PERFORMANCE OF COTTON UNDER HIGH DENSITY PLANTING WITH VARIED SPACING AND LEVELS OF NITROGEN

By
BOBBILI DEVI
B. Sc. (Ag)

**THESIS SUBMITTED TO THE
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CHAIRPERSON: Dr. S. BHARATHI

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2017

DECLARATION

I, **BOBBILI DEVI,** hereby declare that the thesis entitled **"PERFORMANCE OF COTTON UNDER HIGH DENSITY PLANTING WITH VARIED SPACING AND LEVELS OF NITROGEN"** submitted to the **Acharya N.G. Ranga Agricultural University** for the degree of **Master of Science in Agriculture** is the result of original research work done by me. I also declare that no material contained in the thesis has been published earlier in any manner.

Place**:**	**(BOBBILI DEVI)**
Date:	**I.D. No. BAM-15-01**

CERTIFICATE

Ms**. BOBBILI DEVI** has satisfactorily prosecuted the course of research and that thesis entitled **"PERFORMANCE OF COTTON UNDER HIGH DENSITY PLANTING WITH VARIED SPACING AND LEVELS OF NITROGEN"** submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that neither the thesis nor its part thereof has been previously submitted by her for a degree of any University.

Date:

(S.BHARATHI)
Chairperson
Senior Scientist
AICCIP (Agronomy)
RARS, LAM

CERTIFICATE

This is to certify that the thesis entitled **"PERFORMANCE OF COTTON UNDER HIGH DENSITY PLANTING WITH VARIED SPACING AND LEVELS OF NITROGEN"** submitted in partial fulfilment of the requirements for the degree of '**Master of Science in Agriculture'** of the Acharya N. G. Ranga Agricultural University, Guntur is a record of the bonafide original research work carried out by **Ms. BOBBILI DEVI** under our guidance and supervision.

No part of the thesis has been submitted by the student for any other degree or diploma. The published part and all assistance received during the course of investigations have been duly acknowledged by the author of the thesis.

Thesis approved by the Student Advisory Committee:

Chairperson : **Dr.S.BHARATHI**
Senior Scientist
AICCIP (Agronomy)
RARS, LAM.

Member : **Dr.M. SREE REKHA**
Associate Professor
Department of Agronomy
Agricultural College, Bapatla

Member : **Dr. K. JAYA LALITHA**
Associate Professor
Department of Crop Physiology
Agricultural College, Bapatla

Date of final viva-voce :

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Place : (DEVI BOBBILI)

Date :

Chapter -I

INTRODUCTION

Cotton is popularly called as “white gold” and is an important fibre as well as cash crop of India. It is considered as “king of fibre crops”. It occupies 33 per cent of the world global area under cotton making it first in area and ranking next to china in production globally. The global production increased from a meagre 169 kg lint ha^{-1} in 1980-81 to a high of 517 kg lint ha^{-1} during 2013 (Foreign Agriculture Service, USDA, 2014). It is grown in an area of 126.22 lakh hectares with an annual production of 351 lakh bales and a productivity of 568 kg lint ha^{-1} in the country. In Andhra Pradesh, cotton is one of the most important commercial crop and occupies an area of about 4.41 lakh hectares with an annual production of 13.1 lakh bales and productivity of 719 kg lint ha^{-1} (AICCIP, Annual Report, 2016-2017).

In India, the seed cotton yield per unit area is still far below than many other cotton growing countries of the world. Among the various factors responsible for low yield of cotton in the country, low plant population and use of low potential varieties are of primary importance. Among the various cultural practices, selection of cultivars, spacing and plant population are crucial factors which influence the yield in cotton. Selection of agro techniques *viz*., high yielding varieties, maintaining optimum plant population, use of optimum dose of nutrition, growth regulators *etc*. are being used in enhancing commercial cotton productivity.

Cotton production is labour intensive in almost all the developing countries. A novel way to avoid labour problem is to go for mechanical harvesting. Cotton being indeterminate in nature, it is difficult to harvest the seed cotton at one time. But, research results suggest that, by manipulating the crop geometry especially by providing closer spacing and use of growth hormones one time harvest is possible and the yield reduction may be compensated by increasing the plant population by way of High Density Planting System (HDPS). Growing genetically modified *Bt* cotton hybrids is not the only way to bag high yields but an outstanding new technology High Density Planting System is evolved by Central Institute for Cotton Research (CICR), Nagpur. This system is ideal for shallow to medium soils under rainfed conditions, where conventional late maturity hybrids experience terminal drought. A system of high density planting leading to more rapid canopy closure and decreased soil water evaporation, is becoming popular to address water scarcity challenges. Therefore, the high density planting system is now being conceived as an alternate production system having a potential for improving the productivity and profitability, increasing input use efficiency, reducing input costs and minimizing the risks associated with the current cotton production system in India. The High Density Planting is popular in several countries like Brazil, China, Australia, Spain, Uzbekistan, Argentina, USA and Greece (Rossi *et al.,*2004).

In Brazil, growth regulators are used to arrest the vegetative growth of cotton, mepiquat chloride is sprayed 3-4 times to arrest vegetative growth, which, otherwise hinders higher productivity. Ultimately it increases the the cost of cultivation. However, under Indian conditions, the farmers cannot afford to invest on growth regulators. Hence, development of compact plant types will be a boon for the cotton cultivation under High Density Planting System. Compact plant type with zero monopodia and short sympodia is suitable for high density planting system. The absence of monopodial branches envisages to accommodate more number of plants per unit area without competition for light. Further, the bolls closer to the main stem receive better nutrition and ultimately expected to produce lint of good quality and with short inter branch and inter boll distance, they reveal a synchronous maturity. Due to this, the crop can be harvested in just one or two pickings.

A pertinent question to be resolved is whether the demand for nutrients is greater under HDPS since the plant population is higher. Multi location trials were conducted (under Technology Mission on Cotton) to determine whether the recommended fertilizer dose (RDF) for conventional cotton (at normal density) is also applicable for cotton planted under HDPS. Preliminary results indicated that 25% additional fertilizers would be needed to meet the increased requirement of the crop under HDPS (Singh *et al.*, 2012). Fertilizer requirement is most likely to be higher under HDP (Jost and Cothren, 2000). Nitrogen is one of the most important element for crop production and cotton crop needs nitrogen at all stages of plant growth and development because it is the essential element of both structural and non structural components of the plant (Majid Rashidi *et al.*, 2011). Nitrogen requirement is most likely to be higher under high density planting.

There is much scope to improve the cotton production in India by increasing the productivity through adoption of appropriate agronomic practices and optimum fertilization. There is need to find out the suitable plant spacing and nitrogen requirement for every cotton crop under high density planting system.

Keeping this in view, the present trial is proposed with the following objectives.

1. To evaluate the growth and yield of cotton under high density planting.
2. To optimize the nitrogen dose for high density planting of cotton.
3. To study the interaction of plant density and different nitrogen levels on growth and yield of cotton.

Chapter – II

RIVEW OF LITERATURE

A field experiment entitled “Performance of cotton under high density planting with varied spacing and levels of nitrogen” was conducted at Agricultural College Farm, Bapatla. The available literature on impact of varied spacing and levels of nitrogen on growth and yield parameters was reviewed and presented in this chapter under the following heads.

2.1. Growth and yield of cotton under high density planting

2.2. Nitrogen dose for high density planting

2.3. Interaction of plant spacing and nitrogen levels

2.4. Economics

2.1 GROWTH AND YIELD OF COTTON UNDER HIGH DENSITY PLANTING

2.1.1 Growth Parameters

Yasar and Fatih (2004) conducted a experiment at Agricultural Research Institute, Kahramanmars, Turkey on sandy clay loam and observed that plant height and number of sympodial branches per plant were significantly higher with row spacing of 60 cm than 70 cm and 80 cm in Maras cotton variety.

Moola Ram and Giri (2006) conducted an experiment on newly released cotton varieties NH 545 and PH 348 during *kharif* on clay soil and concluded that drymatter accumulation per plant and number of sympodial branches per plant were significantly higher with plant densities of 27777 plants ha^{-1} than 37037 and 55555 plants ha^{-1} at Parbhani.

Siddiqui *et al.*(2007) concluded that plant height was significantly higher with intra row spacing of 15 cm than 25 cm and 35 cm at Sindh Agricultural University, Pakistan.

Bhalerao *et al.* (2008) conducted a field trial during *kharif* season on clayey soils of Akola and observed significantly taller plants and higher number of sympodia plant^{-1} in *Bt* cotton with a spacing of 90 cm x 90 cm and was on a par with 90 cm x 120 cm than the 90 cm x 60 cm and 90 cm x 45 cm. Maximum number of monopodia plant^{-1} were recorded at 90 cm x 45 cm plant spacing.

Ahmad *et al*. (2009) conducted an experiment with variety of BH-160 during *kharif* and reported that plant height and number of sympodial branches per plant were significantly higher with spacing of 22.5 cm than 15 cm, 30 cm and 37.5 cm at department of Agronomy, Pakistan.

Asghar Ali *et al*. (2009) conducted a experiment in cotton varieties during *kharif* and reported that plant height was significantly higher with spacing of 75 cm × 15 cm than 75 cm × 22.5 cm and 75 cm × 30 cm at Cotton Research Station, Pakistan.

The plant geometry of 90 cm x 60 cm resulted in significantly higher plant height, number of sympodial branches plant^{-1} and total drymatter production of *Bt* cotton than 90 cm x 30 cm on deep black soils of Agricultural College Farm, Raichur during *kharif* (Shwetha *et al*., 2010)

Manjunatha *et al*. (2010[b]) reported that plant height of *Bt* cotton was not affected by various planting densities tested. However, sympodial branches plant^{-1} and drymatter production was significantly higher with 90 cm x 60 cm spacing than that of 90 cm x 20 cm , 75 cm x 30 cm and 60 cm x 30 cm on clayey soils during *kharif* at Raichur.

Similarly, Pendharkar *et al*. (2010) observed that plant height of *Bt* cotton was significantly higher at 180 cm x 30 cm spacing than that of 120 cm x 30 cm and 90 cm x 60 cm, and was at par with 150 cm x 30 cm. However, more number of sympodial branches and total drymatter production was observed under 90 cm x 60 cm and 120 cm x 45 cm plant spacing than 180 cm x 30 cm and 150 cm x 30 cm in clay soils during *kharif* at Parbhani.

On sandy loam soils of Modipuram, plant spacing of 100 cm x 60 cm was found significantly superior to 67.5 cm x 60 cm in increasing biomass (g $plant^{-1}$) of cotton; whereas, no significant influence was observed on seed cotton yield and boll weight with different spacings (Devendra Singh *et al*., 2011).

Hensh *et al.* (2011) observed that plant height and drymatter accumulation of *Bt* cotton were significantly higher at a spacing of 45 cm × 30 cm at 150 DAS compared to 60 cm × 30 cm and 75 cm × 30 cm during *kharif* on sandy loam soil at Birbhum.

Bharathi *et al.* (2012) conducted an experiment on clay loam soils during *kharif* at Lam, Guntur and observed that plant height, monopodial and sympodial branches per plant of *Bt* cotton were significantly higher at spacing of 90 cm × 90 cm than 90 cm × 45 cm and was at a par with 120 cm × 60 cm.

Jat *et al.* (2014) conducted experiment at Agronomy Research Farm, CCS Haryana Agricultural University, Hisar during *Kharif* and reported that maximum plant height in *Bt* cotton was at 100 cm × 40 cm spacing followed by 100 cm × 50 cm and 100 cm × 60 cm.

Kulvir Singh (2015[a]) conducted an experiment on loamy sand soils of Punjab Agricultural University, Faridkot and reported that plant height was not significantly affected by plant geometry. The monopodial and sympodial branches per plant of cotton hybrid were significantly more with a wider spacing of 67.5 cm × 75 cm than 67.5 cm × 60 cm.

Pasalwar *et al.* (2015) conducted an experiment on early and dwarf stature variety on black cotton soils at Akola and concluded that drymatter accumulation and sympodial branches per plant were significantly higher with spacing of 60 cm × 10 cm than 45 cm × 10 cm, 45 cm × 15 cm and 45 cm × 20 cm.

2.1.2 Yield Attributes

Maitra *et al*. (2000) conducted an experiment on clay loam soil during *rabi* and concluded that bolls per plant and boll weight were significantly higher with spacing of 60 cm × 45 cm than 45 cm × 30 cm and 60 cm × 30 cm.

Basanagouda *et al*.(2002) conducted an experiment with compact cotton variety and reported that number of bolls per m^2 and boll weight were significantly higher with spacing of 60 cm × 15 cm than 60 cm × 10 cm and 60 cm × 20 cm during *kharif* at Agricultural Research Station, Dharwad.

Bhalerao *et al.* (2008) reported that spacing of 90 cm x 120 cm resulted in more number of harvested bolls $plant^{-1}$ than 90 cm x 90 cm, 90 cm x 60 cm and 90 cm x 45 cm in *Bt* cotton on clay soils of Akola. However, the boll weight was not significantly affected with the variation in plant population.

Shwetha *et al.* (2010) from an experiment conducted at Agricultural College Farm, Raichur during *kharif* observed that boll weight recorded at wider spacing of 90 cm x 60 cm was significantly superior to that of 90 cm x 30 cm on deep black soils.

Manjunatha *et al.* (2010[b]) observed that, total number of harvested bolls of *Bt* cotton were significantly higher at 90 cm x 60 cm spacing than that of 90 cm x 20 cm, 60 cm x 30 cm and 75 cm x 30 cm plant spacings.

Pendharkar *et al*. (2010) conducted a field trial during *kharif* season on clayey soils of Parbhani and found that number of picked bolls $plant^{-1}$ was significantly higher at a spacing of 90 cm x 60 cm and 120 cm x 45 cm than at 180 cm x 30 cm and 150 cm x 30 cm in *Bt* cotton. While, the boll weight was not significantly altered by different plant spacings.

Hensh *et al*. (2011) observed that number of boll per m^2 of *Bt* cotton were significantly higher at 90 DAS with the spacing of 45 cm × 30 cm over 60 cm × 30 cm and 75 cm × 30 cm on sandy loam soil during *kharif* at Rathindra Krishi Vigyan Kendra, Srinikethan, Birbhum.

Sankaranarayanan *et al*. (2011) observed that no of bolls per m^2 were significantly higher at the spacing of 75 cm ×60 cm than 90 cm × 45 cm and 90 cm × 60 cm on clay loam soil at Regional Station, Central Institute for Cotton Research, Coimbatore.

Mandeep Kumar *et al*. (2011) conducted field experiment during *kharif* on sandy loamy soil at Hisar and reported that bolls per plant and boll weight of *Bt* cotton were significantly higher at 67.5 cm × 60 cm than 100 cm × 45 cm and 100 cm × 60 cm.

Nehra and Yadav (2012) reported that number of bolls per plant and boll weight were significantly increased with spacing of 67.5 cm × 60 cm than 67.5 cm × 30 cm and 67.5 cm × 45 cm in cotton variety on sandy loam soil during *kharif* at Agriculture Research Station, Sriganganagar.

Jat *et al*. (2014) reported that boll weight was significantly higher with the spacing of 100 cm × 60 cm than 100 cm × 50 cm and 100 cm × 40 cm at Agronomy Research Farm, CCS Haryana Agricultural University, Hisar.

Kulvir Singh (2015[a]) conducted an experiment and observed that number of bolls per plant and boll weight were significantly higher with spacing of 67.5 cm × 90 cm than 67.5 cm × 75 cm in *Bt* cotton during *kharif* on sandy loam soil at Punjab Agricultural University, Faridkot.

Munir *et al.* (2015) reported that no of bolls per m^2 were significantly higher with row spacing of 60 cm than 90 cm and boll weight was significantly higher with row spacing of 90 cm than 60 cm on loam soil during *kharif* at Department of Agronomy, Pakistan.

2.1.3 Yield

Solanke *et al.* (2001) revealed that spacing of 60 cm × 60 cm recorded 17.2 per cent more seed cotton yield than spacing of 60 cm × 90 cm.

Basanagouda *et al*. (2002) conducted a experiment on compact variety during *kharif* at Agricultural Research Station, Dharwad and concluded that seed cotton yield was significantly higher with spacing of 60 cm × 15 cm than 60 cm × 10 cm and 60 cm × 20 cm.

Reddy *et al*. (2009) conducted a field experiment at RARS, Warangal in *kharif* and reported that the seed cotton yield of *Bt* cotton was significantly higher with closer spacing of 90 cm × 30 cm than 90 cm × 90 cm.

