RESPONSE OF COTTON (*Gossypium hirsitum* L.) VARIETIES TO IRRIGATION METHODS AND NITROGEN FERTILIZATION.

BY

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DECLARATION

I hereby declare that the work in the dissertation titled "Response of Cotton (*Gossypium hirsitum* L.) Varieties to Irrigation Methods and Nitrogen Fertilization." was performed by me in the Department of Agronomy, under the supervision of Professors I.U. Abubakar, B. Tnimu and M. Mahmud. The information derived from the literature has been dully acknowledged in the text and a list of references provided. No part of this work has been presented for another degree or diploma at any institution.

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CERTIFICATION

This dissertation titled "Response of cotton (G*ossypium hirsitum* l.) varieties to irrigation methods and nitrogen fertilization" meets the regulations governing the award of the degree of Doctor of Philosophy (PhD) of Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

This work is dedicated to Almighty God, Allah (SWT) the Sustainer.

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ABSTRACT

Field trials were conducted during the dry seasons of 2007, 2008, and 2009, at the Irrigation Research Station Farm, Kadawa ($11^0 39^{'}$N, $08^0 27^{'}$E; altitude 500m), of the Institute for Agricultural Research to study the response of cotton varieties to irrigation methods and nitrogen fertilization. Treatments consisted of factorial combinations of four levels of nitrogen fertilizer (40, 70, 100 and 130 kg ha^{-1}), three irrigation methods (border strip, check basin and furrow), and three cotton varieties (SAMCOT 10, SAMCOT 11 and SAMCOT 13), laid out in a split plot design replicated three times. Nitrogen and irrigation methods were factorially combined and assigned to the main plots while cotton varieties were assigned to the sub-plots. Agronomic practices where done to ensure good crop growth. In the three years the performance of the varieties was generally better in 2008 than the other two years due to better weather and nutrient status of the area. The study showed that among the varieties tested, SAMCOT 13 exhibited superior growth and yield performance in most of the characters measured than the other two varieties. SAMCOT 13 variety had significantly higher dry matter production, leaf area index, crop growth rate, net assimilation rate, number of branches per plant, number of bolls per plant, boll weight, number of seeds per boll, 100-seed weight, percentage oil content of cotton seed, fibre finess, seed cotton (600 kg ha^{-1}) and lint yield per ha. Check basin irrigation method gave higher seed cotton yield only in 2007 while lint yield was not affected by irrigation method. Border strip significantly resulted in taller plants, earlier flowering and boll opening while furrow irrigation resulted in higher percentage of protein content of cotton seeds. Furrow irrigation resulted in higher water use efficiency and fibre finess. Increasing nitrogen fertilization significantly increased growth characters like plant height, total dry matter, leaf area index, CGR and number of branches per plant but significantly delayed days to 50% flowering and boll opening. The seed cotton yield and most of the yield components were significantly increased with application of 70 kg N ha^{-1} but further increase resulted in significantly lower yields. Seed cotton yield had positive and significant correlation with total dry matter, LAI, number of branches per plant, days to 50% flowering and boll opening, number of bolls $plant^{-1}$ boll weight and number of seeds per boll. Path analysis indicated that the highest contribution to seed cotton yield by growth characters was through total dry weight and leaf area index while highest contribution by yield components to seed cotton yield was through boll weight and number of seeds per boll. Polynomial responses of seed cotton yield to varied nitrogen rates showed a quadratic response with 93.0 kg N ha^{-1} as the optimum rate for seed cotton yield during the combine mean. The partial economic analysis showed that it is more economical to apply 70 kg N ha^{-1} to SAMCOT 13 cotton variety under border strip irrigation method. Furrow irrigation method gave highest water use efficiency, percentage oil and protein content of cotton seed. The use of SAMCOT 13 and 93.0 kg N ha^{-1} using border strip irrigation method will be better adopted for maximum seed cotton yield during dry season.

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CHAPTER ONE

1.0 INTRODUCTION

The cotton plant is a deciduous, indeterminate perennial plant in the genus *Gossypium* of the family Malvaceae, or mallow family, and is native to subtropical climates. Two old world diploid (2n =2x=26) species, *G. arboretum* and *G. herbaceum*, and two new world tetraploid (2n=4x=52) species, *G. barbadense* and *G. hirsutum*, have been domesticated independently for cultivation throughout the world. The most widely grown species worldwide is *G. hirsutum* which is grown over 95% of the world hectarage, followed by *G. barbadense* (Wendel *et al*. 2010). Upland cotton, *G. hirsutum*, is native to Mexico and a part of Central America, and Pima, Egyptian or American-Egyptian; G. *barbadense* is native to South America (Brubaker, *et al*., 1999).

Cotton *(G. hirsutum* L.*)* is an important commercial crop in the world. Cotton is known as the king of fibre crops and nowadays is being referred as the "white gold". Cotton is the most important vital crop of commerce to many countries. It has a relatively long history in Nigeria. The cultivation of the crop started well before the colonial era, even though it was not produced for exports until the onset of the activities of the British Cotton Growing Association (BCGA) (now Cotton and Agricultural Processors Limited CAP) around 1903. Cotton is a plant that has been known and cultivated for a very long time. The use of its fibre dates back to as far as 3000 BC in the Indus Valley, and to 2400 BC in Peru. Its culture was extended into the Mediterranean Basin by the Arabs in about the 9^{th} century. The primary product of cotton plant has been the lint that covers the seeds within the seed pod or boll.

1.1 Production

Cotton is currently cultivated in all parts of the world with a sufficiently warm climate. The extreme limits of its production region stretch from about 40^0N to about 35^0S. Annual production of cotton in the world stood at 68.3 million metric tons when Nigeria contributed to an estimated amount of 485,940 tons of seed cotton yield (FAO, 2010). The major cotton producing countries in the world are the, China, India, U.S.A., Pakistan, Uzbekistan, Egypt, Mexico, Russian, Japan, Turkey and Sudan. In Africa major producing countries are Egypt, Sudan, South Africa, Zimbabwe and Tanzania. In Nigeria, cotton production is concentrated in three cotton growing zones: The northern cotton zone produces about 60 – 65 percent of the crop; the eastern zone produces about 30–35 percent; while less than 5 percent of the crop comes from the southern zone, a relatively minor producer of the crop (Ado *et al*, 2008 and icac.org). Practically, the entire cotton crop is produced under subsistence agriculture by farmers with small scale holdings scattered all over the three cotton production zones. In Africa, cotton yields are extremely variable from small holdings which range on average, from 250 to 800 kg with Nigeria having 400 to 500 kg (Adeniji, 2007) seed cotton with world average of 756 kg $ha^{-1}$and from 85 to 310 kg fibre per ha. On large scale mechanized farms the average yields vary between 2,000 and 2,500 kg seed cotton per hectare in China, India and U.S.A. with world average of 756 kg seed cotton per hectare.

1.2 Environmental Requirements

Cotton is a short day plant but day neutral varieties exist. However the effect of day length on flowering is influenced by temperature. The optimum temperature for germination is about 30^0C while that for growth ranges between 25^0 and 30^0C during the day and between 15^0 and 20^0C at night. Both higher temperatures (Pettegrew, 2008) and drought stress (Pettegrew, 2004)

can limit cotton productivity. Its water requirements vary according to the development stage and climatic condition, but theoretically, 400-500 mm water should allow the crop to complete its cycle. However, in practice, because of water losses, average water needs are estimated at about 700 mm per annum. For water not to be a limiting factor on yield, cotton needs between 550 mm and 950 mm during the season in a consistent and regular pattern (Doorenbos and Pruitt,1984, Abdulmumin and Misari, 1990). The best soils for cotton cultivation are homogeneous, deep, permeable (e.g. clay and sands or sandy clays) soils which are rich in nutritive elements. The recommended fertilizer rates for late sown cotton production in the Northern cotton growing zone is 60 kg Nha^{-1}, 30 kg P ha^{-1} (Ogunlela *et al.,* 1979) and 30 kg K per ha.

1.3 Economic Importance and Use

In the world over, cotton is used more than any other crop for fibre (Saleem, 2008). Throughout the countries of Asia, Africa and Latin America, cotton is a major cash crop, and cotton production and processing is an important source of income at household level for many millions of small farmers. It is a source of foreign exchange for a number of countries. Lint is used to produce clothes, bandages, wicks, felt and cotton wool. The hull of cotton seeds are often used as fuel in factory boilers or as fillers in animal feeds formulation. Refined cotton seed oil is used as vegetable oil and seed cake emanating from this process is fed to ruminant animals.

1.4 Basin, Border and Furrow Irrigation

Basin irrigation is the simplest of the surface irrigation methods. Especially if the basins are small, they can be constructed by hand or animal traction. Their operation and maintenance is simple. A controlled volume of water is applied from one end or one corner of a basin, completely enclosed with perimeter dikes to prevent runoff. The

irrigation water is applied rapidly so that most of the infiltration occurs from relatively stagnant ponded water. Basin irrigation usually requires higher volume (40-70 mm) of irrigation water, thus able to retain moisture for relatively longer period of time. Crops like wheat, barley, maize, cotton, vegetables and tree crops are usually planted in basins.

Border irrigation can be used on sloping land up to 2% on sandy soil and 5% on clay soil. A minimum slope of 0.05% is recommended to ensure adequate drainage. Border irrigation is particularly suitable for close growing crops such as small grains, but border irrigation can also be used for row crops and trees. Irrigation water application is moderate (30-60 mm).

Furrow irrigation can be used on flat land (short, near horizontal furrows), and on mildly sloping land with a slope of maximum 0.5%. On steeper sloping land, contour furrows can be used up to a maximum land slope of 3%. A minimum slope of 0.05% is recommended to assist drainage. Furrow irrigation is best used for irrigating row crops such as maize, cotton, vegetables and trees. With least irrigation water application with furrow irrigation (20-50mm) Furrow requires accurate level of grading

1.5 Justification and Objectives

In Nigeria, most of cotton production is carried out during the rainy season and the yield is often adversely affected due to shortage of rainfall especially in the late-sown cotton. The crop has become increasingly affected by severe environmental and management factors which include reduced soil fertility, salinization, water pollution, adverse changes in water balance, drought, government policy etc. Yayock and Kumar (1988) attributed decline in cotton production to diminishing rainfall. The Federal Government has included cotton among other crops to be given priority in order to boost their production. This is with a view to reducing the high importation,

save foreign exchange and increase local production of the commodities, thus supplying more food and raw materials for Nigerian industries.

Cotton is one of the most important industrial crops grown in many parts of the world. Nigeria grows cotton solely under rainy conditions in almost nearly all parts of growing zones. The optimum yield of cotton is often not achieved due to erratic and uncertain rainfall duration. The semi arid tropics (Nigeria) is characterized by harsh and erratic rainfall and soils low in nutrients especially nitrogen and phosphorous (Lehmann *et al*. 1998). Complete crop failure due to drought and reduced crop yields due to frequent intra-seasonal dry spells make rainy season cotton production risky. Irrigation therefore could be the missing link towards attaining maximum yield of cotton. Irrigation methods and nitrogen fertilization are the key factors of yield increase in cotton (Janat, 2000). Rainfall in semi-arid region is distributed so unevenly in time or space that rainfed agriculture is not often viable (Reij and Begemann,1988). Rockstrom and Falkenmark (2000) noted that due to high rain fall variation in semi-arid regions a decrease of one standard deviation from mean annual rainfall often lead to the complete loss of the crop. Low rainfall areas that receive between 300-600mm annually may be able to combat these problems using supplemental irrigations, but regions receiving less than 300mm of annual rainfall must resort to complete irrigation (Oweis, *et al*., 1999). It is imperative therefore to try its production in the dry season under irrigation condition with a view to compensate for the low production in the rainy season. There is the need for all year round cotton production with a view to harnessing the natural resources and climatic potentials of the Northern Nigeria since water is the principal limiting factor in its production in the rainy season.

Irrigation is important to offset insufficient growing season rainfall and to maintain optimum seed cotton yield. Surface irrigation methods are being practiced widely by Nigerian

farmers in crop production. It is normally used when conditions are favourable: mild and regular slopes, soil type with medium to low infiltration rate, and a sufficient supply of surface or groundwater. Basin, furrow or border irrigations are common types practised by most farmers depending on crop or soil types during dry season farming. Also nitrogen is one of the most important nutrients in the tissues of plants and one of the limiting nutrient elements in the savanna soils. Soil fertility and crop management are two of the most important factors modern crop production. Research in these areas is driven by the need to intensify production to obtain higher yields. Managing the balance of vegetative and reproductive growth is the essence of managing cotton crop. Fertilizer experiments have indicated that the yield of an agricultural crop strongly depends on the supply of mineral nutrients such as nitrogen (N) which are needed for full exploitation of crop genetic potentials (Khan, 1996). Biswas *et al.* (1984) observed that generally, local varieties of cotton under irrigated condition responded to more than 100 kg N ha^{-1}, while hybrids responded to more than 300 kg N per ha.

Cotton varieties have been bred for different purpose and their responses to different irrigation production system will be important. Therefore due to the fact that there was little or no research carried out under irrigation condition (dry season), this study was undertaken to determine the appropriate irrigation methods in the irrigated areas of the country. In Nigeria, different cotton cultivars with different morphological characteristics respond differently to various management practices especially nitrogen and irrigation methods. Therefore this trial was carried out under irrigated condition during the dry season with the following objectives.

1. To determine the effect of irrigation methods on growth, yield and quality of cotton varieties.
2. To determine the effect of nitrogen on growth, yield and quality of cotton varieties.

3. To determine the performance cotton varieties in dry season irrigation.
4. To determine the effects of N, irrigation method and variety on water use and water use efficiency.
5. To determine the profitability of dry season irrigated cotton.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Effects of Irrigation Methods on Cotton Growth

Adequate soil moisture is necessary for cotton to achieve optimal yields. Early- and mid-season water requirement of cotton should be met to avoid yield loss that may occur if the crop experiences water stress (Jordan, 1986; Wanjura, *et al*., 1996). If the soil becomes either too wet or too dry, cotton plants undergo stress and begin to shed fruits (Guinn *et al*., 1981)

Du tai *et al*, (2007) indicated that alternate furrow irrigation (AFI) shortened the cotton plant height, had no significant effect on reproductive growth such as bud and boll, and maintained the balance between vegetative and reproductive growth with reducing redundant growth. Always AFI achieved the highest seed cotton yield compared to others. Sagarka *et al*, (2000) reported that application of irrigation through drip method at 0.8 cumulative pan evaporation (CPE) recorded significantly higher growth and yield attributes, seed-cotton yield, oil content, seed and lint index than surface, alternate furrow method and drip irrigation at 0.4 CPE. Aujla *et al.,* (1991) revealed that the growth and yield of cotton was highest in order of alternate furrow> single furrow between paired row> energy furrow. Drip irrigated cotton had significantly higher vegetative and reproductive biomass as compared with furrow irrigated cotton (Lundivar, *et al*., 1995). Sampathkumar *et al*., (2006) in an experiment with four irrigation methods (drip, furrow, check basin and border strip) reported that highest plant height, more LAI, dry matter per plant and seed cotton yield were recorded with drip irrigation than the other methods. Rana *et al. (*2006) reported that about 5.64% and 1.7% more sunflower yield was recorded in Raingun sprinkler irrigation system as compared to basin and furrow irrigation systems, respectively.

According to 1991 report of Central Water Commission of India, irrigating cotton through drip resulted in 27% increase in yield and 53% saving of water over surface irrigation (Anonymous, 1991). Reddy and Thimanegowda (1997) reported increase in cotton yield by 13% and 12% under turbotape and emitter drip over furrow irrigation, respectively.

Furrow irrigation permits more efficient use of irrigation water as compared to other surface irrigation systems, (Khan *et al*. 1998).

Sagarka *et al*. (2002) reported that irrigating the cotton at 0.8 CPE through drip method recorded significantly highest values of yield attributes and yield over other irrigation method and lower in drip irrigation regimes. Aujla *et al*. (2005) reported that when same quantity of water was applied through either drip or check-basin irrigation methods, the cotton growth was increased by 32 percent in check-basin compared to drip irrigation.

2.2 Effects of Irrigation Methods on the Yield of Cotton

Yuksek and Taskin (1974) found no differences in the yields of cotton with either sprinkler and furrow irrigation methods. Significant highest yields were obtained twice from the furrow method and once from sprinkler irrigation practices. They indicated that the furrow method was better in the irrigation of the cotton plant. According to the research carried out by Cetin (1997), sprinkler irrigation resulted in lower cotton yields than either furrow or drip irrigation. Kanber *et al.* (1997) compared different irrigation methods for effective water use on cotton and found that the maximum yield was obtained by ponded level furrow and maximum water use efficiencies (WUE) was in alternate ponded level furrow. According to research by Cetin(1997), sprinkler irrigation resulted in lower cotton yield than either furrow and drip irrigation. The lowest WUE was found for sprinkler irrigation. Thind *et al*. (2008) in a two year

experiment reported that drip irrigation resulted in an increase of 258 and 453 kg ha^{-1} seed cotton yield than check-basin during first and second year, respectively. Thind *et al.* (2010) also compared check-basin irrigation with furrow and alternate furrow irrigation in which there was no significant difference in seed cotton yield, though resulted in a saving of 30 and 49% of irrigation water in furrow and alternate furrow. Yavuz (1993) showed that there was no statistically significant difference between the cotton yield obtained from drip, sprinkle and furrow methods. Istanbulluoglu (1989) in a 3-years research project using 4 irrigation methods (sprinkler, border, narrow-border and furrow) reported significant differences in cotton yield using narrow-border and sprinkler which had 1.92 and 2.05 t/ha of seed cotton respectively. The highest cotton yield of 2.34 t/ha, was obtained using furrow irrigation.

Buks *et al*. (1987) compared drip and level basin irrigation methods for cotton production. Lint yield of more than 2000 kg/ha was obtained for drip irrigation and the WUE was 0.21 kg m^{-3}. A 10-15% higher lint yield resulted from drip irrigation compared to level basin. McConnell *et al*. (1989) tested the furrow and sprinkler irrigation methods for cotton irrigation. They found that, the furrow irrigation method produced 338 $kgha^{-1}$ of fibre yield more than the sprinkler irrigation. Silver *et al* (1990) with different amount of water (400, 600 and 800 mm) observed significant effect of irrigation water on fibre uniformity and strength. Wanjura *et al*. (2000) revealed that maximum cotton yield was attained at an irrigation input of 58 cm or a total water requirement application of 74 cm. The components of total water supply for maximum yield treatments averaged 74 percent irrigation and 26 percent rain. Lint yield response to irrigation up to the point of maximum yield of 11.4 kg ha^{-1} cm^{-1} of irrigation between the limits of 5 and 54 cm and observed lint yield ranging from 855 to 1608 kg ha^{-1}Shende *et al*. (2001) reported that surface method of irrigation required 85.14 cm of irrigation water against 49.12 cm in drip method. While

studying drip and furrow irrigation systems for cotton variety *Savitri* at Rahuni, Bangal *et al.* (1987) reported that 71.9cm of water was required in the furrow system whereas drip required only 41.90cm of water. Similarly, Magarr and Somawane, (1987) reported that 38.7cm of water was required for cotton under drip irrigation compared to 90cm required by surface irrigation.

2.3 Role of Nitrogen Fertilization on Cotton Development

Nitrogen is generally considered as a yield limiting factor in both dryland and irrigated cotton production systems that focus on optimizing seed cotton and lint yield. Among the plant nutrients, nitrogen play a very important role in crop productivity is an important determinant of the growth and yield of irrigated cotton (Ahmad, 2000).

. Nitrogen is the most important element for crop production and agricultural production is highly dependent to this element. Cotton, like most crops, requires N for normal growth and development and farmers rely heavily on N fertilizers. Nitrogen is required through all phases of plant development because this essential element is a constituent of both structural (cell membranes) and non structural (amino acids, enzymes, protein, nucleic acids and chlorophyll) components of the plant. Deficiency symptoms of N in cotton include stunting, chlorosis and fewer small bolls (Radin and Mauney, 1984 and Tisdale *et al*. 1993). Nitrogen requirement of cotton varies considerably depending on the stage of development of the plant. Generally nitrogen requirement is minimal in the early growth stages and increases as the rate of growth accelerates, to a peak during the period between onset of flowering and early boll formation. During the vegetative stage of growth, rapid expansion of leaves requires large amounts of N, and both fruit production and retention are dependent on leaf development and photosynthetic integrity (Oosterhuis *et al.* 1983). Irrigated cotton was generally found to be higher yielding than cotton

grown under dry land conditions mostly related to water stresses at reproductive stage that often resulted in flower and boll abscissions. Fertilizer N requirement of cotton for maximum yield tended to be greater under irrigated production conditions than under dry land production conditions. Over- and under-fertilization may result in delayed maturity and reduced yield, respectively (Maples and Keogh, 1971).

2.4 Effect of Nitrogen on Growth of Cotton

Research involving N has been studied for many years (Phillips *et al*.,1987, McConnell *et al*.,1993, Boquet *et al*.,1995; Boquet and Breitenbeck, 2000). Wankede (1973) and Mamples and Frizzel (1985) reported that higher rates of nitrogen stimulated the vegetative growth parameters, such as plant height, branching and number of internodes in tall cotton varieties but not in short varieties. Singh *et al*. (1973) reported that the number of monopodia branches per plant was increased with increasing rate of nitrogen. Kumbhar, *et al*. (2008), working with cotton-legume crop sequence using varying N level reported that 150:50 NP kg ha^{-1} recorded maximum plant height (103.63cm), monopodia branches per plant (2.61), sympodia branches per plant (13.7), boll per plant (26.40), seed index (6.83), ginning out turn (34.57%,), staple length (28.65mm), oil content (23.10%), seed cotton yield (2538.25 kg ha^{-1}) and N-uptake (113.43 kg ha^{-1}) in legume incorporated than control.

Javeed and Anwar (2005) reported that N applied at the rate of 150 and 200 kg ha^{-1} showed maximum plant height, number of main stem nodes per plant as compared to other lower levels. Lowest values of these parameters were observed at 50 kg N ha^{-1}. Boquet *et al*. (1993) observed that number of sympodial branches increased with increased nitrogen rates. Similar results were found by Brar *et al*., (1993) where they indicated that nitrogen increased plant height and number

of boll per plant. Boquet and Breitenbeck (2002) reported that increasing N rate from 84 to 168 kg N ha^{-1} increased areal biomass and further increased the vegetative growth but the relative proportion of plant vegetative fractions remained similar. Suresh *et al.* (2008) using Bt-cotton showed that dry matter per plant and monopodia branches were significantly increased from 80 to 120 and further to 160 kg N ha^{-1}.

