (t/ha).

3.13.2.6.9 Harvest index

The economic yield (pod yield of groundnut) was divided by the respective biological yield (total produce) to work out the harvest index as given below:

$$\text{Harvest index} = \frac{\text{Economic yield (t ha}^{-1}\text{)}}{\text{Biological yield (t ha}^{-1}\text{)}} \times 100$$

3.13.3 Wheat

3.13.3.1 Plant height (cm)

Five tillers in the demarcated one metre row length were randomly selected and their height up to the base of the ear was measured and averaged.

3.13.3.2 Tillers metre^{-2}

The tillers from one metre^{-2} were recorded, averaged and expressed as average number of tiller metre^{-2}.

3.13.3.3 Dry matter accumulation metre^{-2}

The plant samples were taken from one metre^{-2} selected randomly in each plot. The root portion was removed and the samples were first dried in air and then in oven at 65^{o}C for 48 hours till constant weight is arrived. Thereafter the samples were weighed on electric operated top pan balance (Mettler, Type K7T, Swiss made) and the weight was recorded as dry matter metre^{-2}.

3.13.3.4 Yield attributes

3.13.3.4.1. Number of spike metre^{-2}

The number of effective tillers (ear bearing tillers) was counted from one metre^{2} randomly, averaged and expressed as the number of productive or ear bearing tiller metre^{-2}.

3.13.3.4 .2 Number of grain spike^{-1}

The grain from the sampled wheat ears were separated and counted, and expressed as the number of grain earhead^{-1}.

3.13.3.4 .3 1,000 grain weight (g)

One thousand grain were separated from the harvested produce of the wheat from each plot and their weight in g was expressed as 1,000 grain weight.

3.13.3.5 Yield and harvest index

3.13.3.5.1 Biological yield

The weight of the total produce harvested from each net plot was recorded after sun drying and expressed as biological yield in t ha^{-1}.

3.13.3.5.2 Grain yield

The threshed and cleaned grain produce from net plot of wheat was weighed and converted on ha basis to represent the grain yield in t ha^{-1}.

3.13.3.5.3 Straw yield

The grain yield plot^{-1} was deducted from the total biological yield plot^{-1} to record straw yield in wheat. This was expressed in t ha^{-1}.

3.13.3.5.4 Harvest index

Harvest index was computed as the ratio of grain yield to the total biological yield i.e. total dry matter. The produce was multiplied by 100 to express on percentage basis.

$$\text{Harvest index (\%)} = \frac{\text{Economic (grain) yield}}{\text{Biological yield}} \times 100$$

3.14 Chemical analysis

3.14.1 Plant analysis

The plant samples of cotton, groundnut and wheat collected at harvest were dried in an electric oven at 65°C for 48 hours and ground to pass through a 0.5 mm mesh sieve and analysed for nitrogen phosphorus and potassium. Nitrogen was estimated by Kjeldahl’s method (Jackson, 1973), phosphorus by Vanadomolybdophosphoric yellow colour method (Jackson, 1973) and potassium content was determined using flame photometry method (Jackson, 1973). The nutrient content was expressed in percentage. The uptake of nutrients was computed by multiplying seed/kernel/grain and stalk/haulm/straw yield of cotton, groundnut and wheat respectively, by their respective nutrient contents using the following relationship:

$$\text{Total uptake of N/P/K (kg ha}^{-1}\text{)} = \frac{\text{\% N/P/K in grain} \times \text{Grain yield (kg ha}^{-1}\text{)} + \text{\% N/P/K in stover/straw} \times \text{Stover/Straw yield (kg ha}^{-1}\text{)}}{100}$$

3.14.2 Protein content

Protein content in grain was obtained by multiplying the nitrogen content by 6.25 in case of cotton and groundnut and by 5.75 in case of wheat.

3.14.3 Soil analysis

The composite soil samples were collected from 0-30 cm soil profile before sowing and after the harvest of cotton and wheat crops. The soil samples were air-dried, ground and passed through 2 mm mesh sieve and were analysed for available N, P and K. The available N was estimated by alkaline $KMNO_4$ method suggested by Subbiah and Asija (1956) and expressed in kg ha^{-1}.The available P content in soil was estimated by Olsen's method (Olsen *et al*., 1954). Available K was determined using neutral normal ammonium acetate extraction method and flame photometry as described by Stanford and English (1949) and expressed in kg ha^{-1}.A balance sheet of N, P and K used of the crop sequence was prepared by comparing the net change in nutrient status of soil after cotton-wheat.

3.14.4 Dehydrogenase activity

Dehydrogenase was determined according to Thalamann (1968) after soil incubation with 2, 3, 5 triphenyl-tetrazolium chloride (TTC) and measurement of triphenyl formazon (TPF) absorbance at 546 nm.The results were based on oven dry weight basis and expressed in mg TPF g^{-1} soil day^{-1} .

3.14.5 Total chlorophyll estimation

One gram of sliced leaves were transferred into test tubes and 20 ml of extractant medium (consisting of 450 ml of 99 % acetone,450 ml of 99.7 % alcohol and 100 ml of distilled water) was added to leaf slices and were stored in dark for 24 hours to allow complete extraction of chlorophyll. The suspension was filtered and the chlorophyll was assayed using a spectrophotometer at 652 nm. The total chlorophyll was derived by using the formula:

Chlorophyll content (mg g^{-1}fresh weight) = 34.5 x OD_{652} x 20 ml/1.0 g x 10^{-3}

3.15 Correlation and regression studies

The correlation and regression coefficients were calculated between economic yield and yield components by using the method given by Snedecor and Cochran (1968).

3.16 Cotton equivalent yield

The pod yield of groundnut was converted into cotton equivalent yield by using the following formula:

$$\text{CEY (t ha}^{-1}\text{)} = \frac{\text{Pod yield of groundnut (t ha}^{-1}\text{)}}{\text{Market price of cotton (Rs t}^{-1}\text{)}} \times \text{Market price of groundnut (Rs t}^{-1}\text{)} + \text{Seed cotton yield of cotton (t ha}^{-1}\text{)}$$

3.17 Intercropping indices

3.17.1 Land equivalent ratio

This is the relative land area under sole crops that is required to produce the yields achieved in intercropping system.

LER was worked out by the following formula:

$$\text{LER} = \frac{\text{Yab}}{\text{Yaa}} + \frac{\text{Yba}}{\text{Ybb}}$$

Where : Yaa= Pure stand yield of species ‘a’.

Ybb= Pure stand yield of species ‘b’.

Yab= Mixture yield of species ‘a’ in combination with’b’.

Yba= Mixture yield of species ‘b’ in combination with’a’.

3.17.2 Aggressivity

It shows the relationship between dominant and dominated species grown together in intercropping systems, especially when any of the two offers competition. It is usually denoted by ‘A’, and was calculated by using following formula:

$$\text{Aab} = \frac{\text{Yab}}{\text{Yaa Zab}} - \frac{\text{Yba}}{\text{Ybb Zba}}$$

Where : Yaa = Pure stand yield of species ‘a’.

Ybb = Pure stand yield of species ‘b’.

Yab = Mixture yield of species ‘a’ in combination with’b’.

Yba = Mixture yield of species ‘b’ in combination with’a’.

Zab = Sown proportion of species ‘a’ in mixture with ‘b’

Zba = Sown proportion of species ‘b’ in mixture with ‘a’

3.17.3 Relative crowding coefficient (K)

It indicates whether a species or crop, when grown in mixed population, has produced more or less yield than expected in pure stand. The coefficient was determined separately for cotton and groundnut e.g. mathematically for cotton (a) in association with groundnut (b) the coefficient is-

$$Kab = \frac{Yab \times Zba}{(Yaa-Yab) \times Zab}$$

Where: Yaa= Pure stand yield of species ‘a’

Yab= Mixture yield of species ‘a’ in combination with’b’

Zab = Sown proportion of species ‘a’ in mixture with ‘b’

Zba = Sown proportion of species ‘b’ in mixture with ‘a’

3.17.4 Competition Index

It indicates the yield per plant of both crops in intercropping systems and in their respective pure stand on a unit area basis. The CI value of less than one indicates a positive benefit. CI was calculated by the following equation :

$$CI = \frac{(Ya-Ya^{+}) + (Yb-Yb^{+})}{Ya \times Yb}$$

Where: Ya= Yield of cotton per plant in pure stand

Ya^{+}= Yield of cotton per plant in intercropping

Yb= Yield of cotton per plant in pure stand

Yb^{+}= Yield of groundnut per plant in intercropping

3.17.5 Competition Ratio

It is measure of intercrop competition to indicate number of times by which one component crop is more competitive than the other.

$$CR= \frac{Yab}{Yaa \times Zab} \div \frac{Yba}{Ybb \times Zba}$$

Where : Yaa= Pure stand yield of species ‘a’.

Ybb= Pure stand yield of species ‘b’.

Yab= Mixture yield of species ‘a’ in combination with’b’.

Yba= Mixture yield of species ‘b’ in combination with’a’.

Zab = Sown proportion of species ‘a’ in mixture with ‘b’

Zba = Sown proportion of species ‘b’ in mixture with ‘a’

3.17.6 Relative net return

It is used for comparing intercrops in terms of yield equivalent for particular crop or return in terms of money. It is a ratio between monetary value of base and intercrop.

$$RNR = \frac{[(Yab \text{ x Price of 'a'}) + (Yba \text{ x Price of 'b'})]}{(Yaa \text{ x Price of 'a'})}$$

Where: Yaa= Pure stand yield of species ‘a’.

Yab= Mixture yield of species ‘a’ in combination with’b’

Yba= Mixture yield of species ‘b’ in combination with’a’

3.17.7 Area-time equivalency ratio

It is ratio of number of hectare days required in monoculture to produce the number of hectare days used in intercropping to produce identical quantities of each of the component crop.

$$ATER = [(RYa \text{ x } t_a) + (RYb \text{ x } t_b)] / T$$

Where : RYa = Yab/Yaa

RYb = Yba/Ybb

t_a = duration of species ‘a’

t_b = duration of species ‘b’

T = Total duration of intercropping system

3.18 N use efficiencies

The following N use efficiencies were computed with the formulae given below:

$$\text{Agronomic N use efficiency (kg grain kg}^{-1}\text{ N applied)} = \frac{Y_t - Y_o}{A_t}$$

$$\text{Physiological N use efficiency (kg grain kg}^{-1}\text{ N uptake)} = \frac{Y_t - Y_o}{U_t - U_o}$$

$$\text{Apparent N recovery (\%)} = \frac{U_t - U_o}{N_a} \text{ x } 100$$

Y_d

N efficiency ratio (kg dry matter kg^{-1} N uptake)= $\frac{\quad}{N_h}$

Physiological efficiency index of N (kg grain kg^{-1} N uptake) = $\frac{Y_g}{N_b}$

N harvest index (%) = $\frac{N_s}{N_t} \times 100$

Where,

Y_t	=	Grain yield in the test treatment (kg ha^{-1})
Y_o	=	Grain yield in the control plot (kg ha^{-1})
A_t	=	Units of N applied in the test treatment (kg ha^{-1})
U_t	=	Uptake of N in the test treatment (kg ha^{-1})
U_o	=	Uptake of N in the control plot (kg ha^{-1})
N_a	=	N applied to the test treatment (kg ha^{-1})
Y_d	=	Dry matter yield (kg ha^{-1})
N_h	=	N accumulated at harvest (kg ha^{-1})
Y_g	=	Grain yield (kg ha^{-1})
N_b	=	N absorbed by biomass (kg ha^{-1})
N_s	=	N uptake by the grain at harvest (kg ha^{-1})
N_t	=	N uptake by the whole plant at harvest (kg ha^{-1})

3.18 Economics

3.18.1 Cost of cultivation (Rs ha^{-1})

The prices of the inputs that were prevailing at the time of their use (Appendix I to VI) were utilized for determining the cost of cultivation in rupees ha^{-1}.

3.18.2 Gross return (Rs ha^{-1})

The minimum support prices of cotton, groundnut and wheat after its harvest were used for the calculation of gross returns.

3.18.3 Net return (Rs ha^{-1})

The net return ha^{-1} was worked out by deducting the cost of cultivation from the gross return and expressed in rupees ha^{-1}. The net return for system as a whole was also worked out.

3.18.4 Benefit : cost ratio

Benefit : cost ratio was computed for individual crop and the system as a whole by the following formula:

Benefit : cost = Net return (Rs ha^{-1}) / Cost of cultivation (Rs ha^{-1})

3.19 Statistical analysis

The data collected on different parameters were subjected to appropriate statistical analysis following the procedure described by Cochran and Cox (1957). Significance of difference between means was tested through 'F' test and the critical difference (CD) was worked out where variance ratio was found significant for treatment effect. The treatment effects were tested at 5% probability level for their significance. The data pertaining to cotton and groundnut assigned to main-plots were analysed in randomized block design and data pertaining to wheat assigned to sub-plots were analysed in split-plot design.

Table 3.2. Physical and chemical properties of the soil

Particulars	Values 2006	Values 2007	Method followed
I. Mechanical analysis			
1. Sand (%)	66.8	67.2	Hydrometer method (Bouyoucos, 1962)
2. Silt (%)	14.3	13.6	
3. Clay (%)	18.9	19.2	
Textural class	Sandy loam		
II. Physical properties			
1. Bulk density (Mg m^{-3})	1.52	1.48	Core sampler method (Piper, 1950)
2. Field capacity (%)	17.48	17.36	Field method (Dastane, 1967)
3. Permanent wilting point (%)	4.32	4.53	Pressure membrane method (Richards,1954)
III. Chemical properties			
1. Organic carbon (%)	0.46	0.42	Walkley and Black method (Jackson, 1973)
2. Available N (kg ha^{-1})	227.0	207.0	Alkaline permanganate method (Subbiah and Asija, 1956)
3. Available P (kg ha^{-1})	12.8	13.6	Olsen's method (Olsen *et al*., 1954)
4. Available K (kg ha^{-1})	270.0	282.0	Flame photometer method (Jackson, 1967)
5. pH (1:2.5::soil:water)	7.8	8.1	Beckman's pH meter (Piper, 1950)
6. ECe (dSm^{-1} at 25^{o}C)	0.31	0.34	Richards (1954)
7. CEC (Cmol kg^{-1})	10.3	10.3	Schollen Berger's method (Metson, 1956)

Table 3.3. Schedule of field operations during experimentation

S.No.	Name of operation	Dates 2006-07	Dates 2007-08
A.	***Kharif* (Cotton and groundnut)**		
1.	Collection of soil samples for physico-chemical analysis	11.06.06	25.05.07
2.	Field preparation	14.06.06	27.06.07
3.	Layout and bed preparation	15.06.06	28.06.07
4.	FYM application	16.06.06	29.06.07
5.	Fertilizer application	16.06.06	30.06.07
6.	Sowing	17.06.06	02.06.07
7.	Thinning and gap filling	01.07.06	20.07.07
8.	Intercultural operations	15.07.06	28.07.07
9.	Irrigation(s)		
	I.	28.06.06	01.06.07
	II.	06.08.06	27.08.07
	III.	15.10.06	10.10.07
	IV.	09.11.06	01.11.07
10.	Plant protection measures I.	02.10.06	25.09.07
	II.	20.10.06	23.10.07
11.	Harvesting	15.12.06	20.11.07
B.	***Rabi* (wheat)**		
1.	Collection of soil samples for chemical analysis	20.12.06	26.11.07
2.	Field preparation	22.12.06	29.11.07
3.	Layout and bed preparation	23.12.06	01.12.07
4.	Fertilizer application	23.12.06	05.12.07
5.	Sowing	31.12.06	07.12.07
6.	Gap filling	18.01.07	05.01.08
7.	Intercultural operations	20.01.06	17.01.08
8.	Irrigation (s)		
	I.	23.12.07	28.11.07
	II.	26.01.07	23.12.07
	III.	16.02.07	22.01.08
	IV.	18.03.07	11.03.08
	V.	07.04.07	03.04.08
9.	Harvesting	29.04.07	17.04.08
10.	Collection of soil samples for chemical analysis	02.05.07	18.04.08

4

RESULTS

The results of the field experiment entitled "**Effect of nitrogen management practices through organic and inorganic sources in sole and intercropped *Bt* cotton-wheat system**" are presented in this chapter. The data pertaining to growth, yield attributes, yield and quality of *Bt* cotton, groundnut and wheat recorded during experimentation were statistically analyzed and significance of results verified. The data have been given in tables and also depicted graphically, wherever found necessary to provide better understanding of important trends.

4.1 Cotton

4.1.1 Growth parameters

Data pertaining to growth parameters viz., plant height, leaf area index, dry matter partitioning, root dry weight, number of main stem nodes per plant, unopened bolls and total dry matter accumulation as influenced by cropping system and fertility levels have been presented in Tables 4.1, 4.2, 4.3, 4.4, 4.5, 4.6 and 4.7 respectively.

4.1.1.1 Plant height

Cropping system did not significantly influence the plant height at various stages of crop growth in both the years (Table 4.1).

Fertility levels significantly influenced the plant height at all the stages in both the years. At 60 days, fertility levels failed to affect plant height in 2006, while in 2007, all the fertility levels recorded similar plant height but greater than control. At 90 days, 75% RDN + 25% through FYM being on par with 100% RDN and 50% RDN + 50% through FYM though on par with 100% RDN in both the years and 50% RDN + 50% through FYM in 2007 had taller plants than control. At 150 days, all the fertility levels recorded taller plants than control in 2006, but 75% RDN + 25% through FYM had the tallest plants than other fertility levels and control in 2007. Further, 100% RDN and 50% RDN + 50% through FYM in 2007 also recorded greater plant height than control.

4.1.1.2 Leaf area index

Cropping system did not significantly influence the leaf area index at all the crop growth stages in both the years (Table 4.2).

Fertility levels significantly influenced the leaf area index at all the crop growth stages in both the years. Leaf area index with 75% RDN + 25% through FYM and 100% RDN being on par recorded higher values over 50% RDN + 50% through FYM and control at 60 and 90 days stage. At 120 days, all the fertility treatments being on par had higher LAI over control in 2006, whereas in 2007, 75% RDN + 25% through FYM and 100% RDN being on par recorded higher LAI over 50% RDN + 50% through FYM, which in turn had higher LAI than control. At 150 days, 75% RDN + 25% through FYM being on par with 100% RDN had higher LAI over control in both the seasons and 50% RDN + 50% through FYM in 2007.

4.1.1.3 Dry matter partitioning

The data on the mean values of dry matter partitioning at various crop growth stages as affected by cropping system and fertility levels are presented in Table 4.3, 4.4, 4.5 and 4.6.

In general, the rate of dry matter accumulation in various plant parts like leaves, stem and reproductive parts, was relatively slow up to 60 days. Thereafter, a rapid increase in dry matter accumulation was noticed up to 120 days in both the years. At 60 days, leaves and stem constitutes 50% each of the total dry matter. At 90 days, leaves constituted ~ 32%, stem ~ 50% and rest by reproductive parts. At 120 days, leaves constituted 20-25%, stem 38-40% and rest by reproductive parts. At 150 days, leaves constitutes ~ 10-20%, stem ~ 50% and rest by reproductive parts.

Cropping system did not significantly influence the dry matter accumulation in plant parts at all the crop growth stages in both the years (Table 4.3, 4.4, 4.5 and 4.6).

Fertility levels significantly influenced the dry matter accumulation at all the crop growth stages in both the years. At 60 days, DM in leaf, stem and total DM was similar in all the fertility levels over control in both the seasons, except in leaves in 2006, where 75% RDN + 25% through FYM being on par with 100% RDN recorded higher DM in leaves over 50% RDN + 50% through FYM. Further, the differences between 50% RDN + 50% through FYM and control were marked in 2007 only.

At 90 days, 75% RDN + 25% through FYM being on par with 100% RDN recorded higher DM in leaves, reproductive parts and total DM over 50% RDN + 50% through FYM and control in both the seasons. The DM in stem was however, similar in all the fertility treatments but greater than control in both the seasons. The difference between 50% RDN + 50% through FYM and control was marked in 2007 only where the later recorded lower dry matter in stem as compared to the former treatment.

At 120 days, all the fertility treatments recorded similar DM in stem, reproductive parts and total DM, being greater than control in both the seasons, except DM in stem in 2006, where 50% RDN + 50% through FYM had similar DM to that of control. The DM in leaves showed somewhat differential behaviour in two seasons. In 2006, 75% RDN + 25% through FYM and 100% RDN being on par had higher DM in leaves over 50% RDN + 50% through FYM and control, whereas in 2007, the former treatments recorded higher DM in leaves over control only.

At 150 days DM in different plant parts was almost similar in all the fertility treatments, but greater than control in both the seasons, except in leaves in 2006, reproductive parts and total DM in 2007. Application of 75% RDN + 25% through FYM being on par with 100% RDN recorded higher DM in leaves in 2006, and reproductive parts and total DM in 2007 over 50% RDN + 50% through FYM and control.

4.1.1.4 Root dry weight

Cropping system did not significantly influence root dry weight at 150 DAS in both the years (Table 4.7).

Fertility levels significantly affected the root dry weight in both the years. Root dry weight was the highest with 75% RDN + 25% through FYM being significantly higher over all the treatments in 2007, and over control only in 2006. Root dry weight in control was the lowest in both the seasons. However, the difference between control and 50% RDN + 50% through FYM was not noticed in 2006.

4.1.1.5 Number of main stem nodes plant^{-1}

Cropping system did not significantly affect main stem nodes plant^{-1} at 150 days in both the years (Table 4.7).

Fertility levels significantly affected main stem nodes plant^{-1} in both the years. In 2006, all the fertility levels being on par recorded more main stem nodes plant^{-1} over control. In 2007, 75% RDN + 25% through FYM recorded markedly more stem nodes plant^{-1} than all other treatments, which were on par.

4.1.1.6 Unopened bolls plant^{-1}

Cropping system did not significantly affect unopened bolls plant^{-1} at 150 DAS in both the years (Table 4.7).

Fertility levels significantly influenced unopened bolls plant^{-1} in both the years. Unopened bolls plant^{-1} were the maximum in control, being significantly more than other treatments, except that the difference between 50% RDN + 50% through FYM and control was not marked in 2007.

4.1.1.7 Total dry matter accumulation ha^{-1}

Cropping system did not significantly influence total dry matter accumulation at 150 days, in both the years (Table 4.7).

Fertility levels significantly affected total dry matter accumulation in both the years. Application of 75% RDN + 25% through FYM being on par with 100% RDN in both the years recorded higher dry matter over control. However, 50% RDN + 50% through FYM in 2007 was also on par with former treatments.

4.1.2 Yield attributes and yield

Data pertaining to yield attributes viz., opened bolls plant^{-1}, boll weight, seed cotton yield and stalk yield as influenced by cropping system and fertility levels have been presented in Table 4.8 and Fig.4.1

4.1.2.1 Opened bolls plant^{-1}

Cropping system did not significantly affect opened bolls plant^{-1} at 150 DAS, in both the years.

Fertility levels significantly influenced opened bolls plant^{-1} in both the years. Application of 75% RDN + 25% through FYM being on par with 100% RDN recorded significantly more bolls plant^{-1} than 50% RDN + 50% through FYM and control in both the years. The lowest number of boll plant^{-1} was recorded in control plots.

4.1.2.2 Boll weight

Cropping system did not significantly influence boll weight in both the years.

Fertility levels significantly affect boll weight, in both the years. Boll weight was the highest with 75% RDN + 25% through FYM, being on par with 100% RDN in both the years. Further boll weight with 100% RDN was also on par with 50% RDN + 50% through FYM in both the years. Boll weight in control plots was the lowest and differed significantly from all other fertility levels, in both the years.

4.1.2.3 Seed cotton yield

Cropping system did not significantly influence seed cotton yield in both the years.

Fertility levels caused perceptible variation in seed cotton yield in both the seasons. Application of 75% RDN + 25% through FYM being on par with 100% RDN markedly increased the seed cotton yield over 50% RDN + 50% through FYM and control. Further 50% RDN + 50% through FYM also recorded significantly higher yield over control. The trend was similar in both the seasons. Over the seasons, 75% RDN + 25% through FYM increased the seed cotton yield by 26.0% over 50% RDN + 50% through FYM and 81.0% over control.

4.1.2.4 Stalk yield

Cropping system did not significantly influence stalk yield in both the years.

Fertility levels significantly affect stalk yield in both the years. Application of 75% RDN + 25% through FYM being on par with 100% RDN in both the years recorded higher stalk yield over control in both the seasons and 50% RDN + 50% through FYM in 2007. The difference between 50% RDN + 50% through FYM and control was marked in 2007 only where the former treatment recorded higher stalk yield over the later treatment. Application of 75% RDN + 25% through FYM recorded, on an average, 15.4% higher stalk yield over 50% RDN + 50% through FYM and 30.5% over the control.

4.1.3 Fibre quality

Data pertaining to fibre quality of cotton viz., ginning percentage, seed index, lint index, Bartlett's index, 2.5% span length, 50% span length, uniformity ratio, fibre strength, fibre elongation and micronaire as affected by cropping system and fertility level have been presented in Table 4.9 and 4.10 and 4.11, respectively.

Cropping system did not significantly influence fibre quality parameters in both the years.

Fertility levels significantly affected ginning percentage, seed index, lint index and micronaire value only. Parameters namely 2.5% span length, 50% span length, uniformity ratio, fibre strength and fibre elongation remained unaffected by fertility treatments. Application of 75% RDN + 25% through FYM being on par with 100% RDN recorded higher values of ginning percentage, seed index, lint index and micronaire over control and 50% RDN + 50% through FYM, except micronaire in 2006, where 50% RDN + 50% through FYM was on par with 75% RDN + 25% through FYM. Further the treatments were in the following order in respect of seed index in 2006: 75% RDN + 25% through FYM > 100% RDN > 50% RDN + 50% through FYM > Control.

4.1.4 Nutrient status in plant

4.1.4.1 Nitrogen concentration in different plant parts

Cropping system did not significantly influence N content in different plant parts viz., leaves, stem, seed and fibre, in both the years (Table 4.12).

Fertility levels significantly affected N content in different plant parts in both the years. Application of 75% RDN + 25% through FYM significantly increased the N content in leaves over 50% RDN + 50% through FYM and control in both the seasons and over 100% RDN in 2007 only. Marked increase in N content in stem was noticed with 75% RDN + 25% through FYM only over control in 2006. In 2007, N content in stem was similar with 75% RDN + 25% through FYM and 100% RDN, but greater than control. N content in seed showed increase with 75% RDN + 25% through FYM only in both the seasons. The N content in fibre with 75% RDN + 25% through FYM and 100%

RDN was on par and higher than 50% RDN + 50% through FYM and control. Unfertilized crop recorded the lowest N content in fibre in both the seasons.

4.1.4.2 Chlorophyll content at different growth stages

The data on chlorophyll content at various crop growth stages as affected by cropping system and fertility levels are presented in Table 4.13.

The rate of chlorophyll content, in general, was higher at 60 days and thereafter, it decreased gradually up to 150 days stage in both the years.

Cropping system did not significantly influence chlorophyll content at various crop growth stages in both the years.

Fertility levels significantly influenced chlorophyll content at all crop growth stages in both the years. Application of 75% RDN + 25% through FYM being on par with 100% RDN recorded higher chlorophyll content over 50% RDN + 50% through FYM and control at 60, 120 and 150 days stages in both the seasons. At 90 days, 75% RDN + 25% through FYM recorded the higher chlorophyll content, which was markedly higher over all other treatments. The differences between 100% RDN and 50% RDN + 50% through FYM was not marked. The crop with no fertilizer had the lowest chlorophyll content.

4.1.4.3 Phosphorus concentration in different plant parts

Cropping system did not significantly affect P content in different plant parts viz., leaves, stem, seed and fibre in both the years (Table 4.14).

Fertility level significantly influenced P content in different plant parts in both the years. Data in Table 4.14 revealed that P content in leaves, stem and fibre was similar in 3 N treatments, but greater than control in 2006. In 2007, application of 75% RDN + 25% through FYM being on par with 100% RDN recorded higher P content in three plant parts over that of 50% RDN + 50% through FYM and control. The crop receiving no N had the lowest content of P in these plant parts in both the seasons. Application of 75% RDN + 25% through FYM recorded significantly higher P content in seed as compared to all other treatments, except 100% RDN in 2006.

4.1.4.4 Potassium concentration in different plant parts

Cropping system did not significantly influence K content in different plant parts viz., leaves, stem, seed and fibre in both the years (Table 4.15).

Fertility levels significantly influenced K content in different plant parts in both the years. Application of 75% RDN + 25% FYM in both the seasons and 100% RDN in 2007 recorded significantly higher K content in leaves over control. Further, 75% RDN + 25% through FYM being on par with 100% RDN had higher K content in stem over control in both the seasons and 50% RDN through FYM in 2007. The seed K content was similar in all the N treatments, but higher than control in 2006. In 2007, 75% RDN + 25% through FYM being on par with 100% RDN had higher K content than 50% RDN + 50% through FYM and control. The K content in fibre showed similar behaviour in both the seasons, where 75% RDN + 25% through FYM being on par with 100% RDN registered marked increase over 50% RDN + 50% through FYM and control. However, 100% RDN and 50% RDN + 50% through FYM recorded similar K content in fibre in both the seasons.

4.1.5 Nutrient uptake in plant

4.1.5.1 Nitrogen

Cropping system did not significantly affect N uptake by different plant parts viz., leaves, stem, seed, fibre and total, in both the years (Table 4.16).

Fertility level significantly influenced N content by different plant parts in both the years. Application of 75% RDN + 25% through FYM being on par with 100% RDN recorded significantly higher N uptake in leaves over 50% RDN + 50% through FYM and control. Further, 75% RDN + 25% through FYM being on par with 100% RDN had higher N uptake in stem and seed over control in both the seasons. However, in 2007, 75% RDN + 25% through FYM also had higher N uptake in stem and seed over 50% RDN + 50% through FYM. In 2006, N uptake in fibre was similar in all the N treatments, but higher than control, whereas in 2007, 75% RDN + 25% through FYM recorded significantly higher N uptake in fibre over all the treatments. Application of 75% RDN + 25% through FYM being on par with 100% RDN recorded significantly higher total N uptake over 50% RDN + 50% through FYM and control.

4.1.5.2 Phosphorus

Cropping system did not significantly affect P uptake by different plant parts viz., leaves, stem, seed and fibre in both the years (Table 4.17).

Fertility levels significantly influenced P uptake by different plant parts in both the years. Application of 75% RDN + 25% through FYM and 100% RDN both being on par recorded higher P uptake by leaves over 50% RDN + 50% through FYM and control in both the seasons. The differences between P uptake with 50% RDN + 50% through FYM and control were not marked. Further, application of 75% RDN + 25% through FYM being on par with 100% RDN recording higher P uptake in stem over control in both the seasons, and over 50% RDN + 50% through FYM in 2007 only. The P uptake in seed was similar in all the fertility levels, but greater than control in 2006. In 2007, 75% RDN + 25% through FYM recorded the highest P uptake in seed, being significantly higher over all other treatments. The P uptake in fibre was significantly the highest with 75% RDN + 25% through FYM in both the seasons. Application of 75% RDN + 25% through FYM being on par with 100% RDN had higher total P uptake than 50% RDN + 50% through FYM and control. The control plots recorded the lowest total P uptake.

4.1.5.4 Potassium

Cropping system did not significantly affect K uptake by different plant parts viz., leaves, stem, seed and fibre and total uptake in both the years (Table 4.18).

Fertility levels significantly affected K uptake by different plant parts in both the years. Application of 75% RDN + 25% through FYM being on par with 100% RDN in both the seasons recorded significantly higher K uptake in leaves, stem, seed, fibre and total over control. The differences between 75% RDN + 25% through FYM and 50% RDN + 50% through FYM were not marked in K uptake in leaves in both the years, and K uptake in stem, fibre and total K uptake in 2006.

4.1.6 Post-harvest fertility status

4.1.6.1 Organic carbon

Cropping system did not significantly affect organic carbon content of the soil after harvest of cotton and groundnut in both the years (Table 4.19). Sole groundnut vs. rest was also found to be non-significant in both the years.

Fertility levels significantly influenced the organic carbon content of soil in both the years. Application of 50% RDN + 50% through FYM recorded the highest organic carbon content, being markedly higher over all other treatments in both the seasons. Further, application of 75% RDN + 25% through FYM and 100% RDN had similar organic carbon content in soil. Application of 100% RDN failed to affect organic carbon content in 2006.

4.1.6.2 Available phosphorus

Cropping system did not significantly affect available P content of soil after harvest of cotton and groundnut in both the years (Table 4.19). Sole groundnut vs. rest was found to be significant in both the years.

Fertility levels significantly affected the available soil P in both the years. It was observed that there was significant reduction in available P content of soil with 100% RDN as compared to other treatments including control. Application of 50% RDN + 25% through FYM could improve the available P content in soil over control in 2007 only.

4.1.6.3 Available potassium

Cropping system did not significantly affect available soil K content after harvest of *kharif* crops in both the years. Sole groundnut vs. rest found to be significant in both the years.

Fertility levels significantly affected available soil K in both the years. The highest available K was observed in 50% RDN + 50% through FYM being significantly higher than 100% RDN in both the seasons and 75% RDN + 25% through FYM and control in 2006. Application of 100% RDN had the lowest available soil K in both the seasons.

4.1.6.4 Available N

The data on the available soil N status at various crop growth stages as affected by cropping system and fertility levels are presented in Table 4.20 and Fig. 4.2

The available soil N, in general, showed an increase over initial available N status up to 90 DAS. Thereafter a steady decline was observed up to 150 DAS in both the years.

Cropping system did not significantly influence the available N status of soil at all the crop growth stages except at 150 days in both the years. At 150 days, cotton + groundnut system maintained significantly higher available soil N over other cropping system in 2006, but in 2007, it was on par with sole groundnut. The lowest available soil N was noticed with sole cotton in both the years. Sole groundnut vs. rest was found to be significant at all cropping systems, except at 60 days in both the years.

Fertility levels significantly influenced the available soil N at all the crop growth stages in both the years. Application of 50% RDN + 50% through FYM had the highest available soil N, being significantly higher over 75% RDN + 25% through FYM at 90, 120 and 150 days in 2007. This treatment also recorded markedly higher soil available N over 100% RDN at all the stages except 90 and 120 days in 2006. Control plots had the lowest available soil N at all the stages in both the years.

4.1.6.5 Dehydrogenase activity of soil

The data on dehydrogenase activity of soil at all the crop growth stages as affected by cropping system and fertility levels are presented in Table 4.21.

The dehydrogenase activity of soil, in general, decreased from 60 days onward up to 120 days, and thereafter, there was a sharp increase at 150 days in both the years.

Cropping system significantly affected dehydrogenase activity of soil at all crop growth stages in both the years. The highest dehydrogenase activity of soil was noticed with cotton + groundnut system followed by sole cotton, at all crop growth stages, in both the years. The lowest dehydrogenase activity was observed with sole groundnut. Sole groundnut vs. rest was found to be significant at all the growth stages in both the years.

Fertility levels significantly affected dehydrogenase activity of soil at all crop growth stages in both the years. Higher dehydrogenase activity of soil was observed in 50% RDN + 50% through FYM at all the crop growth stages, except 60 DAS in 2006 where 75% RDN + 25% through FYM recorded higher activity over 50% RDN + 50% through FYM. The lowest dehydrogenase activity of soil was noticed in control at all the crop growth stages in both the years. The differences between the treatments involving FYM were also not marked at 60 and 90 days in 2007.

The interaction effect of cropping system and fertility levels on dehydrogenase activity of soil at 150 days (Table 4.22) revealed that 75% RDN + 25% through FYM and 50% RDN + 50% through FYM with cotton + groundnut system maintained significantly higher soil dehydrogenase activity of soil over sole cotton in 2006. In 2007, 100% RDN and 50% RDN + 50% through FYM with cotton + groundnut had higher dehydrogenase activity of soil over sole cotton. In general, cotton + groundnut system maintained higher dehydrogenase activity of soil over sole cotton at all the fertility levels.

4.1.7 Cotton equivalent yield

Cropping system significantly influenced cotton equivalent yield in both the years. Cotton + groundnut system recorded significantly higher cotton equivalent yield over sole cotton, the mean increase being 19.5 % over the seasons.

Fertility level significantly influenced cotton equivalent yield in both the years. Application of 75% RDN + 25% through FYM recorded markedly higher cotton equivalent yield over 50% RDN + 50% through FYM and control in both the seasons, and over 100% RDN in 2007. Over the seasons, 75% RDN + 25% through FYM recorded 6.5, 23.0 and 65.5 % higher cotton equivalent yield over 100% RDN, 50% RDN + 50% FYM and control, respectively.

4.2 Groundnut

4.2.1 Growth parameters

Data pertaining to growth parameters viz., plant height, number of branch plant^{-1}, leaf area index and dry matter accumulation as influenced by cropping system and fertility levels have been presented in Table 4.24, 4.25, 4.26 and 4.27, respectively.

4.2.1.1 Plant height

Cropping system significantly influenced plant height at all growth stages in both the years. Intercropped groundnut maintained significantly higher plant height at 80 days onwards till harvest in both the years, while sole groundnut had significantly taller plants at 40 DAS over intercropped groundnut in both the years (Table 4.24).

Fertility levels significantly affected plant height of intercropped groundnut in both the years at all growth stages. At 40 DAS, 100% RDN being on par with 75% RDN

+ 25% through FYM recorded taller plants over control in both the seasons, and over 50-% RDN + 50% through FYM in 2006 only. At 80 DAS and at harvest, 75% RDN + 25% through FYM being on par with 100% RDN recorded markedly taller plants than 50% RDN + 50% through FYM and control in both the seasons.