Bhalerao *et al.* (2008) from an experiment conducted on clay soils of Akola reported that seed cotton yield of *Bt* cotton was significantly superior with the spacing of 90 cm x 60 cm compared to other plant spacings.

Sree Rekha *et al*. (2008) conducted a experiment on pre released desi cotton variety MDL- 2463 during *kharif* at Adilabad and reported that seed cotton yield was significantly higher with spacing of 60 cm × 45 cm than 45 cm × 30 cm and 60 cm × 15 cm.

Satyavan *et al*. (2010) conducted a experiment on sandy loam soil during *kharif* and concluded that seed cotton yield was significantly higher with spacing of 60 cm × 30 cm than 45 cm ×20 cm, 60 cm × 20 cm and 90 cm × 40 cm at Research Station, Haryana Agricultural University.

Shwetha *et al.* (2010) from an experiment conducted at Agricultural College Farm, Raichur during *kharif* observed that the seed cotton yield of *Bt* cotton was significantly higher at 90 cm x 30 cm spacing than at 90 cm × 60 cm.

Manjunatha *et al*. (2010[a]) reported that seed cotton yield of *Bt* cotton was significantly higher with the spacings of 60 cm x 30 cm and 90 cm x 20 cm than 90 cm x 60 cm and 75 cm x 30 cm during *kharif* season on medium black soils of at Agricultural College Farm, Raichur.

Krishnaveni *et al*. (2010) conducted a field trial during *kharif* season on clay soils of Agricultural College Farm, Bapatla and found that plant spacing of 90 cm x 30 cm gave significantly higher seed cotton yield than at 60 cm x 60 cm, 90 cm x 60 cm and 120 cm x 60 cm.

Jagdish Kumar *et al.* (2010) observed that seed cotton yield was significantly higher with the spacing of 67.5 cm × 30 cm than 67.5 cm × 60 cm and 100 cm × 30 cm in cotton variety on sandy loam soil during *kharif* at Kanpur.

Salakinkop *et al.* (2010) conducted a field experiment in *Bt* cotton during the *kharif* season on black clay loam soils of Agricultural Research Station, Bheemarayanagudi and found that a spacing of 90 cm x 90 cm resulted in significantly higher seed cotton yield ha^{-1} than with 120 cm x 120 cm, 120 cm x 30 cm, 90 cm x 30 cm, 90 cm x 60 cm and 75 cm x 60 cm; however, it was at a par with the spacing of 120 cm x 60 cm.

Pendharkar *et al.* (2010) conducted a field trial during *kharif* season on clayey soils of Parbhani and reported that the seed cotton yield was significantly higher at a spacing of 90 cm x 60 cm and 120 cm x 45 cm than 180 cm x 30 cm and 150 cm x 30 cm in *Bt* cotton while the boll weight was not significantly increased with different plant spacings.

Chavan *et al.* (2011) concluded that seed cotton yield (17.09 q ha^{-1}) and stalk yield (30.64 q ha^{-1}) were significantly higher with spacing of 60 cm × 60 cm than 60 cm × 90 cm and 90 cm × 90 cm in Bunny *Bt* cotton on clay soil during *kharif* at Agricultural College Farm, Nagpur.

Venugopalan *et al.* (2011) conducted a experiment on cotton genotypes and reported that number of bolls per m^2 and seed cotton seed yield were significantly higher with spacing of 45 cm × 13.5 cm than 30 cm × 20 cm, 30 cm × 30 cm , 45 cm × 20 cm and 60 cm × 30 cm during *kharif* at Central Institute for Cotton Research, Nagpur.

Bharathi *et al.*(2012) reported that seed cotton yield (2985 kg ha^{-1}) was significantly higher with the spacing of 90 cm × 45 cm over the spacings of 90 cm × 90 cm and 120 cm × 60 cm in *Bt* cotton on clay loam soil of Lam, Guntur.

Shekar *et al*. (2012) observed that seed cotton yield (1668 kg ha^{-1}) was significantly higher with the spacing of 90 cm × 30 cm than 90 cm × 45 cm and 90 cm × 60 cm in *Bt* cotton on sandy clay loam soil during *kharif* at college Farm, ANGRAU, Hyderbad.

Arunvenkatesh and Rajendran (2013) conducted an experiment at TNAU, Coimbatore during winter and reported that the spacing of 30 cm × 30 cm gave significantly higher yield than 60 cm × 30 cm and 90 cm × 30 cm in cotton genotypes.

Asewar *et al*. (2013) reported that highest seed cotton yield of 3162 kg ha^{-1} in *Bt* cotton was recorded with a spacing of 150 cm × 30 cm and it was significantly superior over rest of the spacings.

Jahedi *et al*. (2013) conducted an experiment and reported that boll weight and seed cotton yield were significantly higher with row spacing of 70 cm than 50 cm and 30 cm on sandy loam soils of Agricultural Research Station, located in Gonabad, Iran.

Sylla *et al*. (2013) conducted an experiment on cotton variety at Agrarian Research Institute of Mozambique in Namialo and concluded that plant spacing with in rows placed at 20 cm interval provided the highest cotton seed yield than 15, 25 and 30 cm on sandy loam soils during *kharif.*

Ahmed *et al*. (2014) conducted an experiment at Cotton Research Station, Pakistan and reported that number of bolls per m^2 and cotton seed yield were significantly higher with inter plant spacing of 60 cm than 15 cm, 30 cm and 45 cm.

Venugopalan *et al*. (2014) conducted an experiment at Brazil and reported that seed cotton yield was significantly higher with closer spacing of 45 cm × 15 cm than 60 cm × 15 cm and 90 cm × 15 cm.

Pasalwar *et al*. (2015) conducted an experiment on early and dwarf stature variety AKH-081 and concluded that seed cotton yield was significantly higher at spacing of 45 cm × 10 cm than 45 cm × 15 cm , 45 cm × 20 cm and 60 cm × 10 cm on black cotton soils of Akola.

Jadhav *et al*. (2015) reported that plant spacing of 150 cm × 36 cm produced the highest seed cotton yield (36 q ha^{-1}) and produced more biomass at all growth stages which was on par with 120 cm × 45 cm (34.23 q ha^{-1}) and 90 cm × 60 cm (33.4 q ha^{-1}) and 180 cm × 30 cm (31.11 q ha^{-1}) in *Bt* cotton on the clay soil during *kharif* at Parbhani.

Karle *et al*. (2015) conducted an experiment on *desi* cotton variety on clay soil during *kharif* and reported that seed cotton yield was significantly higher with spacing of 45 cm × 15 cm than 45 cm × 22.5 cm and 60 cm × 10 cm at Cotton Research Scheme, Parbhani.

Pradeep Kumar *et al*. (2015) conducted an experiment on desi cotton variety on clay soil during *kharif* and concluded that seed cotton yield was significantly higher with spacing of 45 cm × 15 cm than 45 cm × 30 cm, 60 cm × 10 cm at Cotton Research Scheme, Parbhani.

2.2 NITROGEN DOSE FOR HIGH DENSITY PLANTING OF COTTON

2.2.1 Growth Parameters

Sharma *et al.* (2000) conducted an experiment during *kharif* and observed that plant height and drymatter production significantly increased in *Bt* cotton with increase in N application from 0 to 120 kg N ha^{-1} on loamy soils at Hisar.

Mahatale *et al.*(2002) noticed that plant height and drymatter accumulation increased with increase in the nitrogen application from 0 to 60 kg N ha^{-1} in arboreum hybrid AKDH -7 on clayey soils at Akola.

Mahatale *et al.*(2003) observed that plant height and drymatter accumulation were increased significantly with increase in nitrogen levels from 0 to 75 kg ha^{-1} in Hybrid cotton (AKDH –7) on clay soils of Akola.

Jagvir Singh *et al.* (2003) observed a significant increase in plant height at 120 DAS with the application of 100% recommended dose of fertilizer (RDF) over 75% RDF and it was at a par with 125% RDF in *Bt* cotton. However, the differences in plant height with different fertilizer doses were not significant at 90 DAS.

Nehra and Kumawat (2003) noticed that increase in level of nitrogen from 60 kg to 180 kg ha^{-1} significantly increased plant height from 145 cm to 152 cm in RS-2013 cotton variety on sandy loam soils with low available nitrogen at Sri Ganganagar.

Halemani *et al.* (2004) reported that plant height and drymatter production of Bunny *Bt* cotton increased with increase in fertilizer levels from 75 to 100% recommended dose of fertilizer (120: 60: 60 kg N:P:K ha^{-1}) at Dharwad.

Ram and Giri (2006) from an experiment conducted at Parbhani revealed that application of nitrogen at 60 kg ha^{-1} increased growth characters like plant height and drymatter accumulation of *Bt* cotton over 40 kg and 50 kg N ha^{-1} on clayey soil.

Sonawale *et al.* (2006) observed that among 4 levels of nitrogen (25, 37.5, 50, and 62.5 kg ha^{-1}) tried at Nagpur, application of 62.5 kg N ha^{-1} recorded highest drymatter accumulation.

Suresh and Chellamuthu (2006) reported that application of 80-40-30 kg NPK per hectare significantly increased plant height and drymatter production in *Bt* cotton followed by 60-30-30 kg NPK ha^{-1} and no fertilizer application (control).

Sisodia and Khamparia (2007) revealed that graded level of fertilizer application increased plant height and drymatter accumulation significantly over its preceding level on sandy clay loam soils of Khandwa.

Gadhiya *et al*. (2009) conducted a field experiment on *Bt* cotton during *kharif* at S.D. Agricultural University, Gujarat and reported that plant height and number of sympodial branches were significantly increased with each increment in nitrogen level from 160 kg N ha^{-1} to 240 kg N ha^{-1}.

Mohan Das *et al.* (2009) conducted a field trial during *kharif* season on vertisol of Agricultural Research Station, Adilabad, Andhra Pradesh and found that plant height and number of branches of Bunny *Bt* were significantly increased with each increment in nitrogen application from 90 to 150 kg ha^{-1}.

Parminder Kaur *et al.* (2010) reported that plant height and number of monopodial branches and sympodial branches per plant of *Bt* cotton were significantly higher with spacing of 67.5 cm × 75 cm than 100 cm × 60 cm and 100 cm × 75 cm on sandy loam soil during *kharif* at Punjab Agricultural University, Ludhiana .

Sunitha *et al.* (2010) found that growth characters of *Bt* cotton like plant height, sympodial branches $plant^{-1}$, monopodial branches $plant^{-1}$ and drymatter increased significantly with each successive increase in N from 0 to 240 kg ha^{-1} during *kharif* season on clay soils of Agricultural College Farm, Bapatla, Andhra Pradesh. Whereas, Reddy and Kumar (2010) observed that plant height, monopodial $plant^{-1}$ and sympodial $plant^{-1}$ of *Bt* cotton were not influenced significantly with each increase in nitrogen from 150 to 250 kg ha^{-1} on sandy loam soils of Regional Agricultural Research Station, Warangal, AndhraPradesh.

Plant height increased by 8.19, 18.49 and 24.49% with 50, 100 and 150 kg N ha^{-1}, respectively as compared to control in cotton. (Bibi *et al.,* 2011)

Noor Ullah Kakar *et al*.(2012) conducted an experiment in Sindh Agriculture University, Pakistan and concluded that number of sympodial branches were significantly increased with each increment in nitrogen application from 0 to 180 kg ha^{-1} in *Bt* cotton.

Ramzan Ali Alitabar *et al*. (2013) conducted a field trial at Agriculture Research Station of Gharakil – Ghaemshahr on clay loam and found that the plant height and number of nodes, number of sympodial branches were significantly increased with each increment in nitrogen application from 0 kg ha^{-1} to 225 kg ha^{-1}.

Sandeep Rawal *et al*. (2015) conducted an experiment during *kharif* to study the effect of N and P on growth parameters of *Bt* cotton and reported that plant height and drymatter accumulation per plant and monopodial branches and sympodial branches per plant increased with increase in N application from 75% RD to 150% RD and increase in P application from 75% RD to 125% RD.

Bharathi *et al*. (2016) conducted an experiment at Regional Agricultural Research Station, Lam, Guntur and concluded that plant height and number of monopodial branches and sympodial branches per plant of *Bt* cotton were maximum with application of 150 kg N ha^{-1} and was on a par with 120 kg N ha^{-1}.

2.2.2 Yield Attributes

Brar *et al.* (2000) reported that bolls per plant and boll weight of *Bt* cotton significantly increased with increase in N application from 0 to 150 kg N ha^{-1} on sandy loam soils of Ludhiana.

Increase in N levels from 50 kg to 100 kg N ha^{-1}, the number of bolls per plant, boll weight of *Bt* cotton increased significantly on sandy loam soils of New Delhi (Ramprakash *et al.,* 2001).

Sagarka *et al.* (2002) conducted field experiment during *rabi* and reported that number of bolls per plant and boll weight significantly increased with the increase in N level from 80 to 160 kg N ha^{-1} in winter cotton on loamy soils of Junagadh.

Reddy *et al.* (2009) reported that there was a significant increase in bolls with the application of 120 kg N ha^{-1} over 150 kg N ha^{-1} and 180 kg N ha^{-1}. However, boll weight did not differ significantly with the N levels on sandy loam soils of Warangal.

Mohan Das *et al.* (2009) reported that with increase in N level from 90 to 150 kg ha^{-1} the number of bolls plant^{-1} and boll weight were significantly increased in Bunny *Bt* cotton at Adilabad in vertisols.

Sunitha *et al.* (2010) reported that number of bolls plant^{-1} significantly increased with each increase in application of N from 0 to 240 kg ha^{-1}. The heaviest bolls were noticed with application of 240 kg N ha^{-1} over 0, 60 and 120 kg N ha^{-1} and it was at a par with 180 kg N ha^{-1} on clay soils during *kharif* at Bapatla.

Reddy and Kumar (2010) observed that bolls plant^{-1} and boll weight of *Bt* cotton were not significantly affected by the increase in N application from 150 to 250 kg ha^{-1} on sandy loam soils during *kharif*.

Singh *et al.* (2010) conducted an experiment in Ankur – 651 *Bt* at Regional Research Station, Jodhapur and reported that the number of bolls plant^{-1} increased significantly up to 120 kg N ha^{-1} and boll weight increased up to 160 kg N ha^{-1} in comparison to 80 kg ha^{-1} and further increase in nitrogen did not increase these parameters significantly.

Hallikeri *et al.* (2011) conducted an experiment at Agricultural Research Station Farm, University of Agricultural Sciences, Dharwad and reported the response of *Bt* cotton to 160 kg N ha^{-1} with a significant increase in number of bolls plant^{-1} over that of 80 and 120 kg N ha^{-1} on medium black soils.

Rashidi and Gholami (2011) conducted an experiment and reported that boll number and boll weight were significantly increased with application of 200 kg N ha^{-1} and there was no significant difference among 200 and 300 kg N ha^{-1} on clay loam soil at Research Site of Tehran Province Agricultural and Natural Resources Research Center, Iran.

Mohsen Seilsepour and Majid Rashidi (2011) reported that boll number per plant, boll weight and seed cotton yield significantly increased with increase in N application from 0 to 200 kg N ha^{-1} and further increase in N application reduced the seed cotton yield.

Baraich *et al.*(2012) conducted experiment at Agriculture Training Institute, Pakistan and reported that number of bolls per plant of cotton variety were significantly higher with application of 200 kg N ha^{-1} followed by 150 kg N ha^{-1} and 50 kg N ha^{-1}.

Sandeep Rawal *et al.*(2015) conducted an experiment during *kharif* at KVK Farm, CCS Haryana Agricultural University, Hisar, to study the effect of different levels of N on yield attributing characters of *Bt* cotton and reported that bolls per plant increased with increase in N application from 75% RD to 150% RD.

Ozgui Gormus (2015) conducted experiment to evaluate cotton growth and yield response to nitrogen and sulphur application and reported that boll weight and seed cotton weight per boll and seed cotton yield were significantly increased with increase in N application from 0 to 120 kg N ha^{-1} and further increases reduced the seed cotton yield in Cukurova University, Turkey.

Rafi and Muhammad (2015) conducted an experiment during *kharif* at Central Cotton Research Institute Sakrand, Pakistan and reported that number of bolls per plant and boll weight increased with increase in N application from 50 to 200 kg N $ha^{-1.}$

Munir *et al*. (2015) conducted an experiment during *Kharif* at department of Agronomy, Pakistan and reported that no of bolls per m^2 and boll weight increased with increase in N application from 0 to 180 kg ha^{-1}.