Reddy and Rao (1970) reported that increased levels of nitrogen linearly increased the number of functional leaves. Kai and Morrill (1976) reported that nitrogen significantly increased the number of internodes and vegetative branches of cotton plants. Thomson *et al*. (1976) showed that nitrogen levels between 0 to 134 kg ha^{-1} caused cotton plants to grow slower, flower later, and produce less fruits and seed cotton than N level between 134 to 201 kg ha^{-1}. Smithson *et al*. (1976) reported that nitrogen increased the number of bolls per plant, it prolonged the growth period and enabled the later formed flowers and fruits to develop to maturity. They indicated that early application of nitrogen promoted vegetative growth while split application resulted in high reproductive growth.

2.5 Effects of Nitrogen on Yield and Yield Components of Cotton

The N requirement for optimum cotton yields under different environmental conditions is uncertain due to the indeterminate growth habit of cotton and complexity of N cycle in the soil (Gerik *et al.,* 1988). Since nitrogen nutrition plays an important role on the vegetative and reproductive phases of cotton, the yield contributing characters, yield and the quality of the fibre are likely to be influenced by nitrogen application.

Rashidi and Gholanin (2011) reported that application of 200 kg ha^{-1} N and 1000 g ha^{-1} B resulted in the highest boll number, boll weight, seed cotton yield and lint yield, and enhanced fiber properties. Suresh (2008), working with Bt-cotton indicated that increasing level of N from

80 to 120 and further to 160 kg ha^{-1} significantly improved seed cotton yield by 12 and 18.6 percent respectively. The increase was due to increased yield components such as yield per plant, boll weight, number of squares and green bolls per plant. Sagarka *et al.* (2002) reported that application of 160 kg N ha^{-1} was found to be significantly superior with respect to all the yield attributes, seed cotton and stalk yields over lower nitrogen levels. Abduldahab and Hassanin (1991) found that seed cotton yield per ha, number of nodes per plant increased with the application of 150 kg N ha^{-1}.

Das *et al*., (2006) revealed that with each increment of N, bolls per plant was increased significantly whereas, boll weight was significant only at 60 kg N ha^{-1} as compared to higher rates. Similarly, seed cotton yield was also increased significantly with successive higher dose of N (60 kg ha^{-1}). Increased N rate reduced the lint percentage by 0.16%, increased mineral uptake, photosynthetic assimilation and accumulation in sinks (Sawan *et al*. 2006). Hearn (1981) found that cotton requires about 90 kg N ha^{-1} for one bale of lint and about 140 kg ha^{-1} for two bales of lint depending upon soil texture. Application of fertilizer N of between 100 and 215 kg ha^{-1} is required to optimize lint yield of irrigated cotton in Egypt (Hussein *et al*.1985), USA (McConnel *et al.* 1985), Australia (Constable and Rochester,1988), and China (Jin *et al*. 1997) .

Ogunlela *et al*. (1982), reported increases in yield and yield components of cotton with increased rate of N-application. Seed cotton yield was mainly influenced by increase in boll number per plant. Idem (1984) obtained positive and significant influence of N-application on yield and yield components such as number of bolls per plant, average boll weight and number of seed per boll. Anonymous (1978) reported significant yield response up to 60 kg N ha^{-1} where seed cotton yields of 2110, 2401, 2514 and 2543 kg ha^{-1} were obtained with 0, 30, 60 and 90 kg N ha^{-1}, respectively. Yield components such as seed cotton yield per plant, number of per bolls plant

and seed weight of boll responded in the same manner as seed cotton yield per ha. Lombin and Ogunlela (1979) in summarizing 18 field trials conducted for three year, covering the major cotton growing areas of Nigeria concluded that June-sown cotton did not respond to N beyond 50 kg ha^{-1}. Kumar *et al*. (1982) reported no response of May-sown cotton beyond 90 kg ha^{-1} of nitrogen at Samaru Nigeria.

Bharambe *et al.* (1997) reported that application of 100 kg N ha^{-1} produced significantly higher seed cotton yield than 50 and 75 kg ha^{-1} through drip irrigation and 100 kg ha^{-1} using conventional soil application method. The yield obtained with 75 kg N ha^{-1} through drip was comparable with the 100 kg N ha^{-1} through conventional method. In cotton, excess of N delays maturity, promote vegetative tendencies, and usually result in lower yields ((Jackson and Faulkner, 1962) and (McConnell *et al*. 1996). Excess application of N than required for optimum crop performance can reduce yield or fibre quality (Gerik *et* al., 1989). Hamilton *et al.* (1956) found that increase in nitrogen level increased the number of bolls per plant. Favourable effects of nitrogen fertilization on boll size has been reported by Singh *et al.* (1979). Nayak (1954) reported linear increase in seed index with increased nitrogen levels.

Renoid *et al.* (1934) observed marked increase in number of fruiting branches per plant with nitrogen application. Gomase and Patil (1987) noticed that hybrid cotton (H-4) responded significantly to addition of N up to 100 kg ha^{-1}. Response per kg N at 50 and 100 kg ha^{-1} was 9.72 and 8.82 kg seed cotton, respectively. Angodi *et al.* (1998) indicated that, N application up to 100 kg ha^{-1} to hybrid cotton increased number of bolls, yield per plant and seed cotton yield ha^{-1}. Nitrogen addition beyond 100 kg ha^{-1} did not increase seed cotton yield. Ibrahim *et al.* (1997) found that increasing N application rates increased dry matter and N uptake by the plant. The highest rate (traditional) of 70 kg N per *Fadda* (*Fadda*=0.42 ha) gave the highest growth (total

dry matter) and N uptake by the cotton plant. Examination of the interactions between irrigation and N treatments revealed that the highest boll weight was due to application of irrigation at the initial sign of wilting and N fertilization at the rate of 70 kg N/Fad (166.7 kg/ha, 1 Fad=0.42 ha). Bronson *et al.* (2001) using N-fertilizer at varying level 0, 28, 56, 84 or 112 kg N ha^{-1} and irrigation levels 0, 25, 50 or 75% evaportranspiration (ET) for conventional and conservation tillage cotton showed that cotton lint yields showed a quadratic response to irrigation level in wet year (1996/97) and a linear response in the drought year (1998). Cotton lint yields responded to N at 50 and 75% estimated ET replacement irrigation levels but not at the 0 or 25% ET level.

2.6 **Response of Cotton Varieties to Irrigation and Nitrogen Fertilization**

Saleem *et al*. (2010) working with three cotton varieties (NIAB-111, CIM-496 and FH-901) reported no significant differences between the varieties with respect to boll weight and seed cotton yield decreased after 120 kg N ha^{-1}. The effects of nitrogen x irrigation interaction were not significant for most traits studied (Rezaei *et al*. 2008). However application of 180 kg ha^{-1} nitrogen in three split application (planting, square and flowering stages) and irrigation after 135 mm cumulative A pan evaporation was recommended.

Kalibari (2006) working with four cotton varieties reported that among the cotton genotype, ACP-71 recorded significantly higher seed cotton yield than other genotypes viz., JK-276-8-2, AH-167 and DHH-H. The yield increase in ACP-71 genotype was from 6.77 to 14.9 percent over others. In three years trials using two cotton varieties Acala (*G. hirsutum*) and Pima (*G. barbadense*), Fritschi *et al.,* (2003) reported that Acala produced dry matter of 7800 and 12,600 kg ha^{-1} on two different soils for the 56 and 168 kg N ha^{-1} treatment respectively. Pima produced dry matter of 7600 and 10,800 kg ha^{-1} for 56 and 168 kg N ha^{-1}. Linear increases in lint yield with increased N-fertilization occurred for Acala with a maximum lint yield of 1666 kg ha^{-1}

at 224 kg N ha^{-1}. Pima lint yield responded to N-management in quadratic fashion with maximum yields at the 168 kg N ha^{-1} treatment (1638 kg ha^{-1}). There was a positive relationship between increased N-fertilizer rate and yield. Vulkan *et al*. (1998) reported that Pima cotton's (CV S5) maximum yield of seed cotton (about 5000 kg ha^{-1}) was obtained with a water application of 50cm. Constable and Hodgson (1990) found that, the cultivars differed under irrigation system among D1-90 and Siokra cotton cultivars, Siokra yielded 16% more seed cotton yield under drip irrigation than furrow irrigation method.

2.7 Correlation and Path analysis

Expression of various traits is often changed with changing breeding material and environment changes. Therefore the information of character association between the traits themselves and with the yield is important for the breeding material subjected to selection for high yielding genotypes. Considerable emphasis has been given on the inter relationship between yield and yield components in cotton.

Salahuddin *et al*. (2010) reported significant positive correlation by sympodial branches, boll per plant and boll weight on seed cotton yield while plant height and monopodial branches showed significant association with the yield per plant. Remzi *et al*. (2010) showed that in order to increase seed cotton yield in the studies of breeding program and selection of highness of number of sympodial branches, single boll weight, number of monopodial branches and number of boll characters should be considered important. Iqbal, *et al*. (2006) also reported that number of bolls per plant and boll weight had maximum positive direct effect on seed cotton yield. Number of sympodia, boll weight and bolls per plant were significantly and positively correlated with seed cotton yield. Rauf *et al*. (2004) reported that boll number per plant and sympodial branches had positive and significant correlation with seed cotton yield. Basamma, (2007) reported that the

direct influence of seed index on seed cotton yield was higher in magnitude hence its association with seed yield per plant was positive. Thus selection for high cotton seed yield would be effective in improving seed cotton yield in crosses where significant positive association exists between these two traits. Similar result was also reported by Desalegn *et al*. (2009). Idem, (1984) reported that seed cotton yield was significantly and positively correlated with average boll weight, ginning percentage, seed index, average number of mature bolls per plant and average number of seeds per boll. Tomar and Singh (1992) reported that seed cotton yield showed high order positive and significant association with number of bolls, seed yield, lint yield, ginning (%) and lint index.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Experimental site

Field trials were conducted during the 2006/07, 2007/08 and 2008/09 dry seasons at Irrigation Research Station farm of the Institute for Agricultural Research, Kadawa. The site is located in the Sudan savannah ecological zone of Nigeria ($11^0$39'N, $08^0$27'E; altitude 500m above sea level). The physico-chemical properties of the experimental soil are given in Appendix I while the meteorological data of the area in the three years is indicated in Appendix II.

3.2 Treatments and Experimental Design

The treatments consisted of four nitrogen levels (40, 70, 100 and 130 kg N ha^{-1}), three irrigation methods (border strip, check basin and furrow) and three varieties of cotton (SAMCOT 10, SAMCOT 11 and SAMCOT 13). The treatments were laid out in split-plot design with irrigation method and nitrogen allocated to main plots while variety was allocated to sub-plots and replicated three times. The gross and net plot sizes were 15 and 7.5m^2, respectively.

3.3 Description of Cotton Varieties

3.3.1 SAMCOT 10

This is a medium staple fibre cotton variety. It is a commercial variety in the northern and southern cotton production zones of Nigeria. It was derived from RASA (74) 165 and released in 1989. It has reddish and hairy stem with conical-shaped boll and yellow petal. It is resistant to bacterial blight. It is medium staple, fine lint with good luster. It matures in 130 to 150 days and has potential yield of 1500 to 2000 kg ha^{-1} adapted to northern and southern cotton growing zone.

3.3.2 SAMCOT 11

The pedigree selection was from BAR XL 7(79) 36 and released in 2003. It has greenish purple and short hair stem. The leaves are lobed and glanded with yellow petals, while bolls are

slightly conical. Under good management conditions the variety can produce seed cotton up to 2000 kg ha^{-1}. It is long staple (28 to 29 mm) cotton. The variety is recommended for production in the southern cotton growing zone. It matures in 140 to 150 days. It has moderate resistance to bacterial blight.

3.3.3 SAMCOT 13

Its pedigree selection was from GIZA 45 in Egypt and released in 2003. It has reddish stem without hairs. The leaves are lobed while the bolls are oval in shape with a pointed tip. It has moderate resistance to bacterial blight. It is a long staple (28 to 30 mm) cotton with fine, soft lint and good luster. Its maturity period ranges from 150 to 160 days. It is recommended for production in the northern cotton growing zone under supplementary irrigation.

3.4 Cultural Practices

3.4.1 Land preparation

The main field was harrowed to create fine tilth. The field was divided into treatment plots of furrows, check basins and border strips in accordance with the irrigation method for each treatment. Land leveling for both check basins and border strips was done to allow for uniform distribution of irrigation water over the field.

3.4.2 Seed Source

Seeds of each cotton varieties were obtained from Seed Production Unit of the Institute for Agricultural Research, Samaru.

3.4.3 Seed sowing

The cotton seed was sown by hand at the rate of four seeds per hole at 75 x 45 cm inter and intra row spacing respectively. Sowing was done on first week of February each year. The

cotton seedlings after emergence were thinned to two plants per stand at three weeks after sowing (WAS).

3.4.4 Fertilizer application

Nitrogen fertilizer was applied in two split doses as per treatment of 40, 70, 100 and 130 kg N ha^{-1} at 3 and 6 weeks after sowing using urea (46%N). P and K each at 30 kg ha^{-1} was applied during land preparation using single superphosphate (18% P_2O_5) and muriate of potash (60% K_2O), respectively.

3.4.5 Weed Control

Weed control was done by using pre-emergence application of Pendimenthalin 30 EC at 1.5 kg a.i ha^{-1} a day after sowing. Supplementary hoe weeding was done at 4 and 8 WAS in order to control the weeds that emerged later.

3.4.6 Pest and disease control

Insect pests were controlled using Sherpa plus (a mixture of dimethoate and cypermethrin 15+250 kg ai/ha) at two weeks interval from the day insect pests appeared. A CP-3 knapsack sprayer was used for spraying the insecticide. There was no any serious disease break out throughout the three years.

3.4.7 Application of Irrigation Water

Irrigation water was applied using border strip, check-basin and furrow irrigation method by use of siphon tubes. This was done by pumping the irrigation water through the siphon into the border strips, check basins and furrows when soil tension reaches 35 centibars using tensiometer.

Border irrigation: Water was applied to strips of land diked on two sides and open at the downstream end. Irrigation takes place by allowing the flow to advance and infiltrate along the border.

Check-basin irrigation: Water was applied to levelled surface units (basins) which have complete perimeter dikes to prevent runoff and to allow infiltration after cut-off.

Furrow irrigation: Water was applied to furrows using small discharges to favour water infiltration while advancing down the field.

Water measurement was done by passing the irrigation water through Parshall flume and time recorded per area covered (Border strip = 35, check basin = 40 and furrow = 15 minutes). Discharge rate was computed using the Parshall formula (Parshall, 1953).

$Q = 4W.h^n$ where: Q = discharge rate (l/s) h = height of water (cm)

W = width of flume throat n = exponent (1.547)

3.4.8 Water use

Water use of the three irrigation methods was computed from the discharge rate and time taken to cover the experimental area of the respective methods.

3.4.9 Water use efficiency (WUE) (kg m^{-3})

Water use efficiency was calculated using the formula given by Vietz, (1962).

$$WUE = \frac{\text{Seed cotton yield (kg ha}^{-1})}{\text{Water used (m}^3\text{ha}^{-1})}$$

3.4.10 Harvesting

Harvesting of seed cotton was done whenever the bolls open and dry. The net plot was harvested by hand picking the dry open bolls. Seed cotton was then ginned plot by plot and both the lint and cottonseed were weighed separately to determine their yield and ginning percentage.

3.5 OBSERVATIONS AND DATA COLLECTION

3.5.1 Plant height

Height of five randomly tagged plants were measured from ground level to the tip of the apical bud at 6, 10, 14, and 18 WAS. The means were then computed.

3.5.2 Leaf area index (LAI)

The leaf area was estimated using the specific leaf area (SLA) relationship as described by Evans (1972). Specific leaf area (SLA) is defined as the ratio of leaf area to that of leaf dry weight.

$$\text{Total leaf area (LA)} = a \times \frac{(b + c)}{b}$$

where a = area of 5 leaves disc

b = dry weight of 5 leaves disc in (g)

c = dry weight of remaining leaves from each sample (g)

The LAI was determined by dividing the estimated leaf area of the sampled plants by the ground area occupied by the plants given by the formula:

LAI = LA/GA where LA = Leaf Area; GA = Ground Area (3375 cm^2)

3.5.3 Total dry matter

Three plant samples were taken from each plot at 6, 10, 14 and 18 WAS and oven dried to a constant weight and then weighed to obtain total dry matter per plant.

3.5.4 Crop growth rate (CGR) g $plant^{-1}$ wk^{-1}

This is a measure of the rate of dry matter increment per unit area of land per unit time, calculated from following formula as described by Radford (1967).

$$\text{CGR} = \frac{W_2 - W_1}{t_2 - t_1} \quad (\text{g plant}^{-1}\ \text{wk}^{-1})$$

Where W_1 and W_2 are dry weights in g $plant^{-1}$ at time t_1 and t_2 in weeks, respectively.

3.5.5 Relative growth rate (RGR) $gg^{-1}wk^{-1}$

The RGR was computed using the data from the plant dry matter yield at different sampling periods. This is a measure of dry matter accumulation and efficiency index of a plant. It was computed using the following formula as described by Radford, (1967).

$$RGR = \frac{(\log_e W_2 - \log_e W_1)}{(t_2 - t_1)} \quad gg^{-1}\ week^{-1}$$

where W_1 = weight of total dry matter in g at time t_1

W_2 = weight of total dry matter in g at time t_2

t_1 = time of first sampling

t_2 = time of second sampling

Log_e = natural log = 2.71828.

3.5.6 Net assimilation rate (NAR) g m^{-2} wk^{-1}

Net assimilation rate (NAR) is the plant's rate of increase of dry weight per unit leaf area. This is similar to the unit leaf rate (ULR) as described by Evans (1972). The NAR was determined using the following formula (Gregory, 1926).

$$\frac{(W_2 - W_1)\ (\log_e L_2 - \log_e L_1)}{(t_2 - t_1)\quad (L_2 - L_1)} \qquad g^{-1}m^{-2}week^{-1}$$

Where w_1 and w_2 are dry weights in g $plant^{-1}$ and L_1 and L_2 are leaf area at times t_1 and t_2 in weeks, respectively.

3.5.7 Number of branches

The number of branches per plant was counted and recorded at 14 WAS from five tagged plants.

3.5.8 Days to 50% flowering

The number of days to 50% flowering was recorded from the date of sowing until when 50% of plants in a plot produced flowers.

3.5.9 Days to 50% boll opening

Number of days to boll opening was determined from the date of sowing till when 50% of plants in a plot opened their bolls.

3.5.10 Number of bolls per plant

The total number of open bolls of the five tagged plants were be determined by adding up the number of bolls picked at each picking. From this, the number of mature bolls per plants were be determined.

3.5.11 Boll weight (g)

Boll weight was determined by randomly picking five cotton bolls from the tagged plants and averaged out as boll weight.

3.5.12 Number of seeds per boll

The number of seeds per boll was counted from five bolls picked randomly from each plot and their seeds averaged as number of seeds per boll.

3.5.13 Weight of seeds per boll (g)

The seeds obtained from 3.5.12 above were weighed and averaged as weight of seeds per boll.

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

Seed cotton yield was determined from the total seed cotton picked per net plot. The dried seed cotton was weighed and the yield computed for each plot on per ha basis.

3.5.15 Ginning percentage

Seed cotton picked from the net plot was ginned with a cotton ginner and ginning percentage was calculated from the weights of the lint per seed cotton weight.

Ginning percentage = Lint weight /seed cotton weight × 100

3.5.16 Lint yield (kg ha^{-1})

The lint yield was determined by weighing the lint ginned from seed cotton yield of each net plot and computed on per hectare basis.

3.5.17 Percentage oil content of cotton seed

These were determined by taking cotton seeds samples to the Food Science Laboratory, Institute for Agricultural Research for the analysis of oil content. The oil content was determined using the procedure described by Association of Official Analytical chemist (AOAC, 1980).

3.5.18 Percentage protein content of cotton seed

The protein content of the cotton seeds was determined by Micro-kjeldl method (Bremmer, 1965).

3.5.19 100-seed weight

The cotton seeds from the cotton ginner were treated with concentrated sulphuric acid to remove the furs. The acid effect was neutralized with sodium hydroxide solution and then rinsed thoroughly with water. The cotton seeds were dried and 100 seeds counted and weighed.

3.5.20 Lint index

This was calculated with the use of seed index and ginning percentage as follows:

Lint index = $\frac{\text{Weight of 100 Seeds x Ginning \%}}{}$

100 – Ginning %

3.5.21 Fibre finess

Four samples each of five grammes of the lint from each sub plot were taken and their micronaire measured using Stellometre and then averaged out as the micronaire valure.

3.6 Soil sampling and analysis

Random soil samples of the experimental area were taken using an auger at a depth of 0-30cm before land preparation and analyzed for physico-chemical properties each year. Results of the soil analyses are shown on appendix 1.

Soil pH

Soil pH was determined in 0.01M $CaCl_2$ by using a soil solution ratio of 1:2.5 by means of a Philip analogue pH meter. The soil pH was determined using the pH meter (Black, 1965).

Total nitrogen

The total nitrogen content of the soil was determined by Micro Kjeldahl procedure (Bremmer 1965).

Soil available P

Available phosphorous in the soil was determined by using dilute acid-fluoride extraction as described by Bray and Kurtz, (1945).

Exchangeable basis

The exchangeable bases (Na, K, Ca and Mg) were determined with neutral 1N Ammonium acetate (NH4 OAC) as described by Chapman, (1965).

Soil organic carbon

The organic carbon content of the soil was determined by the wet oxidation method of Walkley-Black as described by Allison, (1965).

3.7 Cost Benefit Analysis of Yield.

Cost benefit analysis was used to assess the economic benefit of producing cotton varieties under different irrigation methods and nitrogen levels. Data collected for the cost of production and the market price of seed cotton yields at production periods was used in the analysis. This was computed as described by Olukosi and Erahabor (1988).

3.8 Statistical Analyses of Data

The data collected were subjected to analysis of variance using General Linear Model procedure of Statistical Analysis System (SAS) package (SAS, 1990) and significant difference between treatments means were compared using the Duncan Multiple Range Test (Duncan, 1955). The strength of relationship among growth, yield and yield parameters was determined using simple correlation coefficient analysis as described by Little and Hills (1978). The direct, individual and combined contributions of growth and yield components to total seed cotton yield were determined using path coefficient analysis (Dewey and Lu, 1959). Regression analysis was conducted to determine the optimum level of nitrogen for maximum seed cotton yield as suggested by Garg and Bansal (1972) and Reddy *et al*. (1975).

CHAPTER FOUR

4.0 RESULTS

4.1 Plant Height

Table 1 shows the effect of irrigation methods and nitrogen fertilization rate on plant height of three cotton varieties in 2007, 2008 and 2009 dry seasons. From the result it showed that every increase in nitrogen rate from 40 to 130 kg ha^{-1} significantly increased plant height at 10, 14 and 18 WAS in 2007, 18 WAS in 2008 and 6, 14 and 18 WAS in 2009. At 6 WAS in 2007, 10 and 14 WAS in 2008 increasing the nitrogen level from 40 to 70 kg ha-1 did not have any significant effect on plant height, further increase to 100 and beyond increases this parameter. While at 6 WAS in 2008 and 10 WAS in 2009 increase in nitrogen level from 40 to 70 significantly resulted in taller plant but further increase only produced taller plant at 130 kg N ha^{-1} in 2009. Irrigating with border strip resulted in taller plants than in other irrigation method at 10 WAS in 2007, 6 WAS in 2008 and 10 and 18 WAS in2009. However at 18 WAS in 2007 and 10 WAS in 2008, check basin resulted in plants with similar height with those in border strip. Generally furrow irrigation resulted in shorter plants across the years.