4.2.1.2 Number of branch plant^{-1}

Cropping system significantly influenced number of branch plant^{-1} at all growth stages in both the years. Sole groundnut maintained significantly higher number of branch plant^{-1} over intercropped groundnut at all crop growth stages in both the years (Table 4.25).

Fertility levels did not significantly influence number of branch plant^{-1} at all growth stages in both the years.

4.2.1.3 Leaf area index (LAI)

Cropping system significantly influenced leaf area index at all growth stages in both the years (Table 4.26). Sole groundnut maintained significantly higher LAI over intercropped groundnut at all growth stages in both the years.

Fertility levels significantly affected LAI of intercropped groundnut at all growth stages in both the years. At 40 DAS, 75% RDN + 25% through FYM, being on par with 100% RDN recorded higher LAI over 50% RDN + 50% through FYM and control in both the years. At later growth stages, control being on par with 50% RDN + 50% through FYM in both the years and 100% in 2006 recorded higher LAI than 75% RDN + 25% through FYM.

4.2.1.4 Dry matter accumulation

Dry matter accumulation, in general, progressively increased up to harvest in both the years (Table 4.27).

Cropping system significantly affected dry matter accumulation at all the growth stages in both the years. Sole groundnut accumulated significantly higher dry matter over intercropped groundnut at all growth stages in both the years.

Fertility levels also significantly influenced dry matter accumulation at all growth stages in both the years. At 40 days, 75% RDN + 25% through FYM being on par with 100% RDN and 50% RDN + 50% through FYM recorded higher dry matter over control in both the years. At later stages, significantly higher dry matter was produced in control, which was on par with 50% RDN + 50% through FYM at 80 days in both the seasons, and at harvest in 2007.

7.2.2 Yield and yield attributes

Data on yield attributes viz., pods plant^{-1}, kernels pod^{-1}, 1,000-kernel weight and yield (pod, haulm and biological) and shelling percentage recorded at harvest as influenced by cropping system and fertility levels have been presented in Table 4.28 and 4.29, respectively.

7.2.2.1 Pods plant^{-1}

Cropping system significantly influenced pods plant^{-1} in both the years. Sole groundnut produced significantly higher pods plant^{-1} over intercropped groundnut in both the years (Table 4.28 and Fig. 4.3).

Fertility levels significantly affected pods plant^{-1} in both the years. Control treatment being on par with 100% RDN in 2006 and 50% RDN + 50% through FYM produced significantly higher pods plant^{-1} in 2007 over other treatments. However, 100% RDN and 75% RDN + 25% through FYM were on par in both the seasons.

7.2.2.2 Kernels pod^{-1}

Cropping system significantly affected kernels pod^{-1} in both the years. Sole groundnut produced significantly higher kernels pod^{-1} over intercropped groundnut in both the years (Table 4.28 and Fig. 4.3).

Fertility levels significantly influenced kernels pod^{-1} in both the years. Control though produced highest kernels pod^{-1} but was on par with 50% RDN + 50% through FYM in both the seasons, and 100% RDN in 2006.

7.2.2.3 1,000-kernel weight

Cropping system significantly affected 1,000-kernel weight in both the years. Sole groundnut produced significantly higher 1,000-kernel weight over intercropped groundnut in both the years (Table 4.28 and Fig. 4.3).

Fertility level did not significantly influence 1,000-kernel weight in both the years.

7.2.2.4 Pod yield

Cropping system significantly influenced pod yield of groundnut in both the years. Sole groundnut produced significantly higher pod yield over intercropped groundnut in both the years (Table 4.29 and Fig. 4.3).

Fertility levels significantly influenced pod yield of groundnut in both the years. Control treatment, being on par with 50% RDN + 50% through FYM in both the seasons and 100% RDN in 2006 produced significantly higher yield over other treatments. Over the seasons, control plots recorded 8%, 14% and 26 % higher mean yield over 50% RDN + 50% through FYM, 100% RDN and 75% RDN + 25% through FYM, respectively.

7.2.2.5 Haulm yield

Cropping system significantly affected haulm yield of groundnut in both the years. Sole groundnut produced significantly higher haulm yield over intercropped groundnut in both the years (Table 4.29).

Fertility levels significantly influenced haulm yield of groundnut in both the years. The haulm yield was significantly higher in control plots as compared to other treatments except 50% RDN + 50% through FYM in 2006. Application of 75% RDN + 25% through FYM produced the lowest haulm yield but it was on par with 100% RDN in both the seasons.

4.2.2.6 Biological yield

Cropping system significantly affected biological yield of groundnut in both the years (Table 4.29). Sole groundnut produced significantly higher biological yield over intercropped groundnut in both the years.

Fertility levels significantly influenced biological yield in both the years. Control plot recorded significantly higher biological yield over all other treatments in 2007, but in 2006, it recorded similar yield to that of 100% RDN and 50% RDN + 50% through FYM. The lowest biological yield was recorded in 75% RDN + 25% through FYM, which was on par with 100% RDN in both the seasons.

4.2.2.7 Shelling percentage

Cropping system significantly influenced shelling percentage of groundnut in both the years (Table 4.29). Sole groundnut had significantly higher shelling percentage over intercropped groundnut in both the years.

Fertility levels did not influence the shelling percentage in both the years.

4.2.3 Quality and nutrient status in plant

4.2.3.1 N concentration in kernel and haulm

Cropping system significantly affected N concentration in kernel and haulm in both the years. Sole groundnut had significantly higher N concentration in kernel and haulm over intercropped groundnut in both the years (Table 4.30).

Fertility levels also significantly affected N concentration in kernel, haulm in both the years. The N content in kernel increased markedly with 100% RDN + 25% through FYM over control in both the seasons and with 50% RDN + 25% through FYM in 2007 only. The N content in haulm increased with all the fertility treatments over control in both the seasons, except 50% RDN + 50 through FYM in 2007.

4.2.3.2 P concentration in kernel and haulm

Cropping system significantly influenced P concentration in kernel and haulm in both the years (Table 4.30). Sole groundnut recorded significantly higher P concentration in kernel and haulm over intercropped groundnut in both the seasons.

Fertility levels also significantly affected P concentration in kernel and haulm in both the years. All the fertility treatments being on par recorded significantly higher P content in kernel over control in both the seasons, except 50% RDB + 50% through FYM in 2007, which failed to increase P content in kernel over control. Application of 75% RDN in both the seasons and 100% RDN in 2007 gave significant increase in P content in haulm over control.

4.2.3.3 K concentration in kernel and haulm

Cropping system significantly influenced K concentration in kernel and haulm in both the years (Table 4.30). Sole groundnut had significantly higher K concentration in kernel and haulm over intercropped groundnut in both the years.

Fertility levels also significantly affected K concentration in kernel and haulm in both the years. Application of 75% RDN + 25% through FYM had significantly higher K concentration in kernel and haulm over other treatments in both the years. Similar trend was also noticed in K content in haulm in 2006. However, in 2007, K content in haulm differed markedly among the treatments and the treatments were in the following order: 75% RDN + 25 through FYM + 100% RDN > 50% RDN + 50% through FYM > Control.

4.2.4 Nutrient uptake and protein yield

4.2.4.1 Nitrogen

Cropping system significantly affected N uptake in kernel, haulm and total N uptake in both the years (Table 4.31). Sole groundnut had significantly higher N uptake in kernel, haulm and total N uptake over intercropped groundnut in both the years.

Fertility levels significantly influenced N uptake in kernel, haulm and total N uptake in both the years. Control treatment being on par with 50% RDN + 50% through FYM recorded higher N uptake in kernel, haulm and total N uptake over 75% RDN + 25% through FYM in both the seasons. The differences between control and 100% RDN were marked in N content in kernel in both the seasons and in haulm and total N uptake in 2007 only.

4.2.4.2 Phosphorus

Cropping system significantly influenced P uptake in kernel, haulm and total P uptake in both the years (Table 4.32). Sole groundnut had significantly higher P uptake in kernel, haulm and total uptake over intercropped groundnut in both the years.

Fertility levels significantly affected P uptake in kernel, haulm and total uptake in both the years. Control treatment had significantly higher P uptake in kernel, haulm and total P uptake over 75% RDN + 25% through FYM in both the years, except P uptake in haulm in 2007, where P uptake was similar in both the treatments. Further, P uptake in kernel, haulm and total P uptake in control was also significantly higher over 100% RDN in 2007.

4.2.4.3 Potassium

Cropping system significantly affected K uptake in kernel, haulm and total K uptake in both the years (Table 4.33). Sole groundnut recorded significantly higher K uptake in kernel, haulm and total K uptake over intercropped groundnut in both the years.

Fertility levels significantly influenced K uptake in kernel, haulm and total K uptake in both the years. Control treatment recorded higher uptake of K in kernel, haulm and total K uptake over all other treatments in 2007. However, in 2006, it was on par with 50% RDN + 50% through FYM, but greater than other treatments with regard to K uptake in kernel, haulm and total K uptake.

4.2.4.4 Protein content and protein yield

Cropping system significantly affected protein content and yield in both the years (Table 4.34). Sole groundnut produced significantly higher protein content and yield over intercropped groundnut in both the years.

Fertility levels significantly affected protein content and yield in both the years. Control treatment being on par with 100% RDN and 50% RDN + 50% through FYM recorded higher protein content over 75% RDN + 25% through FYM in both the seasons. Similar trend was also observed in protein yield in 2006. But in 2007, control treatment recorded significantly higher protein yield over all the treatments.

4.2.5 Intercropping indices

Assessment of intercropping indices is necessary to find out the best combination of cotton and groundnut for enhancing the total productivity.

The data pertaining to assessment of intercropping are set out in Table 4.35 and 4.36.

4.2.5.1 Land equivalent ratio

It is clear from the results that control treatment gave the highest LER followed by 50% RDN + 50% through FYM in both the years. The lowest mean LER was recorded with 100% RDN, however, 100% RDN and 75% RDN + 25% through FYM recorded more or less similar LER.

4.2.5.2 Aggressivity

The aggressivity values in Table 4.35 indicated that cotton had positive values for all fertility levels while reverse was trend for groundnut. This shows that groundnut was dominated by cotton under all fertility levels. 50% RDN + 50% through FYM showed the highest dominance factor followed by 75% RDN + 25% through FYM in both the years (Table 4.35).

4.2.5.3 Relative crowding coefficient

The product of RCC should be more than one for the cropping system to be advantageous. At all fertility levels, the product of coefficient was less than one indicating that intercropping system was not advantageous during both the years. Although lower RCC values were found with 100% RDN in 2006 and 50% RDN + 50% through FYM in 2007 (Table 4.35).

4.2.5.4 Competition index

The values of competition index were less than one in both the years for all fertility levels, which indicated positive benefit of cotton and groundnut in intercropping system.

4.2.5.5 Competition ratio

In cotton, the highest competition ratio was noticed at 75% RDN + 25% through FYM followed by 100% RDN in both the years. In groundnut, the highest competition ratio was noted in control treatment followed by 50% RDN + 50% through FYM in both the years.

4.2.5.6 Relative net return

The highest RNR was recorded in control treatment followed by 50% RDN + 50% through FYM in both the years. The lowest RNR was accrued at 75% RDN + 25% through FYM in both the years. However, 100% RDN and 75% RDN + 25% through FYM in 2007 recorded similar values of RNR.

4.2.5.7 Area time equivalency ratio

The highest ATER was observed in control treatment followed by 50% RDN + 50% through FYM in both the years. The lowest values were noticed with 100% RDN in both the years.

4.3 Wheat

4.3.1 Growth parameters

Data pertaining to growth parameters viz., plant height, number of tiller meter^{-2} and dry matter accumulation of wheat as influenced by residual effect of cropping systems and fertility levels and direct application of N to wheat, have been presented in Table 4.37, 4.38, 4.39 and 4.40, respectively.

4.3.1.1 Plant height

Residual effect of cropping systems and fertility levels

The residual effect of preceding crop(s) and fertility levels applied to it had significant effect on plant height of wheat at all the growth stages in both the years of experimentation. Plant height increased significantly in cotton + groundnut system over sole cotton at all the growth stages, in both of the years. Among residual effects of fertility levels, at 45 days, all the 3 fertility levels, being on par with each other had significantly taller plants as compared with control. At 90 days, 50% RDN + 50% through FYM, being on par with 75% RDN + 25% through FYM had taller plants than other fertility levels. At harvest, 50% RDN + 50% through FYM maintained significantly greater plant height over other fertility levels (Table 4.37).

Direct effect of nitrogen

Nitrogen applied to wheat had significant effect on plant height at all the growth stages in both the years of experimentation. Wheat recorded significantly taller plants with each successive increase in nitrogen dose up to 100 kg ha^{-1} only at all the stages in both the years. There was, however, marked reduction in plant height at 150 kg N ha^{-1} over 100 kg N ha^{-1} at 90 days in 2006. Similar trend was observed for plant height of wheat grown following sole groundnut crop. Sole groundnut vs. rest was found to be significant at all the growth stages in both the years of investigation.

4.3.1.2 Number of tiller meter^{-2}

Residual effect of cropping systems and fertility levels

The residual effect of preceding crop(s) and fertility levels applied to it had significant effect on number of tiller meter^{-2} of wheat at all the growth stages in both the years of experimentation. Number of tiller meter^{-2} of wheat were significantly higher in cotton + groundnut intercropping over sole cotton at all the growth stages in both the years. 50% RDN + 50% through FYM recorded significantly higher number of tiller meter^{-2} of wheat over all other fertility levels at all growth stages during both the years with the exception that it was at par with 75% RDN + 25% through FYM at 45 DAS in 2007-08.

Direct effect of nitrogen

Nitrogen applied to wheat had significant effect on number of tiller meter^{-2} at all the growth stages in both the years of investigation. Wheat recorded significantly higher number of tiller meter^{-2} with each successive increase in N dose up to 100 kg ha^{-1} only at all the stages in both the years. There was, however, marked reduction in number of tiller meter^{-2} at 150 kg N ha^{-1} over 100 kg N ha^{-1} at all the growth stages in both the years. Significantly higher number of tiller meter^{-2} of wheat recorded, when it was grown after sole groundnut. Sole groundnut vs. rest was found to be significant at all the growth stages in both the years of investigation.

4.3.1.3 Dry matter accumulation

Residual effect of cropping systems and fertility levels

The residual effect of preceding crop(s) and their fertility levels had significant effect on dry matter accumulation of wheat at all the growth stages in both the years of experimentation. Wheat accumulated significantly higher dry matter in cotton + groundnut system over sole cotton at all the growth stages, in both the years. Among residual effects of fertility levels, at all the growth stages, in both the years, 50% RDN + 50% through FYM had significantly higher dry matter accumulation of wheat over other fertility levels. However, in 2007-08, the dry matter accumulation at harvest with 50% RDN + 50% through FYM was on par with 75% RDN + 25% through FYM (Table 4.39).

Direct effect of nitrogen

N applied to wheat had significant effect on dry matter accumulation at all the growth stages in both the years of experimentation. Wheat recorded significantly higher dry matter accumulation with each successive increase in N dose up to 100 kg ha^{-1} only, at all the stages in both the years. A further increase in N to 150 kg ha^{-1} caused a marked reduction in dry matter accumulation of wheat. However, in 2006-07 at 90 days and at harvest, dry matter accumulation of wheat was found at par with 100 and 150 kg N ha^{-1}. Further in 2007-08, at 90 days, all the 3 N levels being on par with each other had significantly higher dry matter accumulation over control. Similar trend was observed for dry matter accumulation of wheat grown in following sole groundnut crop. Sole groundnut vs. rest was found to be significant at all the growth stages in both the years.

Interaction of fertility levels and N applied to wheat on dry matter accumulation at 150 DAS was found to be significant in both the years (Table 4.40). 50% RDN + 50% through FYM with 100 kg N ha^{-1} applied to wheat accumulated significantly higher dry matter. Dry matter accumulation at 100 kg N ha^{-1} applied to wheat was significantly higher over all other N doses applied to wheat in both the years. Among fertility levels, 50% RDN + 50% through FYM produced significantly higher dry matter irrespective of N doses applied to wheat in both the years.

4.3.2 Yield attributes and yield

A perusal of data on yield attributes viz., number of spike meter^{-2}, number of grain spike^{-1}, 1,000 grain weight and yield (grain and biological) and harvest index recorded at harvest as influenced by residual effects of cropping systems and fertility levels and direct application of N to wheat have been presented in Table 4.41 and 4.43, respectively.

4.3.2.1 Number of spike meter^{-2}

Residual effect of cropping systems and fertility levels

The residual effect of preceding crop(s) and their fertility levels have significant effect on number of spike meter^{-2} of wheat in both the years of investigation. Significantly higher number of spike meter^{-2} were recorded after cotton + groundnut system than sole cotton. Among residual effects of fertility levels, 50% RDN + 50% through FYM had significantly higher number of spike meter^{-2} over other fertility levels (Table 4.41 and Fig. 4.4).

Direct effect of nitrogen

N applied to wheat had significant effect on number of spike meter^{-2} in both the years. Wheat recorded significantly higher number of spike meter^{-2} with each successive increase in N dose up to 100 kg ha^{-1} only. There was, however, marked reduction in number of spike meter^{-2} at 150 kg N ha^{-1} over 100 kg N ha^{-1}. Similar trend was observed for number of spike meter^{-2} of what grown in following sole groundnut crop. In the year

2006-07, number of spike meter^{-2} was found at par with 100 and 150 kg N ha^{-1} applied to wheat. Sole groundnut vs. rest was found to be significant in both the years of investigation.

4.3.2.2 Number of grain spike^{-1}

Residual effect of cropping systems and fertility levels

Number of grain spike^{-1} of wheat were not significantly affected by preceding cropping systems and their fertility levels in both the years (Table 4.41 and Fig. 4.4).

Direct effect of nitrogen

Number of grain spike^{-1} were significantly affected by N applied to wheat in both the years of study. With each successive increase in N dose to wheat up to 100 kg ha^{-1} only significantly increased number of grain spike^{-1}. There was, however, marked reduction in number of grain spike^{-1} at 150 kg N ha^{-1} over 100 kg N ha^{-1} in both the years. Number of grain spike^{-1} of wheat grown in following sole groundnut crop, being on par with 100 and 150 kg N ha^{-1} produced significantly higher number of grain spike^{-1} over N doses applied to wheat in both the years. Sole groundnut vs. rest was found to be significant in both the years.

Interaction of fertility levels of preceding crops and N applied to wheat on the number of grain spike^{-1} was found to be significant in both the years (Table 4.42). 50% RDN + 50% through FYM in preceding crop along with 100 kg N ha^{-1} fertilization of what produced significantly higher number of grain spike^{-1} in both the years.

4.3.2.3 1,000-grain weight

Residual effect of cropping systems and fertility levels

The residual effect of preceding crop(s) and their fertility levels had significant effect on 1,000-grain weight of wheat in both the years of investigation. 1,000-grain weight of wheat was significantly higher in cotton + groundnut system than sole cotton in both the years. Among residual effect of fertility levels, 50% RDN + 50% through FYM, being on par with 75% RDN + 25% through FYM had significantly higher 1,000-grain weight over other fertility levels (Table 4.41 and Fig. 4.4).

Direct effect of nitrogen

N applied to wheat had significant effect on 1,000-grain weight in both the years. Wheat recorded significantly higher 1,000-grain weight with each successive increase in N dose up to 100 kg N ha^{-1} only in both the years. The 1,000-grain weight of wheat decreased significantly when N dose was increased to 150 kg N ha^{-1} in the year 2006-07, though the trend is same in 2007-08, the yield reduction was not significant. Similar trend was observed for 1,000-grain weight of wheat grown after sole groundnut. Sole groundnut vs. rest was found to be significant in both the years of investigation.

4.3.2.4 Grain yield

Residual effect of cropping systems and fertility levels

The residual effect of preceding crop(s) and their fertility levels had significant effect on grain yield of wheat in both the years of study (Table 4.43 and Fig. 4.4). Wheat grain yield was significantly higher when it was grown after cotton + groundnut system than that after sole cotton in both the years. Among residual effects of fertility levels, all the 3 fertility levels, being on par with each other had significantly higher grain yield of wheat as compared with unfertilized control in both the years.

Direct effect of nitrogen

N applied to wheat had significant effect on grain yield in both the years. Wheat recorded significantly higher grain yield with each successive increase in N dose up to 100 kg N ha^{-1} only in both the years. Similar trend was observed for grain yield of wheat grown following sole groundnut crop in the year 2006-07. In the year 2007-08 all the 3 N levels, being on par with each other had significantly higher grain yield as compared with control. Sole groundnut vs. rest was found to be significant in both the years of investigation.

Interaction of preceding cropping systems and their fertility levels on grain yield of wheat was found to be significant in both the years (Table 4.44). Wheat following groundnut intercropped cotton receiving 50% RDN + 50% through FYM had significantly higher grain yield than that after sole cotton in 2006-07. However, in 2007-08 the yields of wheat in these treatments were at par.

4.3.2.5 Biological yield

Residual effect of cropping systems and fertility levels

Biological yield of wheat was significantly affected by residual effect of preceding crop(s) and their fertility levels in both the years. Biological yield of wheat was significantly higher in cotton + groundnut system than sole cotton in both the years. Among residual effects of fertility levels in the year 2006-07, all the 3 fertility levels, being on par with each other had significantly higher biological yield of wheat as compared with control. However, in 2007-08, 50% RDN + 50% through FYM produced significantly higher biological yield of wheat over other fertility levels (Table 4.43).

Direct effect of nitrogen

Biological yield of wheat was significantly influenced by direct application of N doses to wheat in both the years. All the 3 N doses, being on par with each other had significantly higher biological yield of wheat as compared with control. Similar trend was observed for biological yield of wheat grown in following sole groundnut crop. Sole groundnut vs. rest was found to be significant in both the years of investigation.

4.3.2.6 Harvest index

Residual effect of cropping systems and fertility levels

Harvest index was significantly affected by residual effect of preceding crop(s) and their fertility levels in both the years. Harvest index of wheat was significantly higher when wheat was grown after cotton + groundnut system over sole cotton in both the years. Among residual effect of fertility levels in the year 2006-07, unfertilized control plots have significantly higher harvest index over other 3 fertility levels. However, in 2007-08, 50% RDN + 50% through FYM recorded significantly lower harvest index of wheat than other three fertility levels which were at par with each other (Table 4.43).

Direct effect of nitrogen

Harvest index of wheat was significantly influenced by direct application of N doses to wheat in both the years. In the year 2006-07, control being on par with 150 kg N ha^{-1} recorded significantly higher harvest index over 50 and 100 kg N ha^{-1}. However, in the year 2007-08, control being on par with 100 kg N ha^{-1} maintained significantly higher harvest index over 50 and 150 kg N ha^{-1}. Harvest index of wheat grown in following sole groundnut, being on par with all 3 N doses was significantly lower over control in the year 2006-07. In the year 2007-08, control maintained significantly higher harvest index over all 3 N doses applied to wheat. Sole groundnut vs. rest was found to be significant in both the years of investigation.

4.3.3 Quality and nutrient status in plant

4.3.3.1 N content in grain and straw and protein content

Residual effect of cropping systems and fertility levels

The residual effect of preceding crop(s) and their fertility levels had significant effect on N content in grain, straw and protein content of wheat in both the years (Table 4.45). N content in grain and straw and protein content of wheat was significantly higher after cotton + groundnut system than that after sole cotton in both the years. Among residual effect of fertility levels, 50% RDN + 50% through FYM resulted in significantly higher N content in grain and protein content over all other fertility levels in both the years. The N content in straw being on par with all 3 fertility levels was significantly higher than that of control in both the years.

Direct effect of nitrogen

N applied to wheat had significant effect on protein content and N content in grain and straw in both the years. N content in grain and straw and protein content increased significantly with each successive increase in N dose up to 100 kg ha^{-1} only in both the years. N content in wheat grain grown following sole groundnut was significantly higher with 100 kg N ha^{-1} over other N doses applied to wheat in both the years. N content in straw was not significantly affected by N doses applied to wheat in both the years. Protein content being on par with all 3 N doses applied to wheat (maintained significantly higher protein content) over control in both the years. Sole groundnut vs. rest was found to be significant for all parameters in both the years.

4.3.3.2 Nitrogen uptake by grain and straw

Residual effect of cropping systems and fertility levels

N uptake by grain and straw did not significantly influence by residual effect of preceding crop(s) and their fertility levels in both the years (Table 4.46).

Direct effect of nitrogen

N uptake by grain and straw was significantly affected by direct application of N doses to wheat in both the years. All the 3 N doses being on par with each other had significantly higher N uptake by grain and straw as compared with control in both the years. Similar trend was observed for N uptake in grain and straw of wheat grown in following sole groundnut crop. Sole groundnut vs. rest was found to be significant in both the years of investigation.

4.3.3.3 Total N uptake

Residual effect of cropping systems and fertility levels

The residual effect of preceding crop(s) and their fertility levels was found to have significant effect on total nitrogen uptake by wheat in both the years (Table 4.46). Total N uptake by wheat was significantly higher in cotton + groundnut system over sole cotton in both the years. Among residual effects of fertility levels, 50% RDN + 50% through FYM maintained significantly higher total N uptake over other fertility levels in both the years.

Direct effect of nitrogen

N applied to wheat had significant effect on total N uptake in both the years. Total N uptake by wheat significantly increased with each successive increase in N dose up to 100 kg N ha^{-1} only in both the years. Similar trend was observed for total N uptake by wheat grown following sole groundnut crop in the year 2006-07. In the year 2007-08, all the 3 N levels being on par with each other had higher total N uptake as compared with control. Sole groundnut vs. rest was found to be significant in both the years of investigation.

Interaction of cropping systems and fertility levels on total N uptake by wheat was found to be significant in both the years (Table 4.47). 50% RDN + 50% through FYM with cotton + groundnut system maintained significantly higher total N uptake in both the years.

4.3.3.4 P content in grain and straw

Residual effect of cropping system and fertility levels

The residual effect of preceding crop(s) and their fertility levels had significant effect on P content in grain and straw of wheat in both the years (Table 4.48). The P content of what grain and straw was significantly higher in cotton + groundnut system over sole cotton in both the years. Among residual effect of fertility levels, 50% RDN + 50% through FYM recorded significantly higher P content in grain and straw over all other fertility levels in both the years.

Direct effect of nitrogen

N applied to wheat had significant effect on P content in grain and straw in both the years. P content of wheat grain and stover increased significantly with increase in N dose up to kg N ha^{-1} in both the years. A further increase in N dose to 150 kg N ha^{-1} had resulted in marked reduction in P content of grain, while P content of straw was unaffected by increased N level in both the years. P content in grain and straw of wheat grown following sole groundnut, being on par with 3 N doses applied o wheat was significantly higher than no N applied in both the years. Sole groundnut vs. rest was found to be significant for P content in grain and straw in both the years of investigation.

4.3.3.5 Total P uptake

Residual effect of cropping systems and fertility levels

Total P uptake by wheat was significantly influenced by the residual effect of preceding crop(s) and their fertility levels in both the years (Table 4.48).Cotton + groundnut system maintained significantly higher total P uptake over sole cotton in both the years. Among residual effects of fertility levels, 50% RDN + 50% through FYM had significantly higher total P uptake over all other fertility levels in both the years.

Direct effect of nitrogen

N applied to wheat had significant effect on its total P uptake in both the years. Each successive increase in nitrogen dose upto100 kg ha^{-1} only has resulted in significantly higher total P uptake by wheat in both the years. Total P uptake by wheat grown following sole groundnut, being on par with all 3 N doses applied to wheat was significantly higher than no N application in both the years. Sole groundnut vs. rest was found to be significant for total P uptakes in both the years.

4.3.3.6 K content in grain and straw

Residual effect of cropping systems and fertility levels

The residual effect of fertility levels applied to preceding crop(s) had significant effect on K content in grain and straw of wheat in both the years. The effect of preceding crop(s) on K content in grain and straw was found not significant in both the years (Table 4.49). Among residual effect of fertility levels, all the 3 fertility levels being on par with each other had significantly higher K content in grain and straw than unfertilized control in both the years.

Direct effect of nitrogen

N applied to wheat had significant effect on K content in grain and straw in both the years. The K content of wheat grain and straw increased significantly with each successive increase in N dose to 100 kg ha^{-1} only. Similar trend was observed for K content in grain and straw of wheat grown following sole groundnut. Sole groundnut vs. rest was found to be significant in both the years of investigation.

4.3.3.7 Total K uptake

Residual effect of cropping systems and fertility levels

Total K uptake by wheat was significantly influenced by the residual effect of cropping systems and their fertility levels in both the years (Table 4.49). Cotton + groundnut system maintained significantly higher total K uptake over sole cotton in both the years. Among residual effect of fertility levels, 50% RDN + 50% though FYM had significantly higher total K uptake over all other fertility levels in both the years.

Direct effect of nitrogen

N applied to wheat had significant effect on total K uptake in both the years. Total K uptake by wheat increased significantly with each successive increase in N dose up to 100 kg ha^{-1}. Total K uptake by wheat grow after sole groundnut was significantly higher with 100 kg N ha^{-1} over all other N doses applied to wheat in both the years. Sole groundnut vs. rest was found to be significant in both the years.

4.4 Total N, P, K uptake in cotton-wheat sequence

Data on total N, P and K uptake by cotton-wheat sequence as affected by residual effect of preceding crop(s) and their fertility levels and direct application of N to wheat have been presented in Table 4.50 and Fig. 4.5

Residual effect of cropping systems and fertility levels

Total nutrient (N, P, K) uptake by cotton-wheat sequence was significantly affected by the residual effect of preceding crop(s) and their fertility levels in both the years (Table 4.50). Cotton + groundnut-wheat system had significantly higher total NPK uptake than cotton-wheat system in both the years. Among residual effect of fertility levels, 75% RDN + 25% through FYM had significantly higher total N uptake over other fertility levels in both the years. Further 100% RDN and 50% RDN + 50% through FYM were found to have at par N, P, K uptake.

Direct effect of nitrogen

N applied to wheat had significant effect on total NPK uptake by cotton-wheat sequence in both the years. Total NPK uptake was significantly higher with each successive increase in N dose up to 100 kg ha^{-1} in both the years. Total NPK uptake by sole groundnut-wheat sequence was not significantly affected by direct N doses applied to wheat in both the years. Sole groundnut vs. rest was found to be significant in both the years.

4.5 Cotton-wheat system equivalent yield

Data on cotton-wheat system equivalent yield as affected by residual effect of cropping systems, their fertility levels and direct effect of N doses applied to wheat have been presented in Table 4.51 and Fig. 4.6

Residual effect of cropping systems and fertility levels

Cotton-wheat system equivalent yield was significantly affected by residual effect of cropping systems and fertility levels applied to it in both the years. Cotton + groundnut system recorded significantly higher cotton-wheat system equivalent yield than sole cotton in both the years of investigation. Among residual effect of fertility levels, all the 3 fertility levels being on par with each other had significantly higher cotton-wheat system equivalent yield over that of control.

Direct effect of nitrogen

N applied to wheat had significant effect on cotton-wheat system equivalent yield of wheat in both the years. Cotton-wheat system equivalent yield increased significantly with each successive increase in N dose up to 100 kg ha^{-1} in both the years. Cotton-wheat system equivalent yield grown following groundnut crop was significantly influenced by direct application of N doses to wheat in both the years. Sole groundnut vs. rest was found to be significant in both the years.

4.6 Soil nutrient content changes

4.6.1 Organic carbon after wheat harvest

Residual effect of cropping systems and fertility levels

The residual effect of preceding crop(s) and fertility levels applied to it, had significant effect on organic carbon content of soil after harvest of wheat in both the years (Table 4.52). The organic carbon content of soil was significantly higher in cotton + groundnut system over sole cotton in both the years of investigation. Among residual effect of fertility levels, organic carbon content was highest when N was given as 50% RDN + 50% through FYM. In 2006-07, the increase in OC content of soil was marked when N is substituted (25 or 50% N) through FYM over control and 100% RDN. However, in 2007-08 all fertilizer treatments being on par recorded higher organic carbon content of soil over control only.

Direct effect of nitrogen

N applied to wheat had significant effect on OC content of soil after harvest of wheat in both the years. OC content of soil significantly increased with each successive increase in N dose up to 150 kg ha^{-1} in both the years. OC content of soil after harvest of wheat grown following sole groundnut, was significantly higher with 150 kg N ha^{-1} in the year 2006-07, while in the year 2007-08, it was being on par with 100 and 150 kg N ha^{-1} had significantly higher over 0 and 50 kg N ha^{-1}. Sole groundnut vs. rest was found to be significant in both the years.

Interaction of fertility levels and cropping systems on OC content of soil after harvest of wheat was found to be significant in both the years (Table 4.53). 50% RDN + 50% through FYM with cotton + groundnut system had significantly higher OC content of soil in both the years over other combinations of cropping systems and fertility levels.

4.6.2 Available N after wheat harvest

Residual effect of cropping systems and fertility levels

Available soil N content was not significantly influenced by residual effect of preceding crop(s) in both the years. The fertility levels applied to preceding crop(s) significantly influenced available soil N content of soil after wheat harvest in both the yeas. 50% RDN + 50% through FYM and 75% RDN + 25% through FYM being on par with each other had significantly higher available soil N content over 100% RDN and control in both the years (Table 4.52). 100% RDN in turn had significantly higher soil N content than control.

Direct effect of nitrogen

N applied to wheat had significant effect on available soil N content after wheat harvest in both the years. Each successive increase in N dose up to 150 kg ha^{-1} in both the years had significant increase available soil N content. The N content of sol in unfertilized control and 50 kg N ha^{-1} were found to be at par in both the years. Available soil N content after harvest of wheat grown following sole groundnut crop was found to be non-significant in both the years. Sole groundnut vs.. rest was found to be significant in both the years of investigation.

4.6.3 Dehydrogenase activity of soil after wheat harvest

Residual effect of cropping systems and fertility levels

Dehydrogenase activity of soil after harvest of wheat was not significantly affected by residual effect of preceding crop(s) in both the years, but it was significantly affected by residual effect of fertility levels applied to preceding crop(s) in both the years. Among fertility levels, 50% RDN and 50% through FYM, had significantly higher dehydrogenase activity of soil over other fertility levels in both the years. However, during 2007-08, it has at par dehydrogenase activity as 75% RDN + 25% through FYM. 100% RDN and 75% RD + 25% through FYM, being on par with each other had significantly higher dehydrogenase activity of soil than control in both the years.

Direct effect of nitrogen

N applied to wheat had significantly affected dehydrogenase activity of soil after wheat harvest in both the years. Dehydrogenase activity of soil increased significantly with each successive increase in N dose up to 150 kg N ha^{-1} in both the years. However, 0 and 50 kg N ha^{-1} were found to be at par in both the years. Dehydrogenase activity of soil after harvest of wheat grown following sole groundnut crop was found to be significant in both the years. Sole groundnut vs. rest was found to be significant in both the years.

Interaction effect of cropping systems and direct application of N doses to wheat on dehydrogenase activity of soil after harvest of wheat was found to be significant in both the years (Table 4.54). Wheat receiving no N fertilizer following cotton + groundnut system recorded significantly higher dehydrogenase activity of soil in both the years over that after sole cotton. Further, the dehydrogenase activity of soil in cotton + groundnut system receiving 50 kg N ha^{-1} was significantly higher over sole cotton in 2007-08. At higher N levels (100 and 150 kg N ha^{-1}), the differences in dehydrogenase activity of soil narrowed down and became non-significant in both the cropping systems.

4.6.4 Available soil P after harvest of wheat

Residual effect of cropping systems and fertility levels

Available P content of soil after wheat harvest was significantly influenced by residual effect of preceding crop(s) and fertility levels applied to it in both the years (Table 4.55). Available soil P was significantly higher in sole cotton over cotton + groundnut system in both the years. Among residual effect of fertility levels, 50% RDN + 50% through FYM being on par with 75% RDN + 25% through FYM recorded significantly higher available soil P over 100% RDN and control in both the years.

Direct effect of nitrogen

N applied to wheat had significant effect on available soil P after harvest of wheat in both the years. Available soil P decreased with each successive increase in N dose up to 150 kg N ha^{-1} in both the years. However, available soil P in 0 and 50 kg N ha^{-1} and 100 and 150 kg N ha^{-1} was at par in both the years. Available soil P after harvest of wheat following sole groundnut, was found to be non-significant in both the years. Sole groundnut vs. rest was found to be significant in both the years.

4.6.5 Available soil K status after harvest of wheat

Residual effect of cropping systems and fertility levels

Available soil K after harvest of wheat was not significantly affected by residual effect of preceding crop(s) in both the years (Table 4.55). However, the fertility levels applied to preceding crop(s) had significant effect on soil available K in both the years. 50% RDN + 50% through FYM and 75% RDN + 25% through FYM being on par with each other had significantly higher available soil K content over 100% RDN and control in both the years.

Direct effect of nitrogen

N applied to wheat had significant effect on available soil K content after harvest of wheat in both the years. Available soil K decreased with each successive increase in N dose up to 100 kg N ha^{-1} in both the years. Available soil K after harvest of wheat grown following sole groundnut crop was not significantly affected by direct application of N doses to wheat in both the years. Sole groundnut vs. rest was found to be significant in both the years.

4.7 Economics

Data pertaining to economic evaluation of direct and residual effects of cropping systems and fertility levels and direct effect of N doses applied to wheat in cotton-wheat cropping system have been presented in Table 4.56 and 4.57. The details of cost of cultivation, benefit: cost ratio and economics of different treatments have been given in Appendices I to IX.