Bharathi *et al.* (2016) reported that bolls per plant and boll weight significantly increased with application of 150 kg N ha^{-1} than 120 kg N ha^{-1} in *Bt* cotton during *kharif* on clay loam soils of Regional Agricultural Research Station, Lam, Guntur.

2.2.3. Seed cotton yield

Sharma *et al.* (2000) conducted an experiment in *Bt* cotton on sandy loam soils at Hisar and reported that seed cotton yield significantly increased with increase in N application from 0 to 60 kg N ha^{-1}.

Mahatale *et al.* (2002) noticed that seed cotton yield of AKDH -7 *arboreum* hybrid increased with graded application of nitrogen from 0 to 60 kg N ha^{-1} on clayey soils at Akola.

Sarkar and Majumdar (2002) noticed that seed cotton yield significantly increased with increase in N application from 0 to 120 kg N ha^{-1} on clay loam soils of Baruipur, Kolkata during *kharif.*

Patke *et al.* (2003) conducted an experiment during *kharif* at Akola and observed that the successive increase in the rate of N application from 50 to 100 kg ha^{-1} significantly enhanced the seed cotton yield of *Bt.*

Giri and Gore (2006) observed that seed cotton yield as well as yield per plant were enhanced significantly with every increase in N level from 40 to 60 kg N ha^{-1} in *Bt* cotton in vertisols at Parbhani on Vertisols.

Among four N levels tested at Nagpur *viz,* 25, 37.5, 50 and 62.5 kg ha^{-1}, the seed cotton yield was significantly higher with the application of 62.5 kg ha^{-1} (Sonawale *et al.,* 2006).

Srinivasulu *et al*. (2006) reported that seed cotton yield (2872 kg ha^{-1}) was significantly higher with the application of 120 kg N ha^{-1} than 90 kg N ha^{-1} in *Bt* cotton on clay soil during *kharif* at Lam, Guntur.

Singh and Rathore (2007) at Faridkot observed a significant increase in seed cotton yield by 15.4% and 15.9% at N levels of 75 and 94 kg ha^{-1}, respectively, over that of 56 kg N ha^{-1} in cotton genotypes.

Reddy *et al.* (2009) noticed that seed cotton yield of *Bt* cotton was not significantly influenced beyond the application of 120 kg N ha^{-1} on sandy loam soils of Warangal.

Mohan Das *et al.* (2009) conducted a field trial on vertisols of Agricultural Research Station, Adilabad and found that seed cotton yield of Bunny *Bt* was significantly increased with increase in N application from 90 to 120 kg ha^{-1} and further increase in nitrogen application to 150 kg N ha^{-1} did not show significant influence on seed cotton yield.

Sunitha *et al.* (2010) reported that application of 240 kg N ha^{-1} recorded maximum seed cotton yield of *Bt* cotton and was significantly superior over 60, 120 and 180 kg N ha^{-1} on clay soils during *kharif* season at Bapatla.

Singh *et al.* (2010) concluded that seed cotton yield of *Bt* cotton significantly increased with increased dose of nitrogen from 80 to 160 kg ha^{-1}. Further increase of nitrogen to 200 kg ha^{-1} had no significant influence.

Hallikeri *et al*. (2011) observed that seed cotton yield plant^{-1} and seed cotton yield ha^{-1} of *Bt* cotton were significantly superior with the application of 160 kg N ha^{-1} over 80 and 120 kg N ha^{-1} at Agricultural Research Station Farm, University of Agricultural Sciences, Dharwad.

Mohsen Seilsepour and Majid Rashidi (2011) reported that seed cotton yield increased with increase in N application from 0 to 200 kg N ha^{-1} and further increase in N application reduced the seed cotton yield.

Nehra and Yadav (2012) conducted an experiment during *kharif* at Agricultural Research Station, Sriganganagar and reported that seed cotton yield of cotton variety H-1300 was significantly higher with the application of 125% recommended dose of fertilizers than 75% and 100% recommended dose of fertilizers on sandy loam soil.

Desai *et al.* (2014) conducted an experiment on clay soils in *Bt* cotton at Navsari Agriculture University, Gujarat and concluded that seed cotton yield and stalk yield significantly increased with increase in N application from 180 to 300 kg N ha^{-1}.

Kumara *et al*. (2014) conducted a field experiment on *Bt* cotton at Zonal Agricultural Research Station, Bangalore and concluded that seed cotton yield significantly increased with each increment in fertility levels from 75% recommended NPK and FYM to 150% recommended NPK and FYM during *kharif*.

Gagade *et al.* (2015) conducted a field experiment with three cotton genotypes during *kharif* at Parbhani and concluded that seed cotton yield significantly increased with each increment in recommended dose of fertilizers from 75% RD to 125% RD.

Munir *et al*.(2015) concluded that seed cotton yield significantly increased with increase in N application from 0 to 180 kg N ha^{-1} on loamy soils at Pakistan.

Masram *et al*.(2015) reported that *Bt* hybrid recorded maximum seed cotton yield as compared to non *Bt* hybrid with application of 100% RDF + 1% $MgSO_4$ and was on par with 100% RDF + 1% KNO_3 and 100% RDF+ 2% DAP in deep black soils at Rahuri.

Sandeep Rawal *et al*.(2015) concluded that the seed cotton yield of *Bt* cotton significantly increased with increase in fertilizers from 75% RD to 125% RD, and stalk yield significantly increased with increase in fertilizers from 75% RD to 150% RD on sandy loam soil at KVK Farm, Hisar.

Joao Henrique Zonta *et al*. (2016) conducted an experiment to evaluate the irrigation and nitrogen fertilization influence on cotton and reported that seed cotton yield significantly increased with increased dose of nitrogen from 0 to 210 kg N ha^{-1} on sandy clay soil at Research Farm, Brazil.

Bharathi *et al*.(2016) found highest seed cotton yield (2278 kg ha^{-1}) of *Bt* cotton with application of 150 kg N ha^{-1} than 120 kg N ha^{-1} in clay loam soils at Regional Agricultural Research Station, Lam, Guntur.

2.3 INTERACTION OF PLANT DENSITY AND DIFFERENT NITROGEN LEVELS

Satyanarayana Rao *et al.*(2008) conducted an experiment on medium black soil during *kharif* at Regional Agricultural Research Station , Raichur and observed that plant geometry of 90 cm × 30 cm with application of fertilizer 90: 45: 45(N:P:K) gave significantly higher seed cotton yield than 60 cm × 30 cm and 75 cm × 30 cm in *Bt* cotton.

Narayana *et al.* (2008) reported that increasing the fertilizer dose beyond 120:60:60 kg N:P:K ha^{-1} had no significant impact on growth and yield attributes of *Bt* cotton, whereas, at closer spacing of 90 cm x 30 cm a significant response to seed cotton yield was observed for fertilizer dose beyond 120:60:60 kg N:P:K ha^{-1}

Kalaichelvi (2009) from TNAU, Coimbatore obtained significantly higher sympodia, boll setting percentage, boll number and seed cotton yield at a plant spacing of 90 cm x 60 cm with a fertilizer level of 160:80:80 kg N:P:K ha^{-1} in *Bt* cotton on clay loam soils under irrigated conditions.

Aruna and Reddy (2009) revealed that planting of *Bt* cotton at a spacing of 90 cm x 45 cm with 150:75:75 kg N:P:K ha^{-1} gave higher yields in *Bt* cotton on deep black soils of Nandyal.

The closer spacing of 90 cm x 67.5 cm with application of 150 kg N ha^{-1} recorded significantly the highest seed cotton yield in *Bt* cotton at Punjab Agricultural University, Research Station, Bathinda (Buttar *et al.*, 2010).

Rajendran *et al.* (2010) obtained the maximum seed cotton yield in *Bt* cotton with a spacing of 90 cm x 45 cm along with application of 120:60:60 kg N:P:K ha^{-1} on sandy loam soils of TNAU, Coimbatore. Further, they also observed the highest gross returns, net returns and B:C ratio with the same combination.

Devraj *et al.* (2011) conducted a field trial on sandy loam soils of Hisar, Haryana and found that plant spacing of 67.5 cm x 60 cm combined with a fertilizer dose of 187: 75:75 kg NPK kg ha^{-1} gave higher seed cotton yield.

Kumar *et al.*(2011) reported that maximum seed cotton yield was recorded with 100 cm × 45 cm with application of 150:60:60 NPK kg ha^{-1} on sandy loam soils of Hisar during *kharif*.

Sankaranarayanan *et al.* (2011) obtained the highest seed cotton yield of *Bt* cotton at a spacing of 75 cm x 60 cm fertilized with 150% RDF than 90 cm x 60 cm and 90 cm x 45 cm on clay loam soils of Coimbatore.

Sree Rekha and Pradeep (2012) conducted a field experiment during the *kharif* season on clayey soils of Agricultural Research Station, Adilabad and found that higher plant density (27,777 plants ha^{-1}) gave maximum seed cotton yield in Bunny *Bt* over lower plant densities (18,518 plants ha^{-1} and 13,888 plants ha^{-1}) and increase in nitrogen levels above 120 kg ha^{-1} had no significant effect on seed cotton yield.

Basavanneppa *et al.* (2012) reported that closer spacing of 90 cm x 45 cm and 90 cm x 60 cm with the application of 100 per cent NPK recorded higher yield and monetary advantages of *Bt* cotton on deep black soils of Agricultural Research Station, Siruguppa.

Shah *et al.* (2012) concluded that seed cotton yield was significantly higher with spacing of 90 cm × 45 cm combined with the application of 125% RDF than 90 cm × 60 cm and 90 cm × 90 cm in *Bt* cotton on medium black soil at Cotton Research Center, Khandwa.

Shukla *et al.*(2013) found that closer spacing of 60 cm × 60 cm with the application of 62.5:31.25:31.25 (N:P:K) gave higher yield and monetary advantages of *Bt* cotton than 90 cm × 60 cm on clay soil of Akola.

Jadhav *et al*. (2015) reported that spacing of 150 cm × 30 cm with the application of (200:100:100 kg N:P:K) gave maximum seed cotton yield than 180 cm × 30 cm in *Bt* cotton on clay soil during *kharif.*

Kulvir Singh (2015) conducted a field experiment in *Bt* cotton loamy sand at Punjab Agricultural University, Faridkot and observed highest seed cotton yield at a spacing of 67.5 cm × 60 cm with the application of 75 kg N ha^{-1} in *Bt* cotton.

Munir *et al.* (2015) reported that row spacing of 75 cm combined with the application of 180 kg N ha^{-1} gave higher seed cotton yield on loamy soil at Department of Agronomy, Pakistan.

2.4 ECONOMICS

Manjunatha *et al.* (2010[a]) from an experiment conducted at Agricultural College Farm, Raichur (Karnataka) during the *kharif* season observed significantly higher net returns of *Bt* cotton with the spacing of 60 cm x 30 cm over the 90 cm x 60 cm and 75 cm x 30 cm and was at a par with spacing of 90 cm x 20 cm.

Krishnaveni *et al.* (2010) reported that plant spacing of 90 cm x 30 cm gave significantly higher gross returns, net returns and BCR in *Bt* cotton over the 60 cm x 60 cm, 90 cm x 60 cm and 120 cm x 60 cm on clayey soils at Agricultural College Farm, Bapatla , Andhra Pradesh during *kharif.*

Shekar *et al.* (2012) reported that plant spacing of 90 cm × 30 cm gave significantly higher net returns and benefit cost ratio of *Bt* cotton over the 90 cm × 45 cm and 90 cm × 60 cm on sandy clay loam soil during *kharif* at Department of Agronomy, ANGRAU, Hyderabad.

Pasalwar *et al.*(2015) reported that the plant spacing of 45 cm × 10 cm gave significantly higher gross returns, net returns and BCR over the 45 cm × 15 cm, 45 cm × 20 cm and 60 cm × 15 cm on early and dwarf stature variety AKH-081 in black cotton soils at Akola.

Divya *et al.*(2016) reported that plant spacing of 120 cm × 45 cm gave significantly higher gross returns, net returns and BCR over 120 cm × 60 cm, 120 cm × 90 cm and 150 cm × 60 cm which was at par with the spacing of 150 cm × 45 cm in *Bt* cotton on black cotton soil during *kharif* in a farmer field of Perambalur district in Tamil Nadu.

Chapter-III

MATERIAL AND METHODS

The present investigation entitled "Performance of cotton under high density planting with varied spacing and levels of nitrogen" was conducted during *kharif* 2016 at Agricultural College Farm, Bapatla. The material used and the methods adopted during the experimentation are presented in this chapter under appropriate sub heads.

3.1 LOCATION OF THE EXPERIMENTAL SITE

The experimental site is situated at an altitude of 5.49 m above mean sea level, 15^0 54' N latitude, 80^0 25' E longitude and about 7 km away from the Bay of Bengal in the Krishna Zone of Andhra Pradesh, India. The experiment was laid out in field No. 28 part in the Northern block of the Agricultural College Farm, Bapatla.

3.2 WEATHER CONDITIONS DURING THE CROP GROWTH PERIOD

The data pertaining to weather parameters during the crop growth period (07-08-2016 to 20-01-2017)) at the College Farm, Bapatla are presented in Table 3.1

During the crop growth period, a total rainfall of 491.2 mm was received in 21 rainy days. The weekly mean maximum temperatures ranged from 29.5^0 C to 37.6 ^{0}C with an average of 32.9 ^{0}C and the weekly mean minimum temperatures ranged from 16.5 ^{0}C to 27 ^{0}C with an average of 22.0 ^{0}C. The weekly mean average relative humidity at 8.30 hrs was 81 per cent and at 17.30 hrs was 62 per cent.

3.3 EXPERIMENTAL SOIL

The experiment was laid out in field No. 28 part in Northern block of Agricultural College Farm, Bapatla. Composite soil samples from the experimental site were collected from 0-30 cm depth before conducting the experiment. The soil samples so collected were thoroughly mixed and kept for air drying. A representative soil sample of about one kilogram was drawn by quartering method. The soil sample was analyzed for different physical and physical - chemical properties (Table 3.2).

Table 3.2. Physico - chemical properties of the experimental soil

Soil Properties	Value	Method adopted
A.Mechanical analysis		
1. Sand (%)	20.0	Bouyoucos hydrometer method (Piper, 1966)
2. Silt (%)	32.0	
3. Clay (%)	48.0	
Textural class	Clay	Triangular method (Brady, 1999)
B. Chemical analysis		
pH (1:1.25 soil water suspension)	7.62	Glass electrode method (Richards, 1954)
EC (dS m^{-1} at 25 ^{0}C)	0.4	Digital electrical conductivity meter (Jackson, 1973)
Organic carbon (%)	0.2	Walkley and Black’s modified method (Walkley and Black, 1934)
Available N (kg ha^{-1})	200.3	Alkaline permanganate method (Subbiah and Asija, 1956)
Available P_2O_5 (kg ha^{-1})	25	Olsen’s extractant (Olsen *et al.*, 1954)
Available K_2O (kg ha^{-1})	260	Neutral normal ammonium acetate method (Jackson, 1973)

Based on soil analysis, the soil of the experimental site was classified as clay in texture, slightly alkaline in reaction and low in organic carbon and available nitrogen, medium in phosphorus and high in available potassium.

3.4 CROPPING HISTORY OF THE EXPERIMENTAL SITE FOR PAST 3 YEARS

Cropping history of the experimental site is furnished in Table 3.3

Table 3.3 Cropping history of the experimental site for three consecutive preceding years

Year	Crop	
	Kharif	***Rabi***
2013-2014	Maize	Fallow
2014-2015	Cotton	Fallow
2015-2016	Fallow	Fallow
2016-2017	Present experiment (Cotton)	

3.5 EXPERMENT DETAILS

Details of the experiment are as fallows

3.5.1. Treatment details

Main plots : Spacing (cm)

S_1 : 60 × 10

S_2 : 75 × 10

S_3 : 90 × 10

S_4 : 90 × 45

Sub plots : Nitrogen levels (kg ha^{-1})

N_1 : 60

N_2 : 90

N_3 :120

N_4 : 150

Thus, there were main treatments with 4 spacings and the sub treatments with 4 levels of nitrogen the total treatment combinations being 16.

3.5.2 Experimental Details and Layout

The experiment was laid out in split plot design with three replications. The layout plan is furnished in Fig. 3.1.

3.6 VARIETAL DESCRIPTION

The test variety used was SURAJ (CCH 510-4) (*Gossypium hirsutum*), a new long staple high yielding variety released from Central Institute of Cotton Research, Regional Station, Coimbatore. The crop matures in 165 – 180 days.