SAMCOT 13 significantly resulted in taller plants than all other varieties compared at all sampling periods and years except in 2009 where the variety had similar height with SAMCOT 11. SAMCOT 11 was significantly taller than SAMCOT 10 at 10, 14 and 18 WAS in 2007, while they had similar height at 10 and 18 WAS in 2008. The three cotton varieties had similar height at 6 and 14 WAS only in 2008. There was significant interaction between irrigation method and cotton variety at 14 and 10 WAS in 2007 and 2008 respectively.

Table 1. Influence of nitrogen rate and irrigation method on plant height of cotton varieties in 2007, 2008 and 2009 dry season.

	Plant Height (cm)											
	2007				2008				2009			
	Weeks After Sowing (WAS)											
Treatment	6	10	14	18	6	10	14	18	6	10	14	18
Nitrogen (N) (kg ha^{-1})												
40	12.6c	31.2d	94.4d	104.2d	42.0c	80.6c	95.7c	96.9d	50.8d	96.7c	111.4d	112.7d
70	13.0c	32.7c	100.8c	110.5c	45.9b	82.7c	94.6c	101.5c	53.3c	104.8b	119.4c	121.7c
100	13.8b	34.5b	108.3b	118.7b	51.6a	88.9b	109.0b	108.3b	60.3b	110.1b	125.6b	126.7b
130	14.5a	37.0a	118.5a	129.5a	54.7a	98.5a	136.2a	117.7a	64.8a	123.0a	134.5a	137.8a
SE±	0.58	0.67	0.67	0.64	0.97	1.07	1.67	0.64	2.30	3.55	3.01	2.84
Irrigation Method (I)												
Check basin	14.4a	33.6b	107.4a	117.0a	47.8b	88.1ab	123.1	104.3b	57.1	109.6a	120.6b	122.7b
Border strip	12.7c	34.3a	106.2b	116.1a	51.6a	89.1a	102.1	107.8a	57.1	111.9a	126.3a	128.5a
Furrow	13.4b	33.4b	103.0c	114.0b	46.3b	85.9b	101.4	106.2ab	57.8	104.6b	121.2b	123.1b
SE±	0.50	0.58	0.58	0.55	0.84	0.92	1.45	0.56	2.60	3.07	2.60	2.46
Variety (V)												
SAMCOT 10	13.7b	30.5c	93.8c	106.0c	47.8	81.2b	119.9	101.9b	53.6b	105.1b	116.4b	117.8b
SAMCOT 11	12.4c	31.9b	104.9b	115.4b	48.3	83.4b	99.0	103.7b	58.2a	110.6a	126.0a	127.7a
SAMCOT 13	14.4a	38.9a	117.8a	125.7a	50.0	97.9a	107.7	112.6a	60.1a	110.4a	125.8a	128.8a
SE±	0.45	0.65	0.67	0.46	0.97	0.89	1.46	0.72	1.13	1.70	1.49	1.47
Interactions												
N x I	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
N x V	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
I x V	NS	NS	**	NS	NS	**	NS	NS	NS	NS	NS	NS
N x I x V	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. WAS = Weeks after sowing, **= significant at 1% level of probability. NS = Not significant.

Table 2 shows interaction between irrigation methods and cotton varieties on plant height at 14 WAS in 2007 and 10 WAS in 2008. In 2007, SAMCOT 13 produced significantly taller plants than SAMCOT 10 which in turn taller than SAMCOT 11 in check basin irrigation method. However under furrow irrigation method, SAMCOT 13 was statistically at similar height with SAMCOT 10 but shorter than SAMCOT 11. Similarly, SAMCOT 13 WAS taller than both SAMCOT 10 and 11 which were statistically at par. When irrigation method was considered, Check basin and furrow irrigation resulted in statistically taller plants of SAMCOT 10 than in border strip. However furrow and border irrigation resulted in similar but taller plants of SAMCOT 11 than in check basin. While check basin irrigation resulted in statistically taller plants of SAMCOT 13 than other methods which were at par.

The interaction between irrigation method and variety at 10 WAS in 2008 showed that SAMCOT 10 and SAMCOT 13 produced similar but taller plants than SAMCOT 11 in check basin irrigation method. The cotton varieties had similar height in furrow irrigation method however, SAMCOT 13 was significantly taller than SAMCOT 10 and 11 which were similar in border strip method. When irrigation method was considered, check basin irrigation method resulted in significantly taller plants of SAMCOT 10 than in furrow and border strip. SAMCOT 13 resulted in similar but taller plants in both check basin and border strip than furrow irrigation method. While irrigation method did not affect the height of SAMCOT 11 statistically.

4.2 Total Dry Matter (TDM)

Table 3 shows the influence of irrigation methods and nitrogen rates on total dry matter of cotton varieties in 2007, 2008 and 2009. It showed that each increase in nitrogen rate significantly resulted in higher total dry matter at all sampling periods and years except at 14

Table 2: Interaction between Irrigation method and variety on plant height (cm) at 14 WAS in 2007 and 2008.

	14 WAS in 2007		
	SAMCOT 10	SAMCOT 11	SAMCOT 13
Irrigation Method			
Check-basin	100.4bc	93.1e	106.7a
Furrow	102.1b	99.1cd	102.8b
Border-strip	96.0de	97.1d	102.7b
SE ± 1.162			
	10 WAS in 2008		
Check-basin	105.8a	94.3b	109.2a
Furrow	98.7b	105.5b	102.0b
Border-strip	95.0b	97.1b	111.8a
SE ± 25.33			

Means followed by the same letter(s) within the same row or column are statistically similar at $P \leq 0.05$.

WAS in 2007 and 6 WAS in 2008 where 40 and 70 kg N ha^{-1} produced similar total dry matter. While at 18 WAS in 2008, 70 and 100 kg N ha^{-1} also produced similar total dry matter. Check-basin irrigation method resulted in higher total dry matter compared to other methods except in 2007 where furrow irrigation method significantly resulted in higher total dry matter compared to other method while in 2008 check basin resulted in higher TDM than in other methods except at 10 WAS were irrigation method did not affect TDM.

SAMCOT 13 consistently resulted in significantly higher total dry matter than the other two varieties at all sample periods and years except at 6 WAS in 2007 where no significant effect was observed. SAMCOT 11 produced similar total dry matter with SAMCOT 10 at 10 WAS in 2007, 10 and 14 WAS in 2009. However SAMCOT 10 resulted in higher TDM than SAMCOT 11 at 14 and 18 WAS in 2007, 6 and WAS in 2008, 6 and 18 WAS in 2009. Significant interactions between nitrogen rates and cotton varieties at 14 WAS in 2007 and 2008 were observed.

Table 4 shows the interaction between nitrogen rates and cotton varieties on total dry matter at 14 WAS in 2007 and 2008. In both years, it indicated that each increase in N level significantly increased the total dry matter in all the varieties. When nitrogen level was held constant, the cotton varieties showed significant variation in respect to total dry matter production. SAMCOT 13 significantly accumulated higher total dry matter than SAMCOT 11 which was in turn higher than SAMCOT 10 at all nitrogen levels and in both years.

4.3 **Leaf Area Index** (LAI)

Table 5 shows the influence of nitrogen rate and irrigation method on (LAI) of cotton varieties in 2007, 2008 and 2009. Each increase in nitrogen fertilizer rate significantly resulted in

Table 3. Influence of nitrogen rate and irrigation method on total dry matter of cotton varieties in 2007, 2008 and 2009 dry seasons.

	Total Dry Matter (g) at (WAS)											
	2007				2008				2009			
Treatment	6	10	14	18	6	10	14	18	6	10	14	18
Nitrogen (kg ha^{-1})												
40	40.7d	77.8d	93.5c	94.5d	13.3c	32.1d	100.2d	107.5c	14.7d	32.4d	100.5d	111.0d
70	45.3c	80.9c	95.5c	99.5c	13.6c	34.1c	108.4c	114.9b	15.9c	34.8c	107.6c	118.1c
100	49.8b	84.3b	101.4b	103.8b	14.5b	35.8b	117.8b	120.5b	17.3b	38.9b	122.9b	133.4b
130	53.2a	92.0a	109.6a	115.3a	15.1a	37.7a	130.2a	137.9a	18.6a	41.3a	128.8a	139.4a
SE±	0.138	0.164	0.690	0.549	1.222	0.355	1.146	2.34	0.175	0.494	1.614	1.614
Irrigation Method (I)												
Check basin	46.2b	83.8b	98.6b	102.2b	15.2a	35.0	119.6a	127.0a	18.6a	40.9a	127.9a	139.1a
Border strip	46.0b	80.8c	100.1ab	104.6a	13.2c	35.0	111.8b	116.2b	16.8b	37.3b	116.5b	126.6b
Furrow	50.2a	86.7a	101.3a	102.6b	14.1b	34.7	111.1b	117.4b	14.5c	32.2c	100.5c	110.8c
SE±	0.120	0.142	0.597	0.475	0.106	0.307	0.992	2.026	0.152	0.428	1.398	1.398
Variety (V)												
SAMCOT 10	47.3	78.1b	99.5b	102.2b	14.4b	31.8c	101.3c	108.9c	16.15b	34.96b	109.6b	120.3b
SAMCOT 11	47.0	78.1b	96.4c	99.2c	12.9c	34.0b	110.5b	115.8b	15.42c	34.11b	106.5b	115.6c
SAMCOT 13	48.1	95.1a	104.1a	108.4a	15.1a	39.0a	130.6a	135.8a	18.29a	41.40a	128.8a	140.6a
SE±	0.119	0.222	0.384	0.493	0.106	0.296	0.995	2.157	0.170	0.411	1.219	1.218
Interactions												
N x I	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
N x V	NS	NS	**	NS	NS	NS	**	NS	NS	NS	NS	NS
I x V	NS	NS	NS	NS	NS	NS	NA	NS	NS	NS	NS	NS
N x I x V	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within the same column are not significantly different at 5% level of probability. WAS = Weeks after sowing, ** Significant at 1% level of probability. NS = Not significant

Table 4: Interaction between nitrogen and variety on total dry matter (g) at 14 WAS in 2007 and 2008.

	Nitrogen (kg ha$^{-1)}$			
	40	70	100	130
		2007		
Variety				
SAMCOT 10	87.2j	90.5i	95.6h	101.9f
SAMCOT 11	94.8h	100.3g	107.7e	116.9c
SAMCOT 13	101.0g	111.6d	121.5b	136.7a
SE ±		0.767		
		2008		
SAMCOT 10	91.0g	92.7f	104.3e	117.4d
SAMCOT 11	97.7f	105.9e	112.2d	126.4c
SAMCOT 13	111.9d	126.7c	137.1b	146.8a
SE ±		2.017		

Means followed by the same letter(s) in the same interaction group are statistically similar at P≤ 0.05.

higher LAI at 14 WAS in 2007 and 2009, 6, 10 and 14 WAS in 2008. Nitrogen did not influence LAI at 6, 10 and 18 WAS in 2007. At 18 WAS in 2008 and 6 WAS in 2009 increasing nitrogen rates from 40 to 70 kg ha^{-1} did not influence LAI but each further increase resulted in higher LAI. At 18 WAS in 2009, 130 kg N ha^{-1} resulted in significantly higher LAI than other rates that were statistically at par. Also N did not influence LAI at 6 and 10 WAS in 2007. Irrigation methods did not significantly affect LAI at 6 and 10 WAS in 2007. At 14 WAS in 2007, 14 and 18 WAS in 2008 and 2009, check basin and border irrigation resulted in similar but significantly higher LAI than in furrow irrigation. At 6 and 10 WAS in 2008 and 6 WAS in 2009 check basin irrigation resulted in significantly higher LAI than in border strip and furrow irrigation that were statistically at par. At 10 WAS in 2009 check basin irrigation resulted in higher LAI than furrow which in turn was higher than border irrigation. At 18 WAS in 2007 check basin irrigation resulted in higher LAI than in border strip which in turn was higher than in furrow irrigation.

SAMCOT 13 produced higher LAI than SAMCOT 11 which in turn was higher than SAMCOT 10 at all sampling periods and years except at 10 WAS in 2007, where SAMCOT 10 had higher LAI than other two varieties that were at par, while the reverse was the case at 6 WAS in 2009. Significant interaction between irrigation methods and cotton varieties at 14 WAS in 2007 and 2008 was observed.

Table 6 shows the interaction between irrigation methods and cotton varieties on leaf area index at 14 WAS in 2007 and 2008. In 2007 SAMCOT 13 resulted in higher LAI than SAMCOT 11 which in turn was higher than SAMCOT 10 in each of the three irrigation methods. When varieties were held constant, check basin resulted in higher LAI of SAMCOT 13 and 10 than in other method. While furrow irrigation resulted in higher LAI of SAMCOT 11 than other methods. Similar trend was observed in 2008.

Table 5: Influence of nitrogen rates and irrigation methods on leaf area index of cotton varieties in 2007, 2008 and 2009 dry seasons.

	Leaf Area Index at WAS											
	2007				2008				2009			
Treatment	6	10	14	18	6	10	14	18	6	10	14	18
Nitrogen(N) (kg ha^{-1})												
40	0.35	1.06	1.88d	1.52	0.40d	1.06d	2.26d	1.66c	0.41c	1.09c	2.16d	1.72b
70	0.39	1.07	2.01c	1.54	0.42c	1.08c	2.39c	1.71c	0.42c	1.10b	2.29c	1.75b
100	0.42	1.09	2.31b	1.58	0.44b	1.10b	2.68b	1.74b	0.43b	1.11b	2.59b	1.81b
130	0.41	1.12	2.75a	1.92	0.46a	1.12a	3.12a	2.12a	0.45a	1.13a	3.03a	2.07a
SE±	0.808	0.011	0.384	0.198	0.0029	0.0036	0.3843	0.2057	0.0048	0.0050	0.3840	0.1605
Irrigation Method (I)												
Check basin	0.40	1.09	2.28a	1.71a	0.44a	1.12a	2.65a	1.86a	0.48a	1.16a	2.56a	1.88a
Border strip	0.39	1.09	2.24a	1.64b	0.42b	1.08b	2.61a	1.88a	0.40b	1.06c	2.52a	1.85a
Furrow	0.38	1.08	2.19b	1.58c	0.42b	1.08b	2.57b	1.75b	0.40b	1.11b	2.48b	1.79b
SE±	0.699	0.009	0.042	0.0658	0.0025	0.0032	0.0420	0.0692	0.0042	0.0043	0.042	0.0465
Variety (V)												
SAMCOT 10	0.39	1.11a	1.98c	1.51c	0.42	1.08c	2.33c	1.69c	0.42b	1.08c	2.25c	1.74c
SAMCOT- 11	0.38	1.07b	2.25b	1.53b	0.43	1.09b	2.63b	1.83b	0.42b	1.09b	2.55b	1.79b
SAMCOT- 13	0.40	1.07b	2.48a	1.89a	0.43	1.10a	2.87a	1.98a	0.45a	1.15a	2.76a	1.99a
SE±	0.698	0.010	0.0148	0.006	0.0025	0.0032	0.01479	0.02263	0.0027	0.0027	0.0147	0.0187
Interactions												
N x I	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
N x V	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
I x V	NS	NS	**	NS	NS	NS	**	NS	NS	NS	NS	NS
N x I x V	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. WAS = Weeks after sowing **: significant at 5% and 1% level of probability respectively. NS: Not significant

Table 6: Interaction between irrigation method and variety on leaf area index at 14 was in 2007 and 2008 dry seasons.

	Variety		
	2007		
	SAMCOT 10	SAMCOT 11	SAMCOT 13
Irrigation method			
Check basin	2.05g	2.14f	2.64a
Furrow	2.01h	2.33d	2.38c
Border strip	1.87i	2.27e	2.43b
SE ±		0.009	
	2008		
Irrigation method			
Check basin	2.40f	2.53e	3.03a
Furrow	2.37g	2.71c	2.73c
Border strip	2.23h	2.66d	2.82b
SE ±		0.009	

Means followed by the same letter(s) in the same interaction group are statistically similar at P≤ 0.05.

4.4 Crop Growth Rate (CGR)

Table 7 shows influence of nitrogen rates and irrigation methods on Crop Growth Rate of cotton varieties in 2007, 2008 and 2009 dry season at Kadawa. Each increase in nitrogen rate significantly resulted in increased CGR at all sampling periods and years except at 18 WAS in 2007, 10 and 18 WAS in 2008 and 18 WAS in 2009. At 10 WAS in 2007 increase in nitrogen from 40 to 70k g N ha^{-1} resulted in significant increase in CGR while further increase to 100 did not however, further increase to 130 showed significant increase in CGR. Nitrogen rates did not influence CGR at 18 WAS in all the years.

Check basin irrigation method resulted in significantly increased CGR compared to border strip which in turn higher than furrow method at 10 and 14 WAS in 2007 and 2009. Irrigation methods did not significantly affect CGR at 18 WAS of the three years. However at 10 WAS in 2008, border strip resulted in higher CGR than other two methods which were at par while at 14 WAS check basin irrigation resulted in higher CGR than the other two methods which were at par. At 18 WAS in 2009, check basin significantly resulted in higher CGR than in furrow which in turn higher than border strip irrigation method.

At 10 WAS in 2007, 10 and 14 WAS in 2008 and 18 WAS in 2009 SAMCOT 13 had significantly higher CGR than SAMCOT 11 which in turn higher than SAMCOT 10 however the reverse was the case at 18 WAS in 2007. At 10 and14 WAS in 2009 SAMCOT 13 resulted significantly in higher CGR than other two varieties that were at par. At 14 WAS SAMCOT 13 and SAMCOT 10 resulted in similar but significantly higher CGR than SAMCOT 11 while the cotton varieties had statistically similar CGR at 18 WAS in 2008. There is no significant interaction between the treatment factors.

Table 7: Influence of nitrogen rate and irrigation method on crop growth rate of cotton varieties at Kadawa in 2007, 2008 and 2009 dry seasons.

	Crop Growth Rate (g plant^{-1}week^{-1}) (WAS)								
	2007			2008			2009		
Treatment	10	14	18	10	14	18	10	14	18
Nitrogen(N) (kg ha^{-1})									
40	4.66d	15.80d	2.75	4.70c	17.03d	1.82	4.43d	17.03d	2.63
70	4.93c	17.02c	2.60	5.11b	18.60c	1.62	4.72c	18.21c	2.63
100	5.17b	18.44b	2.44	5.31b	20.52b	1.66	5.38b	21.00b	2.63
130	5.54a	20.45a	2.43	5.63a	23.13a	1.93	5.68a	21.89a	2.64
SE±	0.047	0.161	0.13	0.094	0.210	0.591	0.087	0.286	0.005
Irrigation Method(I)									
Check basin	5.40a	18.43a	2.77a	4.95b	21.16a	1.85	5.59a	21.6a	2.80a
Border strip	5.01b	17.96b	2.48ab	5.46a	19.18b	1.10	5.13b	19.8b	2.52c
Furrow	4.81c	17.39c	2.41b	5.15b	19.11b	1.57	4.43c	17.1c	2.58b
SE±	0.040	0.140	0.110	0.0815	0.187	0.511	0.075	0.247	0.004
Variety(V)									
SAMCOT 10	4.2c	19.72a	3.07a	4.35c	17.40c	1.90	4.70b	18.66b	2.67c
SAMCOT- 11	4.89b	18.26b	2.60b	5.26b	19.14b	1.32	4.67b	18.09b	2.29b
SAMCOT 13	6.12a	19.72a	1.99c	5.96a	22.91a	1.30	5.78a	21.86a	2.94a
SE±	0.062	0.107	0.101	0.084	0.182	0.498	0.071	0.211	0.004
Interactions									
N x I	NS	NS	NS	NS	NS	NS	NS	NS	NS
N x V	NS	NS	NS	NS	NS	NS	NS	NS	NS
I x V	NS	NS	NS	NS	NS	NS	NS	NS	NS
N x I x V	NS	NS	NS	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. WAS = Weeks after sowing, NS = Not significant.

4.5 Relative Growth Rate

Table 8 shows the influence of irrigation methods and nitrogen rates on Relative Growth Rate (RGR) of cotton varieties in 2007, 2008 and 2009. The RGR in all the years was only significantly affected by nitrogen rate at 14 WAS of 2008 in which each increase in nitrogen rate was accompanied with corresponding increase in RGR. Check-basin irrigation method resulted in significantly higher RGR than border strip which in turn higher than furrow at 10 WAS in 2007, however at 14 WAS in 2007 and 2008 check basin was only higher than both border strip and furrow irrigation that were at par. At 18 WAS in 2007 border strip had resulted in higher RGR than either of the two methods that were at par while in 2009 furrow irrigation significantly resulted in higher RGR than other two varieties that were at par. Check basin at 14bWASin 2007 significantly resulted in higher RGR than in border and furrow irrigation methods. Irrigation methods did not significantly affect RGR at18 WAS in 2008 and 10 and 14 WAS in 2009. SAMCOT 13 had significantly higher RGR than SAMCOT 11 which in turn higher than SAMCOT 10 at 10 WAS in 2007 and 2009 and 14 WAS in 2008. SAMCOT 11 had significantly higher RGR than SAMCOT 10 and SAMCOT 13 which were at par at 14 WAS in 2007. At 18 WAS in 2007 SAMCOT 10 resulted in higher RGR than SAMCOT 11 which in turn followed by SAMCOT -13. SAMCOT 11 and -13 resulted in similar but significantly higher RGR than SAMCOT 10 at 10 WAS in 2008. Cotton varieties had statistically equal RGR at 18 WAS in 2008 and 14 WAS in 2009. There is no significant interaction between the treatment factors.

4.6 Net Assimilation Rate (NAR)

Table 9 presents the influence of irrigation method and nitrogen fertilizer rate on net assimilation rate of cotton varieties in 2007, 2008 and 2009. In 2007 at 10 WAS each increase in

Table 8: Influence of nitrogen rate and irrigation method on relative growth rate of cotton varieties at Kadawa in 2007, 2008 and 2009 dry season.