4.7.1 Net return

4.7.1.1 Cotton and groundnut

A perusal of data recorded that cotton + groundnut system had higher net return over sole cotton and groundnut systems in both the years. Sole groundnut was least profitable among the 3 cropping systems. Application of 75% RDN + 25% through

FYM recorded the highest net return among the fertility levels in both the seasons. It was closely followed by 100% RDN in both the years (Table 4.56).

4.7.1.2 Wheat

Residual effect of cropping systems and fertility levels

Wheat following groundnut had highest net return, while that after sole cotton had the least net returns in both the years. Among residual effect of fertility levels, 50% RDN + 50% through FYM recorded the highest net return closely followed by 75% RDN + 25% through FYM in both the years (Table 4.56). Unfertilized control plots have recorded the lowest net returns.

Direct effect of nitrogen

Wheat receiving 100 kg N ha^{-1} fetched he highest net return (Rs 22,725 and Rs 29,736 in 2006-07 and 2007-08, respectively). Application of N @ 100 kg N ha^{-1} to wheat resulted in loss as evident from net return (Rs 2,409 and Rs 2,791 in 2006-07 and 2007-08, respectively). Similar trend was observed for wheat grown following sole groundnut crop in both the years.

4.7.1.3 Cotton-wheat

Residual effect of cropping systems and fertility levels

A perusal of data set out in Table 4.56 revealed that cotton + groundnut – wheat system fetched the highest net return of Rs 72,812 (2006-07) and Rs 65,334 (2007-08) which were higher by 13,522 and Rs 15,319 over sole cotton-wheat, respectively in both the years. The lowest net return was recorded in sole groundnut-wheat system. Among fertility levels, application of 50% RDN + 25% through FYM recorded higher net return closely followed by 75% RDN + 25% through FYM in both the years. Unfertilized plots have the least net returns in both the years.

Direct effect of nitrogen

Wheat receiving 100 kg N ha^{-1} in both the years fetched the highest net return of Rs 70,146 (2006-07) and Rs 62,501 (2007-08). Application of N beyond 100 kg ha^{-1} to wheat has decreased net return by Rs 2,409 and Rs 2,791 in 2006-07 and 2007-08, respectively. Similar trend was observed for wheat grown following sole groundnut crop in both the years.

4.7.2 B: C ratio

4.7.2.1 Cotton and groundnut

A perusal of data (Table 4.57) revealed that cotton + groundnut system had highest B: C ratio which was 24% and 45% higher than that of sole cotton in 2006-07 and 2007-08, respectively. Application of 100% RDN recorded the highest B: C ratio, while 50% RDN + 50% through FYM recorded the lowest B: C ratio in both the years.

4.7.2.2 Wheat

Residual effect of cropping systems and fertility levels

Wheat grown following cotton + groundnut system had higher B: C ratio over sole cotton and groundnut crops in both the years. Among residual effect of fertility levels 50% RDN + 50% through FYM recorded highest B: C ratio while unfertilized control plots have least B: C ratio in both the years (Table 4.57).

Direct effect of nitrogen

Wheat receiving 100 kg N ha^{-1} in both the years fetched highest B: C ratio of 1.54 (2006-07) and 1.88 (2007-08). Application of N beyond 100 kg N ha^{-1} to wheat decreased B: C ratio by 0.18 (2006-07) and 0.23 (2007-08). Similar trend was observed for wheat grown following sole groundnut crop in both the years.

4.7.2.3 Cotton-wheat

Residual effect of cropping systems and fertility levels

A perusal of data set out in Table 4.57 revealed that cotton + groundnut – wheat fetched the highest B:C ratio of 2.09 and 1.74 in 2006-07 and 2007-08, respectively. The net returns of cotton + groundnut – wheat system were higher by 0.34 (2006-07) and 0.38 (2007-08) over sole cotton-wheat system. The B: C ratio was the least in sole groundnut-wheat system in both the years. Among fertility levels, application of 75% RDN + 25% through FYM recorded highest B: C ratio closely followed by 50% RDN + 50% through FYM. Unfertilized control plots have the lowest B: C ratio.

Direct effect of nitrogen

Wheat receiving 100 kg N ha^{-1} in both the years fetched the highest B: C ratio of 2.03 and 1.67 in 2006-07 and 2007-08, respectively. Application of N beyond 100 kg N ha^{-1} decreased B: C ratio by 0.09 in both the years. Similar trend was observed for wheat grown following sole groundnut crop in both the years.

4.8 Response function of N fertilization

Response function of N fertilization in wheat grown after *kharif* crops has worked out by quadratic equations between grain yield of wheat and nitrogen doses applied to wheat (Table 4.58).

The response functions showed economic optimum dose of N for wheat is least when sole groundnut is the preceding *kharif* crop and was highest after sole cotton in both the years of investigation. Yield at economic optimum dose of N was highest when preceding *kharif* crop was sole groundnut as compared to sole and intercropped cotton in both the years. Response at optimum dose of N was also highest with sole groundnut as a preceding *kharif* crop in both the years.

4.9 Soil nutrient dynamics

4.9.1 Organic carbon

4.9.1.1 After harvest of *kharif* crops

Cropping systems

The highest gain of OC content of soil was recorded in cotton + groundnut system followed by sole groundnut in both the years (Table 4.59).

Fertility levels

The negative balance of C content of soil was found with control in both the years. Further, negative balance was also found with 100% RDN in the year 2006-07. The highest gain of OC content of soil was found with 50% RDN + 50% through FYM followed by 75% RDN + 25% through FYM in both the years.

4.9.1.2 After harvest of wheat

Residual effect of cropping system and fertility levels

A negative balance was found with all cropping systems and fertility levels in both the years. However, in 2007-07 50% RDN + 50% through FYM recorded a positive balance of C content of soil. Sole cotton followed by cotton + groundnut system recorded the highest loss of OC content of soil in both the years as compared to sole groundnut. Among fertility levels, the highest loss of OC content of soil was found with control in both the yeas (Table 4.59).

Direct effect of nitrogen

A positive balance was found when 150 kg N ha^{-1} applied to wheat in both the years of study. The negative balance of N was highest with control in both the years.

Similar trend was observed for wheat grown following sole groundnut crop in both the years.

4.9.2 Available soil N

4.9.2.1 After harvest of *kharif* crops

The highest gain of available nitrogen over initial content was recorded with cotton + groundnut system followed by sole groundnut in both the years. Among fertility levels the highest gain was found with 50% RDN + 50% through FYM followed by 75% RDN + 25% through FYM in both the years. A negative balance of available soil N was found with control in the year 2007-08 (Table 4.59).

4.9.2.2 After harvest of wheat

Residual effect of cropping systems and fertility levels

A positive N balance was found with sole groundnut system only in both the years of study, while it was negative in sole cotton and cotton + groundnut system. All the fertility levels, recorded negative balance of available soil N in both the years with the exception of 50% RDN + 50% through FYM, which had a positive balance in 2007-08. The negative N balance was highest in unfertilized control. Substitution of chemical N through FYM reduced the –ve N balance, thus 50% RDN + 50% FYM has least depletion of soil N.

Direct effect of nitrogen

Nitrogen balance was negative in both the years. Each successive increase in nitrogen dose has resulted in reduced negative balance of soil N. Application of 150 kg N ha^{-1} to wheat has resulted in least –ve balance of soil N in both the years. Wheat grown following sole groundnut crop has a positive balance at all N levels and the highest being with 150 kg N ha^{-1} to wheat. However, in 2006-07, the balance was positive with 50% RDN + 50% FYM through FYM treatment only.

4.9.3 Available soil P

4.9.3.1 After harvest of *kharif* crops

The available soil P was depleted when groundnut crop is involved in the cropping system as sole or intercrop with cotton. However, in sole cotton, there is build up of soil phosphorus in both the years. Among fertility levels, 50% RDN + 50% through FYM in both the years and FYM in 2007-08 recorded a positive balance of available soil

P. The highest negative balance of P was found with 100% RDN in both the years of study (Table 4.60).

4.9.3.2 After harvest of wheat

Residual effect of cropping systems and fertility levels

The soil P balance was highest with sole cotton in both the years and there was a build up in the year 2006-07 as compared to other cropping systems. The negative balance was highest with sole groundnut in both the years. Among fertility levels, 50% RDN + 50% through FYM recorded a positive balance in both the years. While all other fertility levels have negative balance. The negative balance was highest with 100% RDN followed by control and 75% RDN + 25% through FYM in both the years.

Direct effect of nitrogen

Soil phosphorus balance was found positive when 0 and 50 kg N ha^{-1} was applied to wheat in the year 2006-07. The highest negative balance was found with 100 kg N ha^{-1} applied to wheat in both the years. Wheat grown following sole groundnut crop recorded a negative balance of available soil P with each successive increase in N doses in both the years.

4.9.3 Available K

4.9.3.1 After harvest of *kharif* crops

The least loss of available soil K after harvest of *kharif* crops was recorded with sole groundnut followed by cotton + groundnut system in both the years. Sole cotton recorded higher loss of available soil K in both the years. Among fertility levels, 50% RDN + 50% through FYM closely followed by 75% RDN + 25% through FYM recorded least lost of available soil K in both the years. The highest negative balance was found with 100% RDN in both the years (Table 4.60).

4.9.3.2 After harvest of wheat

Residual effect of cropping systems and fertility levels

The highest positive balance of available soil K was found with sole cotton closely followed by cotton + groundnut system in both the years. Further, the K balance in sole groundnut was found to be negative in both the years. Among fertility levels the K balance was positive at all the fertility levels in 2006-07, whereas in 2007-08, it was positive in treatments involving FYM only. 50% RDN + 50% through FYM followed by

75% RDN + 25% through FYM recorded the highest positive balance of available soil K in both the years.

Direct effect of nitrogen

Direct application of nitrogen to wheat maintained a positive balance of available soil K for all the N doses in both the years. Each successive increase ein N dose to wheat resulted in lesser positive balance of K up to 100 kg N ha^{-1}, after that it remained constant for 150 kg N ha^{-1} applied to wheat in both the years. Similar trend was observed for wheat grown following sole groundnut crop. Except at 150 kg N ha^{-1}, positive balance was further marginally increased in both the years.

4.10 Agronomic N use efficiency and physiological N use efficiency

Data pertaining to Agronomic N Use Efficiency (ANUE) and Physiological N Use Efficiency (PNUE) in cotton and wheat as influenced by nitrogen have been presented in Table 4.61.

4.10.1 Cotton

4.10.1.1 Agronomic N use efficiency

Application of 75% RDN + 25% through FYM recorded the highest ANUE followed by 100% RDN in both the years of study, while 50% RDN + 50% through FYM recorded the least ANUE in both the years.

4.10.1.2 Physiological N use efficiency

Application of 50% RDN + 50% through FYM followed by 75% RDN + 25% through FYM recorded the highest PNUE in both the years of study. While 100% RDN recorded the least PNUR in both the years.

4.10.2 Wheat

4.10.2.1 Agronomic N use efficiency

Residual effect of fertility levels

Application of 50% RDN + 50% through FYM followed by 75% RDN + 25% through FYM recorded the highest ANUE in both the years. The least ANUE was recorded with 100% RDN in both the years of study.

Direct effect of nitrogen

The highest ANUE was recorded with 50 kg N ha^{-1} applied to wheat followed by 100 kg N ha^{-1} in both the years. At 150 kg N ha^{-1}, a negative ANUE was found.

Similar trend was observed for wheat grown following sole groundnut crop in both the years.

4.10.2.2 Physiological N use efficiency

Residual effect of fertility levels

Application of 100% RDN in year 2006-07 and 75% RDN + 25% through FYM in the year 2007-08 recorded the highest PNUE followed by 75% RDN + 25% through FYM and 100% RDN, respectively, in both the years. The least PNUE was found with 50% RDN + 50% through FYM, in both the years.

Direct effect of nitrogen

The highest PNUE was recorded with 150 kg N ha^{-1} applied to wheat in both the years. The PNUE was similar with 50 and 100 kg N ha^{-1} in both the years. Similar trend was observed for wheat grown following sole groundnut crop in both the years.

4.11 Apparent N recovery and N efficiency ratio

Data relating to Apparent N recovery (ANR) and N efficiency ratio (NER) in *kharif* crops and wheat as influenced by nitrogen have been presented in Table 4.62.

4.11.1 Cotton

4.11.1.1 Apparent N recovery

Application of 75% RDN + 25% through FYM recorded the highest ANR followed by 100% RDN in both the years. The ANR was least with 50% RDN + 50% through FYM treatment in both the years.

4.11.1.2 Nitrogen efficiency ratio

Cropping systems

Sole cotton maintained the highest NER closely followed by cotton + groundnut system in both the years. The least NER was found with sole groundnut in both the years.

Fertility levels

The NER was highest in unfertilized control treatment followed by 50% RDN + 50% through FYM in both the years. The NER of 100% RDN and 25% RDN + 25% through FYM was similar in both the years.

4.11.2 Wheat

4.11.2.1 Apparent N recovery

Residual effect of fertility levels

Application of 50% RDN + 50% through FYM followed by 75% RDN + 25% through FYM recorded the highest ANR in both the years of study.

Direct effect of nitrogen

The highest ANR was recorded with 50 kg N ha^{-1} applied to wheat followed by 100 kg N ha^{-1} in both the years. ANR was least with 150 kg N ha^{-1} application to wheat in both the years. Similar trend was found for wheat grown following sole groundnut crop in both the years.

4.11.2.2 Nitrogen efficiency ratio

Residual effect of cropping systems and fertility levels

The highest NER was found with sole cotton followed by cotton + groundnut system in both the years. Among fertility levels, 100% RDN and 75% RDN + 25% through FYM in 2006-07 and control and 100% RDN in 2007-08 recorded the highest NER.

Direct effect of nitrogen

In the year 2006-07, 50 kg N ha^{-1} followed by no N applied wheat, recorded the highest NER. However, in 2007-08, unfertilized control followed by 50 kg N ha^{-1} applied wheat recorded the highest NER. Similar trend was found for wheat grown following sole groundnut in both the years.

4.12 Physiological efficiency index of N and N harvest index

Data pertaining to physiological efficiency index of N (PEIN) and N harvest index (NHI) in *kharif* crops and wheat as affected by nitrogen have been presented in Table 4.63.

4.12.1 *Kharif* crops

4.12.1.1 Physiological efficiency index of N an nitrogen harvest index

Cropping system

Sole cotton maintained the highest PEIN and NHI followed by cotton + groundnut system in both the years. Sole groundnut recorded the least PEIN and NHI in both the years.

Fertility levels

The highest PEIN and NHI were recorded in unfertilized control treatment followed by 50% RDN + 50% through FYM in both the years. 100% RDN and 75% RDN + 25% through FYM were found to have similar PEIN and NHI in both the years.

4.12.2 Wheat

4.12.2.1 Physiological efficiency index of N

Residual effect of cropping system and fertility levels

In both the years, sole cotton and cotton + groundnut system recorded similar PEIN over sole groundnut system. Among fertility levels unfertilized control followed by 100% RDN recorded the highest PEIN in both the years. The least PEIN was found with 50% RDN + 50% through FYM in both the years.

Direct effect of nitrogen

With each successive increase in N dose resulted in decrease of PEIN in both the years. The same trend was found for wheat grown after sole groundnut as *kharif* crop in both the years. However, per cent decrease was less with higher N dose beyond 50 kg N ha^{-1} in both the years.

4.12.2.2 Nitrogen harvest index

Residual effect of cropping systems and fertility levels

The highest NHI was found with cotton + groundnut system followed by sole cotton in the year 2006-07 and sole groundnut in the year 2007-08. Among fertility levels, control and 75% RDN + 25% through FYM in the year 2006-07 and control and 100% RDN in the year 2007-08 recorded the highest NHI. The least NHI was found with 50% RDN + 50% through FYM in both the years.

Direct effect of nitrogen

Each successive increase in N doses increases NHI up to 100 kg N ha^{-1}. Similar trend was found for wheat grown after sole groundnut as *kharif* crop in both the years.

Table 4.1. Effect of cropping system and fertility level on plant height (cm) of cotton

Treatment	60 DAS		90 DAS		120 DAS		150 DAS	
	2006	2007	2006	2007	2006	2007	2006	2007
Cropping system								
Sole cotton	84.1	58.1	124.3	95.4	136.0	108.0	137.2	112.5
Cotton + Groundnut (1:3)	87.6	63.1	127.9	99.1	141.0	120.0	144.2	123.8
SEm ±	**2.74**	**2.42**	**2.43**	**3.27**	**1.87**	**5.02**	**2.31**	**3.86**
CD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Fertility level								
Control	80.6	50.5	121.1	83.0	129.5	90.0	128.7	94.0
100% RDN	86.3	63.0	128.0	103.2	143.2	117.5	146.5	122.0
75% RDN + 25% through FYM	89.7	67.0	132.4	106.0	145.2	132.5	148.0	139.5
50% RDN + 50% through FYM	84.7	61.0	123.1	92.2	136.0	112.0	139.8	118.0
SEm ±	**3.88**	**3.42**	**3.47**	**4.63**	**2.65**	**7.09**	**3.27**	**5.46**
CD (P=0.05)	**11.84**	**10.37**	**10.52**	**14.04**	**8.03**	**21.52**	**9.92**	**16.56**

DAS = Days after sowing; RDN = Recommended dose of nitrogen; FYM = Farm Yard Manure

Table 4.2. Effect of cropping system and fertility level on leaf area index (LAI) of cotton

Treatment	60 DAS		90 DAS		120 DAS		150 DAS	
	2006	2007	2006	2007	2006	2007	2006	2007
Cropping system								
Sole cotton	1.69	1.60	2.79	2.77	4.05	3.99	2.78	2.78
Cotton + Groundnut (1:3)	1.71	1.63	2.83	2.80	4.13	4.08	2.88	2.87
SEm ±	**0.010**	**0.011**	**0.013**	**0.109**	**0.041**	**0.027**	**0.033**	**0.032**
CD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Fertility level								
Control	1.54	1.49	2.63	2.61	3.90	3.84	2.66	2.64
100% RDN	1.78	1.67	2.93	2.89	4.19	4.09	2.91	2.91
75% RDN + 25% through FYM	1.78	1.70	2.92	2.90	4.20	4.20	2.96	2.97
50% RDN + 50% through FYM	1.69	1.60	2.78	2.75	4.09	4.02	2.80	2.79
SEm ±	**0.014**	**0.017**	**0.019**	**0.015**	**0.058**	**0.038**	**0.047**	**0.045**
CD (P=0.05)	**0.044**	**0.048**	**0.057**	**0.047**	**0.176**	**0.114**	**0.143**	**0.136**

DAS = Days after sowing; RDN = Recommended dose of nitrogen; FYM = Farm Yard Manure

Table 4.3. Effect of cropping system and fertility level on dry matter partitioning (g/plant) of cotton at 60 DAS

Treatment	Leaves		Stem		Total	
	2006	2007	2006	2007	2006	2007
Cropping system						
Sole cotton	39.35	31.05	37.30	26.20	76.60	57.25
Cotton + Groundnut (1:3)	45.22	36.27	46.70	29.65	92.00	66.00
SEm ±	**2.162**	**1.799**	**3.386**	**1.165**	**5.079**	**2.918**
CD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Fertility level						
Control	35.80	21.40	35.10	22.15	71.00	43.65
100% RDN	46.55	38.70	44.50	30.30	91.05	69.00
75% RDN + 25% through FYM	48.05	40.40	46.60	31.50	94.65	71.90
50% RDN + 50% through FYM	38.73	34.15	37.60	27.65	77.20	61.80
SEm ±	**3.058**	**2.545**	**4.789**	**1.648**	**7.183**	**4.127**
CD (P=0.05)	**9.276**	**7.718**	**14.527**	**4.999**	**21.785**	**12.518**

DAS = Days after sowing; RDN = Recommended dose of nitrogen; FYM = Farm Yard Manure

Table 4.4. Effect of cropping system and fertility level on dry matter partitioning (g/plant) of cotton at 90 DAS

Treatment	Leaves		Stem		Reproductive parts		Total	
	2006	2007	2006	2007	2006	2007	2006	2007
Cropping system								
Sole cotton	51.44	59.00	78.10	63.30	31.21	15.21	163.40	137.50
Cotton + Groundnut (1:3)	62.47	67.20	83.70	67.40	36.00	17.52	179.51	152.10
SEm ±	**3.575**	**2.756**	**4.106**	**1.905**	**1.601**	**0.831**	**5.461**	**5.018**
CD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Fertility level								
Control	36.12	36.31	69.80	51.00	16.71	9.32	150.00	96.62
100% RDN	65.46	71.10	84.50	70.51	39.18	19.50	189.14	161.11
75% RDN + 25% through FYM	71.58	80.01	92.00	72.90	43.18	20.32	206.78	173.23
50% RDN + 50% through FYM	54.65	65.02	77.28	67.10	35.35	16.20	170.40	148.31
SEm ±	**5.056**	**3.898**	**5.806**	**2.695**	**2.264**	**1.175**	**7.724**	**7.096**
CD (P=0.05)	**15.335**	**11.825**	**17.611**	**8.174**	**6.866**	**3.564**	**23.426**	**21.523**

DAS = Days after sowing; RDN = Recommended dose of nitrogen; FYM = Farm Yard Manure

Table 4.5. Effect of cropping system and fertility level on dry matter partitioning (g/plant) of cotton at 120 DAS

Treatment	Leaves		Stem		Reproductive parts		Total	
	2006	2007	2006	2007	2006	2007	2006	2007
Cropping system								
Sole cotton	75.21	91.00	133.20	117.90	135.00	194.55	345.78	403.51
Cotton + Groundnut (1:3)	81.20	100.80	141.23	124.48	152.90	212.97	397.22	438.19
SEm ±	**2.396**	**6.657**	**12.200**	**3.635**	**8.211**	**12.747**	**17.013**	**21.541**
CD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Fertility level								
Control	52.60	62.65	95.30	70.00	73.00	121.55	263.00	254.19
100% RDN	88.51	107.17	152.59	135.52	169.69	229.90	410.79	470.59
75% RDN + 25% through FYM	95.41	112.22	169.11	143.90	180.18	242.90	444.70	499.02
50% RDN + 50% through FYM	76.30	93.48	132.88	134.98	153.12	221.60	362.30	436.78
SEm ±	**3.389**	**9.414**	**17.254**	**5.139**	**11.612**	**18.027**	**24.060**	**30.464**
CD (P=0.05)	**10.278**	**28.553**	**52.332**	**15.589**	**35.219**	**54.677**	**72.975**	**92.398**

DAS = Days after sowing; RDN = Recommended dose of nitrogen; FYM = Farm Yard Manure

Table 4.6. Effect of cropping system and fertility level on dry matter partitioning (g/plant) of cotton at 150 DAS

Treatment	Leaves		Stem		Reproductive parts		Total	
	2006	2007	2006	2007	2006	2007	2006	2007
Cropping system								
Sole cotton	81.00	82.78	308.00	121.07	213.86	184.00	602.86	387.90
Cotton + Groundnut (1:3)	95.80	101.42	335.19	124.65	253.90	207.75	984.90	423.52
SEm ±	**4.999**	**5.964**	**9.181**	**5.942**	**16.322**	**8.072**	**24.590**	**12.505**
CD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Fertility level								
Control	57.00	59.82	264.00	73.65	157.31	132.00	478.30	260.00
100% RDN	101.00	106.08	341.00	130.40	256.28	224.50	698.28	480.98
75% RDN + 25% through FYM	106.01	112.12	357.48	142.65	284.02	236.50	747.51	501.27
50% RDN + 50% through FYM	84.49	90.28	324.01	143.75	237.91	200.50	651.41	440.53
SEm ±	**7.070**	**8.435**	**12.984**	**8.404**	**23.083**	**11.418**	**34.776**	**17.684**
CD (P=0.05)	**21.444**	**25.583**	**39.379**	**25.489**	**70.021**	**34.621**	**105.477**	**53.637**

DAS = Days after sowing; RDN = Recommended dose of nitrogen; FYM = Farm Yard Manure

Table 4.7. Effect of cropping system and fertility level on root dry weight, number of main stem nodes, unopened bolls and total dry matter accumulation per ha of cotton at 150 DAS

Treatment	Root dry weight (g/plant)		Number of main stem nodes/plant		Unopened bolls/plant		Total dry matter accumulation (t/ha)	
	2006	2007	2006	2007	2006	2007	2006	2007
Cropping system								
Sole cotton	22.12	23.25	21.62	18.72	24.03	8.21	8.78	5.39
Cotton + Groundnut (1:3)	25.88	24.69	22.88	20.51	20.67	7.22	9.79	5.88
SEm ±	**1.495**	**0.872**	**0.563**	**0.806**	**2.569**	**0.708**	**0.347**	**0.192**
CD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Fertility level								
Control	17.50	16.79	20.00	16.82	41.81	11.50	6.89	3.40
100% RDN	24.75	25.44	22.50	19.68	17.40	6.02	10.37	5.84
75% RDN + 25% through FYM	30.00	30.15	24.25	23.00	11.00	4.50	10.69	6.55
50% RDN + 50% through FYM	23.75	23.47	22.50	18.81	19.22	9.00	9.18	5.76
SEm ±	**2.114**	**1.233**	**0.796**	**1.139**	**3.634**	**1.001**	**0.491**	**0.272**
CD (P=0.05)	**6.412**	**3.739**	**2.41**	**3.456**	**11.021**	**3.037**	**1.490**	**0.827**

DAS = Days after sowing; RDN = Recommended dose of nitrogen; FYM = Farm Yard Manure

Table 4.8. Effect of cropping system and fertility level on yield attributing characters, seed cotton and stalk yield of cotton

Treatment	Opened bolls/plant		Boll weight (g/boll)		Seed cotton yield (t/ha)		Stalk yield (t/ha)	
	2006	2007	2006	2007	2006	2007	2006	2007
Cropping system								
Sole cotton	49.62	33.71	4.33	3.59	2.94	2.24	5.39	4.04
Cotton + Groundnut (1:3)	54.12	36.22	4.62	3.76	3.15	2.53	5.68	4.21
SEm ±	**1.558**	**1.667**	**0.105**	**0.102**	**0.077**	**0.102**	**0.149**	**0.118**
CD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Fertility level								
Control	39.25	23.33	3.92	3.32	2.16	1.52	4.95	3.31
100% RDN	55.25	39.67	4.57	3.75	3.33	2.77	5.72	4.56
75% RDN + 25% through FYM	60.50	40.80	4.95	4.12	3.61	3.05	6.00	4.78
50% RDN + 50% through FYM	52.50	35.87	4.50	3.52	3.06	2.19	5.48	3.86
SEm ±	**2.203**	**1.650**	**0.148**	**0.145**	**0.111**	**0.144**	**0.211**	**0.167**
CD (P=0.05)	**6.683**	**5.004**	**0.450**	**0.439**	**0.331**	**0.436**	**0.641**	**0.505**

RDN = Recommended dose of nitrogen; FYM = Farm Yard Manure

Table 4.9. Effect of cropping system and fertility level on quality parameters of cotton

Treatment	Ginning percentage		Seed index (g)		Lint index		Bartlett's index	
	2006	2007	2006	2007	2006	2007	2006	2007
Cropping system								
Sole cotton	37.01	36.96	8.28	8.21	4.88	4.83	0.8381	0.9027
Cotton + Groundnut (1:3)	37.44	37.37	8.32	8.27	5.00	4.95	0.8385	0.8992
SEm ±	**0.469**	**0.564**	**0.017**	**0.042**	**0.103**	**0.120**	**0.01196**	**0.00491**
CD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Fertility level								
Control	35.89	35.66	8.08	7.93	4.53	4.40	0.9026	0.9167
100% RDN	37.60	37.31	8.41	8.39	5.08	5.00	0.8032	0.8963
75% RDN + 25% through FYM	39.04	39.18	8.50	8.46	5.45	5.46	0.8385	0.8827
50% RDN + 50% through FYM	36.36	36.49	8.21	8.17	4.69	4.69	0.8088	0.9080
SEm ±	**0.663**	**0.797**	**0.024**	**0.059**	**0.146**	**0.170**	**0.01691**	**0.00692**
CD (P=0.05)	**2.010**	**2.417**	**0.073**	**0.182**	**0.444**	**0.516**	**0.05128**	**0.02106**

RDN = Recommended dose of nitrogen; FYM = Farm Yard Manure

Table 4.10. Effect of cropping system and fertility level on quality parameters of cotton

Treatment	2.5% span length (mm)		50% span length (mm)		Uniformity ratio (%)	
	2006	2007	2006	2007	2006	2007
Cropping system						
Sole cotton	26.38	26.36	14.03	14.00	53.1	53.1
Cotton + Groundnut (1:3)	26.83	26.79	14.14	14.09	52.7	52.6
SEm ±	**0.304**	**0.312**	**0.146**	**0.163**	**0.63**	**0.61**
CD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Fertility level						
Control	25.81	25.77	13.64	13.59	52.9	52.8
100% RDN	26.86	26.84	14.32	14.29	53.0	53.3
75% RDN + 25% through FYM	27.17	27.16	14.39	14.36	52.9	52.9
50% RDN + 50% through FYM	26.57	26.54	13.98	13.95	52.6	52.5
SEm ±	**0.429**	**0.441**	**0.206**	**0.231**	**0.88**	**0.86**
CD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

RDN = Recommended dose of nitrogen; FYM = Farm Yard Manure

Table 4.11. Effect of cropping system and fertility level on quality parameters of cotton

Treatment	Fibre strength (g/tex)		Fibre elongation (%)		Micronaire	
	2006	2007	2006	2007	2006	2007
Cropping system						
Sole cotton	21.6	21.3	6.07	5.98	4.79	4.72
Cotton + Groundnut (1:3)	21.8	21.6	6.07	6.02	4.92	4.84
SEm ±	**0.20**	**0.20**	**0.044**	**0.071**	**0.093**	**0.067**
CD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Fertility level						
Control	21.2	21.0	6.00	5.95	4.56	4.50
100% RDN	21.7	21.5	6.11	6.03	4.95	4.84
75% RDN + 25% through FYM	22.3	22.2	6.20	6.05	5.14	5.03
50% RDN + 50% through FYM	21.6	21.3	6.01	5.97	4.77	4.74
SEm ±	**0.29**	**0.29**	**0.062**	**0.099**	**0.131**	**0.095**
CD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**0.398**	**0.288**

RDN = Recommended dose of nitrogen; FYM = Farm Yard Manure

Table 4.12. Effect of cropping system and fertility level on nitrogen content (%) in leaves, stem, seed and fibre of cotton

Treatment	Leaves		Stem		Seed		Fibre	
	2006	2007	2006	2007	2006	2007	2006	2007
Cropping system								
Sole cotton	4.14	3.61	1.09	1.04	3.44	3.34	0.54	0.47
Cotton + Groundnut (1:3)	4.31	3.81	1.20	1.15	3.57	3.40	0.56	0.50
SEm ±	**0.254**	**0.102**	**0.059**	**0.049**	**0.074**	**0.052**	**0.012**	**0.011**
CD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Fertility level								
Control	2.04	1.92	0.97	0.94	3.35	3.27	0.32	0.29
100% RDN	5.32	4.29	1.22	1.19	3.47	3.41	0.67	0.59
75% RDN + 25% through FYM	5.64	4.83	1.28	1.20	3.80	3.50	0.70	0.60
50% RDN + 50% through FYM	3.89	3.82	1.12	1.04	3.41	3.30	0.51	0.45
SEm ±	**0.359**	**0.145**	**0.084**	**0.069**	**0.105**	**0.073**	**0.017**	**0.015**
CD (P=0.05)	**1.092**	**0.439**	**0.256**	**0.211**	**0.319**	**0.223**	**0.050**	**0.045**

RDN = Recommended dose of nitrogen; FYM = Farm Yard Manure

Table 4.13. Effect of cropping system and fertility level on chlorophyll content (mg/g fw) of cotton

Treatment	60 DAS		90 DAS		120 DAS		150 DAS	
	2006	2007	2006	2007	2006	2007	2006	2007
Cropping system								
Sole cotton	3.83	3.79	3.72	3.66	3.40	3.35	2.87	2.81
Cotton + Groundnut (1:3)	3.93	3.90	3.79	3.76	3.53	3.50	3.09	3.00
SEm ±	**0.056**	**0.064**	**0.031**	**0.036**	**0.045**	**0.118**	**0.081**	**0.067**
CD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Fertility level								
Control	3.62	3.59	3.42	3.38	2.97	2.93	2.46	2.35
100% RDN	3.98	3.93	3.80	3.76	3.73	3.69	3.20	3.14
75% RDN + 25% through FYM	4.08	4.03	4.06	4.00	3.90	3.82	3.33	3.27
50% RDN + 50% through FYM	3.83	3.82	3.73	3.69	3.28	3.25	2.93	2.86
SEm ±	**0.079**	**0.091**	**0.044**	**0.050**	**0.064**	**0.167**	**0.115**	**0.067**
CD (P=0.05)	**0.242**	**0.275**	**0.135**	**0.153**	**0.194**	**0.508**	**0.348**	**0.286**

DAS = Days after sowing; RDN = Recommended dose of nitrogen; FYM = Farm Yard Manure, FW= fresh weight

Table 4.14. Effect of cropping system and fertility level on phosphorus content (%) in leaves, stem, seed and fibre of cotton

Treatment	Leaves		Stem		Seed		Fibre	
	2006	2007	2006	2007	2006	2007	2006	2007
Cropping system								
Sole cotton	0.26	0.24	0.11	0.13	0.37	0.36	0.38	0.35
Cotton + Groundnut (1:3)	0.31	0.27	0.13	0.14	0.38	0.36	0.40	0.37
SEm ±	**0.019**	**0.013**	**0.006**	**0.005**	**0.003**	**0.002**	**0.009**	**0.008**
CD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Fertility level								
Control	0.15	0.12	0.11	0.12	0.35	0.35	0.31	0.27
100% RDN	0.33	0.32	0.13	0.14	0.37	0.36	0.42	0.39
75% RDN + 25% through FYM	0.35	0.35	0.14	0.15	0.38	0.37	0.44	0.41
50% RDN + 50% through FYM	0.32	0.23	0.13	0.13	0.36	0.35	0.40	0.36
SEm ±	**0.028**	**0.018**	**0.008**	**0.007**	**0.004**	**0.003**	**0.014**	**0.012**
CD (P=0.05)	**0.084**	**0.056**	**0.024**	**0.020**	**0.012**	**0.009**	**0.042**	**0.036**

RDN = Recommended dose of nitrogen; FYM = Farm Yard Manure

Table 4.15. Effect of cropping system and fertility level on potassium content (%) in leaves, stem, seed and fibre of cotton

Treatment	Leaves		Stem		Seed		Fibre	
	2006	2007	2006	2007	2006	2007	2006	2007
Cropping system								
Sole cotton	0.90	0.82	1.59	1.37	1.25	1.19	0.37	0.36
Cotton + Groundnut (1:3)	1.03	0.92	1.71	1.46	1.29	1.22	0.38	0.37
SEm ±	**0.130**	**0.039**	**0.093**	**0.047**	**0.027**	**0.02**	**0.007**	**0.006**
CD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Fertility level								
Control	0.61	0.67	1.30	1.17	1.15	1.05	0.33	0.32
100% RDN	1.08	0.94	1.73	1.53	1.30	1.28	0.39	0.39
75% RDN + 25% through FYM	1.25	1.05	1.88	1.58	1.33	1.30	0.41	0.41
50% RDN + 50% through FYM	0.91	0.81	1.69	1.36	1.29	1.21	0.37	0.37
SEm ±	**0.184**	**0.055**	**0.132**	**0.066**	**0.038**	**0.026**	**0.009**	**0.008**
CD (P=0.05)	**0.552**	**0.168**	**0.400**	**0.201**	**0.116**	**0.077**	**0.028**	**0.025**

RDN = Recommended dose of nitrogen; FYM = Farm Yard Manure

Table 4.16. Effect of cropping system and fertility level on nitrogen uptake (kg/ha) in leaves, stem, seed and fibre of cotton

Treatment	Leaves		Stem		Seed		Fibre		Total	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
Cropping system										
Sole cotton	52.64	45.58	47.92	43.02	60.53	44.87	6.22	4.05	162.32	137.52
Cotton + Groundnut (1:3)	60.89	58.51	56.68	49.04	70.84	52.16	7.04	4.86	200.46	164.57
SEm ±	**7.142**	**4.503**	**3.918**	**2.749**	**3.433**	**2.409**	**1.028**	**0.309**	**12.752**	**10.678**
CD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Fertility level										
Control	16.52	14.36	35.79	31.13	39.40	32.06	2.51	1.61	94.22	79.16
100% RDN	77.67	73.33	57.49	49.47	74.45	54.89	8.91	5.61	218.52	183.30
75% RDN + 25% through FYM	82.30	84.94	65.96	63.29	80.15	60.02	9.26	7.00	237.67	215.25
50% RDN + 50% through FYM	50.58	35.56	49.79	40.22	68.74	46.10	5.85	3.61	174.43	125.49
SEm ±	**10.099**	**6.368**	**5.541**	**3.887**	**4.855**	**3.408**	**1.453**	**0.437**	**18.034**	**15.101**
CD (P=0.05)	**30.633**	**19.315**	**16.805**	**11.790**	**14.725**	**10.336**	**4.408**	**1.326**	**54.698**	**45.801**

RDN = Recommended dose of nitrogen; FYM = Farm Yard Manure

Table 4.17. Effect of cropping system and fertility level on phosphorus uptake (kg/ha) in leaves, stem, seed and fibre of cotton