3.7 CULTIVATION DETAILS

Details on cultivation practices are presented here under. The calendar of operations are furnished in Appendix-1.

3.7.1 Main Field Preparation

The experimental field was ploughed twice with a tractor drawn cultivator and rotovator to obtain the required fine seed bed for sowing of seeds.

3.7.2 Sowing

Cotton seeds were sown on 7^{th} August 2016 as per the treatments *i.e.* at a spacing of 60 cm × 10 cm, 75 cm × 10 cm, 90 cm × 10 cm and 90 cm × 45 cm.

3.7.3 Fertilizer Application

The recommended dose of 45 kg P_2O_5 and 45 kg K_2O $ha^{-1}$was applied uniformly in the form of single superphosphate and muriate of potash. Entire quantity of phosphorus was applied basally. Nitrogen was applied in the form of urea as per the treatments in three equal splits at 30 DAS, 60 DAS and 90 DAS along with recommended dose of potassium.

3.7.4 Gap Filling and Thinning

To ensure optimum plant population, gap filling and thinning was done at 10 DAS.

3.7.5 Weeding

Three manual weedings were done to remove the weeds from the experimental plots. First weeding was done at 15 DAS and the remaining two weedings were done at 30 DAS and 60 DAS.

3.7.6 Irrigation

Two protective irrigations were given at required intervals during cropping period in addition to the rainfall received during 2016-2017. Further irrigating the field could not be necessitated due to deep root system of cotton crop and high water retentive capacity of black soil in which the crop was raised.

3.7.7 Plant Protection

Acephate @ 2.0 g L^{-1} was sprayed twice at 45 and 80 DAS and Thiomethoxam @ 2.0 g L^{-1} at 110 DAS to control sucking pests. Later, for the control of boll worms, the first spray was taken with Profenophos @ 2 ml L^{-1} at 90 DAS followed by flubendiamide @ 0.1 ml L^{-1} at 100 DAS and Coragen @ 3 ml L^{-1} at 120 DAS.

3.7.8 Harvesting

Seed cotton was harvested in three pickings when the bolls were matured and fully opened. At every picking, first border rows were harvested and collected separately and then the five sampled plants were harvested from the net plot. Finally, the entire net plot was harvested.

3.7.9 Sampling

Five plants were tagged randomly in each net plot area for recording observations that did not involve destructive sampling. All the observations during crop growth were recorded on these plants at different stages *i.e.*, 30, 60, 90 DAS and at harvesting. For recording drymatter production and nitrogen content which involve destructive sampling, five successive plants in the second row from the border row in each plot were sampled at each time.

3.8. SOIL ANALYSIS

A representative soil sample of about one kilogram was drawn by quatering method and stored in neatly labeled polythene lined cloth bag for soil analysis. Soil samples were analysed for available N (Subbiah and Asija, 1956), available P (Olsen *et al*. 1954) and available K (Jackson, 1973).

3.9 BIOMETRIC OBSERVATIONS

3.9.1 Plant height (cm)

Five plants were selected randomly in every net plot and tagged for recording plant height at 30, 60, 90 days after sowing and at harvest. Plant height was measured from base of the plant to the tip of the growing point and expressed as mean plant height in centimeters (cm).

3.9.2 Drymatter accumulation (kg ha^{-1})

Sampling was done at 30, 60, 90 days after sowing and at harvest. Five plants were taken from the second row and were dried first in shade and then in a hot air oven at 60 ^{o}C till a constant weight was obtained. Then dry weights were recorded and drymatter accumulation was expressed in kg ha^{-1}.

3.9.3 Yield attributes and yield

3.9.3.1 Number of monopodial branches per plant

The branches that arise from the auxiliary buds of the leaves in the lower region, which grow at sharp angle to the main stem and develop lateral functional branches with flowers were counted from five tagged plants and averaged as the number of monopodial branches per plant.

3.9.3.2 Number of sympodial branches per plant

The branches that are formed from above portions of main stem, which bear flowers at each node were counted from the five tagged plants, averaged as number of sympodial branches per plant.

3.9.3.3 Number of bolls per m^2

Number of bolls were recorded at harvest by using square quadrant in each plot and expressed as no of bolls per m^2.

3.9.3.4 Mean boll weight (g)

Twenty five bolls at random from net plot were collected and weighed. The average boll weight was calculated and expressed as boll weight in grams.

3.9.3.5 Seed cotton yield (kg ha^{-1})

The total seed cotton was harvested in three pickings. Seed cotton was picked from the plants in the net plot area and weighed. The yield obtained from five tagged plants was also added to this and expressed as seed cotton yield expressed in kg ha^{-1}.

3.9.3.6 Stalk yield (kg ha^{-1})

Plants from each net plot were cut at the soil surface after final picking and dried in the sun. and after through drying, the weights were recorded plot wise and five tagged plants were also included and expressed in kg ha^{-1}.

3.9.3.7 Nutrient uptake by crop

The drymatter samples of the cotton crop collected at the time of harvest, dried, powdered and analysed for nitrogen, phosphorus and potassium by following standard methods.

From chemically analysed data, uptake of individual nutrient was calculated using the following formula.

$$\text{Nutrient uptake (kg ha}^{-1}\text{)} = \frac{\text{Nutrient content (\%)} \times \text{Drymatter production (kg ha}^{-1}\text{)}}{100}$$

3.10 ECONOMICS

The gross returns from each treatment were worked out with the prevailing prices. The net returns from each treatment were calculated by deducting the cost of cultivation from gross returns. Benefit cost ratio for all the treatments was worked out on the basis of net returns and cost of cultivation.

Net returns = Gross returns - Total cost of cultivation

$$\text{Benefit cost ratio} = \frac{\text{Net returns}}{\text{Total cost of cultivation}}$$

3.11 STATISTICAL ANALYSIS

Statistical analysis for the data was done following the analysis of variance technique for split plot design as suggested by Gomez and Gomez (1984). Statistical significance was tested by applying F-test at 0.05 level of probability. Critical differences at 0.05 levels were worked out for the effects, which were significant. The results are presented in various tables and depicted graphically wherever necessary.

Chapter- IV

RESULTS AND DISCUSSION

Results and discussion of the field experiment entitled “Performance of cotton under high density planting with varied spacing and levels of nitrogen” obtained were analysed statistically and are presented in this chapter under suitable heads and subheadings.

4.1 WEATHER CONDITIONS AND SOIL

The weather conditions prevailed during the crop growth period were normal. The weekly mean maximum and minimum temperatures during the crop growth period ranged from 29.5 ^{0}C to 37.6 ^{0}C and 16.5 ^{0}C to 27 ^{0}C, respectively. While, the average minimum and maximum temperatures were 22.0 ^{0}C and 32.9 ^{0}C, respectively. The weekly mean average relative humidity at 8.30 hrs was 81 per cent and at 17.30 hrs was 62 per cent. A total rainfall of 491.2 mm was received in 21 rainy days during the crop growth period. (Fig.4.1)

The crop was sown on clay soil, which was slightly alkaline in reaction (7.62) and low in organic carbon (0.2%) , low in available nitrogen (200.3 kg ha^{-1}) and medium available phosphorus (25 kg ha^{-1}) and high in available potassium (260 kg ha^{-1}).

4.2 EFFECT OF VARIED SPACING AND LEVELS OF NITROGEN ON GROWTH PARAMETERS

4.2.1 Plant height (cm)

Plant growth is a dynamic process and is affected by the complex interaction occurring among soil - plant and weather continuum. Growth in plants has various phases, starting from activation of embryo and ending with maturation of seed. Plant growth in one way is expressed in terms of plant height.

Data pertaining to plant height of cotton recorded at 30 DAS , 60 DAS, 90 DAS and at harvest was significantly affected by plant spacing and levels of nitrogen but their interaction effect was non significant. (Table 4.1 to 4.4)

At 30 DAS, the effect of plant spacing and levels of nitrogen was not significant on plant height. In general, compared to most crops, cotton's early season growth is very slow. The rate of increase in plant height in cotton is slow up to 60 DAS and complete canopy cover is reached only at 90 DAS. On the other hand, the first split application of nitrogen was done only at 30 DAS. (Table 4.1).

At 60 DAS, plant height was not significantly affected by plant spacing, but the nitrogen levels significantly affected the plant height (Table 4.2). The maximum plant height (79.9 cm) recorded at 150 kg N ha^{-1} was significantly superior to that of other levels of nitrogen tested. Lowest plant height (68 cm) was recorded with application of 60 kg N ha^{-1}.

However, at 90 DAS the plant height was significantly affected by plant spacing and levels of nitrogen but not their interaction. (Table 4.3) Taller plants (99.9 cm) were recorded with closer plant spacing 60 cm × 10 cm and was significantly superior to that of other plant spacings tested. Lowest plant height (70.8 cm) was recorded with wider spacing 90 cm × 45 cm. Increase in plant height at closer plant spacing might be due to increase in inter nodal length Jat *et al.* (2014) and overcrowding and competition for solar radiation. This was in conformity with earlier findings of Narayana *et al.* (2008), Pendharkar *et al.* (2010) and Jat *et al.* (2014). The maximum plant height (91.4 cm) was recorded with higher level of N (150 kg N ha^{-1}) and it was significantly superior to all other levels of nitrogen tested. Lowest plant height (78.1 cm) was recorded at 60 kg N ha^{-1}. The increase in plant height at higher levels of nitrogen might be due to more cell division and cell elongation as promoted by application of nitrogen. The increase in plant height in response to higher levels of nitrogen was in conformity with the previous findings of Ram Prakash *et al.* (2001), Sagarka *et al.* (2002), Sunitha *et al.* (2010), Sandeep Rawal *et al.*(2015) and Bharathi *et al.*(2016).

Similar trend was followed at harvest (Table 4.4). Plant spacing and levels of nitrogen was significantly affected the plant height at harvest. Taller plants (116 cm) were recorded with closer spacing of 60 cm × 10 cm which was significantly superior to that of other plant spacings tested. Lowest plant height (91.9 cm) was recorded at a spacing of 90 cm × 45 cm. The maximum plant height (112.8 cm) was recorded with higher level of N (150 kg N ha^{-1}) to that of other levels of nitrogen tested. The lowest plant height (95 cm) was recorded at 60 kg N ha^{-1}.

4.2.2 Drymatter Accumulation (kg ha^{-1})

Drymatter accumulation (kg ha^{-1}) at 30 DAS, 60 DAS, 90 DAS and at harvest was significantly affected by plant spacing and levels of nitrogen tested but not with their interaction.

At 30 DAS, plant spacing significantly influenced the drymatter accumulation. The highest drymatter accumulation (450 kg ha^{-1}) was recorded with closer spacing of 60 cm × 10 cm than that of other plant spacings tested. However, the drymatter accumulation was not affected by levels of nitrogen. and interaction effect of nitrogen and spacing. (Table 4.5)

At 60 DAS, plant spacing and levels of nitrogen significantly affected the drymatter accumulation (kg ha^{-1}). Maximum drymatter accumulation (2038 kg ha^{-1}) was recorded at closer plant spacing of 60 cm × 10 cm and was significantly superior to other plant spacings tested. Lowest drymatter accumulation (1303 kg ha^{-1}) was recorded at wider plant spacing of 90 cm × 45 cm. With each increment in nitrogen level, drymatter accumulation increased and maximum drymatter accumulation (1932 ka ha^{-1}) was recorded with the application of highest level of nitrogen 150 kg N ha^{-1}. Lowest drymatter accumulation (1440 kg ha^{-1}) was recorded with application of 60 kg N ha^{-1} (Table 4.6).

Similarly, at 90 DAS, drymatter accumulation was significantly affected by plant spacing and levels of nitrogen (Table 4.7). The maximum drymatter accumulation (5121 kg ha^{-1}) was recorded at closer plant spacing of 60 cm × 10 cm and was significantly superior to other spacings tested. The lowest drymatter accumulation (3466 kg ha^{-1}) was recorded at wider spacing of 90 cm × 45 cm. The maximum drymatter accumulation with closer spacing might be due to more number of plants accommodated per unit area. Similar observations of higher drymatter accumulation at closer plant spacing compared to wider plant spacing was also reported by Anand (2006), Bhalerao *et al.* (2008), Manjunatha *et al.* (2010[a]), Shwetha *et al.* (2010), Sunitha *et al.*(2010), Bhalerao and Gaikwad (2010), Devraj *et al.* (2011) and Hensh *et al*. (2011). Highest drymatter accumulation (5441 kgha^{-1}) was recorded with 150 kg N ha^{-1} and was superior to other levels of nitrogen tested. The lowest drymatter accumulation (2965 kg ha^{-1}) was recorded at 60 kg N ha^{-1}. The increased drymatter accumulation with increase in nitrogen application from 60 kg N ha^{-1} to 150 kg N ha^{-1} might be due to the fact that nitrogen fertilization made the plants more efficient in photosynthetic activity by enhancing the carbohydrate metabolism resulting in increased drymatter accumulation. The increase in plant drymatter accumulation in response to higher levels of nitrogen was in confirmity with the earlier findings of Ram Prakash *et al*. (2001), Sagarka *et al*. (2002), Giri and Gore (2006) and Sunitha *et al*. (2010) and Hallikeri *et al*. (2011).

Similar trend was followed at harvest, plant spacing and levels of nitrogen was significantly affected the drymatter accumulation. Interaction was non significant. The maximum drymatter accumulation (9031 kg ha^{-1}) was recorded at closer spacing 60 cm × 10 cm and was significantly superior to other spacings tested. The lowest drymatter accumulation (7092 kg ha^{-1}) was recorded at wider spacing of 90 cm × 45 cm. The maximum drymatter accumulation (9608 kg ha^{-1}) was recorded with higher level of N (150 kg N ha^{-1}) and was significantly superior to other levels of nitrogen tested. The lowest drymatter accumulation (6643 kg ha^{-1}) was recorded with 60 kg N ha^{-1}. (Table 4.8) and (Fig. 4.2).

4.2.3 Number of Monopodial and Sympodial Branches per Plant

The data revealed that the number of monopodial branches of plant at harvest were zero because of varietial character (Table 4.9). The number of sympodial branches per plant were significantly influenced by varied spacing and levels of nitrogen, However their interaction was non significant (Table 4.10). The number of sympodial branches (12.9) per plant was maximum at wider plant spacing of 90 cm × 45 cm and was significantly superior than other plant spacings tested. The number of sympodial branches (9.7) per plant was lower at closer spacing of 60 cm × 10 cm. A significant increase in number of sympodial branches per plant was recorded with increase in the inter row from 60 cm to 90 cm and intra row spacing from 10 cm to 45 cm. (Table 4.10). Sympodial branches per plant were maximum in wider spacing than closer spacing due to reduced competition for resources. Similar results were obtained by Narayana *et al.* (2008) and Manjunatha *et al.* (2010 [b]).

A progressive increase in number of sympodial branches per plant were obtained with increase in nitrogen levels from 60 to 150 kg N ha^{-1}. The more number of sympodial branches (12.3) recorded with the application of 150 kg N ha^{-1} was significantly superior to other levels of nitrogen. The number of sympodial branches (10.2) per plant was lower at 60 kg N ha^{-1}. The more number of sympodial branches per plant at higher level of nitrogen application may be due to the fact that nitrogen helps in cell division and cell elongation leading to increased number of lateral branches. Similar results were observed by Hosmath *et al.* (2004), Jagvir Singh *et al.* (2003), Mohan Das *et al.* (2009), Reddy and Kumar (2010), Sunitha *et al.* (2010) and Hallikeri *et al.*(2011).

4.3 YIELD CHARACTERS

4.3.1. Yield attributes

Perusal of the data revealed that varied plant spacing and levels of nitrogen tested significantly influenced the yield attributes, however their interaction was non significant.

Number of Bolls per m^2

Plant spacing and levels of nitrogen significantly influenced the number of bolls per m^2. Maximum number of bolls per m^2 (61.3) was recorded with closer plant spacing of 60 cm × 10 cm than other plant spacings tested and was at a par with plant spacing of 75 cm × 10 cm. Lowest number of bolls per m^2 (46.4) were recorded with wider spacing of 90 cm × 45 cm. In general, more number of bolls per plant were recorded with wider plant spacing but number of bolls per m^2 were recorded at closer plant spacing due to more no of plants accommodated per unit area. The similar results were observed by Reddy and Dileep Kumar (2010), Sankaranarayanan *et al*. (2011) and Venugopalan *et al.* (2011) and Bhalerao *et al.* (2012). An increase in boll number per m^2 was obtained with each increment in nitrogen level from 60 to 150 kg ha^{-1}. The maximum number of bolls per m^2 (59.6) were recorded with 150 kg N ha^{-1} than other levels of nitrogen tested. The lowest number of bolls per m^2 (48.5) was recorded at 60 kg N ha^{-1} (Table 4.11). Maximum number of bolls per m^2 with higher nitrogen levels might be due to good vegetative growth of plant. Similar results were observed by Munir *et al*. (2015) (Fig 4.3).