	Relative Growth Rate ($gg^{-1}week^{-1}$) (WAS)								
	2007			2008			2009		
Treatment	10	14	18	10	14	18	10	14	18
Nitrogen(N) (kg ha^{-1})									
40	0.098	0.121c	0.011	0.096	0.123d	0.008	0.853	0.123b	0.011a
70	0.010	0.123bc	0.010	0.099	0.125c	0.007	0.085	0.123b	0.010b
100	0.099	0.124ab	0.010	0.098	0.129b	0.003	0.087	0.125a	0.009c
130	0.100	0.127a	0.010	0.099	0.135a	0.0062	0.087	0.124ab	0.009d
SE±	0.0012	0.0007	0.0006	0.0015	0.0005	0.0046	0.0008	0.0004	0.0002
Irrigation Method (I)									
Check basin	0.108a	0.125a	0.095b	0.090c	0.133a	0.006	0.085	0.124	0.009b
Border strip	0.098b	0.123b	0.113a	0.106a	0.125b	0.0004	0.086	0.124	0.009b
Furrow	0.092c	0.122b	0.010b	0.097b	0.126b	0.0064	0.085	0.123	0.011a
SE±	0.0010	0.0006	0.0015	0.0013	0.0004	0.0040	0.0007	0.0004	0.0001
Variety (V)									
SAMCOT 10	0.087c	0.122b	0.013a	0.086b	0.125c	0.008	0.083c	0.124	0.011a
SAMCOT 11	0.103b	0.129a	0.010b	0.105a	0.128b	0.009	0.086b	0.123	0.009c
SAMCOT 13	0.108a	0.120b	0.007c	0.103a	0.131a	0.004	0.089a	0.123	0.010b
SE±	0.0010	0.0010	0.0040	0.0014	0.0004	0.0041	0.0007	0.0004	0.0001
Interactions									
N x I	NS	NS	NS	NS	NS	NS	NS	NS	NS
N x V	NS	NS	NS	NS	NS	NS	NS	NS	NS
I x V	NS	NS	NS	NS	NS	NS	NS	NS	NS
N x I x V	NS	NS	NS	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. WAS = Weeks after sowing, NS = Not significant

nitrogen fertilizer rate significantly resulted in higher NAR. However, nitrogen rates did not influence NAR at 14 and 18 WAS in 2007, and 10 and 18 WAS in 2008 and also at 18 WAS in 2009. At 14 WAS in 2008 increasing nitrogen rate from 40 to 70 kg ha^{-1} resulted in significantly higher NAR but further increase did not. At 10 WAS in 2009 each increase in nitrogen rate from 40 up to 100 kg ha^{-1} resulted in corresponding increase in NAR but further increase did not. Check-basin irrigation method had significantly resulted in higher NAR than in border strip which in turn higher than in furrow irrigation method at 10 WAS in 2007 and 14 and 18 WAS in 2009. At 14 WAS in 2007 check basin and furrow irrigation resulted in higher but similar NAR than border strip. While the reverse was the case at 10 WAS in 2009. Border irrigation significantly resulted in higher NAR than furrow which in turn higher than check basin at 10 WAS in 2008. At 14 WAS in 2008 only check resulted in significantly higher NAR than other two methods that were at par. Irrigation methods did not significantly influence NAR at 18 WAS in 2007 and 2008. SAMCOT 13 had significantly higher NAR compared to SAMCOT 11 which in turn higher than SAMCOT 10 at 10 WAS in 2007 but the reverse was the case at 18 WAS. At 14 WAS in 2008 and 10 WAS in 2009, SAMCOT 13 had significantly higher NAR than other two varieties which were statistically similar. In 2009, at 14 WAS, SAMCOT 10 and -13 resulted in statistically similar but higher NAR than SAMCOT 11. At 18 WAS in 2009 SAMCOT 13 significantly resulted in higher NAR than SAMCOT 10 which in turn higher than SAMCOT 11. The cotton varieties had statistically similar NAR at10 WAS in 2008. There is no significant interaction between the treatment factors in all the years.

4.7 Number of Branches per Plant

Table 10 shows the influence of irrigation method and nitrogen rate on number of branches of cotton varieties in the three years and combine mean. Each increase in nitrogen

Table 9: Influence of nitrogen rate and irrigation method on net assimilation rate of cotton varieties at Kadawa in 2007, 2008 and 2009 dry seasons.

	Net Assimilation Rate (g m^{-2} $week^{-1}$) (WAS)								
	2007			2008			2009		
Treatment	10	14	18	10	14	18	10	14	18
Nitrogen (N) (kg ha^{-1})									
40	9.57d	14.27	1.86	2.84	13.84c	1.21	8.15c	11.30b	3.64b
70	10.13c	14.68	1.79	2.95	14.48b	1.04	8.64b	11.65b	3.74b
100	10.62b	14.58	1.78	2.89	14.82ab	0.44	9.57a	12.42a	3.95a
130	11.38a	14.27	1.69	2.93	15.29a	0.99	9.83a	11.31b	3.79ab
SE±	1.459	0.178	0.068	2.93	0.611	0.335	0.015	0.525	0.133
Irrigation Method (I)									
Check basin	11.10a	14.69a	1.62b	2.68c	15.31a	1.07	9.29b	12.74a	4.07a
Border strip	10.29b	14.13b	1.92a	3.14a	14.23b	0.94	9.60a	11.77b	3.90b
Furrow	9.88c	14.71a	1.80ab	2.89b	14.31b	0.74	8.16b	10.50c	3.37c
SE±	0.398	0.330	0.153	2.886	0.630	0.169	0.421	1.121	0.364
Variety (V)									
SAMCOT 10	8.66c	13.61b	2.26a	2.54b	13.72b	1.24	8.62b	12.09a	3.78b
SAMCOT 11	10.04b	14.81a	1.81b	3.11a	14.11b	0.81	8.54b	10.83b	3.49c
SAMCOT 13	12.57a	15.11a	1.26c	3.05a	16.01a	0.71	9.98a	12.09a	4.07a
SE±	3.999	0.107	0.071	3.047	0.141	0.284	0.421	0.158	0.054
Interactions									
N x I	NS	NS	NS	NS	NS	NS	NS	NS	NS
N x V	NS	NS	NS	NS	NS	NS	NS	NS	NS
I x V	NS	NS	NS	NS	NS	NS	NS	NS	NS
N x I x V	NS	NS	NS	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. NS = Not significant

fertilizer rate significantly, increased the number of branches per plant in three years and mean of the three years. In 2007, check-basin irrigation significantly produced more numbers of branches than border strip but was comparable to furrow irrigation. However in 2008 check-basin and furrow has statistically equal but more number of branches than border strip method of irrigation. There was no significance response of irrigation methods on number of branches per plant in 2009 and mean. SAMCOT 13 had significantly more number of branches than either SAMCOT 11 or SAMCOT 10 with latter having the least number of branches in2007 and mean. In 2008, SAMCOT 10 and -11 had similar but lower number of branches than SAMCOT 13. Significant interaction between irrigation method and nitrogen rates was observed in 2008.

Table 11 shows the interaction between irrigation method and nitrogen rate on number of branches per plant of cotton in 2008. When irrigation methods were considered, at constant nitrogen rate, only the application of 130 kg ha^{-1} have a significant effect where check basin irrigation produced more branches per plant than border strip. The difference between furrow and check basin was not significant statistically. At the same method, increasing nitrogen from 40 to 100 kg ha^{-1} did not affect number of branches at all three methods, further increase to 130 kg ha^{-1} resulted in higher number branches per plant.

4.8 Days to 50% Flowering

Table 12 shows the influence of irrigation method and nitrogen rate on days to 50% flowering of cotton varieties. Each increase in nitrogen fertilizer significantly delayed 50% flowering in 2007, 2009 and the mean. However in 2008, 40 and 70 kg N ha^{-1} resulted in statistically similar number of days to 50% flowering. Check basin took fewer days to 50% flowering than border strip which was statistically similar with furrow in 2007 In 2008 and 2009 dry seasons, 50% of the plants in furrow flowered earlier than those in either check-basin or

border strip which were at par with each other. However in the mean, border strip irrigation method significantly flowered earlier than either check-basin but was comparable to furrow irrigation methods with latter having similar days to 50% flowering.

SAMCOT 10 and -11 flowered on the same day and earlier than SAMCOT 13 in 2007 and 2008 dry seasons. However, in 2009 and the combined mean, SAMCOT 10 flowered significantly earlier than the other two varieties with SAMCOT 13 flowering much later than SAMCOT 11. Significant interactions between irrigation method and nitrogen rate and irrigation method and variety during combined mean years were observed.

Table 13 shows the interaction between nitrogen and irrigation method on days to 50% flowering during the combined mean. It revealed that under check basin irrigation nitrogen increment up to 100 kg N ha^{-1} shows earlier flowering as compared to 130 kg N ha^{-1} which flowered much later. Furrow irrigation caused earlier flowering at 40 and 70 kg N ha^{-1}, however, further N increase up to 130 kg N ha^{-1} resulted in delay in number of days to 50% flowering. Table 14 shows the interaction between irrigation method and cotton variety on number of days to 50% flowering during the mean years. When irrigation method was held constant, the varieties produced 50% of their flowers on the same day statistically under check basin irrigation method. SAMCOT 10 significantly flowered earlier in furrow irrigation method than other varieties that were at par. SAMCOT 10 flowered much earlier in border strip than SAMCOT 11 which in turn flowered earlier than SAMCOT 13. The 50% flowering of the three cotton varieties were not significantly influenced by the irrigation methods except SAMCOT 10 that produced its 50% flowers much earlier in check basin and furrow compared to in border strip.

Table 10: Influence of nitrogen rate and irrigation method on number of branches per plant of cotton varieties in 2007, 2008, 2009 dry seasons and combined mean.

	Number of Branches per Plant			
Treatment	2007	2008	2009	Mean
Nitrogen (N) (kg ha^{-1})				
40	9.03d	9.3d	13.0d	10.5d
70	10.11c	10.2c	15.8c	12.0c
100	11.31b	11.3b	19.8b	14.2b
130	12.17a	12.3a	23.7a	16.1a
SE±	0.089	0.086	0.826	0.200
Irrigation Method (I)				
Check basin	10.76a	11.0a	17.3	12.9
Border strip	10.71ab	10.6b	18.5	13.2
Furrow	10.51b	10.8a	18.3	13.6
SE±	0.077	0.074	0.715	0.173
Variety (V)				
SAMCOT 10	9.59c	10.3b	16.9b	12.3c
SAMCOT 11	9.95b	10.5b	18.2ab	12.9b
SAMCOT 13	12.44a	11.6a	19.1a	14.4a
SE±	0.076	0.065	0.472	0.161
Interactions				
N x I	NS	**	NS	NS
N x V	NS	NS	NS	NS
I x V	NS	NS	NS	NS
N x I x V	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. **: significant at 1% level of probability NS = Not significant.

Table 11: Interaction between nitrogen and irrigation methods on number of branches per plant in 2008 dry Season.

	Nitrogen(k gha^{-1})			
	40	70	100	130
Irrigation method				
Check basin	9.3d	10.3d	11.4cd	12.9a
Furrow	9.4d	10.3d	11.4cd	12.3ab
Border strip	9.2d	9.2d	11.2d	11.9bc
SE±		0.219		

Means followed by the same letter(s) in the same interaction group are statistically similar at P≤ 0.05.

Table 12: Influence of nitrogen rate and irrigation methods on days to 50% flowering of cotton varieties in 2007, 2008 and 2009 dry seasons and combined mean.

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Treatment	Days to 50% Flowering			
	2007	2008	2009	Mean
Nitrogen (N) (kg ha^{-1})				
40	60.5d	61.4c	61.0d	61d
70	62.2c	62.2b	63.7c	63c
100	64.9b	62.7b	65.7b	64b
130	67.6a	65.8a	70.1a	67a
SE±	0.22	0.28	0.24	0.14
Irrigation Method (I)				
Check basin	63.5b	63.6a	65.4a	64.3a
Border strip	64.1a	63.3a	65.5a	63.7b
Furrow	63.8ab	62.3b	64.5b	64ab
SE±	0.19	0.24	0.21	0.12
Variety (V)				
SAMCOT 10	63.7b	62.4b	63.8c	63.3c
SAMCOT 11	63.3b	62.7b	65.1b	64b
SAMCOT 13	64.5a	64.1a	66.4a	65a
SE±	0.22	0.23	0.27	0.14
Interactions				
N x I	NS	NS	NS	**
N x V	NS	NS	NS	NS
I x V	NS	NS	NS	**
N x I x V	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. **: Significant at 1% level of probability. NS = Not significant

Table 13: Interaction between nitrogen and irrigation method on number of days to 50% flowering at the combined mean.

	Nitrogen (kg ha^{-1})			
	40	70	100	130
Irrigation method				
Check basin	60.3e	61.3de	61.3de	69.4a
Furrow	62.5cde	63.1cd	65.0abc	64.6bc
Border strip	62.5cde	63.7cd	67.3a	66.9ab
SE±		0.91		

Means followed by the same letter(s) in the same interaction group are statistically similar at P≤ 0.05.

Table 14: Interaction between irrigation method and variety on number of days to 50% flowering at the combined mean.

	Variety		
	SAMCOT 10	SAMCOT 11	SAMCOT 13
Irrigation method			
Check basin	63.6d	63.8cd	62.5d
Furrow	62.5d	64.5bc	64.1bcd
Border strip	66.8a	63.6d	64.7b
SE±		0.274	

Means followed by the same letter(s) in the same interaction group are statistically similar at P≤ 0.05.

4.9 Days to 50% Boll Opening

Table 15 shows the influence of irrigation method and nitrogen rate on days to 50% boll opening of cotton varieties. The result showed that each increase in nitrogen rate significantly increased number of day to 50% boll opening in all the three years and the mean. Check basin irrigation method resulted in higher days to 50% boll opening compared to furrow and border strip whose 50% bolls statistically opened on the same day in 2008 and 2009. In 2007 however, furrow irrigation resulted in higher number of days to 50% boll opening compared to either check-basin or border strip that caused 50% bolls opened on the same day statistically. Number of days to 50% boll opening of SAMCOT 10 was significantly earlier than the other two varieties with 50% of SAMCOT 13 having highest number of days to 50% bolls opening in all the years and the mean. Significant interaction between irrigation method and nitrogen rate and irrigation method and variety in the combine mean were observed.

Table 16 shows interaction between irrigation method and nitrogen rate on days to 50% boll opening in the combine mean of the three years. The interaction showed that varying nitrogen against irrigation methods from 40 to 70 kg ha^{-1} resulted in statistically equal number of days to 50% boll opening in check basin. But further increase to 100 and beyond resulted in corresponding increase in days to 50% boll opening. Similar trend was observed in furrow irrigation method except that 100 and 130 kg N ha^{-1} resulted in statistically equal but more days to 50% boll opening. In border strip method, each increase in nitrogen from 40 to 100 kg ha^{-1} resulted in increase in number of days to 50% boll opening but further increase did not. Irrigation methods did not show significant difference in days to 50% bolls opening at 40, 70 and 130 kg N ha^{-1}. However check basin resulted in fewer days to 50% boll opening than other methods at 100 kg ha^{-1}.

Table 15: Influence of nitrogen rate and irrigation method on days to 50% boll opening of cotton varieties in 2007, 2008 and 2009 dry seasons and combined mean.

	Days to 50% Boll Opening			
Treatment	2007	2008	2009	Mean
Nitrogen (N) (kg ha^{-1})				
40	101.5d	104.1d	105d	104d
70	103.5c	105.8c	107.7c	105c
100	107.7b	109.7b	111b	109b
130	112.6a	115.1a	118a	115a
SE±	0.411	0.321	0.359	0.077
Irrigation Method (I)				
Check basin	105.7b	110.9a	112.4a	110.2a
Border strip	105.8b	107.6b	109.7b	107.5b
Furrow	107.5a	107.6b	109.2b	107.7b
SE±	0.356	0.278	0.311	0.067
Variety (V)				
SAMCOT 10	104c	105.6c	108c	105.9c
SAMCOT 11	106b	109.1b	110.6b	108.7b
SAMCOT 13	108a	111.4a	112.7a	110.9a
SE±	0.346	0.238	0.220	0.158
Interactions				
N x I	NS	NS	NS	**
N x V	NS	NS	NS	**
I x V	NS	NS	NS	NS
N x Ix V	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. **: significant at 1% level of probability. NS = Not significant.

Table 16: Interaction between nitrogen and irrigation method on number of days to 50% boll opening at combined mean.

	Nitrogen (kg ha^{-1})			
	40	70	100	130
Irrigation method				
Check basin	104.7de	104.1e	108.1c	116.0a
Furrow	104.4e	104.5de	112.4b	111.0b
Border strip	101.8e	107.0cd	114.4ab	115.4ab
SE±		1.158		

Means followed by the same letter(s) in the same treatment group are statistically similar at P≤ 0.05.

Table 17: Interaction between nitrogen and variety on number of days to 50% boll opening at the combined mean.

	Nitrogen(kg ha^{-1})			
	40	70	100	130
Variety				
SAMCOT 10	101.0h	103.1g	106.0f	113.3c
SAMCOT 11	103.1g	106.5ef	109.8d	115.4b
SAMCOT 13	106.5ef	107.4e	112.5c	117.0a
SE±		0.316		

Means followed by the same letter(s) in the same treatment group are statistically similar at P≤ 0.05.

Table 17 shows the interaction between nitrogen and variety on number of days to 50% boll opening at the mean. Each increase in nitrogen level significantly resulted in delay to 50% boll opening in SAMCOT 10 and SAMCOT 11. But increasing N from 40 to 70 kg ha^{-1} did not show significant difference in days to 50% bolls opening while each further increase resulted in more days to 50% boll opening of SAMCOT 13. When varieties were considered, SAMCOT 10 significantly resulted in fewer days to 50% boll opening than SAMCOT 11 which in turn resulted in fewer days than SAMCOT 13 at each nitrogen level. Application of 40 kg N ha^{-1} on SAMCOT 10 resulted in the earliest opening of bolls whereas application of 130 kg N ha^{-1} on SAMCOT 13 had the longest days to 50% boll opening.

4.10 Number of Bolls per Plant

Table 18 shows the influence irrigation methods and nitrogen fertilizer rate on number of boll per plant of cotton varieties in 2007, 2008, 2009 dry seasons and combine mean. Increasing nitrogen rate from 40 to 70 kg ha^{-1} increased number of bolls per plant but further increase resulted in progressive decrease in number of bolls per plant in all the three years and the combine mean except at 40 and130 where number of bolls per plant was statistically equal in the combine mean. In 2008, check basin irrigation resulted in more bolls per plant than in border strip and furrow which were statistically at par with each other. In 2009 check basin and border strip irrigation resulted in statistically equal but significantly more number of bolls per plant than in furrow irrigation. However in the combine mean, check-basin significantly resulted in more bolls per plant than furrow method which was in turn higher than border strip on number of bolls per plant. Irrigation methods did not show significant difference in number of bolls per plant in 2007. SAMCOT 13 consistently produced more bolls per plant than SAMCOT 11 which in turn resulted in more bolls per plant than SAMCOT 10 in all the three years and the combined mean.

Significant interactions between irrigation method and nitrogen rate, nitrogen rate and cotton variety and irrigation method and cotton variety at the combine mean were observed.

Table 19 shows interaction between nitrogen and irrigation method on number of bolls per plant at the mean. Increasing nitrogen from 40 to 70 kg N ha^{-1} significantly produced more number of bolls $plant^{-1}$ across all the irrigation methods however, further increase in nitrogen level resulted in successive decrease in number of bolls per plant except at 130 kg N ha^{-1} which resulted in more bolls per plant than 100 kg N ha^{-1} in check basin. Furrow irrigation method resulted in more bolls per plant than border strip which in turn have more bolls per plant than in check basin at 40 and 100 kg N ha^{-1}. At 70 kg N ha^{-1} check basin irrigation resulted in more bolls plant than other two methods that were statistically at par. While at 130 kg N ha^{-1}, furrow irrigation resulted in more bolls per plant than either of the other two methods that were statistically at par.

Table 20 shows interaction between nitrogen and cotton variety on number of boll per plant at the mean. Increasing nitrogen from 40 to 70 kg ha^{-1} resulted in more bolls per plant in each of the cotton variety tested. However, each further increase significantly resulted in successive decrease in the number of bolls per plant. SAMCOT 13 significantly produced more bolls per plant than SAMCOT 11 which in turn resulted in more bolls per plant than SAMCOT 10 at each nitrogen level. SAMCOT 13 produced highest number of bolls per plant at 70 kg N ha^{-1}.

Table 21 shows interaction between variety and irrigation method on number of bolls per plant. The table shows that SAMCOT 13 resulted in more bolls per plant than SAMCOT 11 which in turn produced more bolls per plant than SAMCOT 10 in each of the irrigation method. Furrow irrigation resulted in significantly more bolls per plant of SAMCOT 10 than other two

Table18: Influence of nitrogen rate and irrigation method on number of bolls per plant of cotton varieties in 2007, 2008 and 2009 dry seasons and combined mean.

Treatment	Number of Bolls per Plant			
	2007	2008	2009	Mean
Nitrogen (N) (kg ha^{-1})				
40	12.8c	14.4d	11.9d	13.2c
70	15.8a	17.7a	15.0a	16.5a
100	14.3b	16.5b	14.4b	15.4b
130	12.6c	15.6c	12.7c	13.3c
SE±	0.13	0.05	0.12	0.08
Irrigation Method (I)				
Check basin	13.6b	17.3a	13.5a	15a
Border strip	13.9ab	15.2b	13.7a	13.8c
Furrow	14.1a	15.5b	12.4b	14.4b
SE±	0.11	0.13	0.11	0.16
Variety (V)				
SAMCOT 10	12.3c	13.4c	12.2b	12.6c
SAMCOT 11	13.5b	15.2b	12.3b	13.7b
SAMCOT 13	15.8a	19.5a	15.0a	16.8a
SE±	0.14	0.12	0.12	0.07
Interactions				
N x I	NS	NS	NS	**
N x V	NS	NS	NS	**
I x V	NS	NS	NS	**
N x I x V	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. **: significant at 1% level of probability. NS: Not significant.

Table 19: Interaction between nitrogen and irrigation method on number of bolls per plant in the combined mean.

	Nitrogen (kg ha^{-1})			
	40	70	100	130
Irrigation method				
Check basin	13.4d	16.9a	12.5e	13.2d
Furrow	15.8b	15.7b	15.7b	13.9c
Border strip	13.8c	15.0b	13.5c	13.1d
SE±		0.35		

Means followed by the same letter(s) in the same interaction group are statistically similar at P≤ 0.05.

Table 20: Interaction between nitrogen and variety on number of boll per plant in the combined mean.

	Nitrogen(kg ha^{-1})			
	40	70	100	130
Variety				
SAMCOT 10	11.0i	14.3e	13.4f	11.9h
SAMCOT 11	12.5g	15.1d	14.0e	13.0f
SAMCOT 13	15.6c	19.0a	17.0b	15.5cd
SE±		0.14		

Means followed by the same letter(s) in the same interaction group are statistically similar at P≤ 0.05.

Table 21: Interaction between irrigation method and variety on number of bolls per plant in the combined mean.