Treatment	Leaves		Stem		Seed		Fibre		Total	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
Cropping system										
Sole cotton	3.26	3.01	5.41	2.14	6.83	4.79	4.26	2.87	19.76	12.82
Cotton + Groundnut (1:3)	4.41	4.29	6.14	2.37	7.42	5.53	4.48	3.47	22.85	15.67
SEm ±	**0.392**	**0.434**	**0.462**	**0.095**	**0.299**	**0.282**	**0.205**	**0.219**	**1.283**	**1.021**
CD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Fertility level										
Control	1.23	1.25	4.02	1.17	4.96	3.41	2.37	1.51	12.59	7.34
100% RDN	4.92	4.96	6.78	2.63	7.54	5.36	5.10	3.45	24.34	16.40
75% RDN + 25% through FYM	6.20	5.44	7.00	2.97	8.43	6.88	6.20	4.84	27.83	20.13
50% RDN + 50% through FYM	2.98	2.97	5.29	2.25	7.57	4.99	4.60	2.89	21.89	13.11
SEm ±	**0.555**	**0.614**	**0.654**	**0.135**	**0.423**	**0.399**	**0.290**	**0.311**	**1.185**	**1.444**
CD (P=0.05)	**1.683**	**1.861**	**1.984**	**0.408**	**1.284**	**1.209**	**0.880**	**0.943**	**5.505**	**4.381**

RDN = Recommended dose of nitrogen; FYM = Farm Yard Manure

Table 4.18. Effect of cropping system and fertility level on potassium uptake (kg/ha) in leaves, stem, seed and fibre of cotton

Treatment	Leaves		Stem		Seed		Fibre		Total	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
Cropping system										
Sole cotton	10.57	9.71	69.34	23.68	23.30	16.29	4.10	2.99	107.23	52.67
Cotton + Groundnut (1:3)	14.36	13.48	80.56	25.83	25.57	18.94	4.60	3.55	125.08	61.81
SEm ±	**1.596**	**1.303**	**3.886**	**1.133**	**0.792**	**1.209**	**0.417**	**0.386**	**6.122**	**3.374**
CD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Fertility level										
Control	5.57	5.55	51.32	12.01	16.06	10.33	2.58	1.78	75.62	29.68
100% RDN	15.44	14.55	82.12	30.28	26.23	20.54	4.75	3.46	128.54	68.83
75% RDN + 25% through FYM	17.13	16.05	90.68	32.13	29.52	22.72	5.81	4.89	143.14	75.79
50% RDN + 50% through FYM	11.64	10.23	75.67	24.59	25.94	16.87	4.24	2.95	117.47	54.65
SEm ±	**2.257**	**1.843**	**5.496**	**1.602**	**1.120**	**1.711**	**0.590**	**0.546**	**8.658**	**4.771**
CD (P=0.05)	**6.846**	**5.591**	**16.671**	**4.858**	**3.397**	**5.189**	**1.789**	**1.655**	**26.261**	**14.472**

RDN = Recommended dose of nitrogen; FYM = Farm Yard Manure

Table 4.19. Effect of cropping system and fertility level on soil fertility status after harvest of cotton and groundnut

Treatment	Organic carbon (%)		Available P (kg/ha)		Available K (kg/ha)	
	2006	2007	2006	2007	2006	2007
Cropping system						
Sole cotton	0.464	0.442	14.06	16.76	269.20	262.21
Sole groundnut	0.483	0.450	11.03	13.61	261.85	254.88
Cotton + Groundnut (1:3)	0.485	0.467	12.19	13.08	259.80	251.91
SEm ±	**0.0532**	**0.0156**	**0.654**	**0.474**	**0.791**	**1.877**
CD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Sole Groundnut vs. Rest						
SEd ±	**0.0251**	**0.0331**	**1.388**	**1.006**	**1.678**	**3.983**
CD (P=0.05)	**NS**	**NS**	**2.942**	**2.132**	**3.557**	**8.444**
Fertility level						
Control	0.342	0.355	11.43	12.87	260.40	253.22
100% RDN	0.440	0.440	8.20	10.84	255.10	245.38
75% RDN + 25% through FYM	0.505	0.468	11.80	13.86	261.25	256.10
50% RDN + 50% through FYM	0.612	0.556	13.00	15.81	266.50	259.10
SEm ±	**0.0355**	**0.0221**	**0.925**	**0.670**	**1.118**	**2.655**
CD (P=0.05)	**0.1064**	**0.0662**	**2.773**	**2.009**	**2.371**	**7.959**

RDN = Recommended dose of nitrogen; FYM = Farm Yard Manure

Table 4.20. Effect of cropping system and fertility level on available nitrogen status of soil of cotton and groundnut

Treatment	Available nitrogen status of soil (kg/ha)							
	60 DAS		90 DAS		120 DAS		150 DAS	
	2006	2007	2006	2007	2006	2007	2006	2007
Cropping system								
Sole cotton	288.11	258.56	348.87	249.66	317.53	287.44	279.02	219.69
Sole groundnut	308.43	211.52	356.47	263.32	337.02	310.82	322.49	281.78
Cotton + Groundnut (1:3)	312.41	285.38	432.77	315.72	390.34	333.55	386.20	295.14
SEm ±	**8.272**	**13.531**	**4.352**	**6.948**	**7.236**	**8.135**	**11.722**	**10.269**
CD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**35.288**	**30.783**
Sole Groundnut vs. Rest								
SEd ±	**15.155**	**28.704**	**9.233**	**8.505**	**15.351**	**12.256**	**24.972**	**15.784**
CD (P=0.05)	**NS**	**NS**	**19.574**	**18.031**	**32.544**	**25.983**	**52.940**	**33.462**
Fertility level								
Control	251.51	161.50	314.21	188.91	251.96	142.17	232.35	135.20
100% RDN	296.90	272.69	361.21	268.48	349.60	282.32	292.03	245.93
75% RDN + 25% through FYM	320.53	317.74	362.96	276.32	353.09	285.32	329.60	284.77
50% RDN + 50% through FYM	332.10	335.93	372.28	397.06	354.44	419.36	349.03	337.06
SEm ±	**11.699**	**19.136**	**6.155**	**9.826**	**10.234**	**11.505**	**16.648**	**14.523**
CD (P=0.05)	**35.071**	**57.363**	**18.452**	**29.455**	**30.678**	**34.386**	**49.905**	**43.524**

DAS = Days after sowing; RDN = Recommended dose of nitrogen; FYM = Farm Yard Manure

Table 4.21. Effect of cropping system and fertility level on dehydrogenase activity of soils of cotton and groundnut

Treatment	Dehydrogenase activity of soil (mg TPF/ gm soil/day)							
	60 DAS		90 DAS		120 DAS		150 DAS	
	2006	2007	2006	2007	2006	2007	2006	2007
Cropping system								
Sole cotton	215.45	213.04	117.48	107.36	64.47	35.66	142.53	132.47
Sole groundnut	207.37	168.03	102.84	86.02	57.06	42.57	116.16	94.63
Cotton + Groundnut (1:3)	236.00	219.13	130.22	116.87	74.48	44.19	163.25	162.12
SEm ±	**2.447**	**2.465**	**3.084**	**2.195**	**1.972**	**0.459**	**1.455**	**3.126**
CD (P=0.05)	**7.426**	**7.390**	**9.244**	**6.579**	**5.911**	**1.376**	**4.362**	**9.371**
Sole Groundnut vs. Rest								
SEd ±	**5.225**	**5.229**	**6.542**	**4.656**	**4.183**	**0.974**	**3.087**	**6.631**
CD (P=0.05)	**11.141**	**11.087**	**13.869**	**9.871**	**8.867**	**2.064**	**6.544**	**14.059**
Fertility level								
Control	157.68	138.77	59.34	69.91	17.15	18.71	96.38	70.76
100% RDN	211.71	201.21	107.11	106.16	45.07	30.99	113.60	126.32
75% RDN + 25% through FYM	292.30	263.30	148.33	134.15	91.10	48.06	166.98	152.14
50% RDN + 50% through FYM	241.21	261.05	180.62	138.26	124.57	61.94	234.60	239.96
SEm ±	**3.503**	**3.486**	**4.361**	**3.104**	**2.788**	**0.649**	**2.058**	**4.421**
CD (P=0.05)	**10.502**	**10.451**	**13.074**	**9.304**	**8.359**	**1.946**	**6.169**	**13.253**

DAS = Days after sowing; RDN = Recommended dose of nitrogen; FYM = Farm Yard Manure, TPF= Triphenyl Formazon

Table 4.22. Interaction effect of cropping system and fertility level on dehydrogenase activity of soil (mg TPF/ gm soil/day) of cotton at 150 DAS

Fertility level	Cropping system			
	Sole cotton		Cotton + Groundnut (1:3)	
	2006	2007	2006	2007
Control	95.40	77.44	97.37	84.07
100% RDN	107.54	99.67	113.60	132.98
75% RDN + 25% through FYM	152.93	148.23	166.98	152.14
50% RDF + 50% through FYM	214.26	204.54	234.60	239.96
SEm ±	**2.910**	**6.252**		
CD (P=0.05)	**8.724**	**18.742**		

DAS = Days after sowing; RDN = Recommended dose of nitrogen; FYM = Farm Yard Manure, TPF= Triphenyl Formazon

Table 4.23. Effect of cropping system and fertility level on cotton equivalent yield (t/ha)

Treatment	2006	2007
Cropping system		
Sole cotton	2.94	2.24
Cotton + Groundnut (1:3)	3.51	2.88
SEm ±	**0.076**	**0.041**
CD (P=0.05)	**0.231**	**0.124**
Fertility level		
Control	2.35	1.96
100% RDN	3.69	3.07
75% RDN + 25% through FYM	3.82	3.35
50% RDN + 50% through FYM	3.34	2.55
SEm ±	**0.107**	**0.058**
CD (P=0.05)	**0.326**	**0.175**

DAS = Days after sowing; RDN = Recommended dose of nitrogen; FYM = Farm Yard Manure

Cotton prices for 2006 = Rs 1990/q; 2007 = Rs 2030/q
Groundnut prices for 2006 = Rs 1520/q; 2007 = Rs 1550/q

Table 4.24. Effect of cropping system and fertility level on plant height (cm) of groundnut

Treatment	40 DAS		80 DAS		At harvest	
	2006	2007	2006	2007	2006	2007
Sole groundnut	15.5	19.7	37.7	41.8	51.07	55.2
Intercropping (Cotton + Groundnut 1:3)						
Control	11.7	9.6	42.7	37.7	59.7	57.7
100% RDN	16.2	12.3	47.0	47.0	68.0	69.4
75% RDN + 25% through FYM	15.3	12.0	49.0	49.0	72.2	72.8
50% RDN + 50% through FYM	13.5	11.7	45.0	42.7	61.5	63.2
Mean	**14.2**	**11.4**	**45.9**	**44.1**	**65.3**	**65.8**
Sole Groundnut vs. Rest						
SEd ±	**0.51**	**0.36**	**1.19**	**0.96**	**2.56**	**1.89**
CD (P=0.05)	**1.18**	**0.83**	**2.76**	**2.20**	**5.89**	**4.37**
Fertility level						
SEm ±	**0.46**	**0.32**	**1.07**	**0.85**	**2.29**	**1.69**
CD (P=0.05)	**1.49**	**1.04**	**3.50**	**2.78**	**7.45**	**5.53**

DAS = Days after sowing; RDN = Recommended dose of nitrogen; FYM = Farm Yard Manure

Table 4.25. Effect of cropping system and fertility level on number of branch plant^{-1} of groundnut

Treatment	40 DAS		80 DAS		At harvest	
	2006	2007	2006	2007	2006	2007
Sole groundnut	5.5	4.7	16.0	17.3	29.7	33.1
Intercropping (Cotton + Groundnut 1:3)						
Control	3.3	3.5	13.0	14.0	25.7	25.6
100% RDN	4.2	3.5	12.7	10.9	23.3	21.3
75% RDN + 25% through FYM	5.1	4.2	12.0	10.5	22.7	20.6
50% RDN + 50% through FYM	4.2	3.7	12.7	11.7	23.3	22.3
Mean	**4.2**	**3.7**	**12.6**	**11.8**	**23.7**	**22.5**
Sole Groundnut vs. Rest						
SEd ±	**0.57**	**0.22**	**1.44**	**1.93**	**2.21**	**1.52**
CD (P=0.05)	**1.32**	**0.50**	**3.31**	**4.41**	**5.10**	**3.50**
Fertility level						
SEm ±	**0.51**	**0.19**	**1.28**	**1.72**	**1.98**	**1.36**
CD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

DAS = Days after sowing; RDN = Recommended dose of nitrogen; FYM = Farm Yard Manure

Table 4.26. Effect of cropping system and fertility level on leaf area index of groundnut

Treatment	40 DAS		80 DAS		At harvest	
	2006	2007	2006	2007	2006	2007
Sole groundnut	1.60	1.63	3.34	3.62	3.06	3.33
Intercropping (Cotton + Groundnut 1:3)						
Control	1.35	1.44	3.08	3.12	2.34	2.29
100% RDN	1.53	1.57	3.03	2.88	2.26	2.17
75% RDN + 25% through FYM	1.57	1.63	2.79	2.79	2.04	2.13
50% RDN + 50% through FYM	1.48	1.46	3.06	3.06	2.29	2.19
Mean	**1.48**	**1.52**	**2.99**	**2.96**	**2.23**	**2.19**
Sole Groundnut vs. Rest						
SEd ±	**0.019**	**0.312**	**0.047**	**0.051**	**0.043**	**0.036**
CD (P=0.05)	**0.045**	**0.719**	**0.108**	**0.118**	**0.099**	**0.084**
Fertility level						
SEm ±	**0.018**	**0.029**	**0.042**	**0.046**	**0.038**	**0.033**
CD (P=0.05)	**0.057**	**0.909**	**0.137**	**0.149**	**0.099**	**0.107**

DAS = Days after sowing; RDN = Recommended dose of nitrogen; FYM = Farm Yard Manure

Table 4.27. Effect of cropping system and fertility level on dry matter accumulation (g $plant^{-1}$) of groundnut

Treatment	40 DAS		80 DAS		At harvest	
	2006	2007	2006	2007	2006	2007
Sole groundnut	11.3	14.7	49.8	60.3	143.0	156.2
Intercropping (Cotton + Groundnut 1:3)						
Control	7.4	10.7	43.0	45.3	89.0	87.0
100% RDN	9.2	12.4	32.6	35.4	62.0	63.8
75% RDN + 25% through FYM	9.4	12.6	25.0	32.6	45.1	58.1
50% RDN + 50% through FYM	8.3	11.0	36.1	37.7	73.8	76.4
Mean	**8.6**	**11.7**	**34.2**	**37.8**	**67.5**	**71.3**
Sole Groundnut vs. Rest						
SEd ±	**0.43**	**0.63**	**3.18**	**2.61**	**4.25**	**4.43**
CD (P=0.05)	**0.99**	**1.45**	**7.34**	**6.01**	**9.79**	**10.22**
Fertility level						
SEm ±	**0.38**	**0.56**	**2.84**	**2.33**	**3.80**	**3.96**
CD (P=0.05)	**1.25**	**1.83**	**9.28**	**7.60**	**12.39**	**12.93**

DAS = Days after sowing; RDN = Recommended dose of nitrogen; FYM = Farm Yard Manure

Table 4.28. Effect of cropping system and fertility level on yield attributes of groundnut

Treatment	Pods plant^{-1}		Kernels pod^{-1}		1000-kernel weight (g)	
	2006	2007	2006	2007	2006	2007
Sole groundnut	90.7	92.2	1.58	1.79	270.0	286.3
Intercropping (Cotton + Groundnut 1:3)						
Control	35.7	36.0	1.52	1.60	260.9	260.9
100% RDN	30.0	23.4	1.47	1.46	256.8	252.2
75% RDN + 25% through FYM	28.0	21.7	1.40	1.42	248.2	248.2
50% RDN + 50% through FYM	31.3	31.7	1.50	1.54	257.7	253.4
Mean	**31.2**	**28.2**	**1.47**	**1.50**	**255.90**	**253.7**
Sole Groundnut vs. Rest						
SEd ±	**1.53**	**2.652**	**0.019**	**0.215**	**4.06**	**6.53**
CD (P=0.05)	**3.53**	**6.115**	**0.046**	**0.049**	**9.37**	**15.06**
Fertility level						
SEm ±	**1.37**	**2.372**	**0.018**	**0.019**	**3.63**	**5.84**
CD (P=0.05)	**4.47**	**7.734**	**0.058**	**0.063**	**NS**	**NS**

RDN = Recommended dose of nitrogen; FYM = Farm Yard Manure

Table 4.29. Effect of cropping system and fertility level on yields and shelling per cent of groundnut

Treatment	Pods yield ($t\ ha^{-1}$)		Haulm yield ($t\ ha^{-1}$)		Biological yield ($t\ ha^{-1}$)		Shelling per cent	
	2006	2007	2006	2007	2006	2007	2006	2007
Sole groundnut	1.05	1.08	2.96	3.54	4.01	4.63	65.30	63.28
Intercropping (Cotton + Groundnut 1:3)								
Control	0.54	0.58	2.06	2.18	2.60	2.75	56.40	54.30
100% RDN	0.47	0.40	1.83	1.52	2.30	1.92	51.70	50.17
75% RDN + 25% through FYM	0.43	0.39	1.62	1.47	2.05	1.86	48.91	48.82
50% RDN + 50% through FYM	0.50	0.47	1.98	1.86	2.48	2.33	54.30	52.21
Mean	**0.49**	**0.46**	**1.872**	**1.76**	**2.36**	**2.22**	**52.83**	**51.37**
Sole Groundnut vs. Rest								
SEd ±	**0.025**	**0.041**	**0.094**	**0.107**	**0.124**	**0.119**	**1.836**	**1.443**
CD (P=0.05)	**0.057**	**0.094**	**0.217**	**0.247**	**0.286**	**0.267**	**4.234**	**3.327**
Fertility level								
SEm ±	**0.022**	**0.036**	**0.084**	**0.096**	**0.111**	**0.104**	**1.642**	**1.290**
CD (P=0.05)	**0.073**	**0.118**	**0.275**	**0.313**	**0.361**	**0.338**	**NS**	**NS**

RDN = Recommended dose of nitrogen; FYM = Farm Yard Manure

Table 4.30. Effect of cropping system and fertility level on nitrogen, phosphorus and potassium contents in groundnut

Treatment	N (%) in kernel		N(%) in haulm		P(%) in kernel		P (%) in haulm		K (%) in kernel		K (%) in haulm	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
Sole groundnut	4.52	4.24	2.58	2.65	0.58	0.66	0.15	0.19	1.12	1.23	2.11	2.17
Intercropping (Cotton + Groundnut 1:3)												
Control	3.90	3.67	1.90	1.86	0.42	0.52	0.10	0.13	0.69	0.75	1.40	1.43
100% RDN	4.20	3.97	2.13	2.07	0.49	0.58	0.11	0.16	0.75	0.79	1.70	1.76
75% RDN + 25% through FYM	4.25	4.08	2.16	2.16	0.50	0.62	0.12	0.17	0.88	0.91	1.91	1.91
50% RDN + 50% through FYM	4.08	3.92	2.07	1.92	0.49	0.56	0.11	0.15	0.71	0.75	1.55	1.59
Mean	**4.11**	**3.91**	**2.06**	**2.00**	**0.47**	**0.57**	**0.11**	**0.15**	**0.76**	**0.80**	**1.64**	**1.67**
Sole Groundnut vs. Rest												
SEd ±	**0.084**	**0.078**	**0.053**	**0.037**	**0.017**	**0.021**	**0.004**	**0.009**	**0.040**	**0.038**	**0.105**	**0.035**
CD (P=0.05)	**0.193**	**0.179**	**0.123**	**0.084**	**0.039**	**0.049**	**0.009**	**0.019**	**0.093**	**0.088**	**0.242**	**0.081**
Fertility level												
SEm ±	**0.075**	**0.069**	**0.048**	**0.032**	**0.015**	**0.019**	**0.004**	**0.008**	**0.036**	**0.034**	**0.094**	**0.031**
CD (P=0.05)	**0.244**	**0.227**	**0.155**	**0.107**	**0.050**	**0.062**	**0.012**	**0.025**	**0.117**	**0.112**	**0.306**	**0.101**

RDN = Recommended dose of nitrogen; FYM = Farm Yard Manure

Table 4.31. Effect of cropping system and fertility level on nitrogen uptake (kg/ha) of groundnut

Treatment	Kernel		Haulm		Total	
	2006	2007	2006	2007	2006	2007
Sole groundnut	30.95	28.96	76.88	93.93	107.83	122.89
Intercropping (Cotton + Groundnut 1:3)						
Control	13.13	11.47	44.27	40.37	57.40	51.84
100% RDN	9.92	8.00	37.99	29.88	47.91	39.54
75% RDN + 25% through FYM	8.22	7.69	30.48	31.56	38.70	39.25
50% RDN + 50% through FYM	11.54	9.59	42.21	35.71	53.75	45.30
Mean	**10.70**	**9.19**	**38.74**	**34.38**	**49.44**	**43.98**
Sole Groundnut vs. Rest						
SEd ±	**0.892**	**0.755**	**2.593**	**2.271**	**3.409**	**2.443**
CD (P=0.05)	**2.056**	**1.741**	**5.979**	**5.236**	**7.861**	**5.634**
Fertility level						
SEm ±	**0.797**	**0.675**	**2.319**	**2.031**	**3.049**	**2.185**
CD (P=0.05)	**2.600**	**2.201**	**7.562**	**6.622**	**9.942**	**7.125**

RDN = Recommended dose of nitrogen; FYM = Farm Yard Manure

Table 4.32. Effect of cropping system and fertility level on phosphorus uptake (kg/ha) of groundnut

Treatment	Kernel		Haulm		Total	
	2006	2007	2006	2007	2006	2007
Sole groundnut	3.98	4.48	4.46	6.71	8.45	11.19
Intercropping (Cotton + Groundnut 1:3)						
Control	1.53	1.63	2.48	2.79	4.01	4.42
100% RDN	1.19	1.17	2.03	2.42	3.22	3.59
75% RDN + 25% through FYM	0.89	1.17	1.62	2.68	2.51	3.65
50% RDN + 50% through FYM	1.36	1.36	2.17	2.17	3.53	4.13
Mean	**1.24**	**1.33**	**2.07**	**2.66**	**3.32**	**3.95**
Sole Groundnut vs. Rest						
SEd ±	**0.136**	**0.104**	**0.193**	**0.090**	**0.334**	**0.218**
CD (P=0.05)	**0.313**	**0.240**	**0.446**	**0.207**	**0.769**	**0.503**
Fertility level						
SEm ±	**0.121**	**0.093**	**0.173**	**0.081**	**0.298**	**0.195**
CD (P=0.05)	**0.396**	**0.304**	**0.564**	**0.262**	**0.973**	**0.636**

RDN = Recommended dose of nitrogen; FYM = Farm Yard Manure

Table 4.33. Effect of cropping system and fertility level on potassium uptake (kg/ha) of groundnut

Treatment	Kernel		Haulm		Total	
	2006	2007	2006	2007	2006	2007
Sole groundnut	7.72	8.41	62.96	76.85	70.68	85.26
Intercropping (Cotton + Groundnut 1:3)						
Control	2.11	2.85	39.47	41.75	41.58	44.59
100% RDN	1.87	1.51	28.17	24.23	29.98	25.73
75% RDN + 25% through FYM	1.81	1.39	22.56	21.06	24.44	22.45
50% RDN + 50% through FYM	1.99	1.95	33.74	32.73	35.73	34.68
Mean	**1.94**	**1.92**	**30.98**	**29.94**	**32.93**	**31.86**
Sole Groundnut vs. Rest						
SEd ±	**0.060**	**0.238**	**3.036**	**2.225**	**3.907**	**2.278**
CD (P=0.05)	**0.139**	**0.549**	**7.024**	**5.132**	**9.009**	**5.254**
Fertility level						
SEm ±	**0.054**	**0.213**	**2.725**	**1.990**	**3.494**	**2.038**
CD (P=0.05)	**0.176**	**0.694**	**8.884**	**6.490**	**11.394**	**6.645**

RDN = Recommended dose of nitrogen; FYM = Farm Yard Manure

Table 4.34. Effect of cropping system and fertility level on protein content and yield of groundnut

Treatment	Protein content (%)		Protein yield (kg/ha)	
	2006	2007	2006	2007
Sole groundnut	28.25	26.50	193.46	165.85
Intercropping (Cotton + Groundnut 1:3)				
Control	26.56	24.81	81.69	71.66
100% RDN	25.50	24.12	61.97	49.97
75% RDN + 25% through FYM	24.37	22.93	51.39	48.03
50% RDN + 50% through FYM	26.25	24.50	72.12	59.92
Mean	**25.67**	**24.09**	**66.79**	**57.39**
Sole Groundnut vs. Rest				
SEd ±	**0.522**	**0.787**	**7.155**	**3.476**
CD (P=0.05)	**1.205**	**1.816**	**16.499**	**8.017**
Fertility level				
SEm ±	**0.467**	**0.404**	**6.399**	**3.109**
CD (P=0.05)	**1.523**	**1.212**	**20.867**	**10.139**

RDN = Recommended dose of nitrogen; FYM = Farm Yard Manure

Table 4.35. Assessment of intercropping indices for cotton + groundnut (1:3) cropping system

Treatment	Land equivalent ratio		Aggressivity				Relative crowding co-efficient				Product of K	
			Aab		Aba		Kab		Kba			
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
Control	1.73	1.70	+3.56	+3.93	-3.56	-3.93	-33.50	-21.39	+0.35	+0.38	-11.72	-8.13
100% RDN	1.47	1.47	+3.50	+3.92	-3.50	-3.92	-29.71	-5.84	+0.27	+0.19	-8.02	-5.65
75% RDN + 25% through FYM	1.47	1.48	+3.81	+3.98	-3.81	-3.98	-68.60	-28.41	+0.23	+0.19	-15.80	-5.40
50% RDN + 50% through FYM	1.59	1.59	+3.84	+4.07	-3.84	-4.07	-51.91	-21.45	+0.31	+0.25	-16.09	-5.36
Mean	**1.56**	**1.56**	**+3.68**	**+3.97**	**-3.68**	**-3.97**	**-46.00**	**-19.27**	**+0.29**	**+0.25**	**-13.34**	**-4.82**

RDN = Recommended dose of nitrogen; FYM = Farm Yard Manure

Table 4.36. Assessment of intercropping indices for cotton + groundnut (1:3) cropping system

Treatment	Competition index		Competition ratio				Relative net return		Area time equivalency ratio	
			CRa		CRb					
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
Control	-0.058	-0.175	6.19	6.46	0.16	0.15	1.26	1.48	1.42	1.52
100% RDN	-0.013	-0.065	6.94	9.00	0.14	0.11	1.14	1.22	1.31	1.35
75% RDN + 25% through FYM	-0.029	-0.075	8.00	9.31	0.12	0.11	1.18	1.22	1.36	1.36
50% RDN + 50% through FYM	-0.057	-0.092	6.86	8.02	0.15	0.12	1.23	1.34	1.39	1.45
Mean	**-0.048**	**-0.062**	**7.00**	**8.20**	**0.14**	**0.12**	**1.22**	**1.31**	**1.38**	**1.42**

RDN = Recommended dose of nitrogen; FYM = Farm Yard Manure

Table 4.37. Direct and residual effect of nitrogen on plant height (cm) of wheat

Treatment	45 DAS		90 DAS		At harvest	
	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08
Cropping system						
Sole cotton	30.3	32.2	65.2	69.5	78.3	80.4
Cotton + Groundnut (1:3)	31.8	34.0	70.4	71.1	79.8	81.6
SEm ±	**0.21**	**0.58**	**0.41**	**0.38**	**0.44**	**0.38**
CD (P=0.05)	**0.64**	**1.75**	**1.24**	**1.14**	**1.33**	**1.16**
Fertility level						
Control	29.9	30.7	66.4	67.6	77.0	77.7
100% RDN	31.1	33.4	66.8	68.6	77.4	79.6
75% RDN + 25% through FYM	31.2	34.2	68.9	71.9	79.5	81.1
50% RDN + 50% through FYM	32.0	34.2	69.2	73.1	82.1	85.3
SEm ±	**0.30**	**0.83**	**0.58**	**0.54**	**0.63**	**0.55**
CD (P=0.05)	**0.91**	**2.48**	**1.75**	**1.62**	**1.88**	**1.64**
N applied to wheat (kg/ha)						
0	24.6(24.6)	27.3(28.6)	64.5(60.5)	67.8(65.5)	76.1(77.6)	76.5(77.6)
50	31.9(33.5)	35.5(40.3)	66.7(68.0)	70.8(70.0)	80.1(82.0)	83.1(86.0)
100	35.9(38.5)	39.0(41.7)	70.8(72.0)	72.0(74.5)	82.2(83.7)	85.3(88.3)
150	34.8(36.5)	37.6(42.6)	67.5(65.0)	71.8(75.0)	80.8(82.0)	83.9(86.7)
Mean	**31.8(33.3)***	**34.8(38.3)***	**67.4(66.4)***	**70.6(71.2)***	**79.8(81.3)***	**82.2(84.7)***
SEm ±	**0.83(0.86)**	**0.72(1.65)**	**0.72(1.52)**	**0.53(1.77)**	**0.53(1.77)**	**0.64(1.55)**
CD (P=0.05)	**2.35(2.57)**	**2.38(7.00)**	**2.04(4.95)**	**2.04(4.57)**	**1.51(5.31)**	**1.82(4.64)**

Figures in parentheses show values of subplots having sole groundnut in main plots

* Sole groundnut vs rest found to be significant

Table 4.38. Direct and residual effect of nitrogen on tillers meter $^{-2}$ of wheat

Treatment	45 DAS		90 DAS		At harvest	
	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08
Cropping system						
Sole cotton	440.0	467.1	442.7	456.4	457.8	509.3
Cotton + Groundnut (1:3)	455.0	525.7	455.1	502.7	496.8	537.8
SEm ±	**0.88**	**1.86**	**2.32**	**2.03**	**0.98**	**1.02**
CD (P=0.05)	**2.65**	**5.57**	**7.00**	**6.09**	**2.95**	**3.05**
Fertility level						
Control	419.1	445.3	422.2	442.7	447.1	480.4
100% RDN	434.7	477.8	448.0	471.6	470.2	514.7
75% RDN + 25% through FYM	455.5	501.3	457.8	492.4	482.2	528.4
50% RDN + 50% through FYM	481.8	508.0	467.6	512.0	509.8	570.7
SEm ±	**1.25**	**2.63**	**3.27**	**2.87**	**1.39**	**1.44**
CD (P=0.05)	**3.75**	**7.88**	**9.80**	**8.61**	**4.17**	**4.31**
N applied to wheat (kg/ha)						
0	411.5(434.2)	476.4(523.1)	434.2(417.8)	481.8(462.2)	451.1(476.9)	492.9(520.9)
50	464.4(491.1)	521.3(572.4)	434.7(435.5)	483.1(502.2)	488.9(510.2)	536.0(554.7)
100	488.4(507.1)	544.0(587.6)	472.0(484.4)	502.7(564.4)	513.8(528.4)	570.7(602.7)
150	472.9(498.7)	536.0(580.0)	454.7(457.7)	492.0(511.1)	496.4(517.3)	548.4(576.9)
Mean	**459.1(471.1)***	**519.6(565.8)***	**449.0(448.9)**	**489.8(509.8)***	**487.6(508.0)***	**536.9(563.6)***
SEm ±	**1.19(3.54)**	**1.11(3.44)**	**3.43(9.26)**	**2.99(9.13)**	**1.16(3.94)**	**1.31(4.07)**
CD (P=0.05)	**3.36(10.62)**	**3.14(10.32)**	**9.71(27.78)**	**8.44(27.39)**	**3.29(11.80)**	**3.71(12.20)**

Figures in parentheses show values of subplots having sole groundnut in main plots

* Sole groundnut vs rest found to be significant

Table 4.39. Direct and residual effect of nitrogen on dry matter accumulation (g) meter^{-2} of wheat

Treatment	45 DAS		90 DAS		At harvest	
	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08
Cropping system						
Sole cotton	109.8	139.6	592.0	596.0	1278.2	1357.3
Cotton + Groundnut (1:3)	116.0	149.3	601.3	610.7	1366.7	1454.2
SEm ±	**0.44**	**0.51**	**1.12**	**1.09**	**5.97**	**4.74**
CD (P=0.05)	**1.31**	**1.53**	**3.35**	**3.26**	**17.89**	**14.19**
Fertility level						
Control	99.6	121.8	570.2	579.1	1251.1	1329.8
100% RDN	110.2	126.7	592.4	602.7	1316.4	1383.1
75% RDN + 25% through FYM	115.1	155.1	594.7	604.4	1340.9	1449.3
50% RDN + 50% through FYM	126.7	169.3	628.9	631.1	1380.9	1460.4
SEm ±	**0.62**	**0.72**	**1.58**	**1.54**	**8.44**	**6.69**
CD (P=0.05)	**1.87**	**2.17**	**4.74**	**4.61**	**25.29**	**20.08**
N applied to wheat (kg/ha)						
0	104.4(112.8)	133.8(142.7)	578.2(601.3)	586.2(608.9)	1236.4(1271.1)	1316.0(1360.0)
50	117.8(126.2)	149.8(163.1)	611.1(610.2)	617.8(636.4)	1308.9(1333.3)	1396.0(1422.2)
100	126.7(135.6)	158.7(164.9)	624.4(640.4)	627.6(646.2)	1468.0(1555.6)	1553.3(1644.4)
150	120.4(129.8)	152.4(160.0)	617.8(635.1)	622.2(645.3)	1412.4(1537.8)	1441.3(1513.3)
Mean	**117.3(126.2)***	**148.8(157.3)***	**608.0(630.2)***	**613.3(634.2)***	**1356.4 (1424.4)***	**1441.3(1513.3)***
SEm ±	**0.72(1.76)**	**0.79(2.05)**	**1.19(4.47)**	**1.01(4.35)**	**10.74(23.87)**	**7.82(18.94)**
CD (P=0.05)	**2.05(5.28)**	**2.24(6.13)**	**3.37(13.41)**	**2.84(13.05)**	**30.38(71.55)**	**22.12(56.58)**

Figures in parentheses show values of subplots having sole groundnut in main plots

* Sole groundnut vs rest found to be significant

Table 4.40. Interaction effect of fertility level and nitrogen doses applied to wheat on dry matter accumulation (g) meter^{-2} of wheat at 150 DAS

	N applied to wheat							
	0		50		100		150	
Fertility level	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08
Control	1013.3	1057.8	1186.7	1377.8	1328.9	1488.9	1311.1	1404.4
100% RDN	1248.9	1253.3	1253.3	1315.6	1382.2	1511.1	1342.2	1444.4
75% RDN + 25% through FYM	1266.7	1377.8	1302.2	1391.1	1444.4	1513.3	1413.3	1453.3
50% RDN + 50% through FYM	1311.1	1411.1	1355.6	1455.6	1577.8	1555.6	1422.2	1482.2
SEm ±	**16.581**	**15.643**						
CD (P=0.05)	**49.743**	**44.283**						

Table 4.41. Direct and residual effect of nitrogen on yield attributes of wheat

Treatment	Spikes m^{-2}		Grains $spike^{-1}$		1000-grain weight (g)	
	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08
Cropping system						
Sole cotton	450.7	490.7	47.2	51.8	42.1	42.6
Cotton + Groundnut (1:3)	489.3	538.2	47.5	52.5	43.0	43.5
SEm ±	**0.91**	**0.92**	**0.08**	**0.85**	**0.28**	**0.31**
CD (P=0.05)	**2.73**	**2.76**	**NS**	**NS**	**0.84**	**0.94**
Fertility level						
Control	442.2	474.2	45.6	50.4	41.0	41.5
100% RDN	456.0	504.4	46.6	50.6	42.2	42.4
75% RDN + 25% through FYM	476.4	526.7	48.4	53.7	43.2	43.6
50% RDN + 50% through FYM	505.3	551.6	48.7	54.0	43.8	44.7
SEm ±	**1.29**	**1.28**	**1.18**	**1.20**	**0.39**	**0.44**
CD (P=0.05)	**3.86**	**3.84**	**NS**	**NS**	**1.18**	**1.33**
N applied to wheat (kg/ha)						
0	436.9(464.0)	480.0(493.3)	47.3(49.5)	51.9(54.0)	40.3(41.1)	42.0(42.8)
50	478.2(504.4)	515.1(519.1)	48.7(50.3)	53.5(55.0)	42.2(42.9)	44.0(44.2)
100	505.7(516.7)	538.7(534.2)	51.3(57.8)	55.8(62.5)	46.9(48.3)	45.6(49.3)
150	500.0(514.4)	528.4(516.4)	48.9(52.0)	53.5(55.0)	44.1(47.4)	44.4(49.0)
Mean	**480.0(500.9)***	**515.6(516.0)***	**49.0(52.4)***	**53.7(56.6)***	**43.4(44.9)***	**43.8(46.3)***
SEm ±	**1.05(3.64)**	**1.51(3.62)**	**0.62(3.35)**	**0.64(3.40)**	**0.59(1.12)**	**0.50(1.26)**
CD (P=0.05)	**2.96(10.92)**	**4.28(10.85)**	**1.77(10.03)**	**1.81(10.20)**	**1.67(3.34)**	**1.50(3.77)**

Figures in parentheses show values of subplots having sole groundnut in main plots
* Sole groundnut vs rest found to be significant