Boll weight (g)

The varied plant spacing and levels of nitrogen tested significantly influenced the boll weight. Among the plant spacings tested significantly superior boll weight (3.43 g) was recorded at wider spacing of 90 cm × 45 cm. The boll weight recorded with 60 cm × 10 cm was at a par with 75 cm × 10 cm. Bolls tend to be larger at wider plant spacing due to the availability of more nutrients and ample space. Similar results were observed by Jat *et al.*(2014) and Kulvir Singh (2015), Boll weight significantly increased with increase in nitrogen application. Boll weight was (3.4 g) significantly higher with application of 150 kg N ha^{-1} than other nitrogen levels. Boll weight (2.97 g) was significantly lower at 60 kg N ha^{-1}. Increase in the availability of nitrogen might have increased the dry matter accumulation of plants and it acted as a source to supply nutrients to reproductive parts *i.e.* squares, and bolls. Likewise, heavier boll weight at higher nitrogen levels could be due to a better source-sink relationship established with sufficient quantity of nitrogen. The similar results were observed by Nehra and Yadav (2012) (Table 4.12).

4.3.2 Seed cotton yield (kg ha^{-1})

Similarly, seed cotton yield was significantly influenced by varied plant spacing and levels of nitrogen tested but not their interaction. The ultimate seed cotton yield is the manifestation of yield contributing characters. These yield attributing characters were significantly affected by varied plant spacings. Maximum seed cotton yield (1666 kg ha^{-1}) was recorded with closer plant spacing of 60 cm × 10 cm and was on a par with plant spacing of 75 cm × 10 cm and superior to other plant spacings. Lowest seed cotton yield (1173 kg ha^{-1}) was recorded at wider spacing of 90 cm × 45 cm. Superior yields at closer plant spacing might be due to more number of bolls per unit area. Similar results were observed by Krishnaveni *et al.* (2010), Manjunatha *et al.* (2010[a]), Pawar *et al.* (2010), Rajendran *et al.* (2010), Shwetha *et al.* (2010), Basavanneppa *et al.* (2012), Asewar *et al.*(2013), Venugopalan *et al.*(2014) and Jadhav *et al.* (2015). The highest seed cotton yield (1620 kg ha^{-1}) was recorded with application of 150 kg N ha^{-1} was significantly superior to the rest of the nitrogen levels. Lowest seed cotton yield (1253 kg ha^{-1}) was recorded at 60 kg N ha^{-1}. Progressive and significant increase in seed cotton yield with each increment in nitrogen level was noticed. Increase in yield with nitrogen application might be due to its favorable effect on plant growth and development, which resulted in increased drymatter accumulation and associated betterment in yield attributing characters. Earlier investigators also reported significant and favourable effects of nitrogen on cotton yield Sagarka *et al.* (2002), Giri and Gore (2006), Singh *et al.,* (2010), Sunitha *et al.*, (2010), Nehra and Yadav (2012) and Munir *et al*. (2015). (Table 4.13) and (Fig 4.4).

4.3.3 Stalk Yield (kg ha^{-1})

The data pertaining to stalk yield of cotton was influenced by plant spacing and nitrogen levels but not their interaction (Table 4.14). Higher stalk yield was obtained with plant spacing of 60 cm × 10 cm than other spacings tested. Stalk yield was significantly higher (7118 kg ha^{-1}) at the closer plant spacing of 60 cm × 10 cm. Lowest stalk yield was (5454 kg ha^{-1}) was recorded at wider spacing 90 cm × 45 cm. similar results were observed by Chavan *et al*. (2011) and Uma Nath Shukla *et al*. (2013). Increase in stalk yield was observed with each successive increase in nitrogen levels from 60 to 150 kg N ha^{-1}. Stalk yield (7623 kg ha^{-1}) was significantly higher at 150 kg N ha^{-1} than other nitrogen levels tested. Lower stalk yield (5107 kg ha^{-1}) was recorded at 60 kg N ha^{-1}. Similar results were observed by Bhalerao and Gaikwad (2010).

4.3.4 Percent NPK Content in Plants

NPK content in plants was not significantly affected by plant spacing and levels of nitrogen (Table 4.15 to 4.17).

4.3.5 Nutrient Uptake by Plants

Nutrient uptake by plants at harvest was significantly influenced by plant spacing and nitrogen levels but their interactions were non significant (Table 4.18 to 4.20).

Nitrogen (kg ha^{-1})

Uptake of nitrogen by plants at harvest was influenced by varied spacing and levels of nitrogen, but their interactions were non significant. The maximum uptake of nitrogen (65.8 kg ha^{-1}) by plant was recorded with closer spacing of 60 cm × 10 cm than other spacings tested. The lowest nitrogen uptake (49 kg ha^{-1}) was recorded with wider spacing of 90 cm × 45 cm. Nitrogen uptake by plants was significantly higher at closer spacing might be due to higher drymatter accumulation per unit area which was a result of more number of plants accommodated per unit area. Nitrogen uptake was significantly higher with application of 150 kg N ha^{-1} than other applications tested. Nitrogen uptake by plants was significantly higher (70.4 kg ha^{-1}) at 150 kg N ha^{-1} and lowest nitrogen uptake (45.7 kg ha^{-1}) by plants was recorded at 60 kg N ha^{-1}. Present results were in conformity with Anupdas *et al*. (2006), Sisodia and Khamparia (2007), Devraj *et al*. (2011), Muhammad Ather Nadeem *et al*. (2015) and Rafi Quamar *et al*. (2015).

Phosphorus uptake (kg ha^{-1})

Similar to nitrogen uptake, phosphorus uptake was significantly influenced by spacing and levels of nitrogen but not their interaction. Phosphorus uptake was significantly superior at 60 cm × 10 cm than other spacings tested and it might be due to higher drymatter per hectare obtained from higher plant population. Phosphorus uptake was significantly higher (20 kg P ha^{-1}) at closer spacing of 60 cm × 10 cm, lowest phosphorus uptake (13 kg P ha^{-1}) was recorded at wider spacing of 90 cm × 45 cm. Phosphorus uptake was significantly higher with application of 150 kg N ha^{-1} than other nitrogen applications tested that might be due to favourable effect of nitrogen on phosphorus uptake by plant. Maximum phosphorus uptake (21.7 kg P ha^{-1}) was recorded at 150 kg N ha^{-1} and lowest phosphorus uptake (11.6 kg P ha^{-1}) was recorded at 60 kg N ha^{-1}. Similar results were observed by Dhillon *et al*.(2006) and Jitendra Singh *et al*. (2016).

Potassium uptake (kg ha^{-1})

Potassium uptake was significantly influenced by spacing and levels of nitrogen but not their interaction. Potassium uptake was significantly higher at closer spacing of 60 cm × 10 cm than other spacings tested which might be due to higher drymatter accumulation per unit area. Maximum potassium uptake (56.6 kg K ha^{-1}) was recorded at closer spacing of 60 cm × 10 cm and lowest potassium uptake (40.9 kg K ha^{-1}) was recorded at wider spacing of 90 cm × 45 cm. Potassium uptake was significantly higher with application of 150 kg N ha^{-1} than other nitrogen applications tested and it might be due to favourable effect of nitrogen on potassium uptake. Maximum potassium uptake (59.7 kg K ha^{-1}) was recorded at 150 kg N ha^{-1} and lowest potassium uptake (38.9 kg K ha^{-1}) was recorded at 60 kg N ha^{-1}. Similar results were observed by Babaria *et al*. (2010) and Jitendra Singh *et al*. (2016).

4.4 ECONOMICS

Perusal of data on economics indicated that irrespective of plant spacing, the enhancement in nitrogen application increased the gross, net returns and benefit cost ratio. which was in consonance with the findings of Jat *et al*. (2014) and Munir *et al*. (2015) and Kulvir Singh *et al*. (2015) and Divya *et al*. (2016).

The highest gross returns, net income and benefit cost ratio were obtained at closer plant spacing of 60 cm × 10 cm with application of 150 kg N ha^{-1} followed by 120 kg N ha^{-1} which, might be due to higher seed cotton yield obtained per unit area (Table 4.21).

Chapter V

SUMMARY AND CONCLUSIONS

A field experiment entitled "Performance of cotton under high density planting with varied spacing and levels of nitrogen" was conducted on clay soils at the Agricultural College Farm, Bapatla during *kharif*, 2016-2017. The experiment was laid out in a split plot design and replicated thrice and the treatments consisted of a combination of four plant spacings *viz.*, S_1- 60 cm × 10 cm , S_2 -75 cm × 10 cm, S_3- 90 cm × 10 cm and S_4 - 95 cm × 10 cm and four nitrogen levels N_1- 60 kg N ha^{-1}, N_2- 90 kg N ha^{-1}, N_3- 120 kg N ha^{-1} and N_4- 150 kg N ha^{-1}. The salient findings emerged from this investigation are briefly summarized below.

The affect of plant spacing was not significant on plant height at 30 and 60 DAS. However, at 90 DAS and at harvest maximum plant height was recorded at closer spacing of 60 cm × 10 cm followed by 75 cm × 10 cm and 90 cm × 10 cm and 90 cm × 45 cm. The levels of nitrogen had no significant affect on plant height at all the stages of observations except at 30 DAS. Plant height increased significantly with each increment of nitrogen levels from 60 to 150 kg N ha^{-1}. The maximum plant height was recorded with the application of 150 kg N ha^{-1} at all the stages of crop growth from 60 DAS to harvest.

Drymatter accumulation per hectare was significantly superior at closer spacing of 60 cm ×10 cm compared to other spacings tested at 30 DAS, 60 DAS, 90 DAS and at harvest of crop growth. However, drymatter accumulation was not significantly affected by nitrogen levels at 30 DAS and the maximum dry matter accumulation was recorded with application of 150 kg N ha^{-1} at all the stages of crop growth from 60 DAS to harvest. Drymatter accumulation increased significantly with each increment of nitrogen levels from 60 to 150 kg N ha^{-1}.

The number of monopodial branches were zero due to varietial character. The more number of sympodial branches per plant recorded with wider spacing of 90 cm × 45 cm was significantly superior to other spacings tested. The more number of sympodial branches per plant were recorded with the application of 150 kg N ha^{-1}, which was significantly superior to other levels of nitrogen tested.

Number of bolls per m^2 were significantly higher at closer spacing of 60 cm × 10 cm than other spacings tested and it was on a par with 75 cm × 10 cm. The maximum number of bolls per m^2 were recorded with application of 150 kg N ha^{-1} and it was significantly superior to other levels of nitrogen tested.

Boll weight was significantly superior with wider spacing of 90 cm × 45 cm than boll weight recorded with 60 cm × 10 cm and 75 cm × 10 cm and both were at par with each other. Boll weight was significantly higher with application of 150 kg N ha^{-1} than other nitrogen levels tested.

Seed cotton yield was significantly higher at closer plant spacing of 60 cm × 10 cm than other spacings tested and was at a par with 75 cm × 10 cm. The highest seed cotton yield recorded with application of 150 kg N ha^{-1} significantly superior to the rest of the nitrogen levels tested.

Stalk yield was significantly superior at closer plant spacing of 60 cm ×10 cm than other spacings tested. The highest stalk yield was recorded at 150 kg N ha^{-1} than other levels of nitrogen tested.

The NPK content was not significantly affected by plant spacing and levels of nitrogen.

Nutrient uptake by plant at harvest was significantly influenced by varied spacing and levels of nitrogen. The maximum uptake of nitrogen was recorded at a closer spacing of 60 cm × 10 cm than other spacings tested. The uptake of nitrogen was significantly higher with application of 150 kg N ha^{-1} than other nitrogen levels tested.

Highest phosphorus uptake by plant at harvest was recorded at closer spacing of 60 cm × 10 cm than other spacings tested. The uptake of Phosphorus was significantly superior with application of 150 kg N ha^{-1} than other levels of nitrogen tested.

Potassium uptake by plant at harvest was significantly superior at 60 cm × 10 cm than other spacings tested. The maximum uptake of potassium was recorded at 150 kg N ha^{-1} than other levels of nitrogen.

The higher gross returns and net returns and B:C ratio were obtained with closer spacing of 60 cm × 10 cm and application of 150 kg N ha^{-1}.

CONCLUSIONS :

Based on the results of present investigation, the fallowing conclusions have been drawn :

- Suraj variety responded positively at a closer spacing of 60 cm × 10 cm with higher growth and yield parameters and seed cotton yield.
- With each increment in N level from 60 to 150 kg N ha^{-1} growth and yield attributes increased and the highest was with the application of 150 kg N ha^{-1}.
- The highest net returns and B:C ratio were obtained at closer spacing of 60 cm × 10 cm with application of 150 kg N ha^{-1}.
- Seed cotton yield increased with increase in nitrogen levels tested, thus indicating the need to test at further higher level of nitrogen.

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***Original not seen**

Note: The literature is cited as per the “Thesis Guidelines” prescribed by Acharya N. G. Ranga Agricultural University, Guntur.

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APPENDIX

CALENDAR OF OPERATIONS

S.No.	Particulars of the field operations performed	Date
1.	Preparatory cultivation twice (tractor drawn cultivator)	31-07-2016 & 01 -08 -2017
2.	Rotovator	02-08-2016
3.	Layout of experiment	05-08-2016
4	Fertilizer application (phosphorous as basal dose)	06-08-2016
5.	Sowing of cotton	07-08-2016
6.	Gap filling & Thinning	17-08-2016
7.	Weeding	22-08-2016
8.	Irrigation	08-09-2016
9.	Split application of fertilizer (N&K)	09-09-2016
10.	Weeding	22-09-2016
11.	Spraying against sucking pests (Acephate)	23-09-2016
12.	Split application of fertilizer (N&K)	08-10-2016
13.	Weeding	21-10-2016
14.	Spraying against sucking pests (Acephate)	25-10-2016
15.	Spraying against boll worms (Profenophos)	05-11-2016
16.	Split application of fertilizer (N&K)	08-11-2016
17.	Spraying against boll worms (Flubendiamide)	18-11-2016
18.	Spraying against sucking pests (Thiomethoxam)	30-11-2016
19.	Spraying against boll worms (Coragen)	11-12-2016
20.	Irrigation	12-12-2016
21.	First picking	14-12-2016
22.	Second picking	31-12-2016
23.	Final picking	20-01-2017

LIST OF SYMBOLS AND ABBREVIATIONS

@	:	At the rate of
%	:	Per cent
^0C	:	Degree Celsius
BCR	:	Benefit Cost Ratio
CD (0.05)	:	Critical Difference at 5 per cent level
Cm	:	Centimeter
CV	:	Coefficient of Variation
DAS	:	Days after sowing
dS m^{-1}	:	Decisiemen per metre
EC	:	Electrical conductivity
et al.,	:	And others
Fig.	:	Figure
g	:	Gram
g L^{-1}	:	Gram per litre
g $plant^{-1}$	:	Gram per plant
ha^{-1}	:	Per hectare
i.e.,	:	That is
K	:	Potassium
kg	:	Kilogram
kg ha^{-1}	:	Kilogram per hectare
K_2O	:	Potassium Oxide
m	:	Metre
m^2	:	Square metre
m L	:	Millilitre
Min	:	Minimum
mm	:	Millimetre
MOP	:	Muriate of Potash
N	:	Nitrogen

No.	:	Number
NS	:	Non significant
P	:	Phosphorus
P_2O_5	:	Phosphorus Pentoxide
pH	:	Potential of hydrogen ion concentration
q ha^{-1}	:	Quintal per hectare
RDF	:	Recommended dose of fertilizers
RH	:	Relative humidity
Rs.	:	Rupees
SEm±	:	Standard Error of mean
SSP	:	Single Super Phosphate
viz.,	:	Namely

LIST OF PLATES

ABSTRACT

Author	:	**BOBBILI DEVI**
Title of the thesis	:	**PERFORMANCE OF COTTON UNDER HIGH DENSITY PLANTING WITH VARIED SPACING AND LEVELS OF NITROGEN**
Degree to which it is Submitted	:	**MASTER OF SCIENCE IN AGRICULTURE**
Faculty	:	**AGRICULTURE**
Department	:	**AGRONOMY**
Chairperson	:	**Dr. S. BHARATHI**
University	:	**ACHARYA N. G. RANGA AGRICULTURAL UNIVERSITY**
Year of Submission	:	**2017**

A field experiment was conducted on clay soils of the Agricultural College Farm, Bapatla to study " Performance of cotton under high density planting with varied spacing and levels of nitrogen" during the year 2016 – 2017 under rainfed conditions. The treatments consisted of four plant spacings S_1 - 60 cm × 10 cm , S_2- 75 cm × 10 cm , S_3- 90 cm × 10 cm , S_4- 90 cm × 45 cm in combination with four nitrogen levels N_1- 60 kg N ha^{-1}, N_2- 90 kg N ha^{-1}, N_3- 120 kg N ha^{-1}, N_4- 150 kg ha^{-1} and replicated thrice in split plot design. Test variety was Suraj.