	Variety		
	SAMCOT 10	SAMCOT 11	SAMCOT 13
Irrigation method			
Check basin	12.5f	14.6d	17.8a
Furrow	13.0e	13.4e	16.6b
Border strip	12.4f	13.0e	15.9c
SE±		0.12	

Means followed by the same letter(s) in the same interaction group are statistically similar at P≤ 0.05.

other two methods which are at par. While check basin resulted in more bolls per plant of SAMCOT 11 than in either furrow or border strip which were statistically at par. SAMCOT 13 significantly produced more number of bolls per plant in check basin irrigation than in furrow which in turn more than in border strip.

4.11 Boll Weight

Table 22 shows the influence of nitrogen rate and irrigation method on boll weight of cotton varieties in 2007, 2008, 2009 dry seasons and the combine mean. Increasing nitrogen rate from 40 to 70 kg ha^{-1} significantly resulted in heavier boll, but further increase resulted in significant progressive decrease in boll weight in all the three years and the combine mean. In 2007, border strip irrigation method significantly resulted in heavier bolls than in check basin method which in turn resulted in heavier bolls than in furrow irrigation method. In 2008, however check basin and furrow irrigation methods resulted in significantly heavier but statistically similar boll weight than in border strip irrigation method. The effect of irrigation method was not significant on boll weight in 2009. But in the combine mean, check-basin significantly resulted in heavier bolls than either furrow or border strip which statistically were at par with each other. SAMCOT 13 significantly produced heavier boll than both SAMCOT 10 and SAMCOT 11 which were both statistically at par with each other in all the three years and the combine mean. There were no significant interactions between the treatment factors in the three years and the combined mean.

Table 22: Influence of nitrogen rates and irrigation methods on boll weight of cotton varieties at Kadawa in 2007, 2008, 2009 dry seasons and the combined mean.

	Boll Weight (g)			
Treatment	2007	2008	2009	Mean
Nitrogen (N) (kg ha^{-1})				
40	3.8d	3.9d	3.67c	3.77d
70	4.4a	4.8a	4.24a	4.49a
100	4.2b	4.4b	3.85b	4.15b
130	4.0c	4.1c	3.52d	3.88c
SE±	0.03	0.04	0.07	0.15
Irrigation Method (I)				
Check basin	4.1b	4.3a	3.80	4.2a
Border strip	4.2a	4.2b	3.89	4.1b
Furrow	4.0c	4.4a	3.77	4.0b
SE±	0.02	0.04	0.06	0.13
Variety (V)				
SAMCOT 10	4.0b	4.2b	3.8b	4.0b
SAMCOT 11	4.0b	4.2b	3.7b	4.0b
SAMCOT 13	4.4a	4.4a	4.0a	4.3a
SE±	0.02	0.04	0.04	0.02
Interactions				
N x I	NS	NS	NS	NS
N x V	NS	NS	NS	NS
I x V	NS	NS	NS	NS
N x I x V	NS	NS	NS	NS

Means followed by same letter(s) within the same column are not significantly different at 5% level of probability. NS: Not significant.

4.12 Number of Seeds per Boll

The influence of nitrogen rate and irrigation method on seed number per boll of cotton varieties in 2007, 2008, 2009 dry seasons and combine mean is shown on Table 23. Increasing nitrogen rate from 40 to 70 kg ha^{-1} significantly resulted in more seeds per boll but further increase resulted in progressive decrease in seed number per boll in all the years and the combined mean except in 2007 where further increase beyond 70 did not show significant difference. In 2007, border strip irrigation resulted in more seed per boll compared to either check basin or furrow methods which were statistically at par. In 2008, however check basin irrigation significantly resulted in more seeds per boll than border strip and furrow which were statistically at par with each other. Irrigation method did not affect seed number per boll in 2009. However, in the combine mean, check basin and furrow irrigation methods significantly resulted in more seeds per boll compared to border strip irrigation. SAMCOT 13 significantly produced more seed per boll than SAMCOT 11 which in turn produced more seeds per boll than SAMCOT 10 in all the years and the combine mean. The interactions between the treatment factors were not significant.

4.13 Ginning percentage

The influence of nitrogen fertilizer rates and irrigation methods on ginning percentage of cotton varieties is shown on Table 24. The result revealed that application of 70 kg N ha^{-1} resulted in significantly higher ginning percentage than all other nitrogen rates that were statistically at par with each other in 2007 and mean of three years. In 2008 application of 70 kg N ha^{-1} significantly resulted in higher ginning percentage than application of 100 kg N ha^{-1}. In 2009, increasing nitrogen rate from 40 to 70 kg N ha^{-1} significantly increased ginning percentage

Table 23: Influence of nitrogen rate and irrigation method on number of seed per boll of cotton varieties in 2007, 2008, 2009 and combined mean.

	Number of Seed per Boll			
Treatment	2007	2008	2009	Mean
Nitrogen (N) kg ha^{-1}				
40	23.0c	25.9c	24.4c	24.0d
70	26.3a	28.4a	27.3a	27.0a
100	24.3b	26.9b	25.9b	26.0b
130	24.3b	25.9c	24.7c	25.0c
SE±	0.24	0.23	0.32	0.15
Irrigation Method (I)				
Check basin	23.9b	27.4a	25.6	25.9a
Border strip	25.5a	26.4b	25.6	25.3b
Furrow	23.9b	26.6b	25.5	25.7a
SE±	0.21	0.200	0.28	0.13
Variety (V)				
SAMCOT 10	23.8c	25.7c	24.5b	24.6c
SAMCOT 11	24.4b	26.7b	24.8b	25.3b
SAMCOT 13	25.3a	28.0a	27.4a	26.9a
SE±	0.17	0.25	0.20	0.12
Interactions				
N x I	NS	NS	NS	NS
N x V	NS	NS	NS	NS
I x V	NS	NS	NS	NS
N x I x V	NS	NS	NS	NS

Means followed by same letter(s) within the same column are not significantly different at 5% level of probability. NS=Not significant

but further increase did not significantly affect ginning percentage. In the combine mean, 70 kg ha^{-1} nitrogen rate significantly resulted in higher ginning percentage than all other rates which were statistically at par .Irrigation methods did not significantly affect ginning percentage in the three years. But at the combine means, check-basin and furrow irrigation methods had significantly higher ginning percentage than furrow irrigation.

SAMCOT 11 and 13 had significantly similar but higher ginning percentage than SAMCOT 10 in 2007 and at the combined mean. In 2009 SAMCOT 13 significantly resulted in higher ginning percentage compared to SAMCOT 11 which in turn had significantly higher ginning percentage than SAMCOT 10. However the ginning percentage of the varieties did not differ significantly in 2008. Significant interaction between nitrogen and irrigation method and nitrogen and variety in the combine mean were observed.

Table 25 shows the interaction of nitrogen rate and irrigation method on ginning percentage of cotton varieties during the combine mean at Kadawa. Application of 70 kg N ha^{-1} resulted in significantly higher ginning percentage than at 40 kg N ha^{-1} only under furrow irrigation method, but further increase did not differ in all the irrigation methods. Check basin and border strip irrigation significantly resulted in higher ginning percentage than under furrow irrigation method only at 40 kg N ha^{-1}, but irrigation method did not affect ginning percentage in other nitrogen rates.

Table 26 presents the interaction of nitrogen rate and variety on ginning percentage of cotton varieties during the combine mean. The result shows that SAMCOT 11 and 13 significantly resulted in similar but higher ginning percentage than SAMCOT 10 only at 130 kg N ha^{-1}. While varying N rate did not significantly influence the ginning percentage of each variety.

Table 24: Influence of nitrogen rate and irrigation method on ginning percentage **o**f cotton varieties in 2007, 2008, 2009 dry seasons and combined mean.

	Ginning Percentage			
Treatment	2007	2008	2009	Mean
Nitrogen (N) (kg ha^{-1})				
40	37.98b	40.3ab	39.6b	39.3b
70	39.73a	40.6a	40.8a	40.4a
100	37.33b	39.2b	41.2a	39.2b
130	37.6b	39.8ab	40.3ab	39.2b
SE±	0.48	0.49	0.21	0.22
Irrigation Method (I)				
Check basin	37.6	39.9	40.5	39.6a
Border strip	38.4	39.5	40.7	39.1b
Furrow	38.4	40.5	40.2	39.8a
SE±	0.41	0.43	0.18	0.21
Variety (V)				
SAMCOT 10	37.4b	39.9	39.3c	38.9b
SAMCOT 11	38.6a	40.2	40.5b	39.8a
SAMCOT 13	38.4a	39.9	41.6a	40.0a
SE±	0.33	0.32	0.27	0.18
Interactions				
N x I	NS	NS	NS	*
N x V	NS	NS	NS	*
I x V	NS	NS	NS	NS
N x I x V	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. *: Significant at 5% level of probability, NS: Not significant.

Table 25: Interaction between nitrogen and irrigation method on ginning percentage of cotton varieties at the combined mean.

	Nitrogen (kg ha^{-1})			
	40	70	100	130
Irrigation method				
Check basin	40.0abc	41.0a	39.0bc	38.5c
Border strip	39.7abc	40.3ab	39.8abc	39.6abc
Furrow	38.2d	39.8abc	38.8bc	39.6abc
SE±		0.62		

Means followed by the same letter(s) in the same interaction group are statistically similar at P≤ 0.05.

Table 26: Interaction between nitrogen and variety on ginning percentage of cotton varieties at the combined mean.

	Nitrogen(kg ha^{-1})			
	40	70	100	130
Variety				
SAMCOT 10	39.2ab	40.1ab	38.7bc	37.5c
SAMCOT 11	39.4ab	40.3a	39.4ab	40.0ab
SAMCOT 13	39.4ab	40.6a	39.7ab	40.2ab
SE±		0.0.54		

Means followed by the same letter(s) in the same interaction group are statistically similar at P≤ 0.05.

4.14 100-Seed Weight (g)

The influence of nitrogen rates and irrigation methods on seed index of the cotton varieties is presented on table 27. Nitrogen rate did not significantly affect 100-seed weight in all the years and the mean three over the years except in 2009 where increase N rate from 40 to 70 kg ha^{-1}significantly increased the 100-seed weight. Further increase to 130 significantly resulted in lower 100-seed weight. Irrigation method did not significantly affect 100-seed weight in the three years and the mean. The effect of cotton varieties on 100-seed weight was not significant in 2007 and 2008 however, in 2009 and the mean, SAMCOT 13 significantly produced heavier 100-seed than the other two varieties which were statistically at par with each other. Significant interactions between the treatment factors were not observed.

4.15 Lint Index

The influence of nitrogen rates and irrigation methods on lint index of cotton varieties in the three years and the mean is presented in table 28. Nitrogen rates did not significantly affect lint index in 2007, 2008 and the mean. But in 2009 70 and 100 kg N ha^{-1} significantly resulted in similar but higher cotton lint index than at 40 and 130 kg N ha^{-1} which were both statistically at par with each other. Similarly, irrigation methods did not significantly influence lint index in all the three years, however in the mean, furrow irrigation significantly resulted in higher lint index than in check-basin and border strip irrigation methods which were statistically similar with each other. Also cotton varieties did not show significant difference in lint index in 2007 and 2008. But in 2009 SAMCOT 13 significantly resulted in higher lint index than SAMCOT 11

Table 27: Influence of nitrogen rate and irrigation method on 100-seed weight of cotton varieties in 2007, 2008, 2009 dry seasons and combined mean.

	100-Seed Weight			
Treatment	2007	2008	2009	Mean
Nitrogen (N) (kg ha^{-1})				
40	8.2a	8.6a	8.2b	8.3a
70	8.0ab	8.3ab	8.8a	8.4a
100	7.7b	8.0b	8.7a	8.2ab
130	7.8ab	8.2ab	8.3b	8.1b
SE±	0.14	0.14	0.12	0.08
Irrigation Method (I)				
Check basin	7.9	8.2	8.4	8.4a
Border strip	8.1	8.2	8.5	8.2ab
Furrow	7.8	8.5	8.6	8.1b
SE±	0.12	0.12	0.11	0.07
Variety (V)				
SAMCOT 10	7.8	8.2	8.3b	8.1b
SAMCOT 11	7.9	8.3	8.4b	8.2b
SAMCOT 13	8.1	8.4	8.7a	8.4a
SE±	0.13	0.13	0.09	0.07
Interactions				
N x I	NS	NS	NS	NS
N x V	NS	NS	NS	NS
I x V	NS	NS	NS	NS
N x I x V	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. NS: Not significant.

Table 28: Influence of nitrogen rate and irrigation method on lint index of cotton varieties in 2007, 2008, 2009 dry seasons and combined mean.

	Lint Index			
Treatment	2007	2008	2009	Mean
Nitrogen (N) (kg ha^{-1})				
40	49.8a	58.1a	54.0b	54.0ab
70	49.1a	57.3a	60.3a	55.6a
100	44.7b	52.3b	61.2a	52.7b
130	46.6ab	54.5ab	56.3b	52.5b
SE±	1.12	1.27	0.92	0.41
Irrigation Methods (I)				
Check basin	46.2b	54.7ab	57.4	53.0b
Border strip	49.6a	54.1b	58.6	52.7b
Furrow	46.8ab	57.8a	57.8	55.3a
SE±	0.97	1.10	0.80	0.55
Varieties (V)				
SAMCOT 10	46.8	54.7	53.8c	51.8b
SAMCOT 11	47.9	55.9	57.6b	53.8a
SAMCOT 13	48.0	56.0	62.4a	55.5a
SE±	1.08	1.21	0.84	0.61
Interactions				
N x I	NS	NS	NS	NS
N x V	NS	NS	NS	NS
I x V	NS	NS	NS	NS
N x I x V	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. NS: Not significant

which in turn resulted in higher lint index than SAMCOT 10. At the combined mean, SAMCOT 10 significantly resulted in lower lint index than other two varieties which were statistically at par.

4.16 Seed Cotton Yield (kg ha^{-1})

The effect of nitrogen rate and irrigation method on seed cotton yield of cotton varieties during 2007, 2008, 2009 and the mean is presented on Table 29. The result showed that in 2007 and 2008 increasing nitrogen rate from 40 to 70 kg ha^{-1} resulted in significantly higher seed cotton yield but each further increase resulted in lower but statistically similar seed cotton yield. In 2009 and the mean increasing nitrogen rate from 40 to 70 kg ha^{-1} resulted in significantly increased seed cotton yield however, each further increase in nitrogen rate beyond 70 kg ha^{-1} resulted in significantly successive decrease in seed cotton yield. Significant effect of irrigation method was noticed only in 2007 where check-basin irrigation method resulted in significantly higher seed cotton yield than in furrow irrigation method. In the three years and the combined mean, SAMCOT 13 had consistently the highest seed cotton yield, which was followed by SAMCOT 11 and SAMCOT 10 had the least seed cotton yield. There were significant interaction between nitrogen and irrigation method, nitrogen and variety and irrigation method and variety.

Interaction between nitrogen and irrigation methods on seed cotton yield is presented in Table 30. Irrigation methods have no significant effect on seed cotton yield at all nitrogen rates. While at a fixed irrigation method, when nitrogen rates were varied from 40 to 70 kg ha^{-1} resulted in significant increase in seed cotton yield but further increase to 130 did not affect the crop yield at all sampling period. Table 31 presents the interaction between nitrogen and variety

Table 29: Influence of nitrogen rates and irrigation methods on seed cotton yield of cotton varieties in 2007, 2008, 2009 and combined mean.

Treatment	Seed Cotton Yield (kg ha^{-1})			
	2007	2008	2009	Mean
Nitrogen (N) (kg ha^{-1})				
40	339c	366c	339d	348d
70	581a	632a	597a	603a
100	485b	555b	525b	522b
130	479b	531b	462c	490c
SE±	9.8	13.9	9.6	6.5
Irrigation Method (I)				
Check basin	491a	519	474	494
Border strip	475ab	521	492	481
Furrow	447b	523	476	497
SE±	8.5	12.1	8.3	5.6
Variety (V)				
SAMCOT 10	415c	452c	410c	426c
SAMCOT 11	470b	510b	483b	488b
SAMCOT 13	527a	600a	550a	559a
SE±	11.0	13.4	11.2	6.9
Interactions				
N x I	NS	NS	NS	**
N x V	NS	NS	NS	**
I x V	NS	NS	NS	*
N x I x V	NS	NS	NS	NS

Means followed by same letter(s) within the same column are not significantly different at 5% level of probability. NS: Not significant,*, **: Significant at 5% and 1% level of probability respectively.

on seed cotton yield at combined. Increasing nitrogen from 40 to 70 kg ha^{-1} resulted in significantly higher seed cotton yield of SAMCOT 10. However further increase resulted in significantly corresponding decrease in seed cotton yield. The yield of SAMCOT 11 increased significantly when nitrogen was varied from 40 to 100 kg ha^{-1} but further increase resulted in decrease of the yield. SAMCOT 13 seed cotton yield increased significantly when nitrogen rate was varied from 40 to 70 kg ha^{-1} but further increase to130 kg ha^{-1} resulted in lower but similar yield. Comparing the varieties against nitrogen rates, SAMCOT 11 and SAMCOT 13 resulted in higher but similar yield than SAMCOT 10 at 40, 100 and 130 kg ha^{-1}. However at 70 kg N ha^{-1}, SAMCOT 13 resulted in significantly higher seed cotton yield than SAMCOT 11 which in turn was higher than SAMCOT 10.

The interaction between irrigation method and variety on seed cotton yield at the mean is presented on Table 32. SAMCOT 10 and SAMCOT 13 seed cotton yields were not significantly influenced by irrigation method. SAMCOT 11 produced significantly lower yield in border strip irrigation than in other methods that were comparably higher. In check basin SAMCOT 13 produced significantly higher seed cotton yield than SAMCOT 11 which in turn was higher than SAMCOT 10. SAMCOT 13 and SAMCOT 11 produced statistically similar seed cotton yield but higher than SAMCOT 10 in furrow irrigation method. In border strip method SAMCOT 13 seed cotton yield was significantly higher than either SAMCOT 10 and SAMCOT 11varieties that were statistically at par with each other.

4.17 Lint Yield.

The effects of nitrogen rate and irrigation method on lint yield of cotton varieties in 2007, 2008, 2009 dry seasons and the mean is presented in Table 33. Increasing nitrogen rate from 40

Table 30: Interaction between nitrogen and irrigation method on seed cotton yield (kg ha^{-1}) at combined mean

	Nitrogen(kg ha^{-1})			
	40	70	100	130
Irrigation method				
Check basin	331e	620ab	529bc	497c
Furrow	326e	644a	544abc	473cd
Border strip	387de	546abc	491c	502c
SE±		38.56		

Means followed by the same letter(s) within the same interaction group are statistically similar at P≤ 0.05.

Table 31: Interaction between nitrogen and variety on seed cotton yield (kg ha^{-1}) at combinrd mean.

	Nitrogen (kg ha^{-1})			
	40	70	100	130
Variety				
SAMCOT 10	308g	522c	459d	415e
SAMCOT 11	363f	569b	540bc	479d
SAMCOT 13	373f	720a	566b	578b
SE±		13.79		

Means followed by the same letter(s) within the same interaction group are statistically similar at P≤ 0.05.

Table 32: Interaction between irrigation method and variety on seed cotton yield (kg ha^{-1}) at combined mean.

	Variety		
	SAMCOT 10	SAMCOT 11	SAMCOT 13
Irrigation method			
Check basin	425d	490c	568a
Furrow	422d	518bc	550ab
Border strip	429d	455d	560a
SE±		11.94	

Means followed by the same letter(s) within the same interaction group are statistically similar at P≤ 0.05.

to 70 kg ha^{-1} resulted in significantly higher lint yield, but further increase to 130 kg ha^{-1} resulted in lower but similar lint yield in 2007, 2008 and the combined mean. In 2009 increasing nitrogen rate from 40 to 70 kg ha^{-1} resulted in significant increase in lint yield, however each further increase significantly resulted in correspondingly decrease in lint yield. Irrigation methods did not influence lint yield in the three years and in the mean. SAMCOT 13 significantly produced higher lint yield than SAMCOT 11 which is in turn higher than SAMCOT 10 in the three years years and the mean. No significant interaction between the treatment factors on lint yield was observed.

4.18 Fibre finess

Table 3 shows the influence of irrigation method and nitrogen rate on fibre finess of cotton varieties during 2007, 2008 and 2009 dry seasons. The result showed that increasing nitrogen from 40 to 70 kg ha^{-1} resulted in significantly finer cotton lint but further increase to 100 kg ha^{-1} increased fibre finess. When N was further increased to 130 kg ha^{-1},there was further decrease in fibre finess in all the years and mean. Furrow irrigation resulted in finer cotton lint than either check basin or border strip irrigations which were statistically similar in all the three years and mean. The varieties produced fine cotton only in 2008 with SAMCOT 13 having finer cotton lint. In 2007 and 2009 the varieties produced fairly fine cotton lint with SAMCOT 13 having fairer fine lint. In the combine mean SAMCOT 13 produced finer fibre than SAMCOT 11 which in turn produced finer fibre than SAMCOT 10. There was no significant interaction between the treatment factors.

4.19 Oil Content of Cotton Seed.

Table 35 shows influence of nitrogen rate, irrigation method and cotton variety on oil content of cotton seeds in at Kadawa in 2007, 2008, 2009 and combined mean. The result

Table 33: Influence of nitrogen rate and irrigation method on lint yield of cotton varieties in 2007, 2008, 2009 dry seasons and combined mean.

	Lint Yield (kg ha^{-1})			
Treatment	2007	2008	2009	Combine mean
Nitrogen (N) kg ha^{-1}				
40	128c	147c	134d	137c
70	231a	256a	244a	244a
100	180b	217b	216b	205b
130	180b	211b	187c	193b
SE±	4.2	4.5	4.7	4.4
Irrigation Method (I)				
Check basin	189	207	193	196
Border strip	182	211	201	198
Furrow	168	206	192	189
SE±	10.8	3.1	5.0	5.1
Variety (V)				
SAMCOT 10	155c	180c	161c	165c
SAMCOT 11	182b	205b	196b	194b
SAMCOT 13	203a	239a	230a	224a
SE±	0.56	5.5	4.7	2.7
Interactions				
N x I	NS	NS	NS	NS
N x V	NS	NS	NS	NS
I x V	NS	NS	NS	NS
N x I x V	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. NS: Not significant.

Table 34: Influence of irrigation method and nitrogen rates on fibre finess of cotton varieties in 2007, 2008, 2009 dry seasons and combined mean.