Table 4.42. Interaction effect of fertility level and nitrogen doses applied to wheat on grains spike^{-1} of wheat

Fertility level	N applied to wheat							
	0		50		100		150	
	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08
Control	42.7	47.2	43.5	49.8	47.5	51.5	44.8	51.2
100% RDN	44.8	47.7	46.5	50.0	49.4	52.6	48.1	51.9
75% RDN + 25% through FYM	46.0	49.8	48.1	53.5	50.5	55.0	48.9	54.2
50% RDN + 50% through FYM	46.6	53.2	484	55.0	52.4	56.8	49.2	55.4
SEm ±	**1.249**	**1.281**						
CD (P=0.05)	**3.532**	**3.624**						

Table 4.43. Direct and residual effect of nitrogen on yield (t/ha) and harvest index (%) of wheat

Treatment	Grain yield (t ha^{-1})		Biological yield (t ha^{-1})		Harvest index	
	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08
Cropping system						
Sole cotton	3.03	3.22	7.36	7.78	41.31	41.74
Cotton + Groundnut (1:3)	3.18	3.40	7.66	7.95	41.98	43.06
SEm ±	**0.021**	**0.058**	**0.057**	**0.025**	**0.179**	**0.171**
CD (P=0.05)	**0.064**	**0.175**	**0.173**	**0.076**	**0.537**	**0.513**
Fertility level						
Control	2.99	3.07	5.42	7.27	55.17	42.15
100% RDN	3.11	3.34	7.53	7.81	41.30	42.77
75% RDN + 25% through FYM	3.12	3.40	7.66	7.92	40.73	43.00
50% RDN + 50% through FYM	3.20	3.44	7.70	8.48	41.56	40.58
SEm ±	**0.030**	**0.083**	**0.082**	**0.036**	**0.253**	**0.242**
CD (P=0.05)	**0.091**	**0.248**	**0.245**	**0.107**	**0.758**	**0.726**
N applied to wheat (kg/ha)						
0	2.46(2.46)	2.73(2.86)	5.74(5.58)	6.26(6.12)	42.86(44.09)	43.86(46.73)
50	3.19(3.35)	3.55(4.03)	8.11(9.00)	8.55(9.66)	39.33(37.22)	41.31(41.72)
100	3.59(3.85)	3.90(4.26)	8.83(9.67)	9.19(10.21)	40.66(39.81)	42.17(40.84)
150	3.48(3.65)	3.76(4.17)	8.52(9.25)	9.00(10.05)	40.85(39.46)	41.78(42.39)
Mean	**3.18(3.33)***	**3.48(3.83)***	**7.80(8.37)***	**8.25(9.01)***	**40.92(40.14)***	**42.28(42.92)***
SEm ±	**0.083(0.086)**	**0.084(0.234)**	**0.281(0.231)**	**0.228(0.110)**	**0.784(0.715)**	**0.741(0.685)**
CD (P=0.05)	**0.235(0.257)**	**0.238(0.700)**	**0.796(0.692)**	**0.646(0.330)**	**2.217(2.145)**	**2.096(2.053)**

Figures in parentheses show values of subplots having sole groundnut in main plots
* Sole groundnut vs rest found to be significant

Table 4.44. Interaction effect of cropping system and fertility level on grain yield (t ha^{-1}) of wheat

Fertility level	Cropping system			
	Sole cotton		Cotton + Groundnut	
	2006-07	2007-08	2006-07	2007-08
Control	2.71	2.79	2.90	3.12
100% RDN	2.77	3.01	3.09	3.35
75% RDN + 25% through FYM	2.89	3.11	3.22	3.41
50% RDN + 50% through FYM	3.34	3.55	3.52	3.72
SEm ±	**0.043**	**0.117**		
CD (P=0.05)	**0.128**	**0.350**		

Table 4.45. Interaction effect of cropping system and fertility level on straw yield (t/ha) of wheat

Fertility level	Cropping system			
	Sole cotton		Cotton + Groundnut	
	2006-07	2007-08	2006-07	2007-08
Control	4.00	4.03	4.34	4.37
100% RDN	4.17	4.22	4.48	4.57
75% RDN + 25% through FYM	4.43	4.51	4.53	4.61
50% RDN + 50% through FYM	4.98	5.05	4.55	5.67
SEm ±	**0.059**	**0.022**		
CD (P=0.05)	**0.178**	**0.065**		

Table 4.45. Direct and residual effect of nitrogen on nitrogen content (%) and protein content (%) of wheat

Treatment	N content (Grain)		N content (Straw)		Protein content (Grain)	
	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08
Cropping system						
Sole cotton	1.74	1.76	0.277	0.306	10.01	10.10
Cotton + Groundnut (1:3)	1.77	1.79	0.285	0.338	10.19	10.28
SEm ±	**0.008**	**0.003**	**0.007**	**0.010**	**0.048**	**0.019**
CD (P=0.05)	**0.025**	**0.010**	**0.021**	**0.029**	**0.144**	**0.059**
Fertility level						
Control	1.68	1.69	0.252	0.297	9.64	9.73
100% RDN	1.73	1.74	0.282	0.317	9.93	10.01
75% RDN + 25% through FYM	1.79	1.81	0.293	0.331	10.31	10.41
50% RDN + 50% through FYM	1.83	1.85	0.298	0.342	10.52	10.61
SEm ±	**0.012**	**0.005**	**0.0108**	**0.014**	**0.068**	**0.028**
CD (P=0.05)	**0.035**	**0.014**	**0.0320**	**0.042**	**0.204**	**0.083**
N applied to wheat (kg/ha)						
0	1.61(1.65)	1.63(1.68)	0.239(0.260)	0.284(0.312)	9.24(9.50)	9.37(9.67)
50	1.80(1.87)	1.82(1.89)	0.280(0.300)	0.328(0.341)	10.36(10.80)	10.45(10.90)
100	1.87(1.92)	1.88(1.93)	0.318(0.322)	0.355(0.343)	10.76(11.02)	10.84(11.11)
150	1.85(1.89)	1.87(1.91)	0.312(0.316)	0.327(0.343)	10.66(10.90)	10.75(11.00)
Mean	**1.78(1.83)***	**1.80(1.85)***	**0.287(0.299)***	**0.323(0.335)***	**10.25(10.55)***	**10.35(10.67)***
SEm ±	**0.018(0.033)**	**0.017(0.014)**	**0.012(0.021)**	**0.014(0.039)**	**0.107(0.193)**	**0.098(0.171)**
CD (P=0.05)	**0.052(0.100)**	**0.048(0.041)**	**0.035(NS)**	**0.038(NS)**	**0.301(0.577)**	**0.279(0.341)**

Figures in parentheses show values of subplots having sole groundnut in main plots
* Sole groundnut vs rest found to be significant

Table 4.46. Direct and residual effect of nitrogen on nitrogen uptake (kg ha^{-1}) of wheat

Treatment	N uptake (Grain)		N uptake (Straw)		Total N uptake	
	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08
Cropping system						
Sole cotton	51.25	55.36	13.38	13.73	64.63	71.85
Cotton + Groundnut (1:3)	56.49	61.16	13.77	15.45	70.26	76.61
SEm ±	**2.087**	**2.647**	**0.823**	**0.942**	**1.095**	**0.622**
CD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**3.285**	**1.863**
Fertility level						
Control	49.85	51.60	12.21	12.60	63.09	65.21
100% RDN	53.56	59.71	13.08	14.01	69.02	74.09
75% RDN + 25% through FYM	55.92	60.07	14.10	15.20	69.27	75.86
50% RDN + 50% through FYM	56.14	60.66	14.91	16.55	74.78	81.77
SEm ±	**2.952**	**3.744**	**1.164**	**1.332**	**1.549**	**0.879**
CD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**4.642**	**2.635**
N applied to wheat (kg/ha)						
0	37.46(40.93)	43.05(48.38)	9.38(9.34)	10.45(10.16)	53.66(60.27)	56.07(58.54)
50	59.12(62.96)	64.39(76.49)	15.43(17.27)	16.55(18.83)	74.05(85.18)	81.42(96.97)
100	64.73(72.97)	73.24(81.54)	16.66(18.88)	18.16(20.48)	86.45(101.00)	90.80(101.82)
150	64.59(69.88)	70.37(80.66)	15.98(18.26)	17.01(20.28)	84.53(97.30)	88.53(99.49)
Mean	**56.47(61.69)***	**62.76(71.77)***	**14.36(15.94)***	**15.54(17.44)***	**74.67(85.94)***	**79.20(89.21)***
SEm ±	**2.216(8.350)**	**2.734(10.589)**	**1.009(3.202)**	**1.112(3.767)**	**1.737(4.380)**	**2.226(2.486)**
CD (P=0.05)	**6.268(25.031)**	**7.731(31.742)**	**2.854(9.869)**	**3.144(11.292)**	**4.913(13.130)**	**6.294(7.453)**

Figures in parentheses show values of subplots having sole groundnut in main plots
* Sole groundnut vs rest found to be significant

Table 4.47. Interaction effect of cropping system and fertility level on total nitrogen uptake (kg ha^{-1}) by wheat

Fertility level	Cropping system			
	Sole cotton		Cotton + Groundnut	
	2006-07	2007-08	2006-07	2007-08
Control	58.32	59.14	67.47	71.28
100% RDN	62.28	66.78	67.86	73.93
75% RDN + 25% through FYM	65.73	72.67	69.56	79.86
50% RDN + 50% through FYM	73.08	77.78	75.75	81.39
SEm ±	**2.190**	**1.243**		
CD (P=0.05)	**6.565**	**3.726**		

Table 4.48. Direct and residual effect of nitrogen on phosphorus content (%) and total phosphorus uptake ((kg ha^{-1})) of wheat

Treatment	P content (Grain)		P content (Straw)		Total P uptake (kg ha^{-1})	
	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08
Cropping system						
Sole cotton	0.242	0.244	0.062	0.063	10.28	10.88
Cotton + Groundnut (1:3)	0.251	0.253	0.065	0.066	10.96	11.66
SEm ±	**0.0015**	**0.0014**	**0.0012**	**0.0011**	**0.049**	**0.206**
CD (P=0.05)	**0.0046**	**0.0043**	**0.0036**	**0.0033**	**0.149**	**0.616**
Fertility level						
Control	0.233	0.235	0.058	0.058	9.49	9.79
100% RDN	0.243	0.245	0.061	0.063	10.53	11.17
75% RDN + 25% through FYM	0.251	0.253	0.065	0.066	10.79	11.46
50% RDN + 50% through FYM	0.260	0.262	0.070	0.071	11.68	12.66
SEm ±	**0.0022**	**0.0020**	**0.0017**	**0.0015**	**0.070**	**0.291**
CD (P=0.05)	**0.0065**	**0.0060**	**0.0051**	**0.0046**	**0.211**	**0.871**
N applied to wheat (kg/ha)						
0	0.242(0.252)	0.243(0.253)	0.059(0.065)	0.061(0.066)	8.09(8.22)	8.86(9.37)
50	0.250(0.255)	0.251(0.255)	0.065(0.069)	0.066(0.071)	11.23(12.69)	12.32(14.68)
100	0.260(0.270)	0.261(0.271)	0.070(0.076)	0.071(0.077)	12.84(14.37)	13.83(15.62)
150	0.253(0.261)	0.255(0.263)	0.069(0.075)	0.071(0.077)	12.57(13.91)	13.45(15.52)
Mean	**0.251(0.259)***	**0.252(0.260)***	**0.066(0.071)***	**0.067(0.072)***	**11.18(1230)***	**12.11(13.80)***
SEm ±	**0.0019(0.0061)**	**0.0015(0.0057)**	**0.0009(0.0048)**	**0.0008(0.0044)**	**0.331(0.199)**	**0.322(0.822)**
CD (P=0.05)	**0.0053(0.0183)**	**0.0042(0.0171)**	**0.0026(0.0145)**	**0.0022(0.0131)**	**0.935(0.596)**	**0.911(2.465)**

Figures in parentheses show values of subplots having sole groundnut in main plots
* Sole groundnut vs rest found to be significant

Table 4.49. Direct and residual effect of nitrogen on potassium content (%) and total potassium uptake (kg ha^{-1}) of wheat

Treatment	K content (Grain)		K content (Straw)		Total K uptake (kg ha^{-1})	
	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08
Cropping system						
Sole cotton	0.350	0.361	0.999	1.004	56.92	58.66
Cotton + Groundnut (1:3)	0.363	0.372	1.014	1.032	57.39	60.00
SEm ±	**0.0056**	**0.050**	**0.0076**	**0.0096**	**0.534**	**0.139**
CD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**1.601**	**0.417**
Fertility level						
Control	0.330	0.339	0.958	0.963	50.01	50.98
100% RDN	0.355	0.368	0.995	1.005	55.23	57.48
75% RDN + 25% through FYM	0.367	0.378	1.021	1.035	58.49	60.53
50% RDN + 50% through FYM	0.375	0.381	1.052	1.070	64.89	68.33
SEm ±	**0.0080**	**0.0070**	**0.0107**	**0.0136**	**0.755**	**0.197**
CD (P=0.05)	**0.0240**	**0.0211**	**0.0322**	**0.0406**	**2.265**	**0.589**
N applied to wheat (kg/ha)						
0	0.337(0.360)	0.346(0.367)	0.921(0.983)	0.933(1.000)	40.45(39.57)	42.48(43.00)
50	0.363(0.383)	0.372(0.393)	0.990(1.070)	1.000(1.080)	61.43(76.05)	64.39(80.81)
100	0.405(0.467)	0.402(0.433)	1.188(1.300)	1.192(1.317)	74.71(91.72)	78.00(95.23)
150	0.398(0.446)	0.395(0.420)	1.132(1.287)	1.155(1.300)	73.81(81.60)	76.45(90.27)
Mean	**0.476(0.414)***	**0.379(0.403)***	**1.058(1.160)***	**1.070(1.174)***	**62.60(73.49)***	**65.33(77.33)***
SEm ±	**0.0089(0.0226)**	**0.0074(0.0199)**	**0.0137(0.0303)**	**0.0163(0.0383)**	**3.070(2137)**	**2.681(0.556)**
CD (P=0.05)	**0.0252(0.0677)**	**0.0209(0.0595)**	**0.0389(0.0910)**	**0.0462(0.1194)**	**8.683(6.405)**	**7.581(1.667)**

Figures in parentheses show values of subplots having sole groundnut in main plots
* Sole groundnut vs rest found to be significant

Table 4.50. Total N, total P and total K uptake (kg ha^{-1}) in cotton-wheat cropping system as influenced by nitrogen management

Treatment	Total N uptake		Total P uptake		Total K uptake	
	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08
Cropping system						
Sole cotton	229.85	171.88	30.13	23.70	164.37	111.54
Cotton + Groundnut (1:3)	320.43	251.59	37.00	31.29	214.34	154.74
SEm $\pm$	**16.116**	**9.428**	**1.961**	**0.952**	**7.006**	**3.420**
CD (P=0.05)	**48.307**	**28.263**	**5.878**	**2.853**	**21.002**	**10.252**
Fertility level						
Control	176.64	147.20	23.24	19.34	148.38	93.32
100% RDN	270.31	229.20	32.92	27.84	182.48	139.17
75% RDN + 25% through FYM	373.67	265.67	43.63	34.41	226.87	162.11
50% RDN + 50% through FYM	279.96	204.86	34.35	28.38	199.71	137.97
SEm $\pm$	**22.790**	**13.334**	**2.773**	**1.346**	**9.908**	**4.837**
CD (P=0.05)	**68.316**	**39.970**	**8.313**	**4.035**	**29.701**	**14.500**
N applied to wheat (kg/ha)						
0	223.68(158.11)	188.70(181.43)	26.20(16.66)	23.41(20.57)	157.22(124.83)	115.47(113.69)
50	246.29(189.68)	214.06(219.87)	29.34(21.14)	26.86(25.88)	177.91(161.31)	137.08(151.49)
100	256.43(199.06)	223.50(224.72)	30.94(22.81)	28.38(26.82)	191.19(176.98)	150.70(165.95)
150	254.59(194.98)	221.17(223.39)	30.67(22.36)	27.99(26.71)	190.29(171.86)	149.14(160.91)
Mean	**245.47(185.46)***	**211.86(212.10)***	**29.29(20.75)***	**26.66(25.00)***	**179.15(158.74)***	**138.10(148.01)***
SEm $\pm$	**2.082(64.459)**	**2.226(37.713)**	**0.331(7.844)**	**0.322(3.807)**	**3.067(28.024)**	**2.650(13.680)**
CD (P=0.05)	**5.888(NS)**	**6.294(NS)**	**0.935(NS)**	**0.911(NS)**	**8.674(NS)**	**7.493(NS)**

Figures in parentheses show values of subplots having sole groundnut in main plots
* Sole groundnut vs rest found to be significant

Table 4.51. Direct and residual effect of nitrogen on cotton equivalent yield (t ha^{-1}) of cotton-wheat cropping system

Treatment	2006-07	2007-08
Cropping system		
Sole cotton	3.99	3.77
Cotton + Groundnut (1:3)	4.71	4.21
SEm ±	**0.249**	**0.153**
CD (P=0.05)	**0.748**	**0.459**
Fertility level		
Control	3.44	3.04
100% RDN	4.60	4.45
75% RDN + 25% through FYM	4.94	4.69
50% RDN + 50% through FYM	4.40	3.78
SEm ±	**0.351**	**0.216**
CD (P=0.05)	**1.059**	**0.648**
N applied to wheat (kg/ha)		
0	3.09(2.10)	3.25(2.49)
50	3.72(2.48)	3.69(3.07)
100	4.20(2.69)	3.86(3.18)
150	3.86(2.08)	3.80(3.14)
Mean	**3.72(2.47)***	**3.65(2.94)***
SEm ±	**0.177(0.989)**	**0.048(0.612)**
CD (P=0.05)	**0.502(NS)**	**0.135(NS)**

Figures in parentheses show values of subplots having sole groundnut in main plots
* Sole groundnut vs rest found to be significant

Table 4.52. Direct and residual effect of nitrogen on post-harvest status of soil organic carbon (%), available nitrogen (kg ha^{-1}) and dehydrogenase activity (mg TPF gm soil^{-1} day^{-1}) after wheat

Treatment	Organic carbon		Available nitrogen		Dehydrogenase activity	
	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08
Cropping system						
Sole cotton	0.381	0.367	187.39	181.27	226.55	224.08
Cotton + Groundnut (1:3)	0.383	0.370	188.47	182.31	228.68	225.70
SEm ±	**0.0015**	**0.0043**	**4.623**	**4.581**	**5.843**	**5.735**
CD (P=0.05)	**0.0046**	**0.0128**	**NS**	**NS**	**NS**	**NS**
Fertility level						
Control	0.365	0.325	154.85	151.42	183.61	181.29
100% RDN	0.367	0.353	182.79	176.00	222.79	219.38
75% RDN + 25% through FYM	0.377	0.353	200.81	194.05	241.22	239.50
50% RDN + 50% through FYM	0.419	0.362	213.27	205.69	262.85	259.40
SEm ±	**0.0022**	**0.0060**	**6.538**	**6.479**	**8.264**	**8.110**
CD (P=0.05)	**0.0065**	**0.0181**	**19.600**	**19.421**	**24.773**	**24.312**
N applied to wheat (kg/ha)						
0	0.304(0.360)	0.393(0.353)	196.48(220.03)	190.26(213.23)	239.81(270.03)	237.00(266.56)
50	0.376(0.410)	0.363(0.400)	196.51(223.64)	190.28(216.85)	240.12(273.64)	237.28(270.19)
100	0.422(0.430)	0.410(0.520)	201.20(226.35)	194.95(219.47)	244.54(276.35)	241.45(272.80
150	0.493(0.530)	0.481(0.520)	210.08(239.37)	203.36(232.69)	252.30(289.37)	249.18(286.00)
Mean	**0.399(0.432)***	**0.387(0.423)***	**201.07(227.35)***	**194.71(220.55)***	**244.19(277.3)***	**241.23(273.9)***
SEm ±	**0.0115(0.0061)**	**0.0102(0.017)**	**1.626(18.493)**	**1.569(18.324)**	**1.614(23.37)**	**1.211(22.94)**
CD (P=0.05)	**0.0325(0.0092)**	**0.0288(0.051)**	**4.598(NS)**	**4.564(NS)**	**4.564(NS)**	**3.424(NS)**

Figures in parentheses show values of subplots having sole groundnut in main plots

* Sole groundnut vs rest found to be significant

Table 4.53. Interaction effect of cropping system and fertility level on post harvest organic carbon status (%) of wheat

Fertility level	Cropping system			
	Sole cotton		Cotton + Groundnut	
	2006-07	2007-08	2006-07	2007-08
Control	0.345	0.332	0.352	0.342
100% RDN	0.366	0.345	0.357	0.352
75% RDN + 25% through FYM	0.372	0.361	0.387	0.373
50% RDN + 50% through FYM	0.382	0.364	0.435	0.420
SEm ±	**0.0031**	**0.0085**		
CD (P=0.05)	**0.0092**	**0.0256**		

Table 4.54. Interaction effect of cropping system and nitrogen applied to wheat on dehydrogenase activity (mg TPF gm soil^{-1} day^{-1}) after wheat harvest

	Cropping system			
	Sole cotton		Cotton + Groundnut	
N applied to wheat (kg/ha)	2006-07	2007-08	2006-07	2007-08
0	166.88	155.61	222.66	221.66
50	222.54	218.48	225.92	224.18
100	227.93	224.47	229.33	227.08
150	233.40	228.15	238.55	229.00
SEm ±	**2.282**	**1.712**		
CD (P=0.05)	**6.454**	**4.843**		

Table 4.55. Direct and residual effect of nitrogen on post-harvest status of available soil phosphorus and potassium contents (kg ha^{-1}) of wheat

Treatment	Available P		Available K	
	2006-07	2007-08	2006-07	2007-08
Cropping system				
Sole cotton	13.45	11.62	288.47	283.32
Cotton + Groundnut (1:3)	11.26	9.76	287.39	282.29
SEm ±	**0.406**	**0.399**	**4.623**	**4.436**
CD (P=0.05)	**1.218**	**1.197**	**NS**	**NS**
Fertility level				
Control	11.20	10.90	282.79	279.34
100% RDN	8.00	7.82	254.85	251.41
75% RDN + 25% through FYM	11.40	11.90	300.81	294.00
50% RDN + 50% through FYM	12.83	13.00	313.27	306.48
SEm ±	**0.574**	**0.565**	**6.538**	**6.273**
CD (P=0.05)	**1.723**	**1.692**	**19.600**	**18.806**
N applied to wheat (kg/ha)				
0	14.00(11.11)	12.33(9.44)	310.08(339.37)	304.52(332.66)
50	13.54(10.44)	11.87(8.78)	301.20(326.35)	395.51(319.47)
100	7.75(7.23)	6.08(5.28)	296.48(320.03)	290.80(313.23)
150	7.93(7.35)	6.26(5.61)	296.51(323.64)	290.82(316.85)
Mean	**10.80(9.03)***	**9.13(7.28)***	**301.07(327.35)***	**295.41(320.55)***
SEm ±	**0.358(1.625)**	**0.351(1.597)**	**1.626(18.493)**	**1.593(8.872)**
CD (P=0.05)	**1.012(NS)**	**0.993(NS)**	**4.598(NS)**	**4.505(NS)**

Figures in parentheses show values of subplots having sole groundnut in main plots
* Sole groundnut vs rest found to be significant

Table 4.56. Effect of nitrogen on net return (Rs ha^{-1}) from cotton, groundnut, what and cotton-wheat system

Treatment	*Kharif* crops		Wheat		Cotton-wheat	
	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08
Cropping system						
Sole cotton	41,285	25,992	18,005	24,024	59,290	50,015
Sole groundnut	4,753	5,512	21,328	31,109	25,081	36,621
Cotton + Groundnut (1:3)	53,557	39,539	19,256	25,796	72,812	65,334
Fertility level						
Control	34,012	19,928	17,182	21,912	51,195	41,840
100% RDN	53,223	43,668	18,735	25,199	64,815	51,196
75% RDN + 25% through FYM	57,039	44,522	19,198	25,699	72,421	67,943
50% RDN + 50% through FYM	45,408	24,366	19,407	26,830	75,774	69,721
N applied to wheat (kg/ha)						
0			12,522(11,919)	17,888(19,190)	60,043(16,672)	50,654(24702)
50			18,859(23,079)	25,070(34,717)	66,280(27,832)	57,835(40229)
100			22,725(26,081)	29,736(35,782)	70,146(30,834)	62,501(41294)
150			20,316(24,233)	26,945(34,748)	67,737(28,986)	59,710(40260)

Figures in parentheses show values of subplots having sole groundnut in main plots

Sale price of seed cotton:	Rs 1990/q (2006)	Rs 2030/q (2007)
Sale price of cotton sticks:	Rs 60/q (2006)	Rs 65/q (2007)
Sale price of groundnut pods:	Rs 1520/q (2006)	Rs 1550/q (2007)
Sale price of groundnut haulm:	Rs 80/q (2006)	Rs 85/q (2007)
Sale price of wheat grain:	Rs 850/q (2006-07)	Rs 1000/q (2007-08)
Sale price of wheat straw:	Rs 150/q (2006-07)	Rs 160/q (2007-08)

Table 4.57. Effect of nitrogen on B:C ratio from cotton, groundnut, wheat and cotton-wheat system

Treatment	*Kharif* crops		Wheat		Cotton-wheat	
	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08
Cropping system						
Sole cotton	2.15	1.25	1.23	1.54	1.75	1.36
Sole groundnut	0.35	0.38	1.33	1.66	0.92	1.22
Cotton + Groundnut (1:3)	2.67	1.81	1.35	1.99	2.09	1.74
Fertility level						
Control	2.11	1.11	1.24	1.40	1.66	1.22
100% RDN	3.00	2.16	1.29	1.62	1.67	1.25
75% RDN + 25% through FYM	2.67	1.92	1.31	1.64	2.24	1.94
50% RDN + 50% through FYM	1.85	0.92	1.33	1.72	2.11	1.80
N applied to wheat (kg/ha)						
0			0.92(0.92)	1.22(1.31)	1.78(0.61)	1.39(0.85)
50			1.35(1.39)	1.65(2.19)	1.93(0.69)	1.57(1.34)
100			1.54(1.57)	1.88(2.28)	2.03(1.06)	1.67(1.36)
150			1.36(1.42)	1.65(2.20)	1.94(1.02)	1.58(1.35)

Figures in parentheses show values of subplots having sole groundnut in main plots

Table 4.58. Response function of N fertilization in wheat grown after sole and intercropped cotton

Cropping systems	Regression equation		Economic optimum dose of N for wheat (kg ha^{-1})		Yield at economic optimum dose of N (t ha^{-1})		Response at optimum dose of N (kg kg N^{-1})	
	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08
Sole cotton	$Y=24.47+0.244x-0.001x^2$; R^2 0.996	$Y=25.11+0.193x-0.008x^2$; R^2 0.988	104.9	113.6	3.8	4.7	0.13	0.19
Sole groundnut	$Y=25.44+0.20x-0.001x^2$; R_2 0.963	$Y=29.11+0.25x-0.0011x^2$; R_2 0.962	93.5	108.0	3.9	5.6	0.15	0.25
Cotton + groundnut	$Y=23.27+0.193x-0.0009x^2$; R^2 0.992	$Y=27.68+0.198x-0.001x^2$; R_2 0.965	100.0	110.0	3.3	3.7	0.10	0.10

Table 4.59. Direct and residual effect of nitrogen on net change (net gain/loss) of soil organic carbon (%) and available nitrogen (kg ha^{-1}) in soil

Treatment	After *kharif* crops				After wheat			
	Organic carbon		Available N		Organic carbon		Available N	
	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08
Cropping system								
Sole cotton	+0.004	+0.022	+52.0	+12.7	-0.079	-0.053	-39.6	-25.7
Sole groundnut	+0.023	+0.030	+95.5	+74.8	-0.028	-0.003	+0.3	+13.6
Cotton + Groundnut (1:3)	+0.025	+0.047	+159.2	+88.2	-0.077	-0.050	-38.5	-24.7
Fertility level								
Control	-0.118	-0.065	+5.35	-71.8	-0.095	-0.115	-72.1	-55.6
100% RDN	-0.020	+0.020	+65.03	+39.0	-0.093	-0.067	-44.2	-31.0
75% RDN + 25% through FYM	+0.045	+0.048	+102.6	+77.8	-0.083	-0.067	-26.2	-13.0
50% RDN + 50% through FYM	+0.152	+0.136	+122.0	+130.1	-0.041	+0.058	-13.7	-1.3
N applied to wheat (kg/ha)								
0					-0.156(-0.10)	-0.027(-0.067)	-30.5(-7.0)	-16.7(+6.2)
50					-0.084(-0.05)	-0.057(-0.020)	-30.5(-3.4)	-16.7(+9.8)
100					-0.038(-0.03)	-0.010(+0.10)	-25.8(-0.6)	-12.0(+12.5)
150					+0.033(+0.07)	+0.061(+0.10)	-16.9(+12.4)	-3.6(+25.7)

Figures in parentheses show values of subplots having sole groundnut in main plots

Initial soil organic carbon level in 2006 = 0.46%; 2007 = 0.42%; Initial available N in 2006 = 227 kg ha^{-1}; 2007 = 207 kg ha^{-1}

Table 4.60. Direct and residual effect of nitrogen on net change (net gain/loss) of available phosphorus and potassium (kg ha^{-1}) in soil

Treatment	After *kharif* crops				After wheat			
	Available P		Available K		Available P		Available K	
	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08
Cropping system								
Sole cotton	+1.3	+3.2	-10.0	-30.0	+0.6	-2.0	+18.5	+1.3
Sole groundnut	-1.8	0.0	-1.0	-20.0	-3.8	-6.3	-57.3	-38.5
Cotton + Groundnut (1:3)	-0.6	-0.5	-8.0	-27.0	-1.5	-3.8	+17.4	+0.3
Fertility level								
Control	-1.4	-0.7	-9.6	-28.8	-1.6	-3.7	+12.8	-2.7
100% RDN	-4.6	-2.8	-15.5	-36.6	-4.8	-6.8	+15.2	-30.6
75% RDN + 25% through FYM	-1.0	+0.3	-8.8	-25.9	-1.4	-1.7	+30.8	+12.0
50% RDN + 50% through FYM	+0.2	+2.2	-3.5	-22.9	+0.0	+1.4	+43.3	+24.5
N applied to wheat (kg/ha)								
0					+1.2(-1.7)	-1.3(-4.2)	+40.1(+69.4)	+22.5(+50.7)
50					+0.7(-4.0)	-1.7(-4.8)	+31.2(+56.3)	+13.5(+37.5)
100					-5.0(-5.6)	-7.5(-8.3)	+26.5(+50.0)	+8.8(+31.2)
150					-4.9(-5.5)	-7.3(-8.0)	+26.5(+53.6)	+8.8(+34.8)

Figures in parentheses show values of subplots having sole groundnut in main plots

Initial soil available P level 2006 = 12.8 kg ha^{-1}; 2007 = 13.6 kg ha^{-1}; Initial soil available K 2006 = 270 kg ha^{-1}; 2007 = 282 kg ha^{-1}

Table 4.61. Effect of cropping system, fertility level and N doses applied to wheat on agronomic N use efficiency (kg grain kg N^{-1}) and physiological N use efficiency (kg grain kg N^{-1}) in cotton and groundnut and their residual and direct effect on wheat

Treatment	Cotton				Wheat			
	ANUE		PNUE		ANUE		PNUE	
	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08
Cropping system								
Sole cotton	-	-	-	-	-	-	-	-
Sole groundnut	-	-	-	-	-	-	-	-
Cotton + Groundnut (1:3)	-	-	-	-	-	-	-	-
Fertility level								
Control	-	-	-	-	-	-	-	-
100% RDN	7.80	8.30	9.41	12.46	0.08	0.18	2.02	3.04
75% RDN + 25% through FYM	9.65	10.19	10.09	12.55	0.09	0.22	1.81	3.10
50% RDN + 50% through FYM	5.98	4.47	11.18	15.12	0.14	0.25	1.96	2.23
N applied to wheat (kg/ha)								
0					- (-)	- (-)	- (-)	- (-)
50					1.68(1.78)	1.64(2.34)	3.58(3.57)	3.23(3.04)
100					1.46(1.39)	1.17(1.31)	3.45(3.41)	3.37(3.03)
150					-0.1(-3.6)	-1.3(-5.3)	26.5(53.6)	8.8(34.8)

Figures in parentheses show values of subplots having sole groundnut in main plots

Table 4.62. Effect of cropping system, fertility level and N doses applied to wheat on N recovery (%) and N efficiency ratio (kg DM kg N uptake^{-1}) in cotton and groundnut and their residual and direct effect on wheat

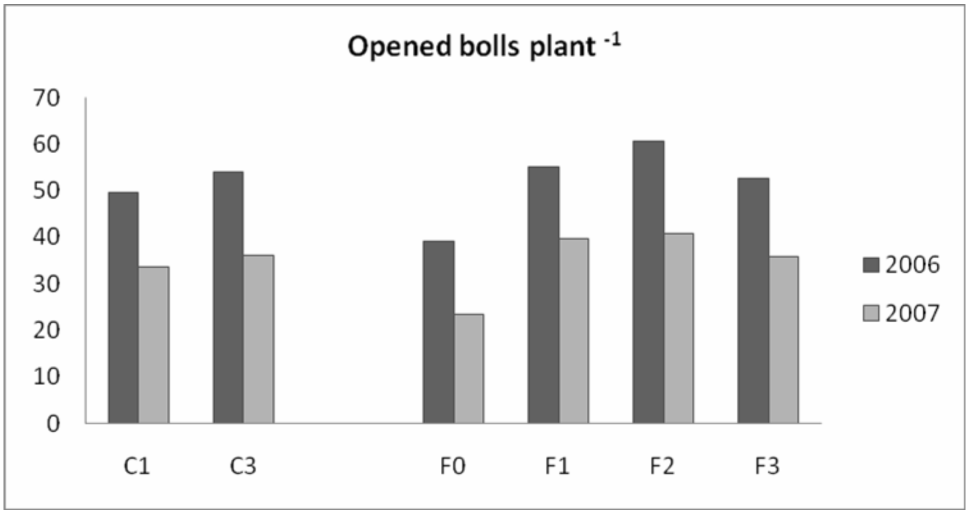
Treatment	Cotton and groundnut				Wheat			
	ANR		NER		ANR		NER	
	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08
Cropping system								
Sole cotton	-	-	54.07	49.71	-	-	10.90	10.83
Sole groundnut	-	-	3.72	3.77	-	-	9.74	10.10
Cotton + Groundnut (1:3)	-	-	48.82	44.90	-	-	10.85	10.38
Fertility level								
Control	-	-	73.09	60.70	-	-	8.59	11.15
100% RDN	82.9	66.6	47.44	42.00	4.0	5.0	10.91	10.54
75% RDN + 25% through FYM	95.6	81.1	44.98	38.45	5.0	7.0	10.91	10.44
50% RDN + 50% through FYM	53.5	29.6	52.64	57.38	7.0	11.0	10.44	10.37
N applied to wheat (kg/ha)								
0					- (-)	- (-)	10.69(9.26)	11.16(10.45)
50					41.0(50.0)	51.0(77.0)	10.95(10.57)	10.50(9.96)
100					33.0(41.0)	35.0(43.0)	10.21(9.57)	10.12(10.03)
150					21.0(25.0)	22.0(27.0)	10.08(9.51)	10.17(10.10)

Figures in parentheses show values of subplots having sole groundnut in main plots

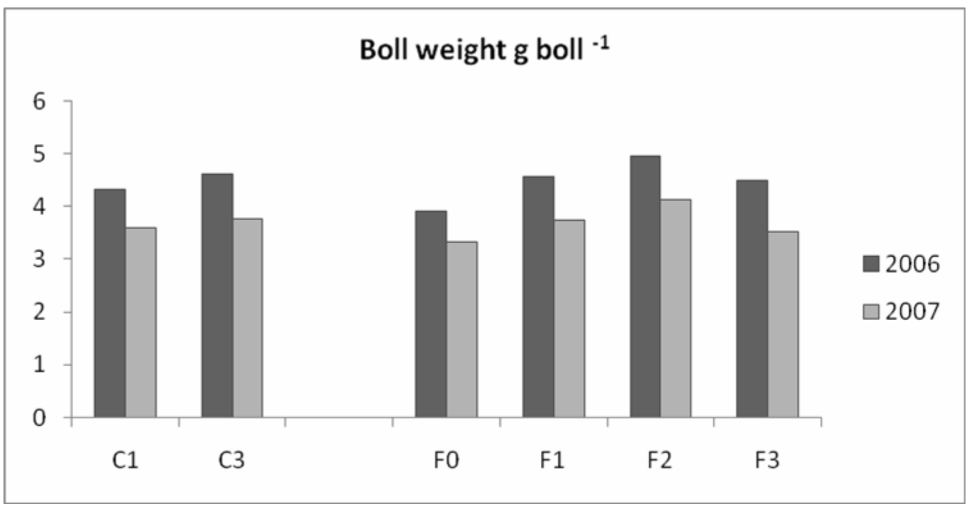
Table 4.63. Effect of cropping system, fertility level and N doses applied to wheat on physiological efficiency index of N (kg grain kg N uptake^{-1}) and N harvest index (%) in cotton and groundnut and their residual and direct effect on wheat