Plant height of cotton was significantly influenced by varied spacing and levels of nitrogen at different stages except at 30 DAS. Further, plant height was not influenced by spacings at 60 DAS. The highest plant height was recorded with closer spacing of 60 cm × 10 cm and was significantly superior to other spacings tested at 90 DAS and at harvest. Maximum plant height was observed at 150 kg N ha^{-1} than other levels of N tested at all the stages of crop growth. Interactions were non significant.

Drymatter accumulation was significantly higher at closer spacing of 60 cm × 10 cm than other spacings at all the growth stages. Highest drymatter accumulation was recorded with 150 kg N ha^{-1} and interactions were not significant.

The number of monopodial branches per plant were zero due to varietial character. Maximum number of sympodial branches per plant were recorded at wider spacing of 90 cm × 45 cm than other spacings tested. Further, sympodial branches per plant recorded were maximum with application of 150 kg N ha^{-1} and were significantly superior to the other nitrogen levels tested. The interaction effect was non significant.

Number of bolls per m^2 was significantly higher at closer spacing of 60 cm × 10 cm than other spacings tested and was on a par with 75 cm × 10 cm. Maximum number of bolls per m^2 was recorded at 150 kg N ha^{-1} than other nitrogen levels tested. Interactions were non significant.

Maximum boll weight was recorded at wider spacing of 90 cm × 45 cm than other spacings tested, however, the recorded boll weight at closer spacing of 60 cm × 10 cm was on a par with 75 cm × 10 cm. Regarding nitrogen leves maximum boll weight was recorded at 150 kg N ha^{-1} and was significantly superior to other nitrogen levels tested. Interaction effect was non significant.

Maximum seed cotton yield was recorded at closer spacing of 60 cm × 10 cm than other spacings tested and was on a par with 75 cm × 10 cm. Highest seed yield was recorded with application of 150 kg N ha^{-1} than other nitrogen levels tested. Interaction effect was non significant.

Maximum stalk yield was recorded at a closer spacing of 60 cm × 10 cm than other spacings tested. Highest stalk yield was recorded at 150 kg N ha^{-1} than other nitrogen levels tested. Interaction effect was not significant.

NPK content in plants was not significantly affected by plant spacing and levels of nitrogen.

NPK uptake by plants at harvest was significantly higher at closer spacing of 60 cm × 10 cm than other spacings tested. Maximum NPK uptake by plants was recorded with application of 150 kg N ha^{-1} than other nitrogen levels tested. Interactions were not significantly influenced.

Overal, the results of the trial showed that spacing of 60 cm × 10 cm was found to be optimum to realize higher growth, seed cotton yield and net returns under high density planting system. Secondly, increase in nitrogen levels from 60 kg N ha^{-1} to 150 kg N ha^{-1} recorded higher growth and seed cotton yield.

Table 4.1. Plant height (cm) at 30 DAS as influenced by varied spacing and levels of nitrogen

Nitrogen level (kg ha^{-1})	Plant height				
	Plant spacing (cm)				
	S_1- 60 × 10	S_2- 75 × 10	S_3 – 90 ×10	S_4 – 90 × 45	Mean
N_1- 60	22.5	23.2	22.4	22.7	**22.7**
N_2 - 90	21.8	22.7	21.7	22.4	**22.2**
N_3 - 120	21.8	22.3	23.0	23.5	**22.6**
N_4 - 150	23.8	21.6	22.6	22.2	**22.5**
Mean	**22.5**	**22.4**	**22.4**	**22.7**	

	SEm$\pm$	CD(p=0.05)	CV(%)
Plant spacing (S)	0.4	NS	6.3
Nitrogen level (N)	0.2	NS	5.8
Interaction (S×N)	0.5	NS	

Table 4.2. Plant height (cm) at 60 DAS as influenced by varied spacing and levels of nitrogen

Nitrogen level (kg ha^{-1})	Plant height				
	Plant spacing (cm)				
	S_1- 60 × 10	**S_2- 75 ×10**	**S_3 – 90 ×10**	**S_4 – 90 × 45**	**Mean**
N_1- 60	69.7	69.3	66.7	66.5	**68.0**
N_2 - 90	74.5	70.6	69.4	68.7	**70.8**
N_3 - 120	79.3	74.4	73.6	72.8	**75.0**
N_4 - 150	81.5	80.3	79.5	78.6	**79.9**
Mean	**76.2**	**73.6**	**72.3**	**71.6**	

	SEm$\pm$	CD(p=0.05)	CV(%)
Plant spacing (S)	1.9	NS	12.8
Nitrogen level (N)	0.7	2.2	10.1
Interaction (S×N)	1.5	NS	

Table 4.3. Plant height (cm) at 90 DAS as influenced by varied spacing and levels of nitrogen

	Plant height				
Nitrogen level (kg ha^{-1})	**Plant spacing (cm)**				
	S_1- 60 × 10	**S_2- 75 × 10**	**S_3 – 90 ×10**	**S_4 – 90 × 45**	**Mean**
N_1- 60	91.6	81.1	73.3	66.6	**78.1**
N_2 - 90	96.7	87.9	77.2	69.7	**82.9**
N_3 - 120	103.8	91.7	82.9	71.4	**87.4**
N_4 - 150	107.3	96.3	86.7	75.9	**91.4**
Mean	**99.9**	**89.3**	**80.1**	**70.8**	

	SEm±	CD(p=0.05)	CV(%)
Plant spacing (S)	2.5	8.9	10.5
Nitrogen level (N)	1.3	3.9	6.5
Interaction (S×N)	2.715	NS	

Table 4.4. Plant height (cm) at harvest as influenced by varied spacing and levels of nitrogen

Nitrogen level (kg ha^{-1})	Plant height				
	Plant spacing (cm)				
	S_1- 60 × 10	**S_2- 75 × 10**	**S_3 – 90 ×10**	**S_4 – 90 × 45**	**Mean**
N_1- 60	105.9	97.9	90.9	85.1	**95.0**
N_2 - 90	110.7	105.1	96.4	89.3	**100.4**
N_3 - 120	120.9	110.2	101.1	94.1	**106.6**
N_4 - 150	126.4	117.3	108.0	99.4	**112.8**
Mean	**116.0**	**107.6**	**99.1**	**91.9**	

	SEm$\pm$	CD(p=0.05)	CV(%)
Plant spacing (S)	1.9	6.8	6.6
Nitrogen level (N)	1.7	5.1	5.9
Interaction (S×N)	3.5	NS	

Table 4.5. Drymatter accumulation (kg ha^{-1}) at 30 DAS as influenced by varied spacing and levels of nitrogen

Nitrogen level (kg ha^{-1})	Drymatter accumulation				
	Plant spacing (cm)				
	S_1- 60 × 10	**S_2- 75 ×10**	**S_3 – 90 ×10**	**S_4 – 90 × 45**	**Mean**
N_1- 60	434	407	371	341	**388**
N_2 - 90	447	415	384	344	**398**
N_3 - 120	456	420	391	361	**407**
N_4 - 150	462	427	394	363	**412**
Mean	**450**	**417**	**385**	**353**	

	SEm±	**CD(p=0.05)**	**CV(%)**
Plant spacing (S)	8.6	30.0	7.4
Nitrogen level (N)	6.7	NS	5.8
Interaction (S×N)	13.5	NS	

Table 4.6. Drymatter accumulation (kg ha^{-1}) at 60 DAS as influenced by varied spacing and levels of nitrogen

Nitrogen level (kg ha^{-1})	Drymatter accumulation				
	Plant spacing (cm)				
	S_1- 60 ×10	**S_2- 75 ×10**	**S_3 – 90 ×10**	**S_4 – 90 × 45**	**Mean**
N_1- 60	1765	1538	1327	1129	**1440**
N_2 - 90	1856	1720	1520	1240	**1584**
N_3 - 120	1986	1911	1628	1388	**1728**
N_4 - 150	2546	2007	1720	1455	**1932**
Mean	**2038**	**1794**	**1549**	**1303**	
		SEm±	**CD(p=0.05)**	**CV(%)**	
Plant spacing (S)		70.1	242.7	14.5	
Nitrogen level (N)		49.0	143.2	10.1	
Interaction (S×N)		98.1	NS		

Table 4.7. Drymatter accumulation (kg ha^{-1}) at 90 DAS as influenced by varied spacing and levels of nitrogen

Nitrogen level (kg ha^{-1})	Drymatter accumulation				
	Plant spacing (cm)				
	S_1- 60 ×10	**S_2- 75 ×10**	**S_3 – 90×10**	**S_4 – 90 × 45**	**Mean**
N_1- 60	3620	2801	2737	2705	**2965**
N_2 - 90	4830	4376	3517	2795	**3879**
N_3 - 120	5756	5286	4734	3784	**4890**
N_4 - 150	6280	5826	5074	4585	**5441**
Mean	**5121**	**4572**	**4015**	**3466**	
		SEm±	**CD(p=0.05)**	**CV(%)**	
Plant spacing (S)		158.2	547.5	12.7	
Nitrogen level (N)		149.5	436.6	12.0	
Interaction (S×N)		299.1	NS		

Table 4.8. Drymatter accumulation (kg ha^{-1}) at harvest as influenced by varied spacing and levels of nitrogen

	Drymatter accumulation				
Nitrogen level (kg ha^{-1})	**Plant spacing (cm)**				
	S_1- 60 ×10	**S_2- 75 ×10**	**S_3 – 90×10**	**S_4 – 90 ×45**	**Mean**
N_1- 60	7514	6855	6221	5981	**6643**
N_2 - 90	8452	8122	6855	6731	**7540**
N_3 - 120	9425	9168	7985	7108	**8421**
N_4 - 150	10733	10079	9073	8546	**9608**
Mean	**9031**	**8556**	**7534**	**7092**	
		SEm±	**CD(p=0.05)**	**CV(%)**	
Plant spacing (S)		127.4	440.9	5.4	
Nitrogen level (N)		138.7	404.9	5.9	
Interaction (S×N)		277.4	NS		

Table 4.9. Number of Monopodial branches plant^{-1} as influenced by varied spacing and levels of nitrogen

Nitrogen level (kg ha^{-1})	Monopodial branches per plant				
	Plant spacing (cm)				
	S_1- 60 ×10	S_2- 75 ×10	S_3 – 90×10	S_4 – 90 ×45	Mean
N_1- 60	0	0	0	0	-
N_2 - 90	0	0	0	0	-
N_3 - 120	0	0	0	0	-
N_4 - 150	0	0	0	0	-
Mean	-	-	-	-	

	SEm±	CD(p=0.05)	CV(%)
Plant spacing (S)	-	-	-
Nitrogen level (N)	-	-	-
Interaction (S×N)	-	-	

Table 4.10. Number of Sympodial branches plant^{-1} as influenced by varied spacing and levels of nitrogen

Nitrogen level (kg ha^{-1})	Sympodial branches per plant				
	Plant spacing (cm)				
	S_1- 60 ×10	**S_2- 75 ×10**	**S_3 – 90×10**	**S_4 – 90 ×45**	**Mean**
N_1- 60	8.7	9.6	10.6	11.8	**10.2**
N_2 - 90	9.4	10.4	11.7	12.6	**11.0**
N_3 - 120	9.9	11.0	12.2	13.3	**11.6**
N_4 - 150	10.8	11.8	12.7	13.8	**12.3**
Mean	**9.7**	**10.7**	**11.8**	**12.9**	

	SEm±	CD(p=0.05)	CV(%)
Plant spacing (S)	0.2	0.9	8.8
Nitrogen level (N)	0.1	0.5	5.6
Interaction (S×N)	0.3	NS	

Table 4.11. Number of bolls per m^2 at harvest as influenced by varied spacing and levels of nitrogen

Nitrogen level (kg ha^{-1})	No of bolls per m^2				
	Plant spacing (cm)				
	S_1- 60 ×10	S_2- 75 ×10	S_3 – 90×10	S_4 – 90 ×45	Mean
N_1- 60	55.5	52.1	45.8	40.4	**48.5**
N_2 - 90	60.4	58.2	51.0	45.4	**53.8**
N_3 - 120	63.3	60.6	53.6	48.3	**56.5**
N_4 - 150	66.1	64.1	56.7	51.4	**59.6**
Mean	**61.3**	**58.8**	**51.8**	**46.4**	

	SEm±	CD(p=0.05)	CV(%)
Plant spacing (S)	0.8	2.9	5.4
Nitrogen level (N)	0.7	2.0	4.5
Interaction (S×N)	1.4	NS	

Table 4.12. Boll weight (g) as influenced by varied spacing and levels of nitrogen

Boll weight					
Nitrogen level (kg ha^{-1})	**Plant spacing (cm)**				
	S_1- 60 ×10	**S_2- 75 ×10**	**S_3 – 90×10**	**S_4 – 90 ×45**	**Mean**
N_1- 60	2.74	2.76	3.07	3.29	**2.97**
N_2 - 90	2.93	2.99	3.16	3.34	**3.11**
N_3 - 120	3.12	3.15	3.26	3.45	**3.25**
N_4 - 150	3.29	3.25	3.42	3.63	**3.40**
Mean	**3.02**	**3.04**	**3.23**	**3.43**	
		SEm±	**CD(p=0.05)**	**CV(%)**	
Plant spacing (S)		0.05	0.18	5.6	
Nitrogen level (N)		0.04	0.13	4.9	
Interaction (S×N)		0.09	NS		

Table 4.13. Seed cotton yield (kg ha^{-1}) as influenced by varied spacing and levels of nitrogen

	Seed cotton yield				
Nitrogen level (kg ha^{-1})	**Plant spacing (cm)**				
	S_1- 60 ×10	**S_2- 75 ×10**	**S_3 – 90×10**	**S_4 – 90 ×45**	**Mean**
N_1- 60	1493	1373	1173	974	**1253**
N_2 - 90	1598	1494	1301	1097	**1372**
N_3 - 120	1720	1614	1412	1255	**1500**
N_4 - 150	1853	1722	1538	1367	**1620**
Mean	**1666**	**1550**	**1356**	**1173**	

	SEm±	**CD(p=0.05)**	**CV(%)**
Plant spacing (S)	50.2	174.0	12.1
Nitrogen level (N)	38.2	111.5	9.2
Interaction (S×N)	76.4	NS	

Table 4.14. Stalk yield (kg ha^{-1}) as influenced by varied spacing and levels of nitrogen

Stalk yield					
Nitrogen level (kg ha^{-1})	**Plant spacing (cm)**				
	S_1- 60 ×10	**S_2- 75 ×10**	**S_3 – 90×10**	**S_4 – 90 ×45**	**Mean**
N_1- 60	5776	5269	4820	4565	**5107**
N_2 - 90	6580	6012	5362	4742	**5674**
N_3 - 120	7463	6972	6369	5724	**6632**
N_4 - 150	8654	7953	7103	6783	**7623**
Mean	**7118**	**6551**	**5914**	**5454**	

	SEm±	**CD(p=0.05)**	**CV(%)**
Plant spacing (S)	170.3	420.6	11.4
Nitrogen level (N)	105.2	310.7	9.6
Interaction (S×N)	400.8	NS	

Table 4.15. Nitrogen content (%) as influenced by varied spacing and levels of nitrogen

Nitrogen level (kg ha^{-1})	Nitrogen content				
	Plant spacing (cm)				
	S_1- 60 ×10	S_2- 75 ×10	S_3 – 90×10	S_4 – 90 ×45	Mean
N_1- 60	0.71	0.69	0.68	0.67	**0.68**
N_2 - 90	0.72	0.70	0.69	0.69	**0.70**
N_3 - 120	0.73	0.71	0.70	0.69	**0.70**
N_4 - 150	0.75	0.74	0.73	0.71	**0.73**
Mean	**0.72**	**0.71**	**0.70**	**0.69**	