Treatment	Finess (microgram inch^{-1})			
	2007	2008	2009	Mean
Nitrogen (N)kg ha^{-1}				
40	4.43b	3.97b	4.51b	4.31b
70	3.60c	3.14c	3.68c	3.48c
100	4.40b	3.48b	4.48b	4.27b
130	4.67a	4.21a	4.75a	4.54a
SE	0.053	0.055	0.051	0.030
Irrigation method (I)				
Check basin	4.35a	3.89a	4.45a	4.20a
Border strip	4.33a	3.86a	4.40a	4.19a
Furrow	4.17b	3.71b	4.25b	4.05b
SE	0.046	0.048	0.045	0.028
Variety (V)				
SAMCOT 10	4.43a	3.97a	4.51a	4.30a
SAMCOT 11	4.34a	3.88a	4.42a	4.22b
SAMCOT 13	4.06b	3.60b	4.14b	3.93c
SE	0.046	0.045	0.045	0.028
Interaction				
N x I	NS	NS	NS	NS
N x V	NS	NS	NS	NS
I x V	NS	NS	NS	NS
N x I x V	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. NS: Not significant.

showed that in 2007, 2008 dry seasons and the combined mean increasing nitrogen rate from 40 up to 100 kg ha^{-1} produced significantly higher but similar oil content of the cotton seeds than at 130 kg ha^{-1}. In 2009 application of nitrogen did not have any significant influence on the percentage oil content of the cotton seed. Irrigation method showed varied influences on oil content of cotton seed. Check basin irrigation method resulted in significantly higher oil content than border strip but comparable to furrow irrigation in 2007 and 2009 dry seasons. In 2008 and combined, check basin irrigation resulted in higher oil content than other methods which were statistically at par.

The oil content of cotton seed varieties was statistically similar in all the three years except in the combine mean where SAMCOT 10 and SAMCOT 13 seed produced similar but higher oil content than SAMCOT 11 seeds. Significant interactions between nitrogen and irrigation method in 2009, nitrogen and irrigation method and nitrogen and variety in the combine mean were observed.

Table 36 presents the interaction between nitrogen and irrigation method on oil content of cotton variety in 2009. The result showed that application of 100 kg N ha^{-1} in furrow irrigation only, significantly resulted in higher oil content than other rates. Check basin and border strip irrigation resulted in significantly higher but similar oil content than furrow irrigation method at 40 kg N ha^{-1} but all others were comparable. During the combine mean 40 kg N ha^{-1} significantly resulted in higher oil content than other N rates in the Check basin irrigation method while in other methods, N rate did not influenced significantly oil content of cotton seeds. At 40 kg N ha^{-1} check basin resulted in higher oil content than border strip which in turn higher than furrow irrigation while the reverse was the case at 130 kg N ha^{-1}. At 100 kg N ha^{-1} however, furrow irrigation resulted in significantly higher oil content than other methods which were comparable

Table 35: Influence of nitrogen rate and irrigation method on seed oil content of cotton varieties in 2007, 2008, 2009 dry seasons and combined mean.

	Seed Oil Content			
Treatment	2007	2008	2009	Mean
Nitrogen (N) (kg ha^{-1})				
40	18.76a	18.85a	18.96	18.85a
70	18.64a	18.73a	18.84	18. 73a
100	18.59a	18.68a	18.79	18.69a
130	18.01b	18.10b	18.21	18. 11b
SE±	0.119	0.119	0.120	0.067
Irrigation Method (I)				
Check basin	18.72a	18.81a	18.92a	18.82a
Border strip	18.34b	18.44b	18.54b	18.44b
Furrow	18.44ab	18.53b	18.64ab	18.53b
SE±	0.107	0.153	0.103	0.058
Variety (V)				
SAMCOT 10	18.56	18.65	18.76	18.65a
SAMCOT 11	18.37	18.46	18.57	18.47b
SAMCOT 13	18.58	18.67	18.78	18.67a
SE±	0.109	0.012	0.109	0.026
Interactions				
N x I	NS	NS	**	**
N x V	NS	NS	NS	**
I x V	NS	NS	NS	NS
N x I x V	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. **: significant at 1% level of probability respectively. NS: Not significant

Table 36: Interaction between nitrogen rate and irrigation method on seed oil content of cotton varieties in 2009 and combine mean.

	Nitrogen kg ha^{-1}			
	2009			
	40	70	100	130
Irrigation method				
Check basin	19.59a	19.02abc	18.73bc	18.34cd
Furrow	18.34cd	18.71bcd	19.26ab	17.87d
Border strip	18.93abc	18.80bc	18.39cd	18.43cd
SE±		0.307		
	Combined mean			
Check basin	19.49a	18.91bc	18.62cde	18.24g
Furrow	18.24g	18.60cdef	19.16ab	17.77h
Border strip	18.83bc	18.69cd	18.29efg	18.32def
SE±		0.116		

Means followed by the same letter(s) within the same interaction group are statistically similar at P≤ 0.05.

Table 37: Interaction between nitrogen and variety on seed oil content of cotton varieties in the combined mean.

	Nitrogen (kg ha$^{-1)}$			
	40	70	100	130
Variety				
SAMCOT 10	18.84ab	18.56bc	18.99a	17.83f
SAMCOT 11	18.80ab	18.66ab	18.06de	17.96def
SAMCOT 13	18.63b	18.70ab	18.73ab	18.24cd
SE ±		0.126		

Means followed by the same letter(s) within the same interaction group are statistically similar at P≤ 0.05.

to each other, while at 70 kg N ha^{-1} irrigation method did not influenced significantly oil content of cotton seed.

Table 37 presents the interaction between nitrogen and variety on oil content of cotton seed during the combine mean. Increasing nitrogen from 40 to 100 kg ha^{-1} resulted significantly in higher but similar oil content of SAMCOT 10 and SAMCOT 13 than at 130 kg ha^{-1}. While SAMCOT 11 oil content was significantly higher but similar at nitrogen increase from 40 to 70 kg ha^{-1} than further increase. The varieties had similar oil content at 40 and 70 kg N ha^{-1} but at 100 kg N ha^{-1} SAMCOT 11 was significantly lower than other two varieties while at 130 kg N ha^{-1} SAMCOT 13 was significantly higher than other two varieties.

4.20 Protein Content of Cotton Seed

Table 38 shows percentage protein content of cotton seeds as influenced by nitrogen rate and irrigation method of cotton varieties in 2007, 2008, 2009 dry seasons and the combined mean. Application of 70 and 130 kg N ha^{-1} resulted in significantly higher protein content of cotton seeds than the other nitrogen rates which were statistically at par with each other. Irrigation method did not influence protein content of cotton seeds in 2007 and 2008 years. However, in 2009 check basin irrigation resulted in higher protein content than in other methods which were at par. In the combine mean furrow irrigation resulted in higher protein content of cotton seed than other methods which were statistically at par. SAMCOT 13 had significantly higher protein content than both SAMCOT 10 and 11 which were at par with each other in 2009 and combine mean. In 2008 SAMCOT 13 had significantly higher protein content than SAMCOT 11 which in turn was higher than SAMCOT 10. The protein content of the three varieties was comparable to each other in 2007. Significant interactions between nitrogen and

Table 38: Influence of nitrogen rates and irrigation methods on seed protein content of cotton varieties in 2007, 2008, 2009 dry seasons and combined mean.

Treatment	Seed Protein Content			
	2007	2008	2009	Mean
Nitrogen (N) (kg ha^{-1})				
40	19.67b	21.17b	20.42b	20.43b
70	20.34a	21.83a	21.08a	21.08a
100	19.68b	21.18b	20.43b	20.43b
130	19.90ab	21.40ab	20.65ab	20.65b
SE±	0.177	0.031	0.177	0.099
Irrigation Method (I)				
Check basin	19.74	21.24	20.96a	20.49b
Border strip	19.77	21.28	20.52b	20.54b
Furrow	20.19	21.66	20.93b	20.93a
SE±	0.154	0.024	0.154	0.086
Variety (V)				
SAMCOT 10	19.89ab	21.33b	20.61b	20.61b
SAMCOT 11	19.56b	20.91c	20.24b	20.24b
SAMCOT 13	20.25a	21.93a	21.09a	21.09a
SE±	0.144	0.145	0.144	0.083
Interactions				
N x I	NS	NS	NS	**
N x V	NS	NS	NS	**
I x V	NS	NS	NS	*
N x I x V	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability.*, **: significant at 5% and 1% level of probability respectively. NS: not significant

Table 39: Interaction between nitrogen and irrigation method on protein content of cotton seed in the combined mean.

	Nitrogen (kg ha^{-1})			
	40	70	100	130
Irrigation method				
Check basin	20.03f	20.56cd	20.59cd	20.78bcd
Furrow	20.58cd	20.99b	20.19e	20.33e
Border strip	20.65cd	21.71a	20.50c	20.84bc
SE±		0.116		

Means followed by the same letter(s) within the same interaction group are statistically similar at P≤ 0.05.

irrigation method, nitrogen and cotton variety and irrigation method and cotton variety were observed during the combined mean years.

The interaction between nitrogen and irrigation method on protein content of cotton seeds is presented in Table 39. The application of 40 kg N ha^{-1} in check basin significantly resulted in lower protein content of cotton seeds than in furrow and border irrigations which were at par with each other. At 70 kg ha^{-1} border strip irrigation resulted in higher protein content than in furrow which in turn higher than check basin. At 100 and 130 kg N ha^{-1} furrow irrigation resulted in significantly lower protein content than in other two irrigation methods which were at par with each other. Increasing nitrogen rate from 40 to 70 kg ha^{-1} significantly increased the protein content of cotton seeds but further increase to 130 resulted in significantly lower but similar protein content all the irrigation methods except in border strip where 40 and 130 kg N ha^{-1} were comparable. But when N was fixed, check basin irrigation resulted in lower protein content than other methods at 40 kg N ha^{-1}. Border strip irrigation method resulted in higher protein content than furrow irrigation which in turn higher than in check basin method at 70 kg N ha^{-1}. Check basin and border irrigation resulted in significantly higher protein content of cotton seeds than in furrow irrigation at 100 and 130 kg ha^{-1}.

The interaction between nitrogen and cotton variety on protein content of cotton seeds in the combine mean is presented on Table 40. Increasing nitrogen from 40 to 70 N ha^{-1} resulted in significant increase of protein content of SAMCOT 10 seeds but further increase did not significantly influence the percentage protein content of the seeds. Nitrogen rates did not significantly influenced the protein content of SAMCOT 11. While application only of 70 kg N ha^{-1} resulted in higher protein content of SAMCOT 13 seeds compared to other rates that were statistically at par. The seeds of all the cotton varieties had statistically similar protein content at

40 kg N ha^{-1}. But at 70 kg N ha^{-1} SAMCOT 13 resulted in significantly higher seed protein content than other two varieties which were at par while SAMCOT 11 seeds have lower seed protein content than other two varieties which were at par with each other at 100 and 130 kg N ha^{-1}.

The interaction between irrigation method and cotton variety on protein content of cotton seeds in the combine mean is presented in Table 41. SAMCOT 10 and 13 seeds had significantly higher protein content than SAMCOT 11 that were statistically similar in furrow irrigation method. But in border method, SAMCOT 10 seeds had significantly higher protein content than other two varieties that were statistically at par. In check basin irrigation method, the seeds of the varieties resulted in statistically similar protein content. Irrigation methods did not significantly influenced the protein content of SAMCOT 10 seeds. Furrow irrigation resulted in significantly lower protein content of SAMCOT 11 than the other two varieties which were statistically at par with each other. While in border strip, SAMCOT 13 seeds resulted in lower percentage protein content than other two varieties that were statistically at par with each other.

4.21 Water use

Table 42 presents the influence of nitrogen rates and irrigation methods on the water use of cotton varieties in 2007, 2008, 2009 and combine mean at Kadawa. Check basin irrigation method significantly resulted in higher water use than border strip which in turn was higher than furrow irrigation method in all the three years and combine. Nitrogen rates and cotton varieties did not influence water use significantly in all the three years and combine. There was no significant interaction between the treatment factors in all years and combine.

Table 40: Interaction between nitrogen and variety on protein content of cotton seed in the combined mean.

	Nitrogen (kg ha$^{-1)}$			
	40	70	100	130
Variety				
SAMCOT 10	19.55cd	20.10b	19.82bc	20.07b
SAMCOT 11	19.62bcd	19.95b	19.13d	19.53cd
SAMCOT 13	19.87bc	20.96a	20.08b	20.09b
SE ±		0.172		

Means followed by the same letter(s) within the same interaction group are statistically similar at P≤ 0.05.

Table 41: Interaction between irrigation method and cotton variety on protein content of cotton seed at the combined mean.

	Variety		
	SAMCOT 10	SAMCOT 11	SAMCOT 13
Irrigation method			
Check basin	20.11cd	20.54bc	20.81ab
Furrow	20.80abc	19.77d	20.99a
Border strip	20.92ab	20.39c	20.47c
SE±		0.172	

Means followed by the same letter(s) within the same interaction group are statistically similar at P≤ 0.05.

4.22 Water Use Efficiency

Table 43 presents the influence of irrigation methods and nitrogen rates on water use efficiency of cotton varieties in 2007, 2008, 2009 and combine mean at Kadawa. The result revealed that increasing nitrogen rate from 40 to 70 kg ha^{-1} resulted in significantly higher water use efficiency but each further increase to 130 resulted in significantly lower but similar water use efficiency in 2007, 2008 and combine mean. In 2009 however, increasing nitrogen from 40 to 70 kg ha^{-1} significantly resulted in higher water use efficiency but each further increase up to 130 resulted in significantly successive decrease in water use efficiency. Irrigation method had significant influence on the water use efficiency in all the three years. Furrow irrigation method resulted in significantly higher water use efficiency than border strip which in turn was higher than check basin in all the three years and combine mean. SAMCOT 13 resulted in significantly higher water use efficiency than SAMCOT 11 which in turn was higher than SAMCOT 10 in all the three years and combine mean. There was no significant interaction between the treatments factors in all years and combined.

4.23 Correlation Among Yield, Growth and Yield components

The correlation coefficients among yield, yield components and some growth parameters in 2007, 2008, 2009 dry seasons and the combine mean are presented on Tables 44, 45, 46 and 47, respectively. Seed cotton yield per hectare was positively and highly significantly correlated with total dry matter, leaf area index at 14 WAS, crop growth rate, net assimilation rate, number of branches per plant, days to 50% boll opening, number of bolls per plant, boll weight and number of seeds per boll in 2007. However, plant height, relative growth rate, days to 50% flowering and ginning percentage were not significantly correlated with seed cotton yield. While 100-seed weight and lint index were not significant but negatively correlated with seed cotton

Table 42: Influence of nitrogen rate and irrigation method on water use of cotton variety in 2007, 2008, 2009 dry seasons and combined mean.

	Water Use (m^3)			
Treatment	2007	2008	2009	Mean
Nitrogen (N) (kg ha^{-1})				
40	26.1	29.5	30.9	28.9
70	26.1	29.5	30.9	28.9
100	26.1	29.5	30.9	28.9
130	26.1	29.5	30.9	28.9
SE±	0.00	0.00	0.00	0.00
Irrigation Method (I)				
Check basin	34.5a	36.8a	39.1a	36.8a
Border strip	26.5b	31.1b	33.9b	30.49b
Furrow	17.3c	20.7c	18.4c	18.8c
SE±	0.46	0.21	0.27	1.36
Variety (V)				
SAMCOT 10	26.1	29.5	30.93	28.9
SAMCOT 11	26.1	29.5	30.93	28.9
SAMCOT 13	26.1	29.5	30.93	28.9
SE±	0.00	0.00	0.00	0.00
Interactions				
N x I	NS	NS	NS	NS
N x V	NS	NS	NS	NS
I x V	NS	NS	NS	NS
N x I x V	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. NS = Not significant.

Table 43: Influence of nitrogen rates and irrigation methods on water use efficiency of cotton varieties in 2007, 2008, 2009 dry seasons and combined mean.

	Water Use Efficiency ($kg\ m^{-3}$)			
Treatment	2007	2008	2009	Mean
Nitrogen (N) ($kg\ ha^{-1}$)				
40	14.31c	13.42c	12.57c	13.43c
70	23.34a	22.43a	21.58a	22.45a
100	19.69b	19.82b	19.07b	19.53b
130	19.97b	19.10b	16.95d	18.67b
SE±	0.441	0.484	0.384	0.312
Irrigation Method (I)				
Check basin	14.23c	14.89c	12.12c	13.48c
Border strip	17.92b	16.82b	14.62b	16.45b
Furrow	25.84a	25.17a	25.88a	25.63a
SE±	0.387	0.419	0.334	0.270
Variety (V)				
SAMCOT 10	17.25c	16.20c	15.07c	16.17c
SAMCOT 11	19.05b	18.23b	17.43b	18.24b
SAMCOT 13	21.68a	21.65a	20.13a	21.15a
SE±	0.459	0.473	0.403	0.270
Interactions				
N x I	NS	NS	NS	NS
N x V	NS	NS	NS	NS
I x V	NS	NS	NS	NS
N x I x V	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. NS = Not significant.

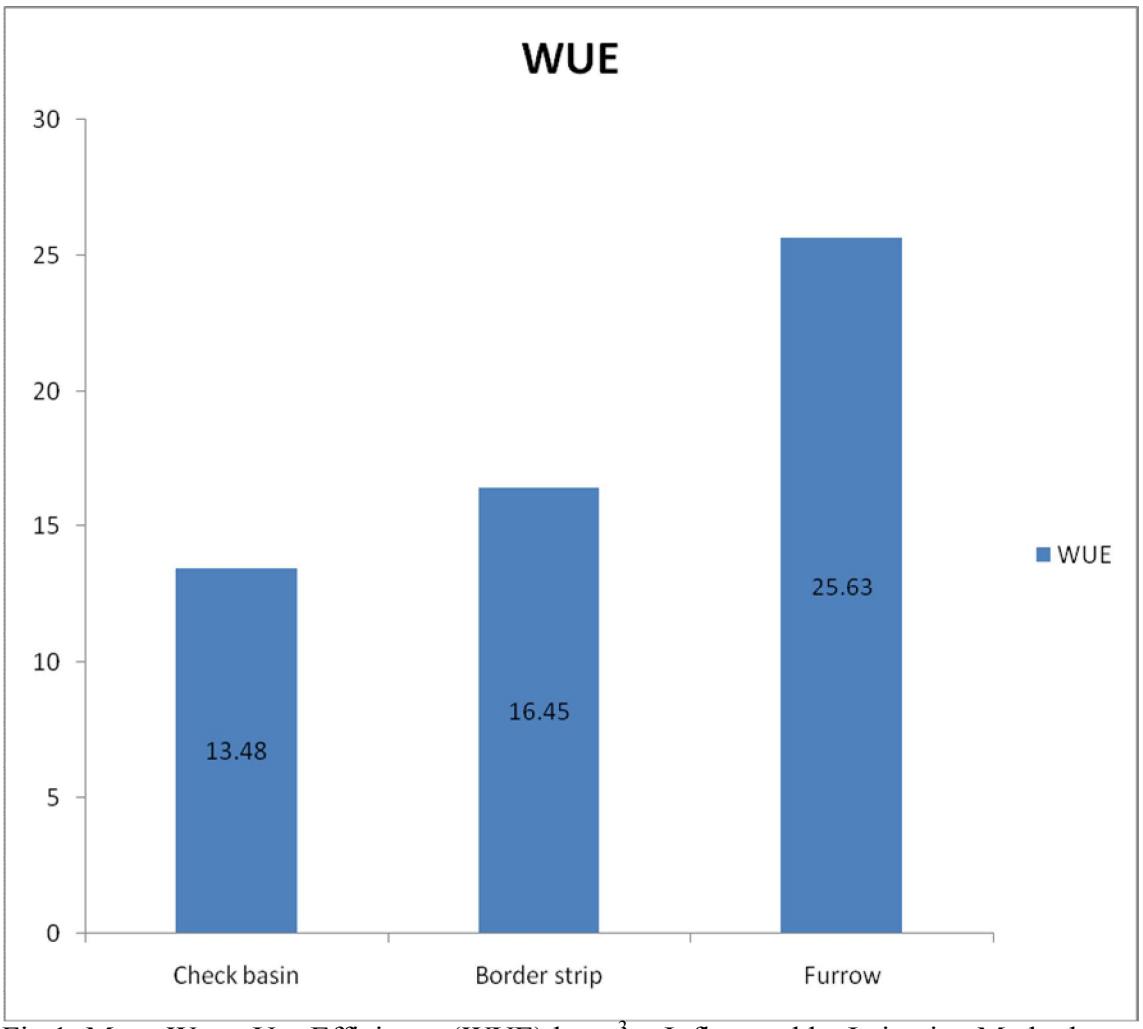


Fig 1: Mean Water Use Efficiency (WUE) kg m^3as Influenced by Irrigation Method.

yield. In 2008, the seed cotton yield was positively and highly significantly correlated with total dry matter, leaf area index, crop growth rate, relative growth rate, net assimilation rate, number of branches per plant, days to 50% flowering, days to 50% boll opening, number of bolls per plant, boll weight and number of seeds per boll. However, plant height, ginning percentage, 100-seed weight and lint index were not significant but negatively correlated with seed cotton yield. In 2009, the cotton seed yield per hectare was positively and highly significantly correlated with plant height, total dry matter, leaf area index, crop growth rate, net assimilation rate, boll weight, number of branches per plant, days to 50% flowering, days to 50% boll opening, number of bolls per plant, number of seeds per boll, ginning percentage, 100-seed weight and lint index. But relative growth rate was not significant and negatively correlated with seed cotton yield. In the combine mean, seed cotton yield per hectare was positively and highly significantly correlated with total dry matter, leaf area index, crop growth rate, number of branches per plant, days to 50% flowering, days to 50% boll opening, number of bolls per plant, boll weight and number of seeds per boll. While plant height, relative growth rate, net assimilation rate, ginning percentage, 100-seed weight and lint index were positive but not significantly correlated with seed cotton yield. Plant height was positively and significantly correlated with total dry matter, leaf area index, crop growth rate, net assimilation rate, number of branches, days to 50% flowering, days to 50% boll opening and number of bolls per plant in 2007. While RGR, boll weight, number of seeds per boll, ginning percentage, 100-seed weight and lint index were not significantly correlated with plant height.

However in 2008 and combined the relationship between plant height and all the parameters on the matrix except boll weight was not significantly correlated. But in 2009, plant height was positive and highly significantly correlated with total dry matter, leaf area index, crop

growth rate, net assimilation rate, number of branches, days to 50% flowering, and days to 50% boll opening, ginning percentage and lint index. While it is negative and non significantly correlated with boll weight.

The total dry matter was positive and highly significantly correlated with leaf area index, crop growth rate, number of branches per plant, days to 50% flowering, days to 50% boll opening, number of bolls per plant and boll weight in 2007 while ginning percentage was negative and non significant. Similar trend was observed in 2008 and 2009 except that 100-seed weight and lint index were not significant and negatively correlated in 2008. In the combine mean total dry matter was significantly correlated with leaf area index, crop growth rate, and number of branches per plant, days to 50% flowering, days to 50% boll opening, number of bolls per plant, boll weight and number of seeds per boll. However, relative growth rate, net assimilation rate, ginning percentage, 100-seed weight and lint index were not significantly correlated with total dry matter.