Treatment	Cotton and groundnut				Wheat			
	PEIN		NHI		PEIN		NHI	
	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08
Cropping system								
Sole cotton	1.81	2.07	41.1	45.1	4.49	4.48	76.0	77.0
Sole groundnut	0.97	0.88	28.7	23.6	3.87	4.29	72.0	80.0
Cotton + Groundnut (1:3)	1.57	1.93	38.8	43.5	4.50	4.44	80.0	80.0
Fertility level								
Control	2.29	2.71	45.0	60.0	4.74	4.71	79.0	81.0
100% RDN	1.52	1.77	38.0	38.8	4.51	4.51	78.0	81.0
75% RDN + 25% through FYM	1.51	1.71	37.6	37.7	4.44	4.48	79.0	79.0
50% RDN + 50% through FYM	1.75	2.18	42.8	49.5	4.34	4.21	76.0	74.0
N applied to wheat (kg/ha)								
0					4.58(4.08)	4.87(4.88)	70.0(68.0)	77.0(83.0)
50					4.31(3.93)	4.36(4.16)	77.0(74.0)	79.0(79.0)
100					4.15(3.81)	4.29(4.09)	77.0(72.0)	81.0(81.0)
150					4.12(3.75)	4.25(4.28)	76.0(72.0)	79.0(80.0)

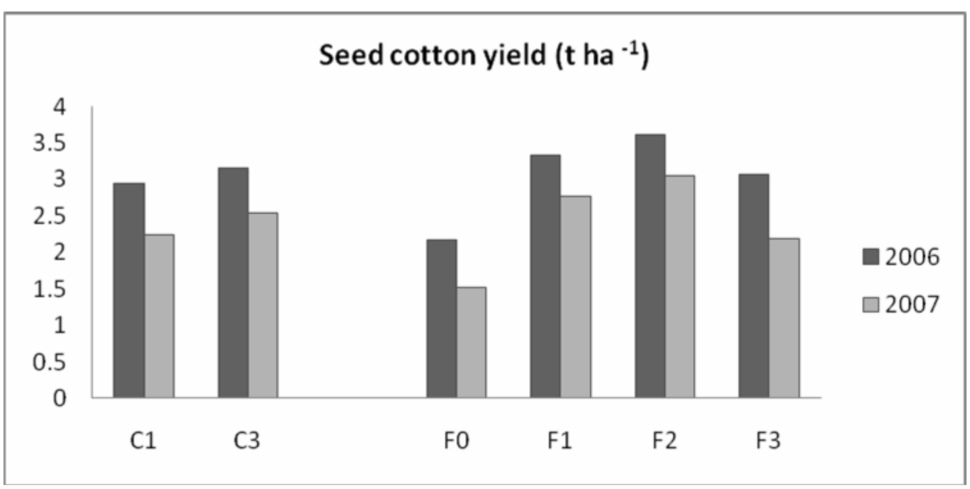
Figures in parentheses show values of subplots having sole groundnut in main plots



Opened bolls plant $^{-1}$
70
60
50
40
30
20
10
0
C1
C3
F0
F1
F2
F3
2006
2007



Boll weight g boll $^{-1}$
6
5
4
3
2
1
0
C1
C3
F0
F1
F2
F3
2006
2007



Seed cotton yield (t ha $^{-1}$)
4
3.5
3
2.5
2
1.5
1
0.5
0
C1
C3
F0
F1
F2
F3
2006
2007

Fig.4.1 Effect of cropping system and fertility level on yield attributes and yield of cotton

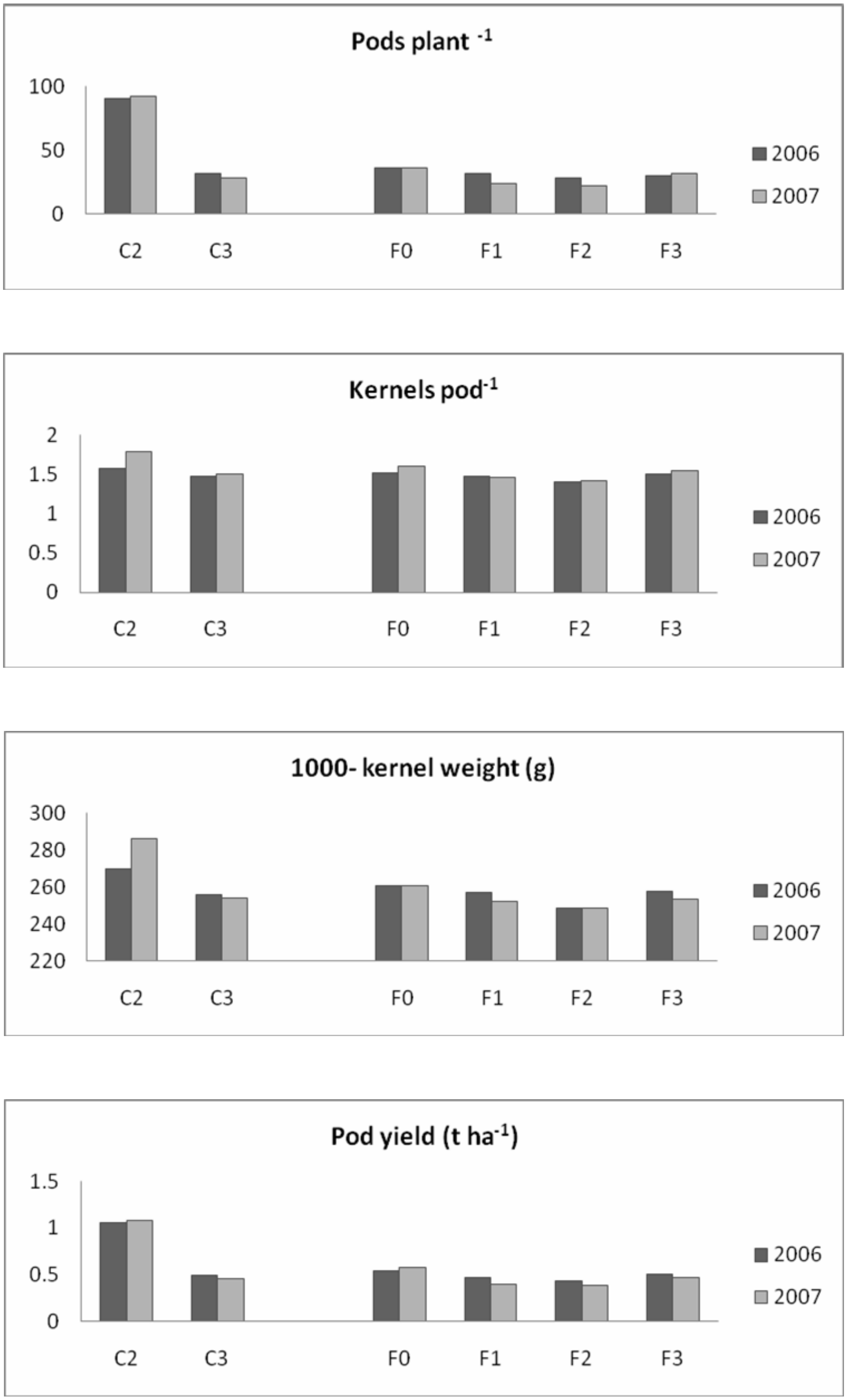
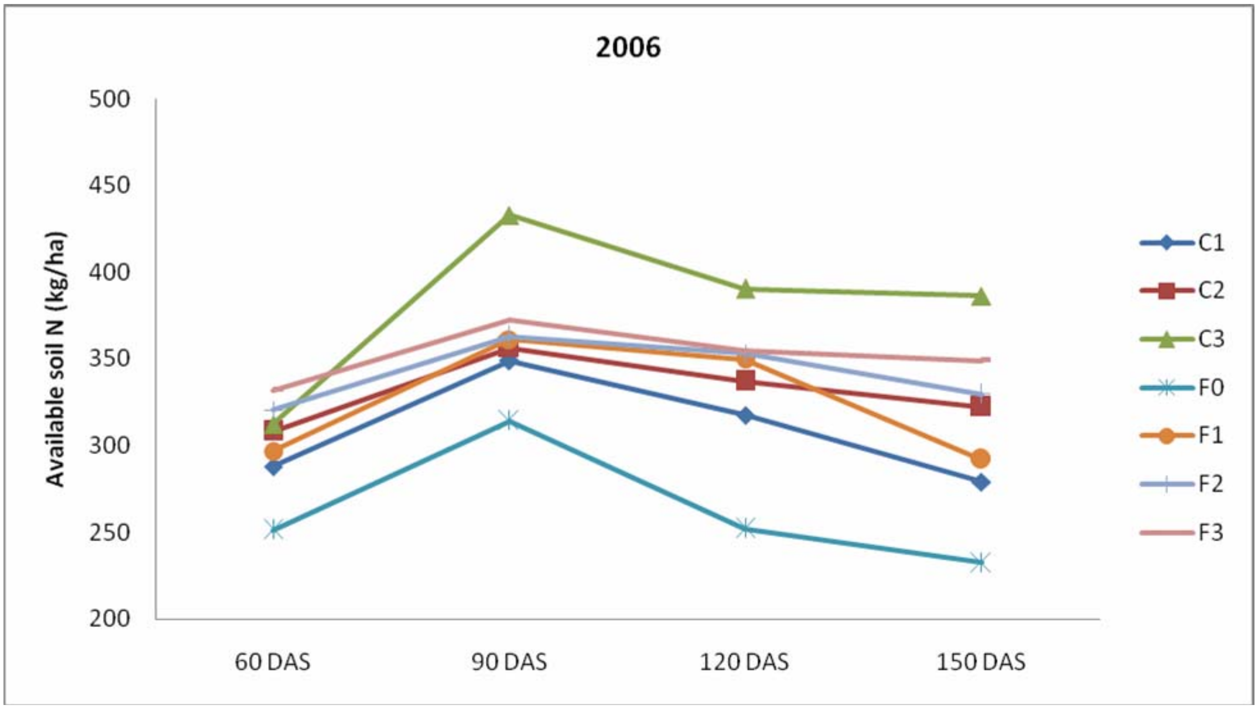


Fig.4.3 Effect of cropping system and fertility level on yield attributes and yield of groundnut



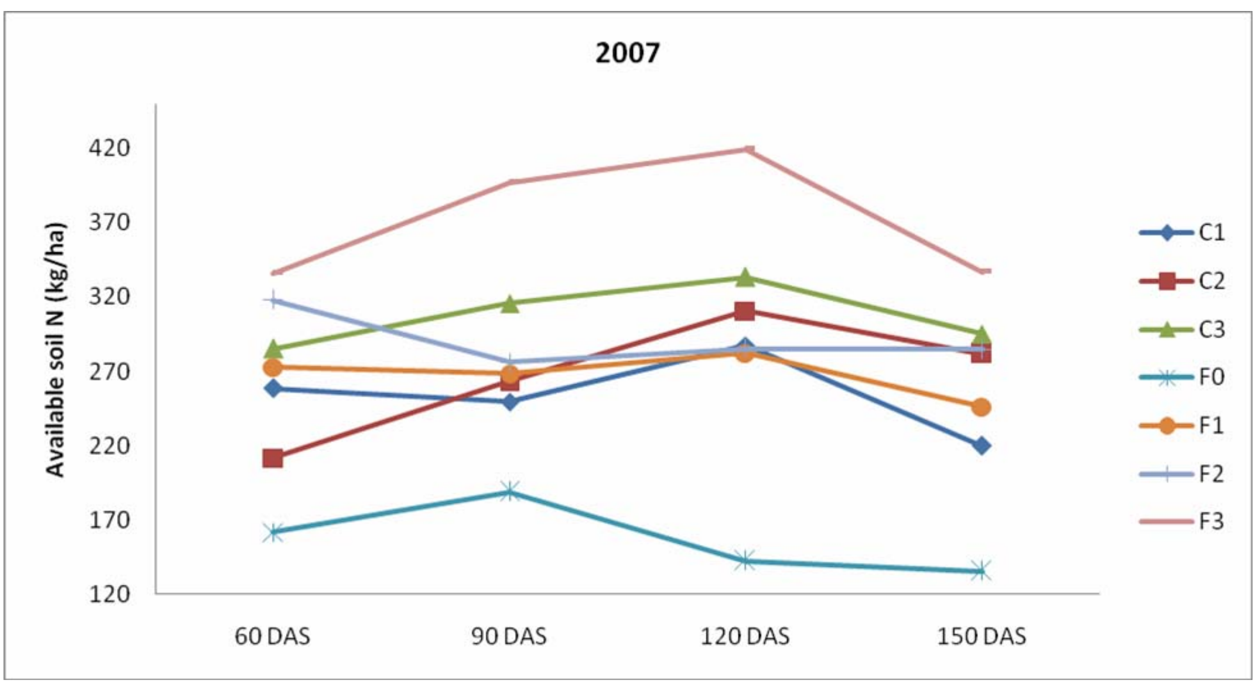
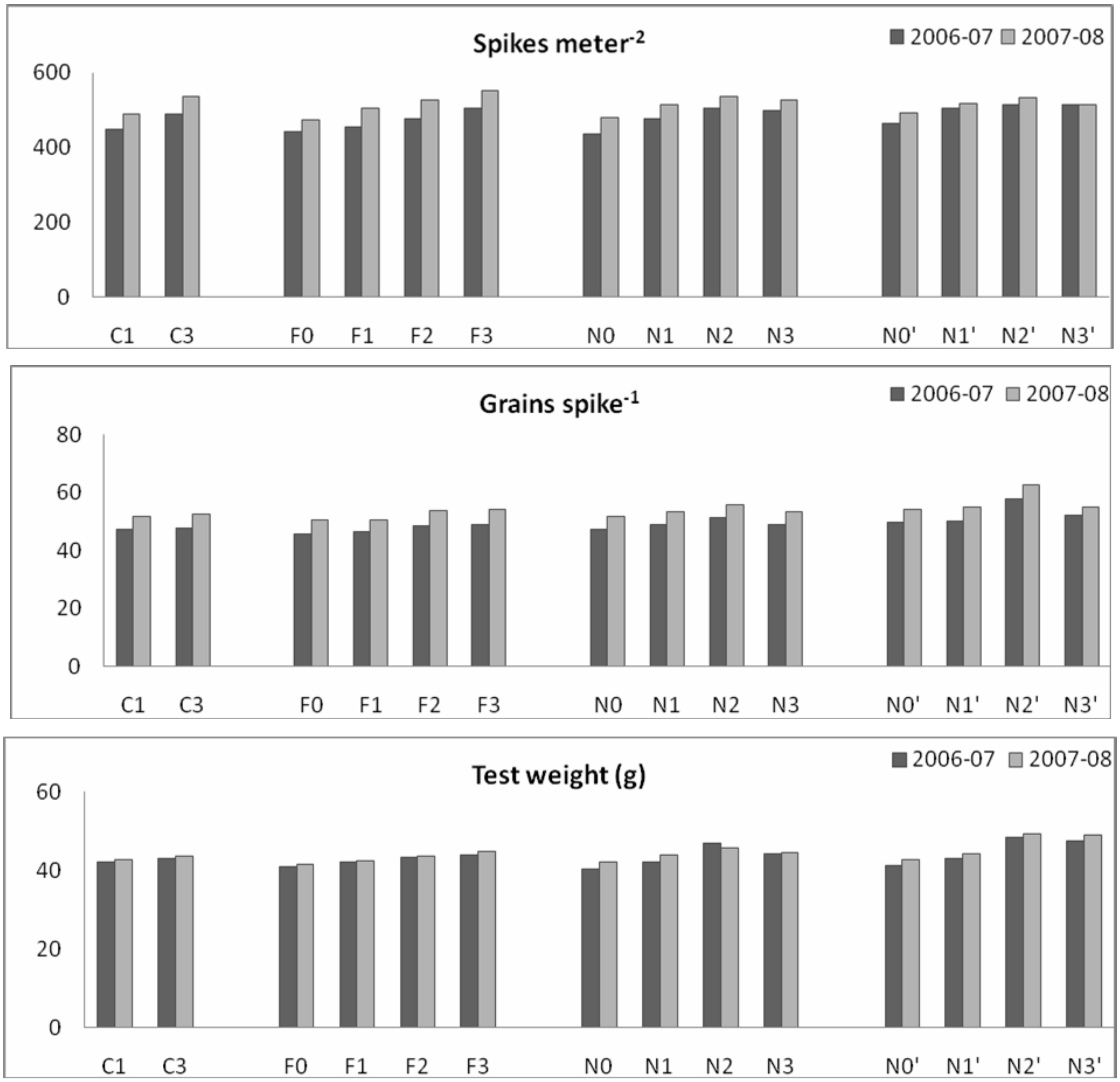


Fig.4.2 Effect of cropping system and fertility level on available soil N dynamics during kharif seasons of 2006 and 2007.



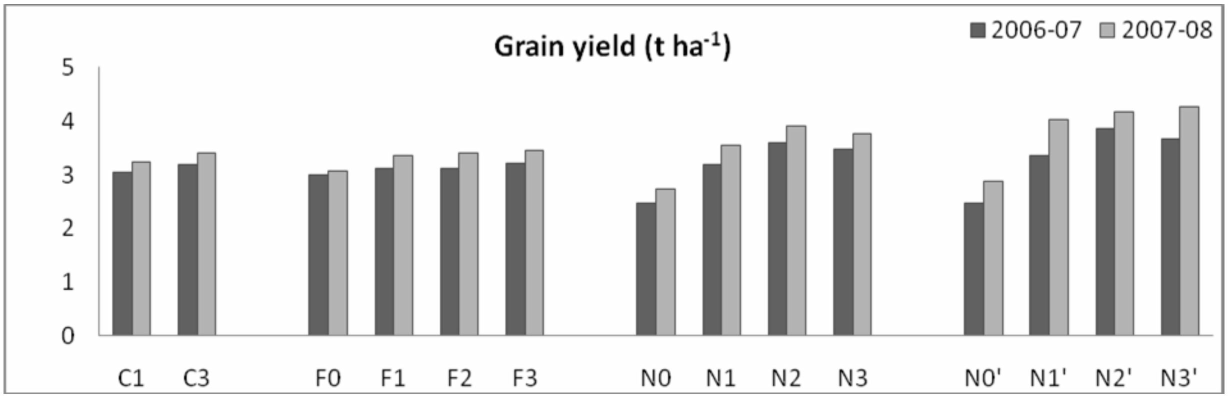
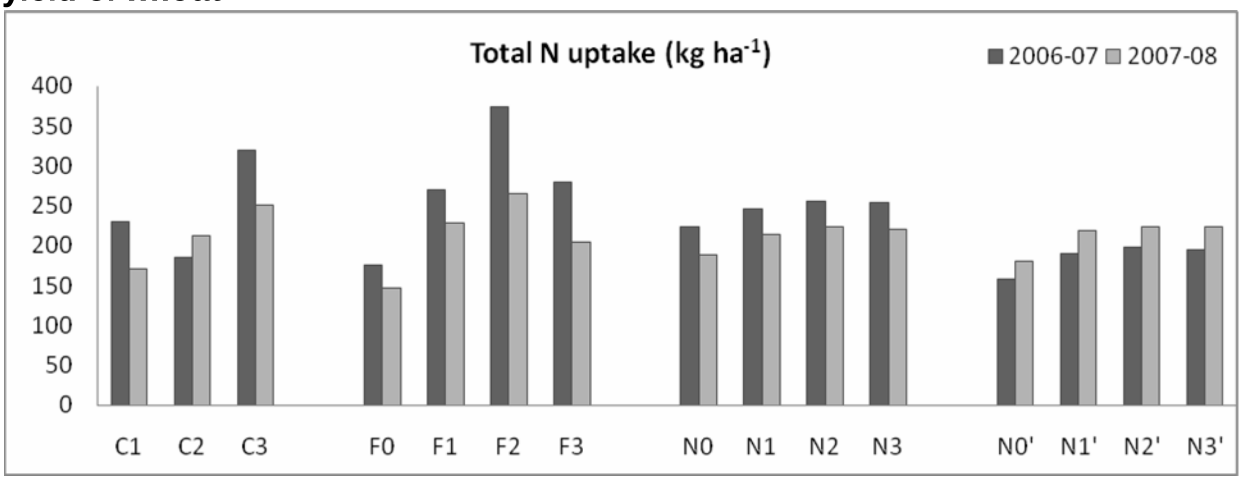
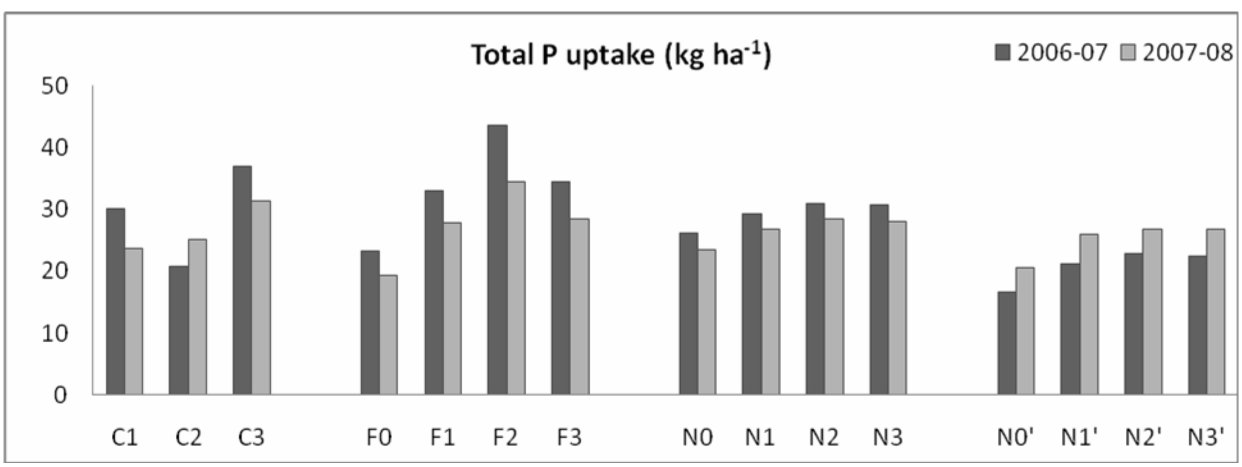


Fig.4.4 Direct and residual effect of nitrogen on yield attributes and grain yield of wheat





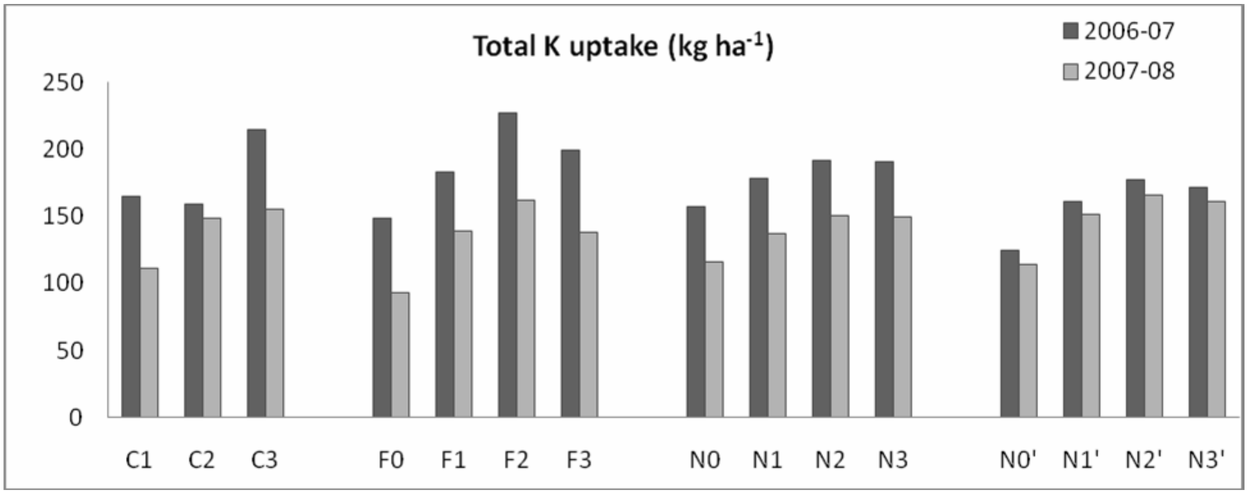


Fig.5 Direct and residual effect of nitrogen on total N, P and K uptake (kg ha^{-1}) by cotton- wheat sequence

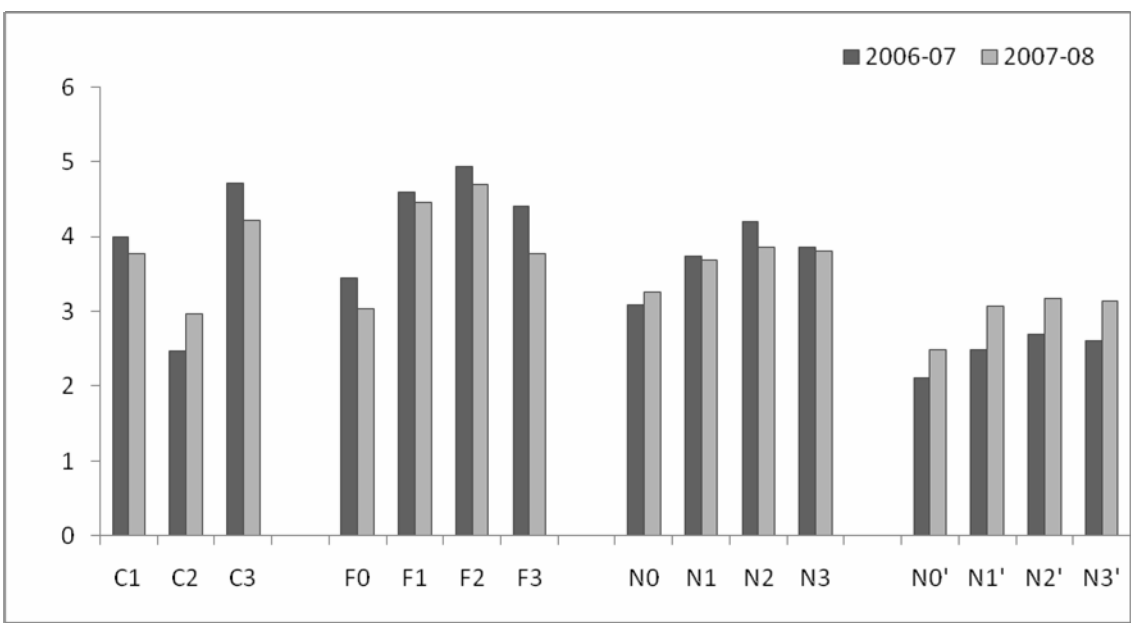


Fig. 6 Direct and residual effect of nitrogen on cotton-wheat system equivalent yield (t ha^{-1})

5

DISCUSSION

The experimental findings of the investigation entitled "**Effect of nitrogen management through organic and inorganic sources in sole and intercropped *Bt* cotton-wheat system**" have been described in the previous chapter. In this chapter, an attempt has been made to analyze the results critically in the light of cause and effect relationship. As the yield is the final criterion for the evaluation of different treatments, the discussion, therefore, necessarily centered around the effects of treatments on various characters as they finally modify the yield. The findings of earlier workers on the subject have also been taken into consideration while discussing the results of the present investigation.

5.1 Weather and crop growth

Weather conditions are known to have a great impact on the performance of crops. Therefore, it becomes utmost important to take into consideration the crop weather relationship in order to arrive at suitable interpretation and conclusion from the experimental results. The weather details during the crop seasons (2006-07 and 2007-08) have been presented in Appendices X and XI and depicted through Fig. 3.1 and 3.2.

The meteorological parameters indicated that climatic factors were, in general, favourable to crop during both the years. The amount of rainfall was slightly higher during 2006-07 than that of 2007-08, but the distribution was almost similar during both the seasons. The productivity of cotton, groundnut and wheat showed only a slight variation in two years of experimentation.

5.2 Cotton

5.2.1 Plant growth parameters

Cropping system did not significantly influence the plant growth parameters viz., plant height, LAI, dry matter partitioning, root dry weight, number of main stem nodes plant^{-1}, unopened bolls and total dry matter accumulation (Table 4.1, 4.2, 4.3, 4.4, 4.5, 4.6 and 4.7, respectively). This might be due to non competitive environment between main crop and the intercrop in respect of growth resources such as moisture, solar radiation and nutrients owing to differential growth habit of base (cotton) and intercrop (groundnut). The findings of Nagre (1979), Rao (1982), Masunde *et al*. (1986) and Balasubramaniyan (1987) are in agreement with the present investigation.

Fertility levels

Fertility levels significantly influenced all the plant growth parameters. Application of 75% RDN + 25% through FYM and 100% RDN being on par recorded higher plant growth parameters over 50% RDN + 50% through FYM and control. Higher plant growth parameters with combined application of organic and inorganic sources of nitrogen might be due to extended period of availability of and other nutrients from combined source compared to inorganic source alone. This might have increased photosynthetic activities of plant which ultimately helped to realize greater plant growth parameters. Better root growth due to combined application of FYM with inorganic N might be attributed to the enhanced availability of native P along with balanced supply of essential nutrients. Increase in main stem nodes plant^{-1} might be attributed to increased meristematic activity and consequent vertical extension of growth due to N application. These results are in harmony with Das *et al*. (2006), Suresh *et al*. (2005), Biswas and Mukherjee (1994), Padole *et al*. (1998) and Srinivasulu *et al*. (2004).

5.2.2 Yield and yield attributes

Cropping systems

Cropping system did not significantly affect yield attributes of cotton viz., opened bolls plant^{-1} and boll weight, seed cotton yield and stalk yield (Table 4.8). It is thus obvious that the conditions for growth and development of cotton in intercropping and solid stand were identical since groundnut intercrop being of different growth habit (canopy, height, growth duration etc.) could not put any competition to cotton. This was also reflected in the growth attributes of cotton. Thus the growth behaviour of the crop performed in a similar way for development activities of plants was reflected in yield attributes and yields of cotton. Similar results were also obtained by Waterworth (1994), Maitra *et al*. (2001), Palchamy *et al*. (1991), Koradi *et al*. (1991), Dayal and Kale (1976), Masunde *et al*. (1982) and Prasad (1989)

Fertility levels

Fertility levels significantly influenced the yield attributes and yields of cotton (Table 4.8). Application of 75% RDN + 25% through FYM being on par with 100% RDN recorded significantly higher yield attributes and yield than 50% RDN + 50% through FYM and control. Further 50% RDN + 50% through FYM also recorded significantly higher yield attributes and yield over control. Based on two years mean, the seed cotton yields were increased by 80.4 per cent (1.21 t ha^{-1}) with 100% RDN over control. Further, the substitution of 25% RDN through FYM has increased the cotton productivity by 8.85 per cent (0.27 t ha^{-1}) over 100% RDN. Increasing the N substitution through FYM to 50% proved non beneficial i.e. evident from the decreased seed cotton yields. The seed cotton yields declined by 13.8 per cent with 50% substitution of RDN through FYM over 100% RDN. The addition of 25% N through FYM might have increased humus content in soil that would have slowed down release of ammonical N and its conversion to nitrates, thereby reducing the leaching loss of N. Decreased soil density might have resulted in better availability of plant nutrients, which ultimately benefited yields and yield attributes. At higher levels of N substitution through FYM i.e. 50%, the N supply through chemical N and N mineralized through FYM might have fallen short of peak demand of the cotton crop thus reducing its performance. Improvement in yield parameters with better N management might be due to diversion of more plant metabolites towards developing buds, flowers and bolls. This was in line with the findings of Rathinakumari *et al*. (2004), Richard (1967), Muthuvel *et al*. (1989), Padole *et al*. (1998), Askerov *et al*. (1992) and Srinivasulu *et al*. (2004).

5.2.3 Fibre quality parameters

Cropping systems

Cropping system did not significantly affect the fibre quality parameters of cotton viz. ginning percentage, lint index, Bartlett's index, 2.5% Span length, 50% Span length, uniformity ratio, fibre strength, fibre elongation and micronaire (Table 4.9, 4.10 and 4.11). This could be attributed to the fact that fibre quality is a genetic character of cotton and it does not change easily by cultivation process (Blaise *et al*., 2005, Mukherjee and Verma, 1994, Chellamuthu and Purusothaman, 1980 and Robinson, 1973).

Fertility levels

Fertility levels significantly affected ginning percentage, seed index, lint index and micronaire values only. Parameters namely 2.5% Span length, 50% Span length, uniformity ratio, fibre strength and elongation remained unaffected by fertility treatments. Application of 75% RDN + 25% through FYM being on par with 100% RDN recorded higher values of ginning percentage, seed index, lint index and micronaire over control and 50% RDN + 50% through FYM, except micronaire in 2006, where 50% RDN + 50% through FYM was on par with 75% RDN + 25% through FYM. This could be attributed to availability of micronutrients with FYM application, besides the major nutrients (P, K, Ca, S, Mg) from well decomposed FYM and some growth promoting substances. Similar results were earlier reported by Mukerji and Verma (1994), Simlote *et al*. (1967) and Khippal and Nehra (1995).

5.2.4 Nutrient content and uptake

Cropping systems

Cropping systems did not bring about any significant change in NPK content and uptake. This might be attributed to the fact that nutrient contents in plant parts is by and large a genetic character and is not affected by intercropping systems (Table 4.12, 4.13, 4.14, 4.15, 4.16, 4.17 and 4.18). Another reason might be that similar conditions available to cotton for growth and development in sole cotton and cotton + groundnut systems. Since, the uptake of N, P and K is a function of yield and its nutrient content, the similar yields and nutrient content finally led to identical values of N, P and K uptake. Similar results were reported by Robinson (1973), Thangamuthu (1979), Satar *et al*. (1983) and Brijdar *et al*. (1987).

Fertility levels

Fertility levels significantly affected the nutrient content and uptake in different plant parts and total nutrients uptake. Application of 75% RDN + 25% through FYM being on par with 100% RDN recorded higher nutrient contents and uptake in different plant parts and total uptake over 50% RDN + 50% through FYM and control. As regards to N, this might be due to initial quick availability of N from inorganic source and later from organic source (as nutrients from FYM is believed to be released slowly but steadily) that led to higher N uptake of cotton. Secondly, the CO_2 produced during mineralization of organic matter play important role in solubilization of native P. The use of well decomposed FYM might have resulted in the formation of phospho-humic complexes which are more easily assimilated by the plants or isomorphous replacement of phosphate ions by humate ions by the coating of sesquioxides particles by humus to form a protective cover which reduces the phosphate fixing capacity of the soil and improved P uptake of crop. Higher K uptake might be due to reduced K fixation and direct addition of K to soil potassium pool resulted from addition of FYM. These findings were in line with Singh (1995), Katkar *et al*. (2002) and Das *et al*. (2006).

5.2.5 Soil nutrient status after *kharif* crops

Cropping systems

Cropping systems did not significantly influence organic carbon, available nitrogen, phosphorus and potassium status of soil after harvest of cotton and groundnut crops (Table 4.19, 4.20, 4.21 and 4.22). Dehydrogenase activity of soil significantly affected by cropping system. The highest dehydrogenase activity of soil was noticed with cotton + groundnut system followed by sole cotton. This might be due to the fact that addition of small amount of organic carbon and available nitrogen from intercropped groundnut, and these were used by base crop (cotton) so that effect of intercropping was nullified. Dehydrogenase enzyme activity increased with leguminous intercrop because of enhanced microbial activity and enzyme synthesis and accumulation due to increased C turnover and nutrient availability. Similar results were reported by Katkar *et al*. (2002), Singh *et al*. (2004), Dinesh *et al*. (2004) and Malero *et al*. (2007).

Fertility levels

Application of 50% RDN + 50% through FYM recorded the highest organic carbon, available soil N, P, K and dehydrogenase activity of soil, being markedly higher over all other treatments. Further application of 75% RDN + 25% through FYM and 100% RDN had similar soil fertility status after harvest of *kharif* crops. This might be due to multidimensional role of FYM ranging from building up of organic matter, improving soil aggregation, soil permeability and related physical properties to long lasting supply of several macro and micronutrients besides improving the cation exchange capacity of soil (Olsen *et al*., 1970, Krishnamoorthy and Ravikumar, 1973 and Gupta *et al*., 1983). Increase in available N might be due to the direct addition of N through the FYM to the available pool of the soil. It could also be attributed to the greater multiplication of soil microbes which could convert organically bound N to inorganic form. The increase in available P might be due to decomposition of organic matter. But increase in available K might be ascribed to direct addition of K to available pool of the soil besides the reduction in K fixing and release of K due to the interaction of organic matter with clay. Organic matter addition often leads to a rapid increase of soil CO_2 evaluation and increases the availability of various enzymes. These findings were in line with Katkar *et al*. (2002), Das *et al*. (2006), Singh *et al*. (2004), Ajwa and Tabatabai (1994), Crecchio *et al*. (2001) and Kandeler *et al*. (1999).

5.2.6 Cotton equivalent yield

Cropping system

Cotton + groundnut system recorded significantly higher cotton equivalent yield over sole cotton (Table 4.23). Similar cotton yield in intercropping as that of sole cotton coupled with additional yield of groundnut pods (0.475 t ha^{-1} on an average) resulted in superior performance of intercropping system. Based on two years mean, intercropped cotton has 23.6 per cent (3.20 t ha^{-1}) higher cotton equivalent yields than sole cotton (2.59 t ha^{-1}). The results are in agreement with those of Koradi *et al*. (1991).