	SEm$\pm$	CD(p=0.05)	CV(%)
Plant spacing (S)	0.009	NS	5.04
Nitrogen level (N)	0.008	NS	4.43
Interaction (S×N)	0.062	NS	

Table 4.18. Nitrogen uptake (kg ha^{-1}) at harvest as influenced by varied spacing and levels of nitrogen

Nitrogen level (kg ha^{-1})	Nitrogen uptake				
	Plant spacing (cm)				
	S_1- 60 ×10	**S_2- 75 ×10**	**S_3 – 90×10**	**S_4 – 90 ×45**	**Mean**
N_1- 60	53.3	47.3	42.3	40.0	**45.7**
N_2 - 90	60.8	56.8	47.3	46.4	**52.8**
N_3 - 120	68.8	65.0	55.8	49.0	**59.6**
N_4 - 150	80.4	74.5	66.2	60.6	**70.4**
Mean	**65.8**	**60.9**	**52.9**	**49.0**	
		SEm±	**CD(p=0.05)**	**CV(%)**	
Plant spacing (S)		1.01	3.5	6.1	
Nitrogen level (N)		0.94	2.7	5.7	
Interaction (S×N)		1.88	NS		

Table 4.16. Phosphorus content (%) as influenced by varied spacing and levels of nitrogen

Nitrogen level (kg ha^{-1})	Phosphorus content				
	Plant spacing (cm)				
	S_1- 60 ×10	S_2- 75 ×10	S_3 – 90×10	S_4 – 90 ×45	Mean
N_1- 60	0.19	0.18	0.17	0.16	**0.17**
N_2 - 90	0.21	0.20	0.19	0.18	**0.19**
N_3 - 120	0.23	0.22	0.21	0.19	**0..21**
N_4 - 150	0.25	0.23	0.22	0.20	**0.22**
Mean	**0.22**	**0.20**	**0.19**	**0.18**	

	SEm±	CD(p=0.05)	CV(%)
Plant spacing (S)	0.008	NS	13.4
Nitrogen level (N)	0.006	NS	11.1
Interaction (S×N)	0.002	NS	

Table 4.19. Phosphorus uptake (kg ha^{-1}) at harvest as influenced by varied spacing and levels of nitrogen

	Phosphorus uptake				
Nitrogen level (kg ha^{-1})	**Plant spacing (cm)**				
	S_1- 60 ×10	**S_2- 75 ×10**	**S_3 – 90×10**	**S_4 – 90 ×45**	**Mean**
N_1- 60	14.2	12.3	10.5	9.50	**11.6**
N_2 - 90	17.7	16.2	13.0	12.1	**14.7**
N_3 - 120	21.6	20.1	16.7	13.5	**17.9**
N_4 - 150	26.8	23.1	19.9	17.0	**21.7**
Mean	**20.0**	**17.9**	**15.0**	**13.0**	

	SEm±	CD(p=0.05)	CV(%)
Plant spacing (S)	0.6	1.9	13.6
Nitrogen level (N)	0.7	2.0	14.9
Interaction (S×N)	1.4	NS	

Table 4.17. Potassium content (%) as influenced by varied spacing and levels of nitrogen

Potassium content					
Nitrogen level (kg ha^{-1})	**Plant spacing (cm)**				
	S_1- 60 ×10	**S_2- 75 ×10**	**S_3 – 90×10**	**S_4 – 90 ×45**	**Mean**
N_1- 60	0.60	0.59	0.58	0.57	**0.58**
N_2 - 90	0.62	0.60	0.58	0.57	**0.59**
N_3 - 120	0.63	0.61	0.59	0.58	**0.60**
N_4 - 150	0.65	0.63	0.61	0.59	**0.62**
Mean	**0.62**	**0.60**	**0.59**	**0.57**	

	SEm$\pm$	CD(p=0.05)	CV(%)
Plant spacing (S)	0.01	NS	8.5
Nitrogen level (N)	0.01	NS	8.2
Interaction (S×N)	0.03	NS	

Table 4.20. Potassium uptake (kg ha^{-1}) at harvest as influenced by varied spacing and levels of nitrogen

Potassium uptake					
Nitrogen level (kg ha^{-1})	**Plant spacing (cm)**				
	S_1- 60 ×10	**S_2- 75 ×10**	**S_3 – 90×10**	**S_4 – 90 ×45**	**Mean**
N_1- 60	45.0	40.4	36.4	34.0	**38.9**
N_2 - 90	52.4	48.7	39.7	38.3	**44.7**
N_3 - 120	59.3	55.9	47.1	41.2	**50.8**
N_4 - 150	69.7	63.4	55.3	50.4	**59.7**
Mean	**56.6**	**52.1**	**44.6**	**40.9**	

	SEm$\pm$	**CD(p=0.05)**	**CV(%)**
Plant spacing (S)	0.7	2.6	5.5
Nitrogen level (N)	0.9	2.6	6.4
Interaction (S×N)	1.8	NS	

Table 4.21. Economics of cotton as influenced by varied spacing and levels of nitrogen

Plant spacing (cm)	Levels of nitrogen added (kg ha^{-1})	Actual yield of cotton (kg ha^{-1})	Gross returns (Rs ha^{-1})	Cost of cultivation (Rs ha^{-1})	Net returns (Rs ha^{-1})	B:C Ratio
60 × 10	60	1493	74650	33006	41643	1.26
	90	1599	79935	33371	46563	1.40
	120	1720	85990	33736	52253	1.55
	150	1853	92650	34102	58547	1.72
75 × 10	60	1373	68650	32874	35775	1.09
	90	1493	74650	33239	41410	1.25
	120	1614	80690	33604	47085	1.40
	150	1722	86100	33970	52129	1.53
90 × 10	60	1174	58685	32782	25902	0.79
	90	1301	65050	33147	31902	0.96
	120	1412	70615	33512	37102	1.11
	150	1538	76920	33878	43041	1.27
90 × 45	60	974	48695	32438	16256	0.50
	90	1097	54865	32803	22061	0.67
	120	1255	62770	33168	29601	0.89
	150	1367	68330	33534	34795	1.04

Cost :

*Seed cotton Rs. 5000 q^{-1}

*Suraj variety cotton seed Rs. 40 kg^{-1}

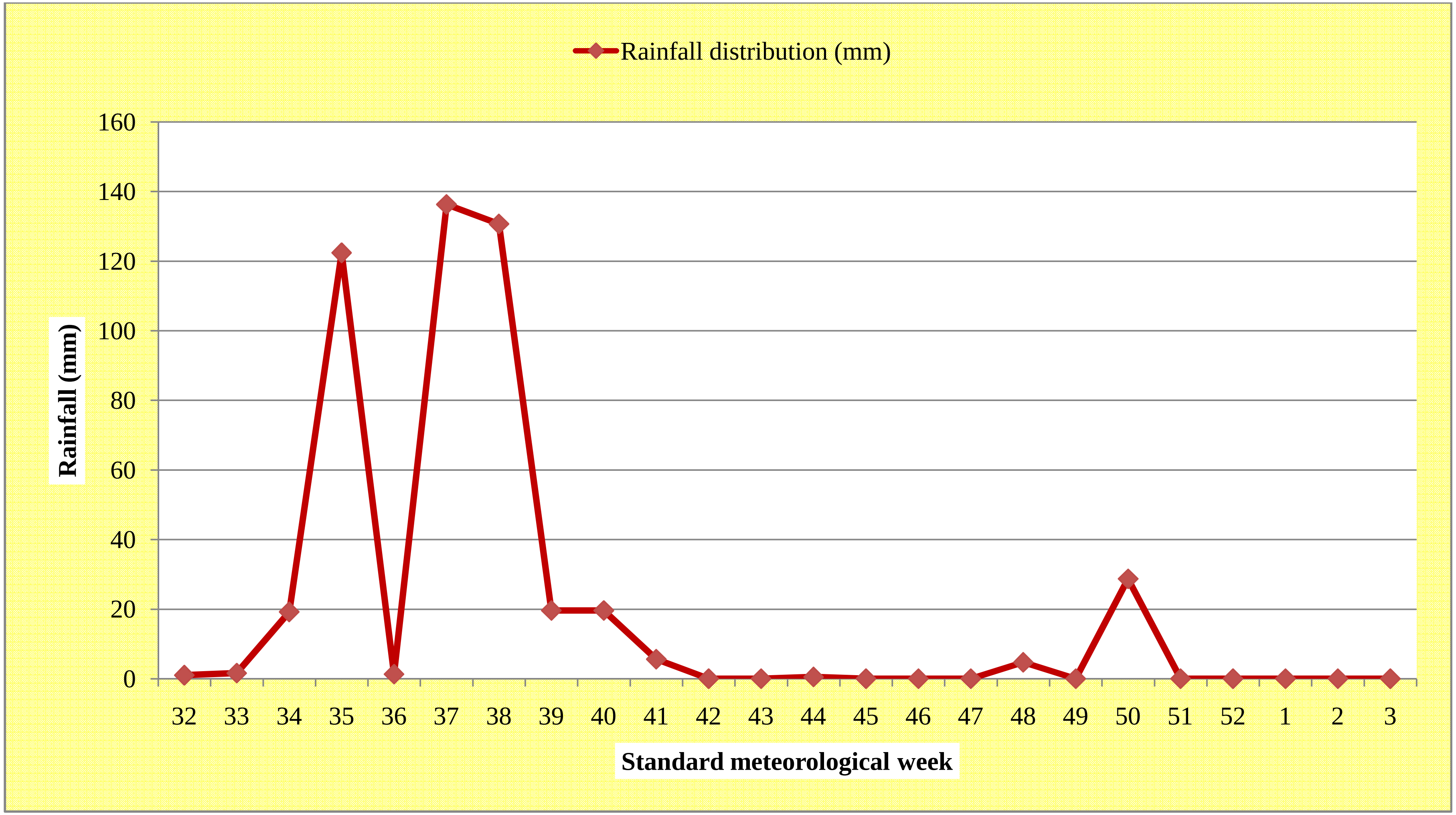


Fig. 4.1. Weekly rainfall data during the crop growth period

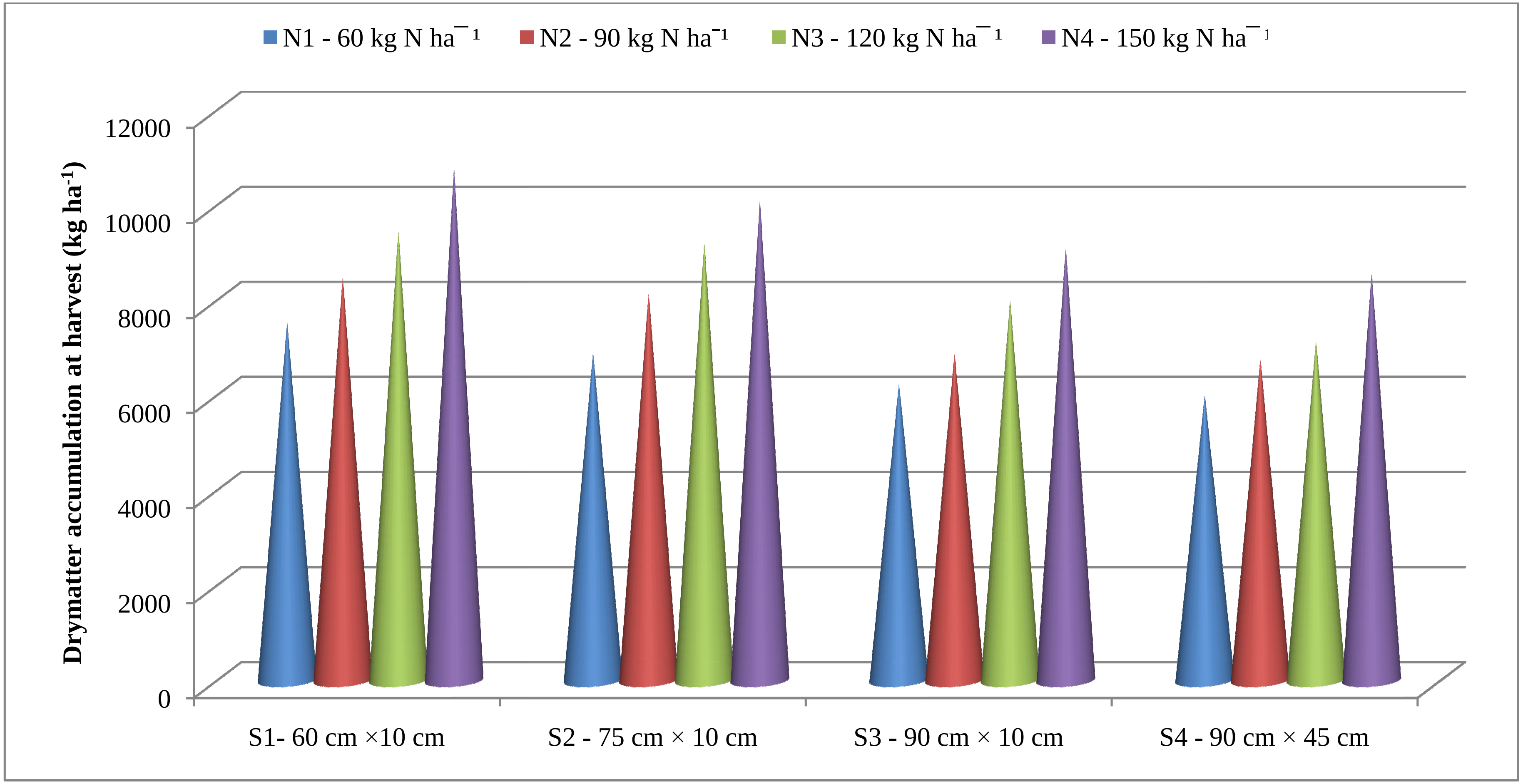


Fig. 4.2 : Drymatter accumulation (kg ha^{-1}) at harvest as influenced by varied spacing and levels of nitrogen

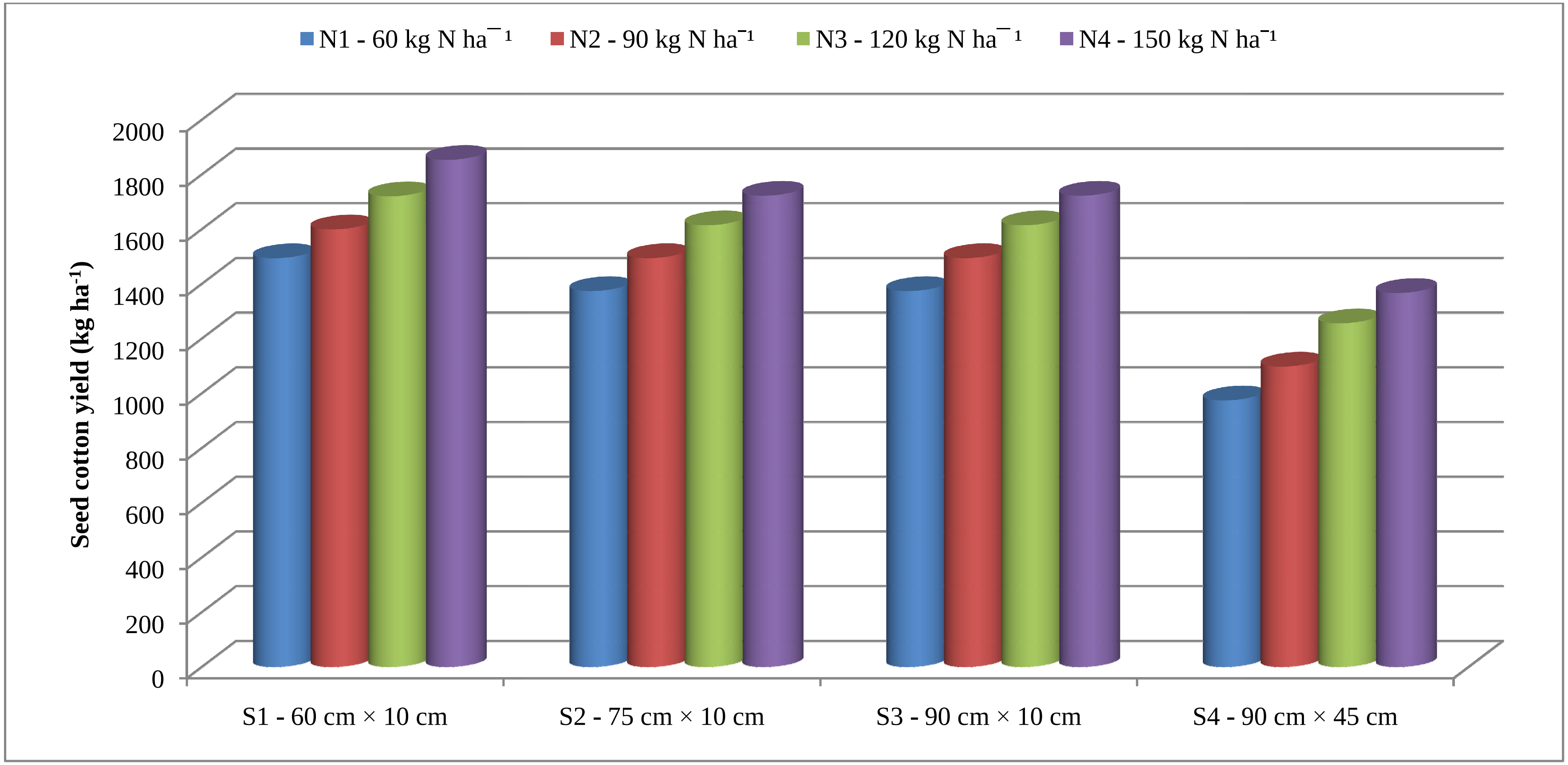


Fig. 4.4 : Seed cotton yield (kg ha-1) as influenced by varied spacing and levels of nitrogen