4.24 Path Analysis and Percentage contribution of Growth and Yield Components to Seed cotton yield.

The direct and indirect effects of the different growth and yield components on seed cotton yield in 2007, 2008, 2009 and combined are shown in Table 48. In 2007 and 2009, the results showed that the direct effect to seed cotton yield of all the parameters taken were positive with the exception of number of bolls per plant. In 2007, highest direct contribution was exhibited by number of seeds per boll (0.4613) followed by leaf area index (0.2287) and total dry matter (0.1713) in that order. However, in 2008 leaf area index exhibited the highest direct effects (0.6720) followed by boll weight (0.6554) and then total dry matter (0.5615). The least

Table 44: Matrix of simple correlation coefficients among some growth, yield and yield components of three cotton varieties in 2007 dry season.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
1	1.0000															
2	0.1417	1.0000														
3	0.7132**	0.6111**	1.0000													
4	0.5927**	0.4948**	0.4949**	1.0000												
5	0.38887**	0.5778**	0.6242**	0.6262**	1.0000											
6	0.1044	0.1153	0.3141**	0.2532*	0.5337**	1.0000										
7	0.3657**	0.4768**	0.9275**	0.4062**	0.9527**	0.5075**	1.0000									
8	0.6952**	0.6656**	0.8120**	0.4775**	0.6923**	-0.1033	0.6574**	1.0000								
9	0.1770	0.7317**	0.5502**	0.5044**	0.5490**	0.2156*	0.4419**	0.6229**	1.0000							
10	0.2372*	0.7046**	0.7491**	0.5461**	0.7379**	0.2694**	0.6591**	0.7027**	0.7251**	1.0000						
11	0.5517**	0.0071	0.7152**	0.6658**	-0.1726	-0.1726	0.2044*	0.3832**	-0.0371	0.0833	1.0000					
12	0.9372**	0.1748	0.7491**	0.5461**	0.3133**	-0.1740	0.3390*	0.7027**	0.2117*	0.2376*	0.0833	1.0000				
13	0.7650**	0.0954	0.4954**	0.3782**	0.3794**	0.1020	0.2029*	0.1794	0.0750	0.0545	0.6725**	0.8350**	1.0000			
14	0.0690	-0.2049*	0.0251	0.0586	0.0307	0.0307	0.0473	-0.0361	-0.1860	-0.0409	0.2518*	0.2079*	0.2932**	1.0000		
15	-0.0847	-0.0510	-0.0070	0.0555	0.0640	0.0640	-0.0035	-0.1166	-0.0212	-0.1388	0.0659	0.0443	0.1537	-0.03780	1.0000	
16	-0.1669	-0.0779	0.0351	0.0359	-0.0074	0.0945	0.00004	-0.1682	-0.1098	-0.1394	0.0483	0.0331	0.2402	0.5041**	0.7543**	1.

1=seed cotton yield
2=plant height@14 WAS
3=total dry matter
4=leaf area index
5=crop growth rate
6=relative growth rate
7= net assimilation rate
8=number of branches
9=days to 50% flowering
10=days to 50% boll opening
11=number of bolls
12=boll weight
13=number of seeds
14=ginning percentage
15=100 seed weight
16=lint index

*and** significant at P≤0.05 and 0.01 probability level

(r)value: 5% =0.195; 1% = 0.254

Table 45: Matrix of simple correlation coefficients among some growth, yield and yield components of three cotton varieties in 2008 dry season.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	1.0000															
2	-0.0165	1.0000														
3	0.5794**	0.1115	1.0000													
4	0.7164**	-0.0229	0.6579**	1.0000												
5	0.4676**	0.1239	0.9943**	0.6992**	1.0000											
6	0.3036**	0.1688	0.7364**	0.7360**	0.8029**	1.0000										
7	0.3036**	0.1688	0.7364**	0.7360**	0.8029**	1.0000	1.0000									
8	0.4916**	0.0427	0.7515**	0.5834**	0.7565**	0.6123**	0.6123**	1.0000								
9	0.2653**	0.0521	0.5861**	0.5088**	0.6017**	0.5372**	0.5372**	0.7279**	1.0000							
10	0.2951**	0.1121	0.7348**	0.5491**	0.7515**	0.6694**	0.6694**	0.7784**	0.6391**	1.0000						
11	0.5726**	-0.0165	0.6224**	0.6395**	0.6224**	0.4276**	0.4276**	0.3513*	0.2232*	0.37648**	1.0000					
12	0.6147**	0.1973*	0.1077	0.1809	0.1077	0.0108	0.0108	0.2381*	0.1320	-0.00436	0.4449**	1.0000				
13	0.5057**	-0.0748	0.2873**	0.3238**	0.2873**	0.1790	0.1790	0.0616	0.0109	0.10649	0.60951**	0.43613**	1.0000			
14	-0.1522	-0.0151	-0.0464	-0.0058	-0.0464	-0.0571	-0.0571	-0.0791	-0.2262	-0.00270	0.02639	0.01404	-0.00855	1.0000		
15	-0.10196	-0.1479	-0.0319	0.0463	-0.0319	0.0004	0.0004	-0.0768	-0.0329	-0.16536	0.00017	-0.01721	0.19355	0.07947	1.0000	
16	-0.1789	-0.1191	-0.0566	0.0303	-0.0566	-0.0416	-0.0416	-0.1099	-0.1701	-0.1164	0.0181	0.0045	0.1236	0.7163**	0.7465**	1.0000

1=seed cotton yield
2=plant height@14 WAS
3=total dry matter
4=leaf area index
5=crop growth rate
6=relative growth rate
7= net assimilation rate
8=number of branches
9=days to 50% flowering
10=days to 50% boll opening
11=number of bolls
12=boll weight
13=number of seeds
14=ginning percentage
15=100 seed weight
16=lint index

*and** significant at P≤0.05 and 0.01 probability level

(r)value: 5% =0.195; 1% = 0.254

Table 46: Matrix of simple correlation coefficients among some growth, yield and yield components of three cotton varieties 2009 dry season.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	1.0000															
2	0.3188**	1.0000														
3	0.5923**	0.2991*	1.0000													
4	0.6973**	0.3202*	0.61573**	1.0000												
5	0.2797**	0.2998*	0.9982**	0.6130**	1.0000											
6	-0.1583	0.0677	0.1698	0.0802	0.2279*	1.0000										
7	0.2432*	0.2655*	0.9626**	0.4067**	0.9662**	0.2542**	1.0000									
8	0.5458**	0.5988**	0.4027**	0.3652**	0.4071**	0.1441	0.3585**	1.0000								
9	0.3191**	0.6052**	0.5941**	0.5344**	0.5957**	0.1423	0.5257**	0.6953**	1.0000							
10	0.2360*	0.5629**	0.6885**	0.4946**	0.6859**	0.0972	0.6314**	0.6354**	0.7861**	1.0000						
11	0.6342**	0.0972	0.3217**	0.4324**	0.3116**	-0.1041	0.2474*	0.0665	0.1133	0.1254	1.0000					
12	0.6180**	-0.0432	0.0011	-0.0096	-0.0024	-0.0518	0.00944	-0.1710	-0.1152	-0.1140	0.5219**	1.0000				
13	0.6077**	0.1598	0.5031**	0.3640**	0.1910*	-0.1560	0.1069	0.3618*	0.1145	0.0385	0.6914**	0.3633*	1.0000			
14	0.3761**	0.2474**	0.2330*	0.3206**	0.2335*	0.0269	0.1805*	0.2939**	0.2441**	0.1516	0.4225**	0.2263**	0.3432**	1.0000		
15	0.2443**	0.0849	0.0317	0.1529	0.0339	0.0370	-0.0105	0.1116	0.0845	0.0725	0.3911**	0.3546**	0.2609**	0.0723	1.0000	
16	0.4230**	0.2387*	0.1938	0.3369**	0.1957*	0.0496	0.1265	0.2786**	0.2382**	0.1647	0.5526**	0.3996*	0.4130**	0.7290**	0.7328**	1.0000

1=seed cotton yield
2=plant height@14 WAS
3=total dry matter
4=leaf area index
5=crop growth rate
6=relative growth rate
7= net assimilation rate
8=number of branches
9=days to 50% flowering
10=days to 50% boll opening
11=number of bolls
12=boll weight
13=number of seeds
14=ginning percentage
15=100 seed weight
16=lint index

*and** significant at P≤0.05 and 0.01 probability level

(r)value: 5% =0.195; 1% = 0.254

Table 47: Matrix of simple correlation coefficients among some growth, yield and yield components of three cotton varieties for combined mean.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	1.0000															
2	0.0283	1.0000														
3	0.6906**	0.1515	1.0000													
4	0.7325**	0.1574	0.5732**	1.000												
5	0.3890**	0.1558	0.9881**	0.4208**	1.0000											
6	0.1516	-0.0407	0.1649	0.1055	0.2718**	1.0000										
7	0.1610	0.0375	0.1009	0.0581	0.9511**	0.0915	1.000									
8	0.4332**	0.2014*	0.4150**	0.6235**	0.3737**	0.0102	0.4040**	1.0000								
9	0.5639**	0.1568	0.5518**	0.4597**	0.5392**	0.1303	0.2952**	0.5924**	1.0000							
10	0.6981**	0.1972*	0.7269**	0.5567**	0.7274**	0.1590	0.1053	0.5602**	0.7064**	1.0000						
11	0.5432**	-0.0305	0.4064**	0.4064**	0.4164**	-0.0889	-0.3694**	-0.1155	-0.0099	0.1725	1.0000					
12	0.6602**	0.0637	0.6024**	0.4244**	0.1013	-0.1130	-0.2738**	0.6010**	-0.0520	-0.0438	0.3184**	1.0000				
13	0.5270**	0.0066	0.2864**	0.3399**	0.2934**	-0.0044	-0.3154**	0.0388	0.0269	0.1175	0.6075**	0.4057**	1.0000			
14	0.0989	0.0629	0.1512	0.3425**	0.1450	0.0224	-0.1054	0.2650**	-0.0043	0.1363	0.1724	0.0562	0.3474**	1.0000		
15	0.0220	-0.0289	0.0607	0.2622**	0.0627	0.0199	-0.0514	0.1780	0.0485	0.0092	0.0901	0.0364	0.2463*	0.1463	1.0000	
16	0.0509	0.04000	0.0607	0.4385**	0.1527	0.037	-0.1411	0.3184**	0.0567	0.1229	0.1406	0.0230	0.3474**	0.7095**	0.7585**	1.0000

1=seed cotton yield
2=plant height@14 WAS
3=total dry matter
4=leaf area index
5=crop growth rate
6=relative growth rate
7= net assimilation rate
8=number of branches
9=days to 50% flowering
10=days to 50% boll opening
11=number of bolls
12=boll weight
13=number of seeds
14=ginning percentage
15=100 seed weight
16=lint index

*and** significant at P≤0.05 and 0.01 probability level

(r)value: 5% =0.195; 1% = 0.254

positive effect was shown by number of seeds per boll. Number of branches and number of bolls per plant exhibited negative direct effect (-0.3204 and -0.4786) on seed cotton yield. In 2009, the highest direct contribution was from boll weight (0.6103) followed by number of branches and total dry matter (0.2776). Least positive direct contribution was from leaf area index (0.1680). Negative and direct contribution was exhibited by number of bolls per plant.

In the combined, the results showed that the direct effect of all growth and yield components to seed cotton yield were positive with highest direct effect by leaf area index (0.3482) followed by number of boll per plant (0.2476), while number of branches exhibited least effect (0.0465). Most of direct effects via other growth and yield components were observed to be positive in all the three years and combine mean. However all indirect effects via number of bolls per plant were negative in all the three years except at combined and via number of branches in 2008. Similarly boll weight and number of boll per plant via number of branches in 2009 (-0.1040) and combined mean (-0.0286) were negative.

The percentage contributions of growth and yield components to seed cotton yield is presented in Table 49. The direct individual contribution varied greatly across the years and combine mean. Highest direct individual contribution was from number of seeds per boll (21.27%) in 2007, leaf area index in (45.16%) 2008, boll weight (37.24%) in 2009 and leaf area index (12.12%) in combine mean. Likewise lowest individual contribution varied across the years and combine mean with 1.56% for number of bolls per plant, 2.32% for number of seeds per boll, 2.82% for leaf area index and 0.22% for number of branches per plant in 2007, 2008, and 2009 and combine mean respectively. Highest combine contribution of 12.87%, 49.65%, 8.74% and 8.69% was made by boll weight and number of seed per boll, crop dry weight and leaf area index, boll weight and number of seed per boll, crop dry weight and leaf area index in 2007,

Table 48: Direct and indirect effects of different growth and yield components to seed cotton yield during 2007, 2008, 2009 and combine mean.

2007							
Seed cotton yield							
Total dry matter	**0.1713**	0.1132	0.1643	-0.0890	0.1251	0.2285	0.7134
Leaf area index	0.0843	**0.2287**	0.0966	-0.0830	0.0912	0.1745	0.5927
Number of branches	0.1390	0.1092	**0.2023**	-0.0478	0.1174	0.1750	0.6952
Number of bolls/plant	0.1225	0.1523	0.0775	**-0.1247**	0.0139	0.3100	0.5517
Boll weight	0.1283	0.1249	0.1422	-0.0104	**0.1670**	0.3850	0.9372
Number of seeds/boll	0.0849	0.0865	0.0768	-0.0839	0.1395	**0.4613**	0.7650
2008							
Total dry matter	**0.5615**	0.4420	-0.2400	-0.2979	0.0706	0.0438	0.5794
Leaf area index	0.3694	**0.6720**	-0.1869	-0.3060	0.1186	0.0493	0.7164
Number of branches	0.4220	0.3920	**-0.3204**	-0.1681	0.1560	0.0094	0.4910
Number of bolls/plant	0.3495	0.4297	-0.1125	**-0.4786**	0.2916	0.0929	0.5726
Boll weight	0.0605	0.1216	-0.0763	-0.2129	**0.6554**	0.0665	0.6147
Number of seeds/boll	0.1613	0.2176	-0.0197	-0.2917	0.2858	**0.1524**	0.5057
2009							
Total dry matter	**0.2776**	0.1034	0.1559	-0.1116	0.0678	0.0991	0.5923
Leaf area index	0.1709	**0.1680**	0.1753	-0.0776	0.1889	0.0717	0.6973
Number of branches	0.1395	0.0950	**0.3102**	-0.0658	-0.1040	0.0713	0.4458
Number of bolls/plant	0.1726	0.0726	0.1137	**-0.1795**	0.3185	0.1362	0.6342
Boll weight	0.0308	0.0520	-0.0530	-0.0937	**0.6103**	0.0716	0.6180
Number of seeds/boll	0.1397	0.0612	0.1122	-0.1241	0.2217	**0.1971**	0.6077
Combined							
Total dry matter	**0.2178**	0.1996	0.0193	0.1006	0.0878	0.0655	0.6906
Leaf area index	0.1248	**0.3482**	0.0193	0.1006	0.0618	0.0777	0.7325
Number of branches	0.0904	0.1445	**0.0465**	-0.0286	0.0876	0.0929	0.4332
Number of bolls/plant	0.0885	0.1415	-0.0054	**0.2476**	0.0464	0.0246	0.5432
Boll weight	0.1312	0.1478	0.0279	0.0788	**0.1457**	0.1288	0.6602
Number of seeds/boll	0.0624	0.1183	0.0188	0.0266	0.0820	**0.2287**	0.5370

Table 49: Percentage contributions of growth and yield components to seed cotton yield in 2007, 2008, 2009 dry seasons and combined mean.

Growth & Yield Components	Percentage Contribution			
	2007	2008	2009	Combined
Direct contribution				
Total dry matter	2.93	31.53	7.71	4.74
Leaf area index (LAI)	5.23	45.16	2.82	12.12
Number of branches	4.09	10.26	9.62	0.22
Number of bolls per plant	1.56	22.90	3.22	6.13
Boll weight	2.79	42.95	37.24	2.12
Number of seeds per boll	21.27	2.32	3.88	5.23
Combined contribution				
Total dry matter + LAI	3.88	49.65	5.74	8.69
Total dry matter + No. of branches	5.63	-27.04	8.66	0.84
Total dry matter + No. of boll	-3.06	-33.45	-6.20	4.38
Total dry matter + boll weight	4.29	7.93	3.76	3.82
Total dry matter + No. of seeds	7.83	4.92	5.51	2.86
LAI + No. of branches	4.42	-25.12	5.89	1.34
LAI + No. of seeds	-3.80	-41.13	-2.61	7.01
LAI + boll weight	4.17	15.93	6.35	4.31
LAI + No. of seeds	7.99	6.63	2.41	5.41
No. of branches + No. of bolls	-1.93	10.77	-4.08	-0.27
No. of branches + boll weight	4.75	-10.00	-6.47	0.81
No. of branches + No. of seeds	7.06	-3.16	4.45	0.72
No. of bolls + boll weight	-0.35	-27.91	-11.44	2.30
No. of bolls + No. of seeds	-7.74	-8.89	-4.89	1.22
Boll weight + No. of seeds	12.87	8.71	8.74	3.75
Residual	16.12	17.02	19.68	22.23
Total	100	100	100	100

No. = number.

2008, and 2009 and combine mean respectively. The lowest combine contribution of -7.74%, -27.91%, -11.44%, and -0.27% to seed cotton yield was made by number of boll per plant and number of seed per boll in 2007, number of boll per plant and boll weight in 2008 and 2009 and number of branches and number of bolls per plant in combine mean respectively. An unaccounted residual of 16.12% in 2007, 17.02% in 2008, 19.68% in 2009 and 22.23% in combine mean were observed

4.25 Regression Analysis

The polynomial responses of seed cotton yield to nitrogen in 2007, 2008, 2009 and combine means are presented in fig 1. The figure shows that the responses across the years and the mean were quadratic. The optimum nitrogen rates were computed to be 94.0, 94.3, 90.7 and 92.9 kg N ha^{-1} in 2007, 2008, 2009 and the combine mean respectively.

2.26 Cost Benefit Analysis of Yield

Table 50 presented the result of gross margin analysis of three cotton varieties production as influenced by irrigation method and nitrogen rate. It indicated that the highest gross margin returns of ₦ 103638.30 was achieved by planting SAMCOT 13 in border irrigation method using 70 kg N ha^{-1}. It is slightly similar with planting of the same cotton variety in check basin irrigation method using similar nitrogen rate of 70 kg ha^{-1} whose gross margin return was ₦102588.30. The least return of ₦34609.27 was realized from planting of SAMCOT 10 under check basin irrigation using lower nitrogen rate of 40 kg ha^{-1}. The gross margin (GM) was given by the difference between total revenue (TR) ha^{-1} and total variable cost (TVC) ha^{-1}. Revenue was calculated by multiplying yield in kg ha^{-1} and average unit price in kg ha^{-1} (obtained from Funtua, Kastina and Danbatta markets in September each year) as per treatments. While cost of production include land preparations, planting, weeding, fertilizer application, pesticides and

herbicides cost and their application, irrigation water application, cotton picking, ginning and transport were computed and recorded.

GM = TR – TVC.

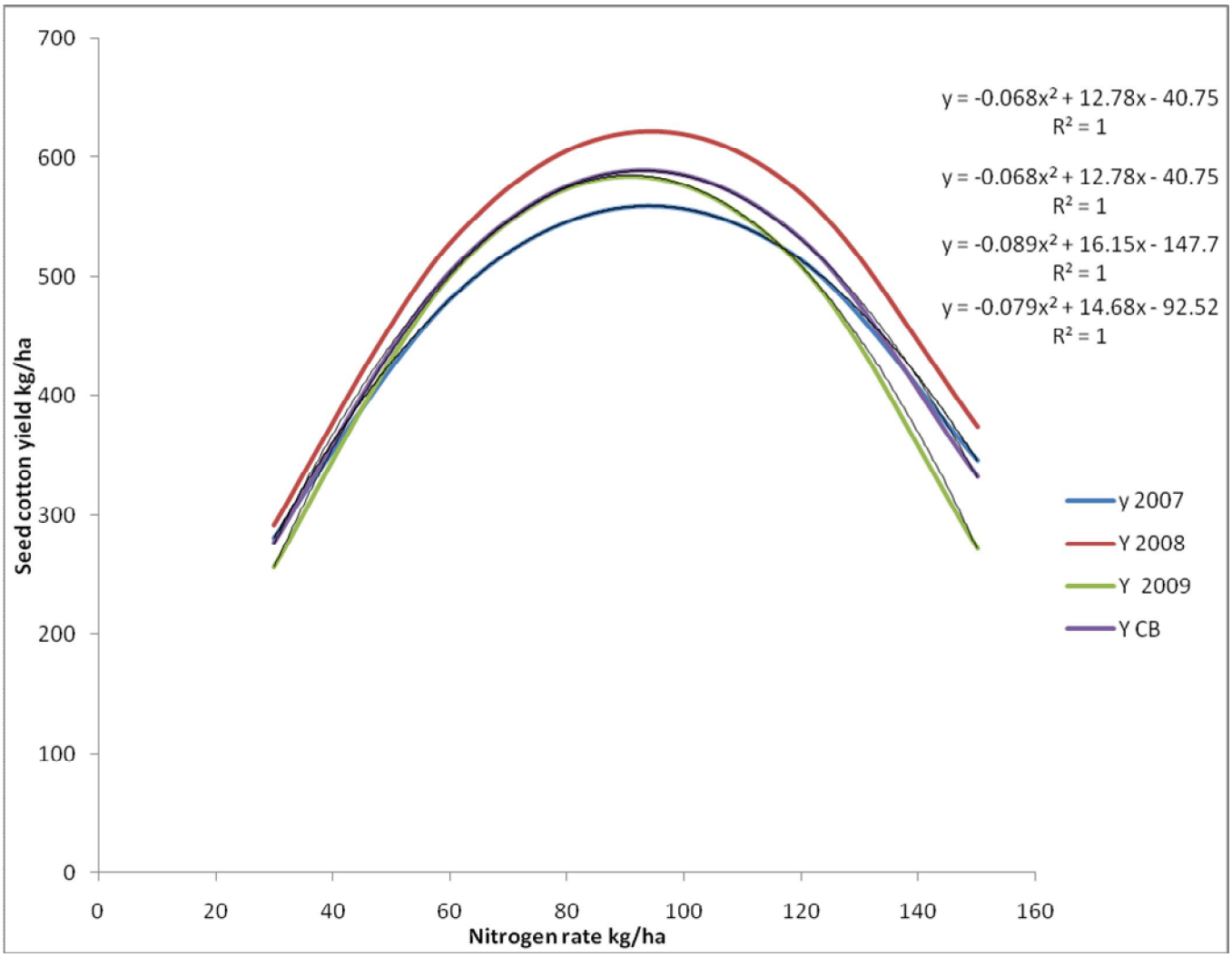


Fig 2: Polynomial curve showing response of irrigated seed cotton yield to nitrogen rates in 2007, 2008 2009 and combined mean.

Table 50: Cost benefit analysis of cotton production as influenced by irrigation methods and nitrogen rates at Kadawa.