Fertility levels

100% RDN increased mean cotton equivalent yield by 1.12 t ha^{-1} (56.5 per cent) over unfertilized control. Substitution of 25% N through FYM has 6.2 per cent (0.21 t ha^{-1}) higher cotton equivalent yield (CEY) than 100% RDN. Further increase in substitution of RDN through FYM proved counter productive. This is evident from the fact that CEY were reduced by 0.43 t ha^{-1} (17.7 per cent) over 100% RDN. The CEY with 75% RDN + 25% through FYM were attributed to the effect of FYM. See cotton yield (Table 4.8) and pod yield of groundnut (Table 4.29) which finally led to increase in cotton equivalent yield. Similar results were also reported by Katkar *et al*. (2002).

5.2.7 Economics

Cropping systems

Cotton + groundnut system on average fetched Rs 12,909 more net return and thus has 0.54 more B: C ratio than sole cotton (Table 4.57 and 4.58). Sole groundnut proved uneconomical of the 3 cropping systems. The higher CEY (0.61 t ha^{-1}) coupled with the corresponding stover yield coupled with minimal increases in cost of cultivation has resulted in higher net return and B: C ratio in cotton + groundnut system. Similar results were also observed by Koradi *et al*. (1991). Ramanjaneyulu and Reddy (2002), Maitra *et al*. (2001) and Palchamy *et al*. (1991).

Fertility levels

Application of 100% RDN through fertilizers enhanced mean net returns by Rs 21,476 over control. Further application of N as 75% RDN + 25% through FYM enhanced net return by Rs 2335 over 100% RDN. Increasing the FYM to 50% reduced net return by Rs 13,559 over 100% RDN. The increase in yield with substitution of 25% RDN through FYM has more than offset the increased cost, thus having a net gain of income. The reduced yield (0.43 t ha^{-1}) coupled with greater cost of FYM (Rs 400 t^{-1}) in 50% RDN + 50% through FYM has resulted in reduced net returns over 100% RDN. The highest B:C ratio was observed with 100% RDN followed by 75% RDN + 25% through FYM. Higher net return with combined N source was due to higher seed cotton yield. The high B:C ratio with FYM application was owing to greater cost of FYM addition. Similar findings were also reported by Katkar *et al*. (2002).

5.2.8 N use indices

Application of 75% RDN + 25% through FYM recorded highest agronomic N use efficiency (mean 9.92), while 50% RDN + 50% through FYM recorded higher physiological N use efficiency (13.15), applied N recovery (88.4) and physiological efficiency index of N (1.975) (Table 4.61,4.62 and 4.63). This could be attributed to increase in seed cotton yield with combined application of inorganic and organic sources of N. Another reason might be that it improved N uptake of crop due to increased humus content of soil that would have slowed down release of ammonical N and its conversion to nitrates, thereby reducing the leaching loss of N. These findings are in line with Soomro *et al*. (1999), Silvertooth *et al*. (2001) and Fritschi *et al*. (2004).

5.3 Groundnut

5.3.1 Plant growth parameters

Cropping system

Cropping system significantly influenced plant growth parameters viz., plant height, number of branch $plant^{-1}$, LAI and dry matter accumulation (Table 4.24, 4.25, 4.26 and 4.27, respectively). Intercropped groundnut maintained significantly higher plant height at 80 days onwards till harvest, while sole groundnut had significantly taller plants at 40 DAS over intercropped groundnut. This might be due to shading effect of cotton on intercropped groundnut, so that plants become taller in search of light for growth and development. Sole groundnut maintained significantly higher number of branch plant^{-1}, LAI and dry matter accumulation over intercropped groundnut at all the crop growth stages. Reduction in growth parameters of groundnut in intercropped was due to shading and competition for natural resources offered by cotton. Similar results were reported by Giri *et al*. (1980), Katti *et al*. (1999), Kalre *et al*. (1989) and Narwal and Malik (1986).

Fertility levels

Fertility levels significantly influenced all plant growth parameters except number of branch plant^{-1}. Application of 75% RDN + 25% through FYM being on par with 100% RDN produced markedly taller plants than 50% RDN + 50% through FYM and control. This might be due to higher growth of base crop (cotton) in 75% RDN + 25% through FYM and 100% RDN. So intercrop groundnut faced shading effect making it plants to grow taller in scarce of light. At harvest, control recorded higher dry matter accumulation of groundnut. This was because intercrop utilizes more solar energy due to less shading from poor cotton crop. Similar results were also reported by Chaithanya *et al*. (2003), Raju and Verma (1984), Singh *et al*. (1990) and Sharma and Singh (1971).

5.3.2 Yield and yield attributes

Cropping system

Cropping system significantly affected pods plant^{-1}, kernel pod^{-1}, 1,000-kernel weight, pod, haulm and biological yields and shelling percentage recorded at harvest (Table 4.28 and 4.29). Sole groundnut produced significantly higher yield and yield attributes over intercropped groundnut. This could be attributed to the reduction in dry matter accumulation of intercropped groundnut caused by shading effect of cotton (Table 4.27). Another reason for lower pod yield of intercropped groundnut was due to combined effect of reduced number of pods plant^{-1} and lower plant population (45% base population in intercropping as compared to sole groundnut). These results are in accordance with the findings of Channal (1983), Subrahmaniyan and Kalaiselvan (2005), Waterworth (1994) and Chaniyara *et al*. (1999).

Fertility levels

Control treatment being on par with 100% RDN in 2006 and 50% RDN + 50% through FYM in 2007 produced significantly higher pods plant^{-1} over other treatments. Control treatment though produced the highest kernels pod^{-1}, pod yield, haulm yield, biological yield and shelling percentage but was on par with 50% RDN + 50% through FYM. 1,000-kernel weight was significantly affected by fertility levels. This might be due to more dry matter accumulation by intercropped groundnut caused by less shading effect in poor canopy cotton crop in control and 50% RDN + 50% through FYM treatment applied to cotton. Another reason for higher pod yield in control was because of increased number of pod plant^{-1} resulted due to less shading effect in poor canopy cotton crop in control. Similar results were reported by Kambale *et al*. (2002) and Subramaniyan *et al*. (2000).

5.3.3 Nutrient content and uptake

Cropping systems

Sole groundnut had significantly higher NPK concentration and uptake over intercropped groundnut. Sole groundnut also produced significantly higher protein content and yield over intercropped groundnut. This might be due to the fact that no extra nutrients were applied to intercropped groundnut, while sole groundnut received recommended dose of fertilizers. Thus groundnut survived by nutrients applied to base crop. Hence, intercropped groundnut faced nutrient starvation over sole groundnut. NPK uptake was suppressed by intercropping because of reduced pods and biomass yield of groundnut. Similarly less protein content and yield was recorded for intercropped groundnut. These results are in accordance with the findings of Aiyer (1949), Dwivedi (1981), Sagare and Bhalkar (1986) and Maliwal *et al*. (1988) (Table 4.30, 4.31, 4.32, 4.33 and 4.34).

Fertility levels

Fertility levels significantly influenced the NPK content and uptake besides protein content and yield. The NPK content in kernel and haulm and protein content increased markedly with 100% RDN and 75% RDN + 25% through FYM over control.

Control treatment being on par with 50% RDN + 50% through FYM recorded higher NPK uptake in kernel, haulm and total uptake, besides protein yield. This might be due to more availability of nutrients with 100% RDN and 75% RDN + 25% through FYM applied to base crop of cotton are efficiently utilized by intercrop groundnut. As nutrient uptake is the function of yield and nutrient content, so control and 50% RDN + 50% through FYM produced higher biomass yield due to less shading effect by base crop of cotton, acquired higher nutrients and protein yield. Similar results were also reported by Mehta *et al*. (1996).

5.3.4 Intercropping indices

Assessment of intercropping indices is necessary to find out the best combination of cotton and groundnut for enhancing the total productivity (Table 4.35 and 4.36).

It is clear from the results that control treatment gave the highest LER, RNR and ATER followed by 50% RDN + 50% through FYM. The higher values could be due to better and efficient utilization of growth resources, resulting from temporal and spatial complementarity. Higher LER in control was due to higher productivity of groundnut owing to more availability of solar energy in poor canopy cotton crop, resulting in less competition among plant for natural resources.

Aggressivity values indicated that cotton had positive values for all fertility levels while more negative for groundnut. This shows that groundnut was dominated by cotton under all fertility levels. Dominating nature of cotton was due to its tall stature, higher leaf area, resource exhaustiveness while it was the reverse for groundnut.

The product of RCC should be more than one for the system to be advantageous. At all fertility levels, the product of coefficient was less than one indicating that intercropping system was not advantageous in terms of intercrop faced adverse effects of base crop like shading effect at reproductive stages of intercrop, resulted in stunted growth and less pod yield. While their association was beneficial because of spatial and temporal complementarity between both crops and also having the different rooting pattern and contrast nature to utilize natural resources efficiently.

The values of competition index were less than one for all fertility levels indicating positive benefits of cotton and groundnut in intercropping system due to complementary use of time and space.

In cotton, the highest competition ratio was noticed at 75% RDN + 25% through FYM followed by 100% RDN. In groundnut, the highest competition ratio was noted in control treatment followed by 50% RDN + 50% through FYM. The highest RNR was recorded in control treatment followed by 50% RDN + 50% through FYM. The lowest RNR was accrued at 75% RDN + 25% through FYM. However, 100% RDN and 75% RDN + 25% through FYM in 2007 recorded similar values of RNR. The highest ATER was observed in control treatment followed by 50% RDN + 50% through FYM. The lowest values were noticed with 100% RDN.

These findings are in accordance with the findings of Waterworth (1994), Maitra *et al*. (2001) and Sarkar *et al*. (1995).

5.4 Wheat

5.4.1 Plant growth parameters

The residual effect of preceding crop(s) and fertility levels applied to it had significant effect on plant height, number of tiller meter^{-2} and dry matter accumulation meter^{-2} at all stages. At harvest, plant height, number of tiller meter^{-2} and dry matter accumulation meter^{-2} on an average were higher in cotton + groundnut intercropping by 1.5, 6.0 and 7.5 %, respectively over sole cotton. Among residual effects of fertility levels, 50% RDN + 50% through FYM being on par with 75% RDN + 25% through FYM recorded significantly taller plants, number of tiller meter^{-2} and dry matter accumulation meter^{-2} at all the growth stages (Table 4.37, 4.38 and 4.39). Significant improvement in growth attributes of wheat due to residual effect from previous crops and fertility levels also reported by Tiwari *et al*. (1980), Wild (1972) and Das *et al*. (2004).

Direct effect of nitrogen

Wheat recorded significantly taller plants, number of tiller meter^{-2} and dry matter accumulation meter^{-2} with each successive increase in nitrogen dose up to 100 kg ha^{-1} only at all the growth stages. There was, however, marked reduction in all growth parameters at 150 kg N ha^{-1} over 100 kg N ha^{-1}. Similar trend was observed for growth parameters of wheat grown following sole groundnut crop. Since N is an important constituent of amino acids, protein and protoplast, its direct application have more pronounced influence on plant growth and development through better utilization of photosynthates (Sharma *et al*., 2000 and Kumpawat and Rathore, 1998).

5.4.2 Yield attributes and yield

Residual effect of cropping systems and fertility levels

The residual effect of preceding crop(s) and fertility levels applied to it had significant effect on number of spikes meter^{-2}, 1,000-grain weight and yield (grain and biological) and harvest index (Table 4.41 and 4.43). The number of spike meter^{-2}, 1,000-grain weight, grain and biological yield and harvest index of wheat were after cotton + groundnut system on an average was higher by 10.0, 2.5, 6.0, 2.5 and 3.2 %, respectively than that after sole cotton. Among residual effects of fertility levels, 50% RDN + 50% through FYM had significantly higher yield attributes (spikes m^{-2} and 1,000-grain weight). The effect of fertility levels was marked in 2007-08. Application of 50% RDN + 50% through FYM produced 0.56 tonnes more biological yield than 75% RDN + 25% FYM. Unfertilized control have significantly higher harvest index over other 3 fertility levels. This could be attributed to higher residual nutrient availability and subsequent better uptake that might have resulted in higher dry matter production and improved yield attributes. Similar results were also reported by Giri and De (1979), Das (1977) and Kairon *et al*. (1996).

Direct effect of nitrogen

Wheat recorded significantly higher number of spike meter^{-2}, grains spike^{-1}, 1,000-grain weight, grain and biological yields with each successive increase in nitrogen dose up to 100 kg ha^{-1} only. There was, however, marked reduction in yield attributes and yields at 150 kg N ha^{-1} over 100 kg N ha^{-1}. The grain yield of wheat was increased by 10.0 and 42.8 % at 100 kg N ha^{-1} over 50 kg N ha^{-1} and control, respectively. In the year 2006-07, control, being on par with 150 kg N ha^{-1} recorded significantly higher harvest index over 50 and 100 kg N ha^{-1}. However, in the year 2007-08, control being on par with 100 kg N ha^{-1} maintained significantly higher harvest index over 50 and 150 kg N ha^{-1}. Similar trend was observed for yield and yield attributes of wheat grown following sole groundnut crop. This could be ascribed to higher N availability and uptake with corresponding higher N levels and subsequent greater production of photosynthates which ultimately led to higher biomass production. Increase in grain yield with higher N levels was mostly due to improved yield attributes. Increased number of spike meter^{-2} with higher N dose might be due to stimulatory effect of N on tillering through cytokinin synthesis resulting in more number of effective tillers of wheat (Sharma *et al*., 2000, Kataria *et al*., 1999 and Jain, 1999).

5.4.3 Nutrient content and uptake

Residual effect of cropping systems and fertility levels

NPK content in grain and straw, protein content in grain, total uptake of N, P and K of wheat was significantly higher after cotton + groundnut system than that after sole cotton. Wheat grown after intercropped cotton + groundnut on an average has 8.0 kg ha^{-1} more NPK uptake than that after sole cotton. Among residual effect of fertility levels, 50% RDN + 50% through FYM resulted in significantly higher N, P, K content in grain and straw, protein content in grain, total uptake of N, P and K of wheat over all other fertility levels. The total uptake of nutrients with 50% RDN + 50% FYM were greater by 20.0 kg ha^{-1} over 100% RDN. This could be ascribed to the availability of residual N, P, K in the soil due to application of FYM to cotton. Total nutrients uptake followed the similar trend as that of dry matter production (Table 4.45, 4.46, 4.48 and 4.49). Similar results were reported by Kairon *et al*. (1996), Das *et al*. (2004) and Tiwari *et al*. (1980).

Direct effect of nitrogen

N, P, K content in grain and straw, protein content in grain, total uptake of N, P and K of wheat recorded significant increase with each successive increase in N dose up to 100 kg ha^{-1} only. Amount of nutrients harvested in grain and straw as well as whole plant increased with the addition of more fertilizer N because of increased grain and straw yields and also nutrient content (Gonita and Joshi, 2000, Khola *et al*., 1959 and Singh *et al*., 1989).

5.4.4 Soil nutrient status after wheat

Residual effect of cropping systems and fertility levels

The organic carbon content of soil after harvest of wheat in cotton + groundnut – wheat system was on an average increased by 0.0025% over sole cotton-wheat system (Table 4.52). However, the available P content of soil after harvest of wheat was significantly higher in sole cotton-wheat system than that after cotton + groundnut – wheat system. The available N and K and dehydrogenase activity of soil were not significantly affected by residual effect of preceding crop(s). Among residual effects of fertility levels when N was given as 50% RDN + 50% through FYM, organic carbon, available N, P and K and dehydrogenase activity were highest. It was increased on an average by 2.55, 16.7, 66.5, 22.0 and 18.3 %, respectively; over 100% RDN. This might be due to the fact that addition of small amount of organic carbon and available nitrogen from intercropped groundnut, and these were used by base crop (cotton) so that effect of intercropping was nullified. Dehydrogenase enzyme activity increased with leguminous intercrop because of enhanced microbial activity and enzyme synthesis and accumulation due to increased C turnover and nutrient availability. Similar results were reported by Katkar *et al*. (2002), Singh *et al*. (2004), Dinesh *et al*. (2004) and Malero *et al*. (2007). Increase in available N might be due to the direct addition of N through the FYM to the available pool of the soil. It could also be attributed to the greater multiplication of soil microbes which could convert organically bound N to inorganic form. The increase in available P might be due to decomposition of organic matter. But increase in available K might be ascribed to direct addition of K to available pool of the soil besides the reduction in K fixing and release of K due to the interaction of organic matter with clay. Organic matter addition often leads to a rapid increase of soil CO_2 evaluation and increases the availability of various enzymes. These findings were in line with Katkar *et al*. (2002), Das *et al*. (2006), Singh *et al*. (2004), Ajwa and Tabatabai (1994), Crecchio *et al*. (2001) and Kandeler *et al*. (1999).

Direct effect of nitrogen

Organic carbon, available N and dehydrogenase activity of soil increased with each successive increase in N dose up to 150 kg ha^{-1}. The organic carbon content build up is observed with 150 kg N ha^{-1} application to whet (on an average by 0.045%), while other N levels recorded a loss, being highest in control plots. The available N content of soils decreased over its initial values in all N levels and the decrease being least with 150 kg N ha^{-1}. A reverse trend was observed for available P and K contents of soil. These findings are in line with the findings of Katkar *et al.* (2002), Singh *et al*. (2004), Dinesh *et al*. (2004) and Malero *et al*. (2007).

5.4.5 Economics

Residual effect of cropping systems and fertility levels

Wheat following sole groundnut had highest mean net return (Rs 26,218) that after sole cotton had the least net returns (Rs. 21,014). The higher net returns of wheat after groundnut was ascribed to N sparing effect of legume groundnut and its beneficial effect has increased wheat yields, thus higher returns. Cotton + groundnut system had highest B:C ratio which was 24% and 45% higher than that of sole cotton in 2006-07 and 2007-08, respectively. Among residual effect of fertility levels, 50% RDN + 50% through FYM recorded the highest mean net return (Rs 23,118) closely followed by 75% RDN + 25% through FYM. The higher net returns of wheat where preceding crops received 50% RDN through FYM due to greater residual effect of FYM. Application of 100% RDN recorded the highest mean B: C ratio while 50% RDN + 50% through FYM recorded the lowest B: C ratio (Table 4.56 and 4.57). This was mainly due to lower cost of cultivation with inorganic N alone compared to combined source (Das *et al*., 2004 and Kairon *et al*., 1996).

5.4.6 N use indices

Residual effect of cropping systems and fertility levels

Application of 50% RDN + 50% through FYM followed by 75% RDN + 25% through FYM recorded the highest ANUE and ANR. Application of 100% RDN in 2006-07 and 75% RDN + 25% through FYM in 2007-08 recorded the highest PNUE followed by 75% RDN + 25% through FYM and 100% RDN, respectively in both the years (Table 4.61, 4.62 and 4.63). Sole cotton maintained the highest NER closely followed by cotton + groundnut system. This could be attributed to the better physical, chemical and biological properties of soil that would have fertilized higher nutrient uptake and yield leading to better fertilizer use efficiencies (Singh *et al*., 1989).

Direct effect of nitrogen

The highest ANUE and ANR were recorded with 50 kg N ha^{-1} applied to wheat while the highest PNUE was recorded with 150 kg N ha^{-1} applied to wheat. In the year 2006-07, 50 kg N ha^{-1} followed by unfertilized control applied to wheat recorded the highest NER. However, in the year 2007-08 unfertilized control followed by 50 kg N ha^{-1} applied, recorded the highest NER. The same trend was followed for wheat grown following sole groundnut crop. This was due to the fact that at lower levels of application, plant used nitrogen efficiently and rapidly for their growth with less wastage. A comparatively lower FUE at higher fertilizer dose could be attributed to less yield advantage for unit quantity of nutrient applied.

5.5 Cotton-wheat sequence

5.5.1 Cotton equivalent yield (CEY)

Residual effect of cropping systems and fertility levels

CEY of cotton+groundnut-wheat system on an average was higher by 14.85 per cent (5.77 q ha^{-1}) than sole cotton-wheat system. The higher CEY of intercropped cotton-wheat system were due to higher intercropped cotton (23.6 per cent) and following wheat (5.11 per cent) over that of cotton-wheat system. Among residual effect of fertility levels, all the 3 fertility levels being on par with each other had significantly higher cotton-wheat system equivalent yield over that of control. However, 75% RDN + 25% through FYM on an average has 47.81 q/ha of CEY i.e. higher by 7.9 and 11.5 per cent over that of 100% RDN and 50% RDN + 25% through FYM, respectively. This might be attributed to increase in economic yields of both the component crops due to residual effects (Table 4.51).

Direct effect of nitrogen

Cotton equivalent yield of cotton-wheat system increased significantly with each successive increase in N dose up to 100 kg N ha^{-1}. 100 kg N ha^{-1} with an average CEY of 40.33 q ha^{-1} has 8.6 % higher productivity than 50 kg N ha^{-1}. Increasing N dose beyond 100 kg N ha^{-1} has reduced CEY by 2.5 q ha^{-1}. The wheat following sole groundnut crop has on an average 9.8 q ha^{-1} lowered CEY than that following after cotton. In the present study, both cotton and wheat need ample supply of N for higher productivity.

5.5.2 Economics

Residual effect of cropping systems and fertility levels

Cotton+groundnut-whet system on an average fetched more net return (Rs 69,073) and B:C ratio over sole cotton (Table 4.56 and 4.57). These values were lowest for groundnut-wheat system. Among fertility levels, application of 50% RDN + 50% through FYM recorded highest net return (Rs 72,747) while 75% RDN + 25% through FYM recorded the highest B: C ratio. The high net returns of cotton+groundnut-wheat system was due to additional net return obtained from groundnut as intercrop. The highest net return of 50% RDN + 50 % through FYM is attributed to higher wheat yield due to residual effect of FYM.

Direct effect of nitrogen

Wheat receiving 100 kg N ha^{-1} fetched the highest net returns (Rs 66,323) and B: C ratio (1.85). Application of N beyond 100 kg ha^{-1} to wheat had decreased net return and B: C ratio. Similar trend was observed for sole groundnut-wheat cropping system. The higher net returns with 100 kg N ha^{-1} application to whet were due to greater increase in yield with lesser input cost in comparison to 50 kg N ha^{-1}.

5.5.3 Total NPK of the system

Cotton+groundnut-wheat system had significantly higher total NPK uptake (504.64 kg ha^{-1}) than cotton-wheat system (365.73 kg ha^{-1}). Among residual effect of fertility levels, 75% RDN + 25% through FYM had significantly higher total NPK uptake (553.20 kg ha^{-1}) over 100% RDF (440.96 kg ha^{-1}). Total NPK uptake was highest with 100 kg N ha^{-1} fertilization of wheat (428.35 kg ha^{-1}). Total NPK uptake by sole groundnut-wheat system did not significantly affect by direct N dose applied to wheat. This could be attributed to the fact that added nitrogen increased the availability of NPK to plants which in turn might have resulted in profuse shoot and root growth and thereby achieving greater absorption of NPK from soil.

5.6 Interaction effect of cropping systems and fertility levels

The interaction effect of cropping systems and fertility levels on the dehydrogenase activity of soil at 150 DAS (Table 4.22) revealed that 75% RDN + 25% through FYM and 50% RDN + 50% through FYM with cotton+groundnut system maintained significantly higher soil dehydrogenase activity of soil over sole cotton in 2006. In 2007, 100% RDN and 50% RDN + 50% through FYM with cotton+groundnut system had higher dehydrogenase activity of soil over sole cotton.

Interactions of preceding cropping systems and their fertility levels on grain yield, nitrogen uptake and OC status after harvest of wheat revealed that wheat following groundnut intercropped cotton receiving 50% RDN+50% through FYM had significantly higher grain yield, nitrogen uptake and OC status after harvest of wheat than that after sole cotton. It could be explained on the basis that dehydrogenase enzyme activity increased with leguminous intercrop because of enhanced microbial activity and enzyme synthesis and accumulation with increased C turn over and nutrient availability due to application of combined sources of N (Dinesh *et al*, 2004 and Malero *et al*., 2007).

5.7 Interaction effect of fertility levels and direct application of N doses to wheat

The interaction effect of fertility levels and direct application of N doses to wheat on dry matter accumulation meter^{-2} at 150 days and grains spike^{-1} of wheat (Table 4.40 and 4.42) revealed that 50% RDN + 50% through FYM applied to preceding crop with 100 kg N ha^{-1} applied to wheat recorded significantly higher dry matter accumulation and grains spike^{-1} over all other N doses applied to wheat. Among fertility levels, 50% RDN + 50% through FYM produced significantly higher dry matter and grains spike^{-1} irrespective of N doses applied to wheat. This could be ascribed to the more availability of residual NPK in the soil due to application of FYM to cotton along with the direct application of 100 kg N ha^{-1} to wheat (Das *et al*., 2004 and Kairon *et al*., 1996).

5.8 Interaction effect of cropping systems and direct application of N doses to wheat

Wheat receiving no N fertilizer following cotton + groundnut system recorded significantly higher dehydrogenase activity of soil over that after sole cotton. At higher N levels (100 and 150 kg N ha^{-1}), the differences in dehydrogenase activity of soil narrowed down and became non-significant in both the cropping systems (Table 4.54). It could be explained on the basis that dehydrogenase enzyme activity increased with leguminous intercrop because of enhanced microbial activity and enzyme synthesis and accumulation with increased nitrogen availability due to application of lower doses of N. At higher doses of N applied to wheat, this effect was nullified.

6

SUMMARY AND CONCLUSION

A field experiment entitled "**Effect of nitrogen management through organic and inorganic sources in sole and intercropped *Bt* cotton-wheat system**" was conducted during *kharif* and *rabi* seasons of 2006-07 and 2007-08 at the research farm, Division of Agronomy, Indian Agricultural Research Institute, New Delhi to evaluate the effect of cropping systems, fertility levels and direct application of N doses to wheat on the productivity of *Bt* cotton-wheat cropping system. The salient findings of the investigation have been summarized here under.

6.1 Cotton

Cropping systems (sole cotton and cotton + groundnut) had no effect on growth (plant height, LAI, dry matter partitioning, root dry weight, number of main stem nodes plant^{-1}, unopened bolls and total dry matter accumulation) and yield attributes (opened bolls plant^{-1} and boll weight), yield (seed cotton yield and stalk yield), fiber quality parameters (Bartlett's index, 2.5% Span length, 50% Span length, uniformity ratio, fibre strength, fibre elongation and micronaire), nutrient content and uptake (N, P, K) in different plant parts and chlorophyll content at various growth stages.

Application of 75% RDN + 25% through FYM and 100% RDN being on par recorded higher plant growth and yield parameters, yield, fibre quality (ginning percentage, seed index, lint index and micronaire values only), nutrient content and uptake of different plant parts and chlorophyll content at various growth stages over 50% RDN + 50% through FYM and control. Further 50% RDN + 50% through FYM also recorded significantly higher all these parameters over control.

Cropping system had no significant effect on organic carbon, available soil N, P and K after harvest of *kharif* crops. Dehydrogenase activity of soil alone was significantly influenced by cropping system, being highest with cotton + groundnut system followed by sole cotton over sole groundnut. Application of 50% RDN + 50% through FYM recorded higher organic carbon, available soil NPK and dehydrogenase activity of soil over all other treatments. Further application of 75% RDN + 25% through FYM and 100% RDN had similar soil fertility status after harvest of *kharif* crops.

Cotton + groundnut system recorded significantly higher cotton equivalent yield over sole cotton. Application of 75% RDN + 25% through FYM recorded markedly higher cotton equivalent yield over 50% RDN + 50% through FYM and control.

Cotton + groundnut system fetched higher net return and B: C ratio over sole cotton and groundnut crops. Further, application of 75% RDN + 25% through FYM recorded higher net return followed by 100% RDN. The highest B: C ratio was observed with 100% RDN followed by 75% RDN + 25% through FYM.

Application of 75% RDN + 25% through FYM recorded higher agronomic N-use efficiency, while 50% RDN + 50% through FYM recorded higher physiological N-use efficiency, Apparent N recovery, Physiological efficiency index of N and N-harvest index over other fertility levels.

6.2 Groundnut

Sole groundnut recorded significantly higher plant growth (number of branch plant^{-1}, LAI and dry matter accumulation) and yield attributes (pods plant^{-1}, kernel pod^{-1}, 1,000-kernel weight and shelling percentage), yield (pod, haulm and biological) and higher NPK concentration and uptake in kernel and haulm over intercropped groundnut. However, intercropped groundnut maintained significantly taller plants at 80 days onwards till harvest, while sole groundnut had significantly taller plants at early stage (40 DAS) over intercropped groundnut.

Fertility levels significantly influenced all plant growth parameters, except branch plant^{-1}. At 40 days, 100% RDN being on par with 75% RDN + 25% through FYM recorded taller plants, higher LAI and dry matter accumulation over control. At 80 days and at harvest, 75% RDN + 25% through FYM being on par with 100% RDN recorded taller plants, higher LAI and dry matter accumulation over 50% RDN + 50% through FYM and control. Control was on par with 100% RDN in 2006, and 50% RDN + 50% through FYM in 2007 and produced significantly more pods plant^{-1} over other fertility levels. Control though produced the highest kernels pod^{-1}, pod yield, haulm yield, biological yield and shelling percentage, but was on par with 50% RDN + 50% through FYM.

The NPK content in kernel and haulm and protein content in kernel markedly increased with 100% RDN and 75% RDN + 25% through FYM over control. Control treatment being on par with 50% RDN + 50% through FYM recorded higher NPK uptake in kernel, haulm and total uptake, besides protein yield.

Control treatment gave the highest LER, RNR and ATER followed by 50% RDN + 50% through FYM. Aggressivity values indicated that cotton had positive values for all fertility levels while the trend was reverse for groundnut. This shows that groundnut was dominated by cotton under all fertility levels. At all fertility levels, the product of RCC was less than one indicates unsuitability of groundnut as intercrop in cotton due to adverse effect of cotton on intercrop. Competition index values were less than one for all fertility levels indicate positive benefit of cotton and groundnut in intercropping due to complementary use of time and space.

6.3 Wheat

Residual effect of cropping system and fertility

Plant growth (plant height, number of tiller meter^{-2} and dry matter accumulation meter^{-2}) and yield attributes (number of spike meter^{-2} and 1,000-grain weight), yield (grain and biological), harvest index, nutrient content and uptake (N, P and K in grain, straw and total) in wheat were significantly higher after cotton + groundnut intercropping over sole cotton. The organic carbon content of soil after harvest of wheat was significantly higher in cotton + groundnut system over sole cotton. Available P content of soil after wheat harvest was, however, significantly higher in sole cotton over cotton + groundnut system. Wheat following sole groundnut had the highest net return while that after cotton + groundnut system had the highest B: C ratio.

All plant growth and yield parameters, yield, nutrient content and uptake, organic carbon content of soil, available N, P and K content of soil, net return, ANR, ANUE were the highest with 50% RDN + 50% through FYM. 100% RDN recorded the highest B:C ratio. Application of 100% RDN in 2006-07 and 75% RDN + 25% through FYM in 2007-08 recorded the highest PNUE.

Direct effect of nitrogen

Wheat recorded significantly higher plant growth and yield parameters, yield, nutrient content and uptake, net return and B: C ratio, with each successive increase in nitrogen dose up to 100 kg ha^{-1} only. There was, however, marked reduction in all parameters at 150 kg N ha^{-1} over 100 kg N ha^{-1}. Organic carbon, available N and dehydrogenase activity of soil were significantly increased with each successive increase in N dose up to 150 kg ha^{-1}. A reverse trend was, however, observed for available P and K content of soil. The highest ANUE and ANR were recorded with 50 kg N ha^{-1} applied to wheat, while the highest PNUE was recorded with 150 kg N ha^{-1}. Similar trend was observed for all parameters of wheat following sole groundnut crop.

6.4 Cotton-wheat sequence

In cotton-wheat system, cotton equivalent yield of the system, net return, B: C ratio and total NPK uptake were significantly higher with cotton + groundnut system as compared with sole cotton. All the 3 fertility levels, being on par with each other, had significantly higher cotton equivalent yield over that of control. Application of 50% RDN + 50% through FYM recorded the highest net return, while 75% RDN + 25% through FYM recorded the highest B: C ratio and total uptake of N, P and K.

Cotton equivalent yield of cotton-wheat system, net return, B: C ratio and total uptake of N, P and K were increased with each successive increase in N dose up to 100 kg ha^{-1}. Same trend was observed for sole groundnut-wheat system.

Conclusion

Based on the findings of present investigation, it may be concluded that:

(1) Groundnut intercropping had no significant effect on growth and yield attributes, yield, nutrient uptake and fibre quality of cotton as compared to sole cotton.

(2) Among N management practices of cotton, substitution of 25% RDN through FYM was good as 100% RDN and both recorded significantly higher growth and yield attributes, yield, nutrient uptake and fibre quality of cotton over 50% RDN substitution through FYM and unfertilized control.

(3) Intercropping of groundnut in cotton was advantageous as evident from intercropping indices. Intercropped groundnut performed best where cotton growth was poor *i.e.* under control where no N was applied to cotton.

(4) Performance of wheat was markedly superior after cotton + groundnut system. Wheat crop responded to direct application of 100 kg N ha^{-1} in terms of growth and yield attributes, yield and nutrient uptake.

(5) Groundnut intercropped in cotton with 50% RDN substitution through FYM and direct application of 100 kg N ha^{-1} to wheat recorded the highest cotton equivalent yield of system and net return. However, B: C ratio was higher with 25% RDN substitution through FYM and direct application of 100 kg N ha^{-1} to wheat.

(6) Substitution of 50% RDN through FYM and direct application of 150 kg N ha^{-1} to wheat resulted in higher organic carbon, available N content of soil in cotton-wheat system.

Future line of research work

In view of findings of the present investigation, following future lines of research thrust may be suggested:

(i) Similar studies may be made with other nutrients especially P and K to find out the requirement of these nutrients in cropping system.

(ii) Other leguminous intercrops in cotton may also be tested to assess the total productivity and soil health.

(iii) Various indigenous sources of P like rock phosphate and pressmud with phosphate solubilizers i.e. PSB and AM may be tried in this cropping system.