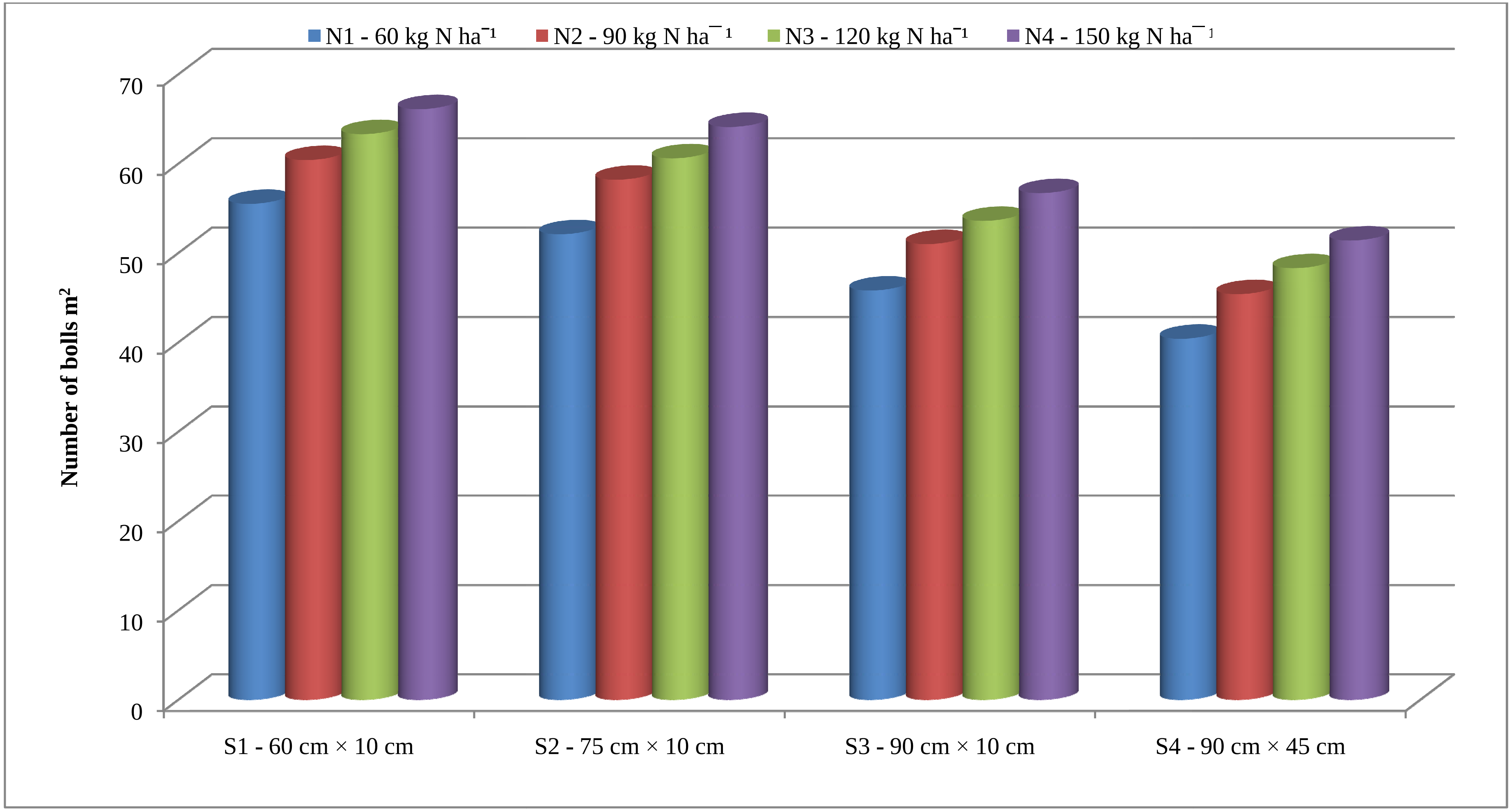
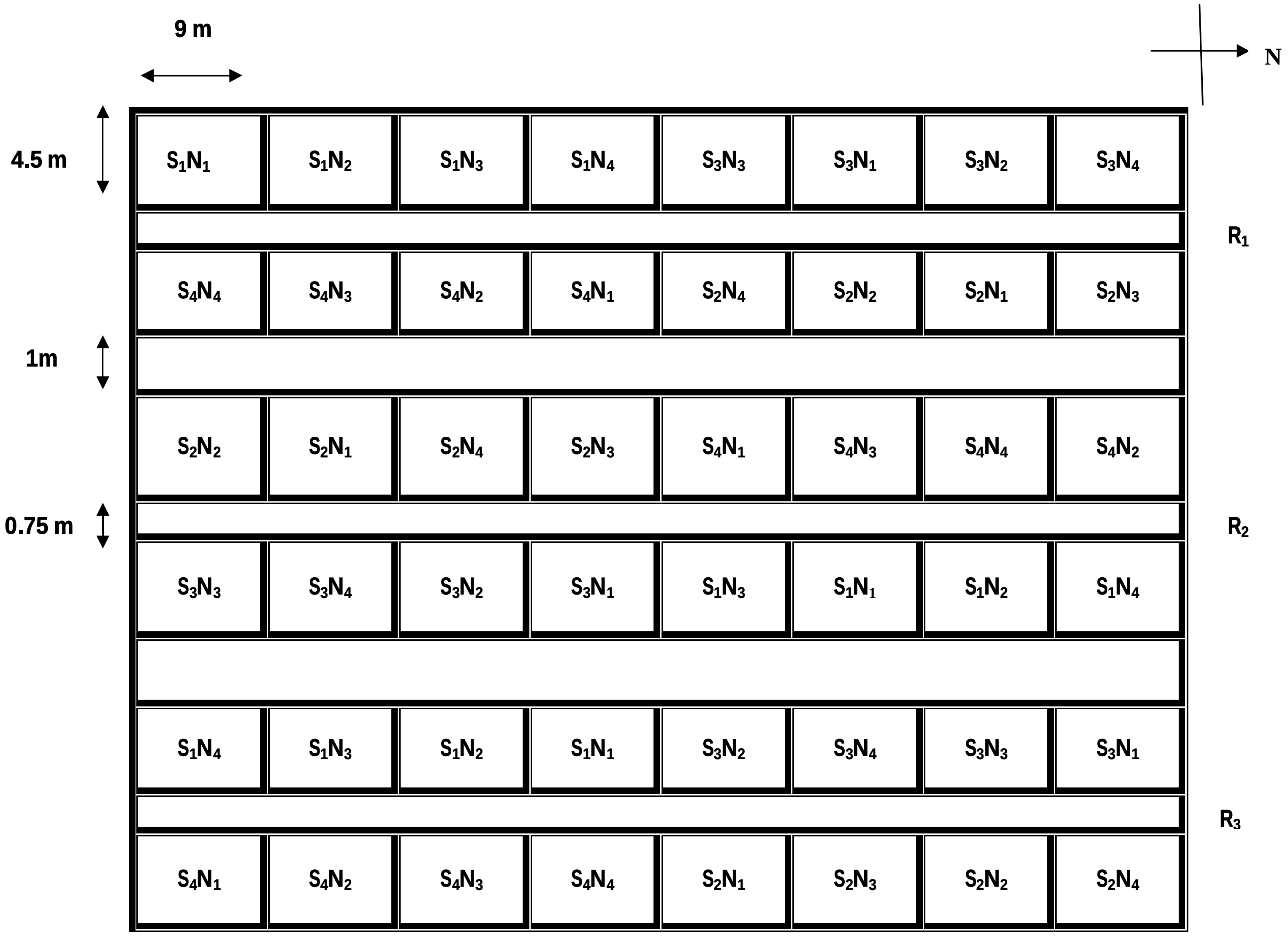


Fig. 4.3 : Number of bolls m^2 as influenced by varied spacing and levels of nitrogen



Season *: kharif*

Location : Agricultural College Farm, Bapatla

Gross plot size : 9 m × 4.5 m

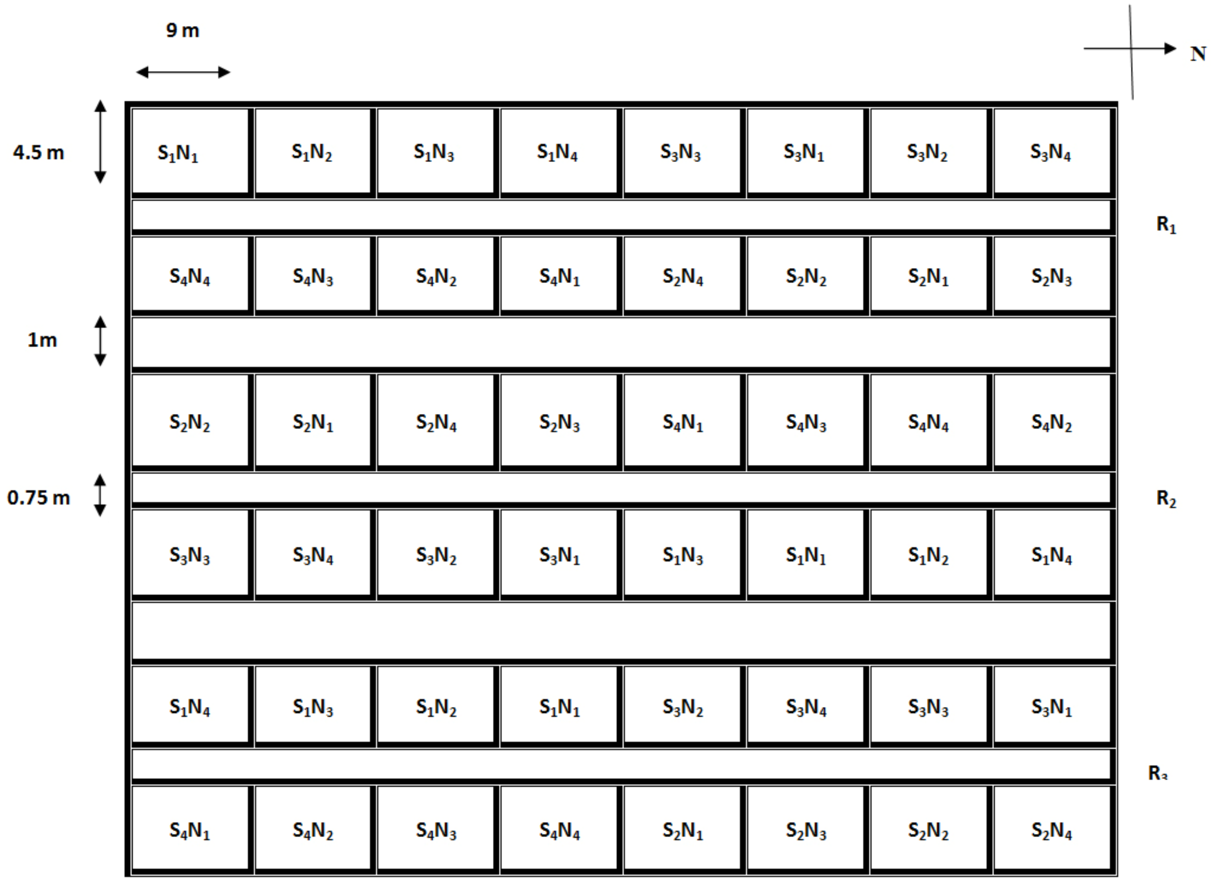
Net plot size : 7.2 m × 3.6 m

Replications : 3

Treatments : 16

Main Plots : Spacing (cm)	Sub Plots : Nitrogen levels (kg ha^{-1})
S1 – 60 cm × 10 cm	N1 – 60 kg N ha^{-1}
S2 – 75 cm × 10 cm	N2 – 90 kg N ha^{-1}
S3 – 90 cm × 10 cm	N3 – 120 kg N ha^{-1}
S4 – 90 cm × 45 cm	N4 – 150 kg N ha^{-1}

Fig. 3.1. Layout plan of the experiment field



Season : *kharif*

Location : Agricultural College Farm, Bapatla

Gross plot size : 9 m × 4.5 m

Net plot size : 7.2 m × 3.6 m

Replications : 3

Treatments : 16

Main Plots : Spacing (cm)

S1 – 60 cm × 10 cm

S2 – 75 cm × 10 cm

S3 – 90 cm × 10 cm

S4 – 90 cm × 45 cm

Sub Plots : Nitrogen levels (kg ha^{-1})

N1 – 60 kg N ha^{-1}

N2 – 90 kg N ha^{-1}

N3 – 120 kg N ha^{-1}

N4 – 150 kg N ha^{-1}

Fig. 3.1. Layout plan of the experiment field

Table 3.1. Weather prevailed during the crop growth period from 07 - 08 - 2016 to 20 – 01 – 2017

Standard meteorological week	Date & Month	Mean Temp (^{0}C)		Mean R.H. (%)		Rainfall (mm)	Rainy days
		Max	Min	8:30 hrs	17:30hrs		
32	06-12 Aug	37.2	26.2	62	41	1	0
33	13-19 Aug	37.6	27.0	59	39	1.6	0
34	20-26 Aug	36.7	26.0	67	66	19.2	2
35	27 Aug -02 Sep	32.7	24.0	89	81	122.4	5
36	03-09 Sep	35.1	25.1	69	55	1.3	0
37	10-16 Sep	31.1	24.1	87	82	136.3	3
38	17-23 Sep	31.9	25.1	84	78	130.7	3
39	24-30 Sep	32.1	25.6	83	75	19.6	2
40	01-07 Oct	33.6	24.8	85	74	19.6	1
41	08-14 Oct	33.8	24.7	81	66	5.6	1
42	15-21 Oct	34.3	21.2	71	50	0	0
43	22-28 Oct	34.4	20.8	69	57	0	0
44	29 Oct - 4 Nov	33.1	23.6	84	67	0.5	0
45	05-11 Nov	33.4	20.4	73	50	0	0

Standard Meteorological week	Date & Month	Mean Temp (^{0}C)		Mean R.H. (%)		Rainfall (mm)	Rainy days
		Max	Min	8:30 hrs	17:30hrs		
46	12-18 Nov	31.8	22.7	84	73	0	0
47	19-25 Nov	31.3	19.0	87	61	0	0
48	26 Nov -02 Dec	33.0	18.7	84	61	4.7	1
49	03-09 Dec	31.5	19.8	82	62	0	0
50	10- 16 Dec	29.5	20.4	84	74	28.7	3
51	17- 23 Dec	30.9	16.5	85	59	0	0
52	24- 31 Dec	34.8	19.3	92	62	0	0
1	01-07 Jan	30.6	17.5	89	67	0	0
2	08-14 Jan	29.9	18.6	87	66	0	0
3	15-21Jan	30.5	16.8	87	50	0	0
	TOTAL	**-**	**-**	**-**	**-**	**491.2**	**21**
	MEAN	**32.9**	**22.0**	**81**	**62**		

Plate 1. General view of the experimental plot