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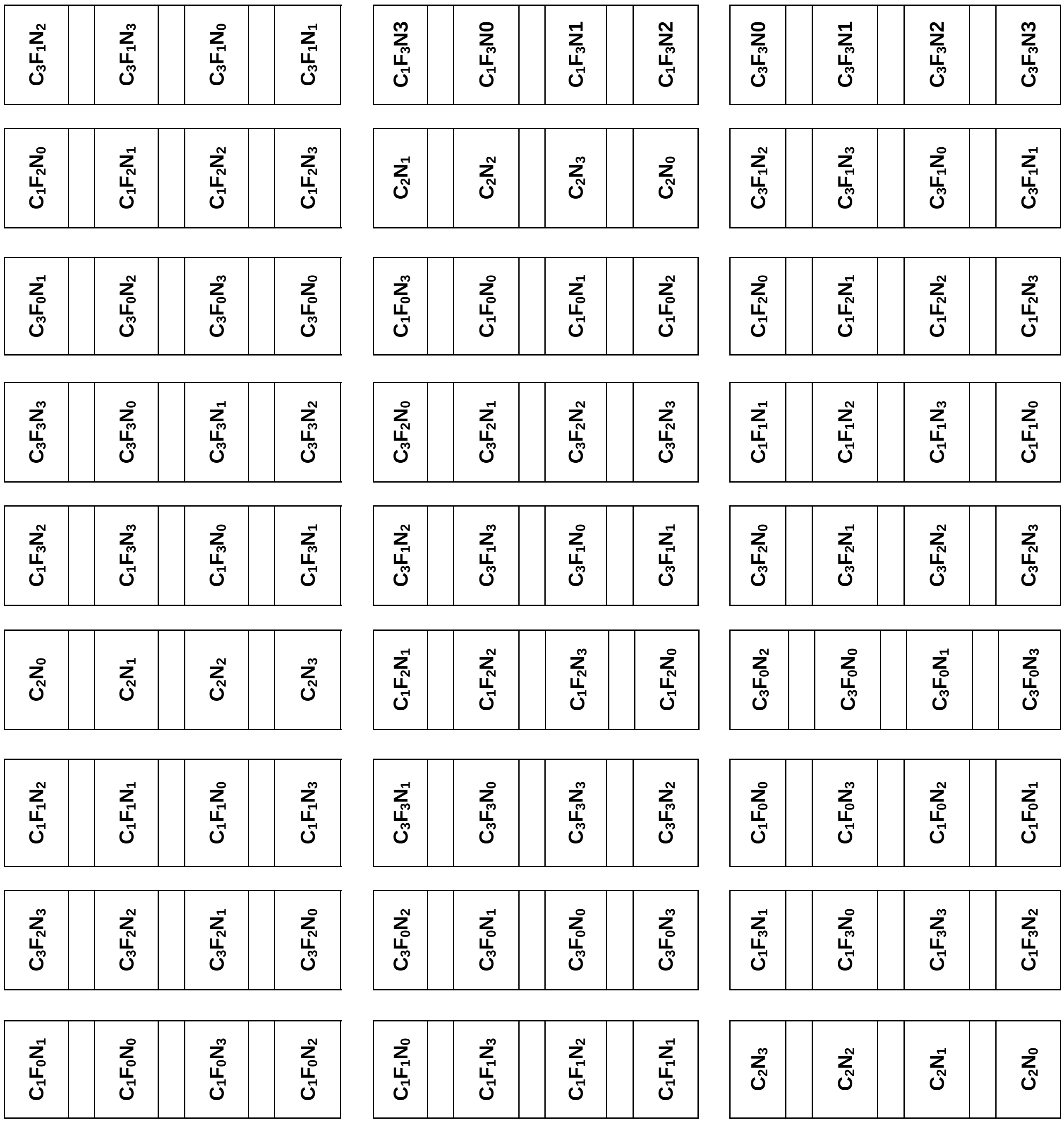

REP 1 **REP 2** **REP 3**

Fig.3.3 Layout plan of experiment field

Treatment details

Main plot treatments (Nine)

A. cropping systems	**Symbol**
i.Sole cotton	C_1
ii.Cotton + groundnut (1:3)	C_3
B.Fertility levels	
i.Control (no application of N)	F_0
ii.100 % RDN	F_1
iii.75% RDN + 25 % FYM	F_2
iv.50% RDN + 50 % FYM	F_3
C. An additional main plot with sole groundnut receiving recommended fertilizer dose	C_2

Sub-plot treatments (Four)

B. N applied to wheat (kg ha^{-1})	**Symbol**
1. Control	N_0
2. 50	N_1
3. 100	N_2
4. 150	N_3

Replication : Three

Appendix I. Estimation of common cost of cultivation for cotton for the year 2006

S.No.	Particulars	Rates (Rs unit $^{-1}$)	Actual cost (Rs)
1.	Land preparation		
	(a) Ploughing	575 ha $^{-1}$	575
	(b) Harrowing	575 ha $^{-1}$	575
	(c) Planking	175 ha $^{-1}$	175
2.	Layout (2 mandays)	122 manday $^{-1}$	244
3.	Seed (2 kg/ha)	1667 kg $^{-1}$	3334
4.	Cost of fertilizer other than treatment (60 kg P_2O_5 through SSP)	27.50 kg $^{-1}$	1650
5.	Sowing	400 ha $^{-1}$	400
6.	Thinning and gap filling (4 mandays)	122 manday $^{-1}$	488
7.	Interculture operations		
	Hand weeding (8 mandays)	122 manday $^{-1}$	976
8.	Plant protection		
	(a) Monocrotophos @ 2.5 litre/ha (two)	215 litre $^{-1}$	1075
	(b) Application of insecticides (4 mandays)	122 manday $^{-1}$	488
9.	Irrigations (5)		
	(a) Water charges	200 ha $^{-1}$	1000
	(b) Labour charges (10 mandays)	122 manday $^{-1}$	1220
10.	Pickings (12 mandays)	122 manday $^{-1}$	1464
11.	Cutting of stickes (8 mandays)	122 manday $^{-1}$	976
12.	Rental value of land (6 months)	200 month $^{-1}$	1200
13.	Interest on capital investment @ 9% per annum	1057	528
14.	Miscellaneous	150	150
Total			Rs.15, 542

Appendix II. Estimation of common cost of cultivation for *cotton* for the year 2007

S.No.	Particulars	Rates (Rs unit $^{-1}$)	Actual cost (Rs)
1.	Land preparation		
	(a) Ploughing	625 ha $^{-1}$	625
	(b) Harrowing	625 ha $^{-1}$	625
	(c) Planking	200 ha $^{-1}$	200
2.	Layout (2 mandays)	127 manday $^{-1}$	254
3.	Seed (2 kg/ha)	1667 kg $^{-1}$	3334
4.	Cost of fertilizer other than treatment (60 kg P_2O_5 through SSP)	28.00 kg $^{-1}$	1680
5.	Sowing	450 ha $^{-1}$	450
6.	Thinning and gap filling (4 mandays)	127 manday $^{-1}$	508
9.	Interculture operations		
	Hand weeding (10 mandays)	127 manday $^{-1}$	1270
10.	Plant protection		
	(a) Monocrotophos @ 2.5 litre/ha (two)	215 litre $^{-1}$	1075
	(b) Application of insecticides (4 mandays)	127 manday $^{-1}$	508
9.	Irrigations (5)		
	(a) Water charges	200 ha $^{-1}$	1000
	(b) Labour charges (10 mandays)	127 manday $^{-1}$	1270
10.	Pickings (12 mandays)	127 manday $^{-1}$	1524
11.	Cutting of stickes (8 mandays)	127 manday $^{-1}$	1016
12.	Rental value of land (6 months)	200 month $^{-1}$	1200
13.	Interest on capital investment @ 9% per annum	1092	546
14.	Miscellaneous	150	150
Total			Rs.17, 235

Appendix III. Estimation of common cost of cultivation for groundnut for the year 2006

S.No.	Particulars	Rates (Rs unit $^{-1}$)	Actual cost (Rs)
1.	Land preparation		
	(a) Ploughing	575 ha $^{-1}$	575
	(b) Harrowing	575 ha $^{-1}$	575
	(c) Planking	175 ha $^{-1}$	175
2.	Layout (2 mandays)	122 manday $^{-1}$	244
3.	Seed (100 kg/ha)	25 kg $^{-1}$	2500
4.	Cost of fertilizers		
	(a) 20 kg N through urea	11.09 kg $^{-1}$	222
	(b) 50 kg P_2O_5 through urea	27.50 kg $^{-1}$	1375
5.	Sowing	400 ha $^{-1}$	400
6.	Thinning and gap filling (4 mandays)	122 manday $^{-1}$	488
11.	Interculture operations		
	Hand weeding (8 mandays)	122 manday $^{-1}$	976
12.	Plant protection		
	(a) Monocrotophos @ 2.5 litre/ha (two)	215 litre $^{-1}$	1075
	(b) Application of insecticides (4 mandays)	122 manday $^{-1}$	488
9.	Irrigations (4)		
	(a) Water charges	200 ha $^{-1}$	800
	(b) Labour charges (8 mandays)	127 manday $^{-1}$	976
10.	Digging (8 mandays)	122 manday $^{-1}$	976
11.	Rental value of land (6 months)	200 month $^{-1}$	1200
12.	Interest on capital investment @ 9% per annum	1092	546
13.	Miscellaneous	150	150
Total			Rs.13, 723

Appendix IV. Estimation of common cost of cultivation for groundnut for the year 2007

S.No.	Particulars	Rates (Rs unit $^{-1}$)	Actual cost (Rs)
1.	Land preparation		
	(a) Ploughing	625 ha $^{-1}$	625
	(b) Harrowing	625 ha $^{-1}$	625
	(c) Planking	200 ha $^{-1}$	200
2.	Layout (2 mandays)	127 manday $^{-1}$	254
3.	Seed (100 kg/ha)	27 kg $^{-1}$	2700
4.	Cost of fertilizers		
	(a) 20 kg N through urea	11.50 kg $^{-1}$	230
	(b) 50 kg P_2O_5 through urea	28.00 kg $^{-1}$	1400
5.	Sowing	450 ha $^{-1}$	450
6.	Thinning and gap filling (4 mandays)	127 manday $^{-1}$	508
13.	Interculture operations		
	Hand weeding (8 mandays)	127 manday $^{-1}$	1016
14.	Plant protection		
	(a) Monocrotophos @ 2.5 litre/ha (two)	215 litre $^{-1}$	1075
	(b) Application of insecticides (4 mandays)	127 manday $^{-1}$	508
9.	Irrigations (4)		
	(a) Water charges	200 ha $^{-1}$	800
	(b) Labour charges (8 mandays)	127 manday $^{-1}$	1016
10.	Digging (8 mandays)	127 manday $^{-1}$	1016
11.	Rental value of land (6 months)	200 month $^{-1}$	1200
12.	Interest on capital investment @ 9% per annum	1057	528
13.	Miscellaneous	150	150
Total			Rs.14,301

Appendix V. Estimation of common cost of cultivation for wheat for the year 2006-07

S.No.	Particulars	Rates (Rs unit $^{-1}$)	Actual cost (Rs)
1.	Land preparation		
	(i) Ploughing	575 ha $^{-1}$	575
	(ii) Double discing (two)	575 ha $^{-1}$	1150
	(iii) Planking	175 ha $^{-1}$	175
2.	Layout (2 mandays)	122 manday $^{-1}$	244
3.	Seed (125 kg/ha)	25 kg $^{-1}$	3125
4.	Cost of fertilizer other than treatments (60 kg P_2O_5 through SSP)	27.50 kg $^{-1}$	1650
5.	Sowing	400 ha $^{-1}$	400
6.	Thinning and gap filling (2 mandays)	122 manday $^{-1}$	244
7.	Interculture operations		
	(a) Hand weeding (4 mandays)	122 manday $^{-1}$	488
	(b) Isoproturon (1.0 kg a.i./ha)	487 kg $^{-1}$	487
	(c) Spray of isoproturon (2 mandays)	122 manday $^{-1}$	244
8.	Irrigations (5)		
	(a) Water charges	200 ha $^{-1}$	1000
	(b) Labour charges (5 mandays)	122	610
9.	Harvesting (8 mandays)	122 manday $^{-1}$	976
10.	Threshing and cleaning (6 mandays)	122 manday $^{-1}$	732
11.	Rental value of land (5 months)	200 month $^{-1}$	1000
12.	Interest on capital investment @ 9% per annum	1123	472
13.	Miscellaneous	120	120
Total			Rs. 13692

Appendix VI. Estimation of common cost of cultivation for wheat for the year 2007-08

S.No.	Particulars	Rates (Rs unit $^{-1}$)	Actual cost (Rs)
1.	Land preparation		
	(i) Ploughing	625 ha $^{-1}$	625
	(ii) Double discing (two)	625 ha $^{-1}$	1250
	(iii) Planking	200 ha $^{-1}$	200
2.	Layout (2 mandays)	127 manday $^{-1}$	254
3.	Seed (125 kg/ha)	30 kg $^{-1}$	3750
4.	Cost of fertilizer other than treatments (60 kg P_2O_5 through SSP)	28.00 kg $^{-1}$	1680
5.	Sowing	450 ha $^{-1}$	450
6.	Thinning and gap filling (2 mandays)	127 manday $^{-1}$	254
7.	Interculture operations		
	(a) Hand weeding (3 mandays)	127 manday $^{-1}$	381
	(b) Isoproturon (1.0 kg a.i./ha)	487 kg $^{-1}$	487
	(c) Spray of isoproturon (2 mandays)	127 manday $^{-1}$	254
8.	Irrigations (5)		
	(a) Water charges	200 ha $^{-1}$	1000
	(b) Labour charges (5 mandays)	127	635
9.	Harvesting (8 mandays)	127 manday $^{-1}$	1016
10.	Threshing and cleaning (6 mandays)	127 manday $^{-1}$	762
11.	Rental value of land (5 months)	200 month $^{-1}$	1000
12.	Interest on capital investment @ 9% per annum	1172	492
13.	Miscellaneous	150	150
Total			Rs. 14,640

Appendix VII. Economics of different treatment (cotton and groundnut)

Treatment	Common cost		Added cost		Total cost		Gross returns		Net returns		Benefit: cost ratio	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
C_1F_0	15,542	17,235	0	0	15542	17235	42995	29944	27453	12709	1.77	0.74
C_1F_1	15,542	17,235	1664	1725	17206	18960	63052	55193	45846	36233	2.66	1.91
C_1F_2	15,542	17,235	5261	5314	20803	22549	72184	60490	51381	37941	2.47	1.68
C_1F_3	15,542	17,235	8370	8413	23912	25648	64372	42731	40460	17083	1.69	0.66
C_2	15,542	17,235	0	0	13723	14301	18476	19813	4753	5512	0.35	0.38
C_3F_0	15,542	17,235	1000	1050	16542	18285	57114	45432	40572	27147	2.45	1.48
C_3F_1	15,542	17,235	2664	2775	18206	20010	78807	68266	60601	48256	3.33	2.41
C_3F_2	15,542	17,235	6261	6364	21803	23599	84501	74702	62698	51103	2.87	2.16
C_3F_3	15,542	17,235	9370	9463	24912	26698	75268	58347	50356	31649	2.02	1.18

Cost of nitrogen through urea: Rs 11.09 kg^{-1} N (2006)
Rs 11.50 kg^{-1} N (2007)

Sale price of seed cotton: Rs 1990 q^{-1} (2006)
Rs 2030 q^{-1} (2007)

Sale price of cotton sticks: Rs 60 q^{-1} (2006)
Rs 65 q-1 (2007)

Sale price of groundnut pods: Rs 1520 q^{-1} (2006)
Rs 1550 q^{-1} (2007)

Sale price of groundnut haulm: Rs 80 q^{-1} (2006)
Rs 85 q^{-1} (2007)

Appendix VIII. Economics of different treatments (Wheat)

Treatment	Common cost		Added cost		Total cost		Gross returns		Net returns		Benefit:cost ratio	
	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08
$C_1F_0N_0$	13692	14640	0	0	13692	14640	19028	21870	5336	7230	0.39	0.49
$C_1F_0N_1$	13692	14640	554	575	14246	15215	28772	33370	14526	18155	1.02	1.19
$C_1F_0N_2$	13692	14640	1109	1150	14801	15790	35575	41590	20774	25800	1.40	1.63
$C_1F_0N_3$	13692	14640	1663	1725	15355	16365	34700	40490	19345	24125	1.26	1.47
$C_1F_1N_0$	13692	14640	0	0	13692	14640	21414	27084	7722	12444	0.56	0.85
$C_1F_1N_1$	13692	14640	554	575	14246	15215	32331	39440	18085	24225	1.27	1.59
$C_1F_1N_2$	13692	14640	1109	1150	14801	15790	35073	42801	20272	27011	1.37	1.71
$C_1F_1N_3$	13692	14640	1663	1725	15355	16365	34417	42000	19062	25635	1.24	1.57
$C_1F_2N_0$	13692	14640	0	0	13692	14640	30386	37494	16694	22854	1.22	1.56
$C_1F_2N_1$	13692	14640	554	575	14246	15215	34231	41714	19985	26499	1.40	1.74
$C_1F_2N_2$	13692	14640	1109	1150	14801	15790	39959	48607	25158	32817	1.70	2.08
$C_1F_2N_3$	13692	14640	1663	1725	15355	16365	35467	43120	20112	26755	1.31	1.63
$C_1F_3N_0$	13692	14640	0	0	13692	14640	31664	39550	17972	24910	1.31	1.70
$C_1F_3N_1$	13692	14640	554	575	14246	15215	33578	41713	19332	26498	1.36	1.74
$C_1F_3N_2$	13692	14640	1109	1150	14801	15790	36928	45790	22127	30000	1.49	1.90
$C_1F_3N_3$	13692	14640	1663	1725	15355	16365	36928	45790	21573	29425	1.40	1.80
C_2N_0	13692	14640	0	0	13692	14640	25611	33830	11919	19190	0.87	1.31
C_2 N_1	13692	14640	554	575	14246	15215	37325	49963	23079	34748	1.62	2.28
C_2 N_2	13692	14640	1109	1150	14801	15790	39034	50507	24233	34717	1.64	2.20
C_2 N_3	13692	14640	1663	1725	15355	16365	41436	52147	26081	35782	1.70	2.19
$C_3F_0N_0$	13692	14640	0	0	13692	14640	26286	31867	12594	17227	0.92	1.18
$C_3F_0N_1$	13692	14640	554	575	14246	15215	34481	41050	20235	25835	1.42	1.70
$C_3F_0N_2$	13692	14640	1109	1150	14801	15790	38070	45370	23269	29580	1.57	1.87
$C_3F_0N_3$	13692	14640	1663	1725	15355	16365	36736	43707	21381	27342	1.39	1.67
$C_3F_1N_0$	13692	14640	0	0	13692	14640	30117	37223	16425	22583	1.20	1.54
$C_3F_1N_1$	13692	14640	554	575	14246	15215	35534	43070	21288	27855	1.49	1.83
$C_3F_1N_2$	13692	14640	1109	1150	14801	15790	41778	50570	26977	34780	1.82	2.20
$C_3F_1N_3$	13692	14640	1663	1725	15355	16365	39106	47423	23751	31058	1.55	1.90
$C_3F_2N_0$	13692	14640	0	0	13692	14640	26361	32580	12669	17940	0.93	1.23
$C_3F_2N_1$	13692	14640	554	575	14246	15215	32272	39883	18026	24618	1.27	1.62
$C_3F_2N_2$	13692	14640	1109	1150	14801	15790	35078	42580	20277	26790	1.37	1.70
$C_3F_2N_3$	13692	14640	1663	1725	15355	16365	32311	39683	16956	23318	1.10	1.42
$C_3F_3N_0$	13692	14640	0	0	13692	14640	25253	32560	11561	17920	0.84	1.22
$C_3F_3N_1$	13692	14640	554	575	14246	15215	33642	42087	19396	26872	1.36	1.77
$C_3F_3N_2$	13692	14640	1109	1150	14801	15790	37747	46903	22946	31113	1.55	1.97
$C_3F_3N_3$	13692	14640	1663	1725	15355	16365	35703	44263	20348	27898	1.33	1.70

Cost of Nitrogen: Rs 11.09 kg^{-1} N (2006-07)
Rs 11.50 kg^{-1} N (2007-08)

Sale price of wheat grain: Rs 850 q^{-1} (2006-07)
Rs 1000 q^{-1} (2007-08)

Sale price of wheat straw: Rs 150 q^{-1} (2006-07)
Rs 160 q^{-1} (2007-08)

Appendix IX. Economics of different treatment (Cotton-Wheat system)

Treatment	Total cost (Rs ha^{-1})						Net return (Rs ha^{-1})						Benefit:cost ratio	
	Cotton		Wheat		Cotton-wheat		Cotton		Wheat		Cotton-wheat			
	2006	2007	2006-07	2007-08	2006-07	2007-08	2006	2007	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08
$C_1F_0N_0$	15542	17235	13692	14640	29234	31875	27453	12709	5336	7230	32789	19939	1.12	0.63
$C_1F_0N_1$	15542	17235	14246	15215	29788	32450	27453	12709	14526	18155	41979	30864	1.41	0.95
$C_1F_0N_2$	15542	17235	14801	15790	30343	33025	27453	12709	20774	25800	48227	38509	1.59	1.17
$C_1F_0N_3$	15542	17235	15355	16365	30897	33600	27453	12709	19345	24125	46798	36834	1.51	1.10
$C_1F_1N_0$	17206	18960	13692	14640	30898	33600	45846	36233	7722	12444	53568	48677	1.73	1.45
$C_1F_1N_1$	17206	18960	14246	15215	31452	34175	45846	36233	18085	24225	63931	60458	2.03	1.77
$C_1F_1N_2$	17206	18960	14801	15790	32007	34750	45846	36233	20272	27011	66118	63244	2.07	1.82
$C_1F_1N_3$	17206	18960	15355	16365	32561	35325	45846	36233	19062	25635	64908	61868	1.99	1.75
$C_1F_2N_0$	20803	22549	13692	14640	34495	37189	51381	37941	16694	22854	68075	60795	1.97	1.63
$C_1F_2N_1$	20803	22549	14246	15215	35049	37764	51381	37941	19985	26499	71366	64440	2.04	1.71
$C_1F_2N_2$	20803	22549	14801	15790	35604	38339	51381	37941	25158	32817	76539	70758	2.15	1.85
$C_1F_2N_3$	20803	22549	15355	16365	36158	38914	51381	37941	20112	26755	71493	64696	1.98	1.66
$C_1F_3N_0$	23912	25648	13692	14640	37604	40288	40460	17083	17972	24910	58432	41993	1.55	1.04
$C_1F_3N_1$	23912	25648	14246	15215	38158	40863	40460	17083	19332	26498	59792	43581	1.57	1.07
$C_1F_3N_2$	23912	25648	14801	15790	38713	41438	40460	17083	22127	30000	62587	47083	1.62	1.14
$C_1F_3N_3$	23912	25648	15355	16365	39267	42013	40460	17083	21573	29425	62033	46508	1.58	1.11
$C_2 N_0$	13723	14301	13692	14640	27415	28941	4753	5512	11919	19190	16672	24702	0.61	0.85
$C_2 N_1$	13723	14301	14246	15215	27969	29516	4753	5512	23079	34748	27832	40260	1.00	1.36
$C_2 N_2$	13723	14301	14801	15790	28524	30091	4753	5512	24233	34717	28986	40229	1.02	1.34
$C_2 N_3$	13723	14301	15355	16365	29078	30666	4753	5512	26081	35782	30834	41294	1.06	1.35
$C_3F_0N_0$	16542	18285	13692	14640	30234	32925	40572	27147	12594	17227	53166	44374	1.76	1.35
$C_3F_0N_1$	16542	18285	14246	15215	30788	33500	40572	27147	20235	25835	60807	52982	1.98	1.58
$C_3F_0N_2$	16542	18285	14801	15790	31343	34075	40572	27147	23269	29580	63841	56727	2.04	1.66
$C_3F_0N_3$	16542	18285	15355	16365	31897	34650	40572	27147	21381	27342	61953	54489	1.94	1.57
$C_3F_1N_0$	18206	20010	13692	14640	31898	34650	60601	48256	16425	22583	77026	70839	2.41	2.04
$C_3F_1N_1$	18206	20010	14246	15215	32452	35225	60601	48256	21288	27855	81889	76111	2.52	2.16
$C_3F_1N_2$	18206	20010	14801	15790	33007	35800	60601	48256	26977	34780	87578	83036	2.65	2.32
$C_3F_1N_3$	18206	20010	15355	16365	33561	36375	60601	48256	23750.67	31058.47	84352	79314	2.51	2.18
$C_3F_2N_0$	21803	23599	13692	14640	35495	38239	62698	51103	12669.33	17940.27	75367	69043	2.12	1.81
$C_3F_2N_1$	21803	23599	14246	15215	36049	38814	62698	51103	18026	24618.07	80724	75721	2.24	1.95
$C_3F_2N_2$	21803	23599	14801	15790	36604	39389	62698	51103	20276.67	26789.87	82975	77893	2.27	1.98
$C_3F_2N_3$	21803	23599	15355	16365	37158	39964	62698	51103	16956.33	23318.47	79654	74421	2.14	1.86
$C_3F_3N_0$	24912	26698	13692	14640	38604	41338	50356	31649	11560.67	17920	61917	49569	1.60	1.20
$C_3F_3N_1$	24912	26698	14246	15215	39158	41913	50356	31649	19396	26871.93	69752	58521	1.78	1.40
$C_3F_3N_2$	24912	26698	14801	15790	39713	42488	50356	31649	22946.33	31113.47	73302	62762	1.85	1.48
$C_3F_3N_3$	24912	26698	15355	16365	40267	43063	50356	31649	20347.67	27898.47	70704	59547	1.76	1.38

Appendix XI Mean weekly meteorological data during the 2007-08

Month	Std. Week	Rainfall (mm)	Temperature(^{0C}) Maximum	Minimum	Sunshine (hrs/day)	Wind velocity (km/hr)	RH (%)	Evaporation (mm)
June	23	0	43.2	30.2	8.2	9.3	31	13.2
	24	31.2	37.8	26.8	3.5	5.6	67	11.9
	25	24.2	32.6	25.7	6.4	3.1	70	9.3
	26	28.4	34.6	26.8	7.3	4	67	10.9
July	27	11.2	34.6	26.4	6.3	6.2	79	9.1
	28	45	35.2	26	6	6.9	69	7.7
	29	11.2	36	26.9	6.7	8.4	57	9.2
	30	16.2	34.4	26.4	1.7	5.5	71	7.9
	31	201	33.1	25	2.7	1.2	77	6.8
Aug.	32	2.8	34.1	26.9	8.2	2.4	69	7.2
	33	8.8	34	26	5.2	3.2	71	6.9
	34	1.4	33.1	25.6	6.5	1	73	7.9
	35	2.8	33.8	25.6	4.8	1.6	76	7.6
Sept.	36	26.8	33.7	24.9	4.2	0.7	74	7.7
	37	37.4	33.1	22.6	5	1.4	70	8
	38	0	32.1	25.2	7.6	1.7	64	7.5
	39	8.6	27.4	22	5.7	2.9	75	6.5
Oct.	40	0	34.6	16.9	9	3.6	74	6.7
	41	0	33.7	14.1	8.3	3.7	75	7.3
	42	0	31.5	14.8	7.3	1.7	79	6.1
	43	0	32.2	14.6	7	2.2	78	5.8
	44	0	30.8	12	7.3	1.2	81	4.8
Nov.	45	0	28.9	12.4	3	1.8	89	3.8
	46	0	28.6	11.5	3.6	1	91	3.4
	47	0	26.8	7.8	3.8	1.6	92	3
	48	0	26.3	9.7	2.3	1.2	94	2.6
Dec.	49	0	22.9	6.9	3.1	2.9	92	2.6
	50	0	19.7	6.9	1.1	5.3	92	2.1
	51	0	21.8	4.4	6.5	5.6	88	2.7
	52	0	21.5	5	5.4	5	93	2.8
Jan.	1	0	19.4	2.3	4.6	1.6	95	2.2
	2	1.8	21.8	8.9	3.9	5.6	90	2.5
	3	0	21	8.7	5.9	5	86	3.1
	4	0	16.6	3.3	4.9	3.5	79	2.7
Feb	5	0	17.7	3.4	4.3	2.9	95	2.1
	6	0	18.1	5.6	3.9	4.7	84	2.9
	7	0	22.8	5.9	8	4.9	71	3.7
	8	0	25.6	10	5	2.4	75	4.4
	9	0	28.4	10.4	4.5	2.9	77	4.7
March	10	0	30.6	14.3	4.7	2.2	89	4.5
	11	0	30.5	13.5	6.4	2.9	79	5.4
	12	0	33.4	14.4	7.6	3	71	6.8
	13	0.8	34.5	16	8.1	3.6	60	9
April	14	30.2	28.1	16.1	5.3	3.7	83	6.7
	15	0	35.6	20.4	8.5	4.8	54	9.9
	16	0	36.8	20.3	9.6	4.3	46	11.8
	17	0	40.3	20.5	9.5	3	51	12
	18	0	40.9	23.2	8.3	4.3	43	12.2

Appendix X Mean weekly meteorological data during the 2006-07

Month	Std. Week	Rainfall (mm)	Temperature(0C) Maximum	Minimum	Sunshine (hrs/day)	Wind velocity (km/hr)	RH (%)	Evaporation (mm)
June	23	0	37.4	25.1	7.3	4.2	60	8.7
	24	0	41	26.2	4.5	7.8	47.1	10.5
	25	24	37.4	25.9	6.3	5.6	55	9.5
	26	73.6	34.3	26.6	4.5	3.8	78	7
July	27	0	37.8	29	9.1	5.9	65	10
	28	162	32.5	26.3	0.8	4.2	88	5.5
	29	9.8	33.5	26.9	4.2	2	86	5.9
	30	91.2	31.8	25.9	3.4	4.5	89	4.5
	31	18.5	32.5	25.8	7.7	6.2	83	7.1
Aug.	32	5.6	32.8	25.7	8.9	5.9	82	7.9
	33	0	35.1	26.5	8.5	3.2	76	8.9
	34	1.6	34.2	25.8	7.2	4.5	72	9.3
	35	81.2	33	24	4.7	9	80	7.6
Sept.	36	13.2	32.3	24.6	8.5	2.9	82	6.5
	37	13.2	34.1	24.6	7.9	3.5	76	7.6
	38	11.5	34.8	24.1	8.2	3.4	83	8
	39	0	34	20.2	7.1	3.1	78	8
Oct.	40	0	36	19.8	8.9	2.1	75	8.5
	41	0	35.5	20.6	9.1	5.7	65	8.6
	42	0.4	32.5	18.8	6.7	4.1	81	6.8
	43	0	29.4	19.9	7.3	1	85	5.8
	44	0	30.1	14.7	7.5	0.1	90	4
Nov.	45	0	30.2	14.2	4	0.5	90	3.3
	46	0	28.8	13	4.8	1	88	3.3
	47	0.3	27	12.4	6.6	5.3	78	4
	48	0	24.4	7	6.8	3.7	77	4.2
Dec.	49	0	24.1	11	2.4	2.9	77	3.1
	50	0	21.7	7.8	2.7	4	80	2.3
	51	0	23.3	7.3	2.3	2.7	90	2.8
	52	2.4	20.1	5.6	6.2	3.2	92	2.5
Jan.	1	0	17.4	4.8	4.5	4.64	83	2
	2	0	18.2	2.2	4.1	2.6	94	2
	3	0	20.7	4.2	5.8	3.2	91	2.9
	4	0	22.9	6.3	6.5	3.5	86	3.5
Feb	5	0	25.9	9.6	5.3	2.7	92	3.7
	6	30.6	22.3	11.9	3	4.5	94	3.2
	7	22.6	20.1	9.2	4.6	3.3	95	2.4
	8	0	24.6	10.5	7	4.3	90	4.1
	9	31.6	23	11.4	5.1	4.1	89	3.6
March	10	0	25.5	11.5	8.6	6.6	81	4.5
	11	23.6	23.8	12.8	6.9	7.2	82	3.3
	12	11.8	28.2	13.6	8	3.4	84	4.2
	13	0	33.1	15.7	8.7	4.3	83	6.3
April	14	0	34.4	18.6	8.7	7.2	73	7.9
	15	0	37.5	18.4	8.6	4.7	68	10.1
	16	0	38.3	23.2	8.7	5.4	66	10.5
	17	0	40.4	21.7	8.7	5.5	56	10.8
	18	0.8	37.4	22	7.3	6.2	69	9.6

“Effect of nitrogen management practices through organic and inorganic sources in sole and intercropped *Bt* cotton-wheat system”

ABSTRACT

A field experiment was conducted during 2006-08 at New Delhi on a sandy loam soil with 227 and 207 kg ha^{-1} of available nitrogen to assess the effect of nitrogen management through organic and inorganic sources in sole and intercropped *Bt* cotton-wheat system. Eight N management practices (Control, 100% RDN, 75% RDN + 25% through FYM and 50% RDN + 50% through FYM) along with sole groundnut receiving recommended fertilizer. During *rabi* season, the main plots were subdivided into four to accommodate doses of N fertilization (0, 50, 100 and 150 kg ha^{-1}) to wheat in split plot design. Cotton RCH-1 *Bt*, groundnut, ‘Punjab Groundut-1’ and wheat ‘Pusa Gold’ cultivars were used in the investigation. Intercropping of cotton and groundnut in 1:3 additional series were followed.

Groundnut intercropping did not significantly affect growth and yield attributes, yield, nutrient uptake and fibre quality of cotton as compared to sole cotton. Among N management practices of cotton, substitution of 25% RDN through FYM being on par with 100% RDN recorded significantly higher growth and yield attributes, yield, nutrient uptake and fibre quality of cotton over 50% RDN substitution through FYM and unfertilized control. Intercropping of groundnut in cotton was advantageous as evident from intercropping indices. Total productivity in terms of cotton equivalent yield was significantly higher in cotton + groundnut system and 75% RDN + 25% through FYM, over other treatments. Intercropped groundnut performed best where cotton growth was poor *i.e.* under control where no N fertilizers were applied to cotton.

Performance of wheat was markedly superior after cotton + groundnut system. Wheat crop responded to direct application of 100 kg N ha^{-1} in terms of growth and yield attributes, yield and nutrient uptake. Groundnut intercropped cotton with 50% RDN substitution through FYM and direct application of 100 kg N ha^{-1} to wheat recorded the highest cotton equivalent yield and net returns, however, B: C ratio was higher with 25% RDN substitution through FYM and direct application of 100 kg N ha^{-1} to wheat. Agronomic N use efficiency (ANUE) and apparent N recovery (ANR) were higher with 25% RDN substitution through FYM to cotton and direct application of 50 kg N ha^{-1} to wheat. This was followed by 100% RDN to cotton and direct application of 100 kg N ha^{-1} to wheat. Substitution of 50% RDN through FYM and direct application of 150 kg N ha^{-1} to wheat resulted in higher organic carbon, available N contents of soil in cotton-wheat system. These parameters were highest with groundnut-wheat system. In unfertilized plots, the soil fertility (OC, N) was declined after harvest of wheat.

सम्मिलत एवं एकल बीटी कपास-गेहूं प्रणाली में कार्बनिक एवं अकार्बनिक स्रोतों के उपयोग के माध्यम से नाइट्रोजन प्रबंध संबंधी क्रियाओं का प्रभाव

सारांश

वर्ष 2006-08 के दौरान नई दिल्ली में बलुआ दुमट मिट्टी में प्रति हैक्टर 227 और 207 कि.ग्रा. की दर से उपलब्ध नाइट्रोजन के संदर्भ में कार्बनिक एवं अकार्बनिक स्रोतों के एकल उपयोग में और बीटी कपास-गेहूं प्रणाली में उपयोग करने के पश्चात नाइट्रोजन प्रबंध के प्रभाव का मूल्यांकन करने के लिए एक क्षेत्र प्रयोग किया गया। आठ छ प्रबंध प्रथाओं नियंत्रित, 100ः आरडीएन, 75ः आरडीएन + 25ः एफवाईएम के माध्यम से और 50ः आरडीएन + 50ः एफवाईएम के माध्यम से) के साथ एकमात्र मूंगफली की फसल में उर्वरक की अनुशंसित मात्रा का उपयोग किया गया। रबी मौसम के दौरान मुख्य प्लाटों को चार उपखंडों में विभाजित किया गया, ताकि नाइट्रोजन उर्वरक की खुराकों 0, 50, 100 और 150 कि.ग्रा./हैक्टर) को गेहूं की फसल में स्प्लिट प्लॉट डिजाइन में दिया जा सके। इस अन्वेषण के दौरान कपास की आरसीएच-1 बीटी, मूंगफली की 'पंजाब ग्राउंडनट-1' और गेहूं की 'पूसा गोल्ड' किस्मों का उपयोग किया गया। कपास और मूंगफली की 1ः 3 अतिरिक्त श्रृंखलाओं वाली अंतरफसल प्रणाली को अपनाया गया।

मूंगफली की अंतरफसल से वृद्धि, एवं उपज संबंधी गुणों, उपज, पोषक तत्वों को ग्रहण करने और कपास के रेशे की गुणवत्ता पर केवल कपास की फसल की तुलना में कोई उल्लेखनीय प्रभाव नहीं पड़ा। कपास की फसल में प्रबंध प्रथाओं में से गोबर की खाद एफवाईएम) के माध्यम से 25ः आरडीएन प्रतिस्थापन को 100ः आरडीएन के बराबर पाया गया और इससे, गोबर की खाद के माध्मय से 50ः आरडीएम प्रतिस्थापन तथा उर्वरक न उपयोग करने जैसी नियंत्रित स्थिति की तुलना में, वृद्धि एवं उपज संबंधी गुणों, उपज, नाइट्रोजन को ग्रहण करने और कपास के रेशे की गुणवत्ता के मामले में उल्लेखनीय वृद्धि रिकॉर्ड की गई। जैसा कि अंतरफसलन सूचकांकों से स्पष्ट हुआ, कपास में मूंगफली की अंतरफसल उगाना लाभदायक था। कपास समतुल्य उपज की दृष्टि से कुल उत्पादकता कपास+मूंगफली प्रणाली और 75ः आरडीएन+25ः एफवाईएम के माध्यम से, अन्य उपचारों की तुलना में, उल्लेखनीय रूप से उच्च थी। अंतरफसलित मूंगफली से सर्वश्रेष्ठ निष्पादन प्राप्त हुआ, जबकि कपास की वृद्धि नियंत्रित स्थितियों में तब कमजोर रही जब कपास में किसी भी प्रकार के नाइट्रोजन उर्वरक का उपयोग नहीं किया गया।

कपास + मूंगफली प्रणाली के पश्चात गेहूं की फसल का उत्पादन भी श्रेष्ठ स्तर का रहा। गेहूं की फसल पर बढ़वार एवं उपज संबंधी गुणों, उपज एवं पोषक तत्वों के उद्‌ग्रहण करने के संदर्भ में 100 कि.ग्रा. प्रति हैक्टर की दर से नाइट्रोजन का प्रत्यक्ष उपयोग, सकारात्मक पाया गया। कपास की फसल में मूंगफली की अंतरफसल प्रणाली के अंतर्गत एफवाईएम के माध्यम

से 50ः आरडीएन प्रतिस्थापन और गेहूं की फसल में 100 कि.ग्रा. प्रति हैक्टर की दर से नाइट्रोजन के प्रत्यक्ष उपयोग से कपास की सर्वोच्च समतुल्य उपज और निवल लाभ रिकॉर्ड किए गए तथापि ठरूब अनुपात, गेहूं की फसल में एफवाईएम के माध्यम से 25ः आरडीएन प्रतिस्थापन तथा 100 कि.ग्रा. प्रति हैक्टर की दर से नाइट्रोजन का उपयोग करने पर, गेहूं की सर्वोच्च उपज ली गई। कपास की फसल में एफवाईएम के माध्यम से 25ः आरडीएन प्रतिस्थापन और गेहूं की फसल में 50 कि.ग्रा. प्रति हैक्टर की दर से नाइट्रोजन के प्रत्यक्ष उपयोग से सस्यविज्ञानी नाइट्रोजन उपयोग दक्षता ।छन्म्) और नाइट्रोजन की भासक वसूली ।छत्) उच्च पाए गए। इसके पश्चात, कपास की फसल में 100ः आरडीएन और गेहूं की फसल में 100 कि.ग्रा. प्रति हैक्टर की दर से नाइट्रोजन के प्रत्यक्ष उपयोग जैसी सस्यविज्ञानी क्रियाओं का स्थान था। गेहूं की फसल में एफवाईएम के माध्यम से 50ः आरडीएन प्रतिस्थापन और 150 कि.ग्रा. प्रति हैक्टर की दर से नाइट्रोजन के प्रत्यक्ष उपयोग से, कपास-गेहूं प्रणाली में खेत की मिट्टी में कार्बनिक कार्बन व उपलब्ध नाइट्रोजन अंश उच्च मात्रा में पाए गए। मूंगफली-गेहूं प्रणाली में ये प्राचल सर्वोच्च थे। जिन प्लाटों में उर्वरकों का उपयोग नहीं किया गया उनकी मृदा उर्वरता ब्ए छ) गेहूं की फसल की कटाई के पश्चात कम हो गई।