Treatment	Production cost (₦)	Yield kg ha^{-1}	Unit price ₦ kg^{-1}	Total revenue ₦ kg^{-1}	Profit ₦ kg^{-1}
$N_1I_1V_1$	**7090.73**	**278**	**150**	**41700**	**34609.27**
N_1 I_1V_2	7090.73	352	150	52800	45709.27
N_1 I_1V_3	7090.73	401	150	60150	53059.27
N_1 I_2 V_1	7090.73	288	150	43200	36109.27
N_1 I_2 V_2	7090.73	357	150	53550	46459.27
N_1 I_2 V_3	7090.73	378	150	56700	49609.27
N_1 I_3 V_1	7090.73	410	150	61500	54409.27
N_1 I_3 V_2	7090.73	422	150	63300	56209.27
N_1 I_3 V_3	7090.73	407	150	61050	53959.27
N_2 I_1 V_1	12311.73	533	150	79950	67638.27
N_2 I_1 V_2	12311.73	606	150	90900	78588.27
N_2 I_1 V_3	**12311.73**	**766**	**150**	**114900**	**102588.3**
N_2 I_2 V_1	12311.73	664	150	99600	87288.27
N_2 I_2 V_2	12311.73	591	150	88650	76338.27
N_2 I_2 V_3	**12311.73**	**773**	**150**	**115950**	**103638.3**
N_2 I_3 V_1	12311.73	432	150	64800	52488.27
N_2 I_3 V_2	12311.73	590	150	88500	76188.27
N_2 I_3 V_3	12311.73	735	150	110250	97938.27
N_3 I_1 V_1	17522.73	506	150	75900	58377.27
N_3 I_1 V_2	17522.73	544	150	81600	64077.27
N_3 I_1 V_3	17522.73	625	150	93750	76227.27
N_3 I_2 V_1	17522.73	485	150	72750	55227.27
N_3 I_2 V_2	17522.73	665	150	99750	82227.27
N_3 I_2 V_3	17522.73	544	150	81600	64077.27
N_3 I_3 V_1	17522.73	459	150	68850	51327.27
N_3 I_3 V_2	17522.73	487	150	73050	55527.27
N_3 I_3 V_3	17522.73	675	150	101250	83727.27
N_4 I_1 V_1	22695.73	505	150	75750	53054.27
N_4 I_1 V_2	22695.73	489	150	73350	50654.27
N_4 I_1 V_3	22695.73	615	150	92250	69554.27
N_4 I_2 V_1	22695.73	372	150	55800	33104.27
N_4 I_2 V_2	22695.73	549	150	82350	59654.27
N_4 I_2 V_3	22695.73	610	150	91500	68804.27
N_4 I_3 V_1	22695.73	493	150	73950	51254.27
N_4 I_3 V_2	22695.73	470	150	70500	47804.27
N_4 I_3 V_3	22695.73	671	150	100650	77954.27

CHAPTER FIVE

5.0 DISCUSSION

5.1 Effect of Season

Generally the performance of the three cotton varieties was generally good with higher yield performance in 2008 than in 2007 and 2009. This could probably be due to relatively higher soil nitrogen content, cation exchange capacity of the soil and relatively higher temperature during the growing period of 2008 dry season as par appendix I and II.

5.2 Effect of Nitrogen

Among the plant nutrients, nitrogen plays a very important role in crop productivity and is an important determinant of the growth and yield of irrigated cotton (Ahmad, 2000). Application of nitrogen increased most of growth parameters of cotton as expressed by the higher values observed in plant height, total dry matter, leaf area index, crop growth rate and number of branches per plant. These increases in growth parameters could be related to the importance of nitrogen as a constituent of protein and also integral component of many other compounds essential for plant growth processes including chlorophyll and many other enzymes. Generally, the effect of nitrogen on growth of cotton is attributed to increases in cell division, cell expansion and increase in size of all morphological parts (Oosterhuis *et al.,* 1983). Besides, Kumbhar, *et al*. (2008), reported higher increases in growth parameters of cotton when using 150 kg N ha^{-1}. The increased total dry matter is the result of vigorous plant growth. This result is in agreement with those of Kumbhar *et al.* (2008) and Rochester *et al*. (2001) that plant height in cotton increases with increase in nitrogen application. Similarly the dry matter was significantly influenced by increasing N levels. Highest N level of 130 kg ha^{-1} gave maximum total dry matter. This significant increase could be attributed to the photosynthetic ability of the cotton crop in the presence of N fertility that resulted in the manufacture of more carbohydrate in the

vegetative parts. Application of nitrogen up to 130 kg ha^{-1} significantly increased LAI and CGR of cotton in all the three seasons. This could be attributed to the well utilization of nitrogen by cotton plant in metabolic and meristimatic activities which resulted in increased vegetative growth and development of the cotton plant. The beneficial effect of LAI on seed cotton yield has been explained in part due to higher supply of photosynthate to the developing bolls and early maturity of bolls. The higher increase in nitrogen rate increased delay in 50% flowering and 50% boll opening. The effect was envisaged due to excessive vegetative growth of cotton crop at the expense of reproductive growth. This is similar to earlier finds reported by Maples and Keogh, (1971). On the other hand inadequate N application resulted in general poor growth and development of cotton and other crops especially cereals, which consequently results in early maturation. Jackson and Faulkner (1962), and Gopalawamy and Palaniswamy, (1974) reported moderate levels of N to increase earliness while higher levels delayed the maturity. Idem (1984) reported that the number of days to 50% flowers was hastened by one day and number of days to boll opening was hastened by three days using lower nitrogen rate.

The number of branches per plant was increased with the increase in the nitrogen application rates. Maximum number of branches was observed in experimental units where 130 kg N ha^{-1} was applied. Nitrogen played its part in the exuberant vegetative growth of the plants, thus cotton branches being vegetative showed better response to the increased nitrogen levels. This result was similar to the findings of Idem (1984), Boquet *et al.* (1993), Swaji *et al.* (1994), Javeed and Anwer (2005), David and Reddy (2007) and Kumbhar *et al*. (2008) who reported maximum number of branches at 150 kg N ha^{-1}, .

The 70 kg N ha^{-1} rate significantly resulted in higher values of cotton yield components. Number of bolls of $plant^{-1}$, boll weight, number of seeds $boll^{-1}$, ginning percentage, lint index

fibre finess and water use efficiency were significantly higher at the 70 kg N ha^{-1} rate. Moderate application of nitrogen enhanced high photosynthetic rate, moisture and nutrient absorption, cell division, cell expansion and differentiations, high LAI early in the season and so high rates of protein synthesis. These processes enhanced the rate of boll development and maturation. Jackson and Faulkner (1962), and Gopalawamy and Palaniswamy, (1974) reported moderate levels of N to increase earliness while higher levels delayed the maturity. Ogunlela (1984) who also reported similar result where increased seed cotton and lint yield by moderate nitrogen rates of 52 kg ha^{-1}. However Ogunwole (2003) reported 90 kg N ha^{-1} to have significantly produced the highest seed cotton yield. Idem (1984) also reported economic optimum level of N at 64 kg N ha^{-1} of seed cotton yield. Results of earlier work seem to suggest that cotton yield respond to nitrogen rates much higher than 70 kg ha. McConnell *et al*. (1993) 112 kg N ha^{-1}, Weir *et al.* (1996) 224 kg N ha^{-1}, Bharambe *et al.* (1997) (100 kg N ha^{-1}), Fritschi *et al.* (2003) 224 kg N ha^{-1}, David and Reddy (2007) (168 kg N ha^{-1}), Kumbhar *et al*. (2008) (150), Majid and Gholani, (2011) 200 kg N ha^{-1} among others. Application rates decisions often must factor in such variables as soil texture and realistic yield goals (McCarthy and Funderburk, 1990). The N requirement uncertainty for optimal cotton yields under different environmental conditions is due to the indeterminate growth habit of cotton and complexity of N cycling in the soil (Gerik *et al*. 1998). Deficiency of N in cotton can reduce both vegetative and reproductive growth and induce premature senescence leading to potential yield loss (Gerik *et al*. 1994). Alternatively, excess N promotes vegetative development often at the expense of reproductive development, especially at bloom or at early boll filling stage (Howard *et al.* 2001). Also Excess N can indirectly affect cotton yield by enhancing aphid infestation and can cause sticky cotton problems because of aphid honeydew secretions. In spite of using high yielding cultivars and the best agronomic

practices the seed cotton yield have not increased substantially. Excess vegetative growth, poor bud development flower shedding, and growth imbalance between the source and sink are responsible for the unpredictable behavior of the crop. The 70 kg ha^{-1} gave the highest water use efficiency because the seed cotton yield was higher at this rate as water use was similar at all rates. Ibragimov *et al.,* (2007) also related higher water use efficiency with increased cotton yield at closer spacing.

Seed oil content was not significantly different with increased N application up to 100 kg ha^{-1} but further increase reduced percentage oil content. Similar result was obtained by Ogunlela and Abed (1984) who reported decreased seed oil percentage in cotton with nitrogen increase rate. Also Sawan et al., (2006) reported similar result where seed oil content of cotton seeds was slightly decreased when additional N was applied. Froment *et al*. (2000) in linseed and Zubillage *et al*. (2002) in sunflower have also reported similar trend. Although nitrogen is an essential nutrient increasing the plant dry matter, as well as many energy rich compounds which regulate photosynthesis and plant production (Wu *et al.* 1998), synthesis of fat which require both N and Carbon skeletons during the course of seed development (Patil, *et al*.1996) may be affected by several environmental and genetic factors.

Seed protein content was significantly increased up to70 kg ha^{-1}. Studies have shown that increases in nitrogen generally increases protein content. Stitt, (1999) indicated that nitrate (NO_3G) induces genes involved in different aspect of carbon metabolism including the synthesis of organic acids used for amino acid synthesis. Higher N-rates increases the amino acids synthesis in the leaves and stimulate the accumulation of protein in the seeds. Sawan *et al.,* (2006) also reported increases in seed protein with N increment.

5.3 Effect of Irrigation Method

Choosing a suitable irrigation method is essential for good irrigation farming to achieve optimum crop productivity and to reduce land and water degradation as well as for better nutrient and pesticide control in crop production. An optimum yield can be obtained with available water by applying best irrigation management practices. Furthermore, a good management and timely application of water may result in prevention of land degradation. The three irrigation methods viz check-basin, border strip and furrow showed significant variation on some growth, yield and yield components of cotton. Check basin and border irrigation methods resulted in taller plants increased total dry matter, LAI, CGR, RGR, number of branches per plant. This may be due to probably longer moisture duration of the check nature of the method, which consequently allowed for enhanced growth of the cotton plant. Also the amount of water that the check basin consumed is higher which gave the cotton plant more advantage for meeting its evaportranspiration demand without much stress, unlike with other methods (furrow and border strip) that retained less water and soon drained down the end exposing the plant to earlier moisture stress. Furrow irrigation method resulted in early flowering and boll opening. This could probably be because of relative shorter moisture duration (mild moisture stress) that stimulated the cotton plant to produce its flowers and opened its bolls earlier. Some of the yield components like number of bolls per plant, boll weight and number of seeds per boll were significantly higher in check basin irrigation. These increases could be associated with the increases in some vegetative characters like LAI, CGR, RGR and number of branches and thus higher accrued dry matter due to moisture availability which later translocated into these yield components. Similar result by Pettigrew, (2001) reported increased irrigation rate increased total number of seeds per boll. In this study the seed cotton yield, lint yield, ginning percentage and

lint index were not significantly influenced by irrigation method. Similar result was reported by Boquet *et al.* (1989), in which irrigation had no effect on seed cotton yield, decreased lint yield and delayed crop maturity by >20 days. McCornell, *et al*. (1989) also reported no single irrigation method gave optimum yield using furrow or Sprinkler irrigation. Also Yuksek and Taskin (1974) and Yavuz, (1993), reported no differences in the yields of cotton with sprinkler and furrow irrigation methods. However Bharambe *et al.* (1997) saving 25 kg N ha^{-1} through drip irrigation compared with conventional method. Cetin (2002) reported that drip irrigation produced 21% more seed cotton yield than the furrow and 30% more than the sprinkler method. Furrow irrigation gave the highest water use efficiency and fibre finess. This could probably be due to the low amount of water use in the method. Similar result was reported by Rana *et al*. (2006) in which higher water use efficiency was recorded by sprinkler, furrow and basin irrigation methods in that order.

5.4 Varietal Response

The cotton growth and development is much influenced by its genetic variability and to some extent environment. Among the cotton varieties tested in this study, SAMCOT 13 proved to be superior in most of the growth parameters than either SAMCOT 10 or SAMCOT 11. SAMCOT 13 exhibited taller plant, accrued higher dry matter, CGR, NAR, thus gave it a competitive advantage of producing more branches. However, it took longer days to attain 50% flowering and boll opening than the other two varieties. These higher growth values could be ascribed to its genetic make-up which differentiated between the other varieties. The delay in reaching 50% flowering and boll opening exhibited by SAMCOT 13 could also be related probably to its longer growth cycle. Higher seed cotton and lint yield was exhibited by

SAMCOT 13 probably because of its higher values in some of its yield components. The variety produced more number of bolls per plant, number of seeds per boll, heavier boll weight, higher ginning percentage and fibre finess than the other two varieties. The higher percentage of protein content of SAMCOT 13 could probably be related to its inherent genetic make-up in efficient utilization of nitrogen for manufacture of amino acid which is the building block of protein. SAMCOT 13 had the highest water efficiency. This could probably be due to its higher seed cotton yield productivity.

5.5 Interaction Effect.

5.5.1 Nitrogen and irrigation method

Irrigation and nitrogen managements are two aspects of successful cotton production. The significant interaction between nitrogen and irrigation method revealed the importance of these factors in influencing cotton growth and development. The interaction of nitrogen rate and irrigation method on some growth parameters could probably due to the response of cotton plant to different moisture regimes in the irrigation methods as nitrogen fertility varied. The importance of moisture regimes influenced the effective transport of nitrogen ions from soil up the plant for photosynthesis and dry matter accumulation which is translocated for various growth and yield components of the plant. The interaction of nitrogen rate and irrigation method on 50 percent flowering and boll opening was probably due to the effect of two factors that encouraged the vegetative growth. This invariably increased the number of potential fruiting forms (number of boll per plant, boll weight) due to abundance of water in check-basin method which lengthened the boll development period and therefore affected cotton maturity. Similar reports by Ritchie *et al.* (2004) and Feng *et al*. (2011) that increased soil water may reduce

maturity. However interaction of N and irrigation method on some yield components like number of bolls plant^{-1}, boll weight and seed cotton yield occurred at lower N (70 kg N ha^{-1}) using check basin method, compared to higher N that might have led to excessive vegetative growth at the expenses of yield and yield component.

5.5.2 Irrigation method and variety

The cotton varieties significantly showed varied response to the applied irrigation methods. The interaction was pronounced on plant height, LAI, number of bolls and seed cotton yield per hectare among the three varieties. This indicated the significance of moisture on growth, development and yield of cotton plant. It also showed the complimentary role of exhibited by these factors on both vegetative and reproductive growth of the cotton plant. This could be attributed to the variability of cotton genotypes that could be related to their inherent genotypic characteristic and available soil moisture to promote vigorous foliage growth, increased meristimatic and physiological activities in the plant thereby enhancing the manufacture of more photosynthates which is translocated for higher yield. The moisture regimes of each method varied significantly thus affecting crop growth and development. Physiological and morphological differences among cultivars influence the impact of moisture regime on yield and fibre quality (Mert, 2005). Feng *et al.* (2010) reported irrigation x cultivar interaction variability in some yield components among three cultivars tested, suggesting that a variety could be more sensitive to environmental changes than the other.

5.5.3 Nitrogen and variety.

The interaction of nitrogen levels and cotton varieties signifies the important of the two factors in affecting growth and development of the crop. All the three varieties significantly responded to increasing nitrogen level. Linear response was observed by the varieties in total

dry matter accumulation and 50% boll opening. Highest dry weight was exhibited by SAMCOT 13 with more response at 130 kg N ha^{-1}. The role of nitrogen in promoting vegetative growth has led to high dry matter accumulation combined and has significantly delayed crop maturity of all the varieties. This was more pronounced by SAMCOT 13 at 130 kg N ha^{-1}. However lower N rate of 40 kg ha^{-1} stimulated early boll opening probably due to induced relative nutrient stress. Polynomial response was shown by all the varieties on number of bolls and seed cotton yield by increasing N rate. All the varieties had their highest yield at 70 kg N ha^{-1} with SAMCOT 13 having the highest seed cotton yield over others probably because of its higher values of some of its yield components. This suggests that in nitrogen management realistic yield goal should be targeted rather than maximum yield, especially with regard to cotton genotypes and environment.

5.6 Regression Analysis

A polynomial response was observed when nitrogen rate was regressed against seed cotton yield. The optimum for nitrogen rate observed for 2007, 2008 and 2009 dry seasons and combined were 94.0, 94.3 90.7 and 93.0 kg ha^{-1} respectively.

5.7 Correlation and Path coefficient Analysis

5.7.1 Correlation

Positive and significant correlations were obtained between seed cotton yield and growth parameters such as total dry matter, LAI, NAR and number of branches. This could be related to the fact that these growth attributes are important factor for photosynthetic activity and translocation of assimilates towards final yield of seed cotton. Similarly, significant and positive correlations were also observed between the seed cotton yield and some yield component such as number of bolls, boll weight and number of seeds. This could be explained on the fact that these

parameters are important yield determinants. Similar results were reported by Rouf *et al.* (2004), Aujla *et al*. (2006), Salahuddin *et al*. (2010), Baloch *et al*. (2011).

5.7.2 Path Coefficient Analysis

The path coefficient analysis of seed cotton yield revealed that the highest direct contribution by growth parameters to seed cotton yield was by leaf area index at combined analysis. This explained the importance of cotton leafiness in tapping more photosynthetically active radiation for assimilate production which will later be translated into seed cotton yield. This finding agrees with Valero *et al*. (2005) who reported that a high crop growth rate resulting from high LAI, NAR or combined of both tends to lead to high yield. An analysis of direct contribution of yield characters to seed cotton yield showed that the highest contribution was made by number of seeds per boll. This is due to the fact that the lint fibres arises directly from the seeds, thus increase in seed number resulted in higher seed cotton fibres which led to higher yield. Therefore these growth and yield characters could be used as breeding tool in increasing seed cotton yield.

5.8 Cost Benefit Analysis

The research result shows that highest gross margin of ₦ 103638.30 was realized from planting of SAMCOT 13 cotton variety under border strip irrigation method at 70 kg N ha^{-1}. It is followed by same treatment but under check basin irrigation method (₦ 102,588.30). This could be related to the fact that border strip irrigation requires less money during land preparation compared to check basin that require extra money for construction of checks. The lowest gross margin of ₦ 34,609.27 comes from planting of SAMCOT 10 under check basin using lower nitrogen rate. This may be as a result of more money spent on construction of checks coupled with use of low nitrogen.

CHAPTER SIX

6.0 Summary and Conclusion

A three year field research was conducted during the dry seasons of 2007, 2008 and 2009 at the Research Farm of the Irrigation Research Station of the Institute for Agricultural Research, Kadawa (11^0 39'N, $08^0$2'E), 500m above sea level to determine the response of cotton (G*ossypium hirsitum* L.) varieties to irrigation methods and nitrogen fertilization. The treatments consisted of three irrigation methods (furrow, check-basin and border strip), four nitrogen fertilizer rates (40, 70,100 and 130 kg N ha^{-1}) using three cotton varieties (SAMCOT 10, SAMCOT 11 and SAMCOT 13). A split-plot design was used with nitrogen and irrigation method assigned to main plot while cotton variety was allocated to the sub-plot. The treatments were randomized and replicated three times.

The results revealed that SAMCOT 13 exhibited superior growth and yield performance in most of the parameters measured than the other two varieties such as dry matter production, leaf area index, crop growth rate, net assimilation rate, number of branches per plant, number of bolls per plant, boll weight, number of seeds per boll, seed index, percentage oil content of cotton seed, seed cotton per ha, lint yield and water use efficiency. Increasing nitrogen rates significantly increased growth parameters like plant height, total dry matter, leaf area index, CGR and number of branches per plant but significantly delayed to 50% flowering and boll opening. The water use efficiency, seed cotton yield and most of the yield components were significantly increased with application of 70 kg N ha^{-1} but further increases resulted in significantly lower values.

Seed cotton yield had positive and significant correlation with total dry matter, LAI, number of branches per plant, days to 50% flowering and boll opening, number of bolls per

plant, boll weight and number of seeds per boll. Check-basin irrigation method resulted in increased most of growth and yield parameters however, furrow irrigation method gave the highest water use efficiency. Path analysis indicated that the highest contribution to seed cotton yield by growth parameters was through total dry matter and leaf area index while highest contribution by yield components to seed cotton yield was through boll weight and number of seeds per boll. Polynomial responses of seed cotton yield to varied nitrogen rates showed a quadratic response with regression analysis result showing 92.9 kg N ha^{-1} as the optimum rate for seed cotton yield during combine.

Significant interaction between irrigation method and N rates showed that all the three methods resulted in higher seed cotton yield at 70 kg N ha^{-1}. The three cotton varieties observed similar trend. However significant interaction between cotton varieties and irrigation methods indicated that SAMOT 10 and 13 performed better in any of the irrigation method while SAMCOT 11 performed better in either furrow or check basin.

The partial economic analysis showed that it is more economical to apply 70 kg N ha^{-1} to SAMCOT 13 cotton variety under border irrigation method.

Based on the results obtained from this research, it can be concluded that the use of SAMCOT 13 and 93 kg N ha^{-1} using border strip irrigation method are recommended for increased seed cotton yield in Kadawa. However, 70 kg N using furrow irrigation resulted in highest quality parameters of cotton varieties.

Further studies on irrigation frequency, sowing date and plant population effects on cotton development especially during dry season might be necessary to achieve a realistic yield goal.

6.1 Recommendation

1. It is hereby recommended to apply 93 kg nitrogen fertilizer per hectare for maximum seed cotton yield under irrigation condition preferably using SAMCOT 13.
2. The use of border strip irrigation method is recommended for higher yield of cotton and net return.

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APPENDICES

Appendix 1. Physico-chemical analysis of experimental soils at Kadawa 2007-2009 dry Season.

Soil properties	**2007**	**2008**	**2009**
Sand ($g\ kg^{-1}$)	610	490	570
Silt ($g\ kg^{-1}$)	250	300	270
Clay ($g\ kg^{-1}$)	140	210	160
Textural class	Sandy loam	Sandy loam	Sandy loam
pH in water (1:2:5)	6.7	6.4	6.4
pH in $CaCl_2$ (1:2:5)	6.3	6.0	5.7
Organic carbon ($g\ kg^{-1}$)	0.44	0.35	0.46
Available phosphorous ($mg\ kg^{-1}$)	2.23	5.64	2.70
Total Nitrogen ($g\ g^{-1}$)	0.14	0.21	0.16
Exchangeable bases (c mol g^{-1})			
Ca	4.97	5.31	5.12
Mg	0.38	0.72	0.49
K	0.10	0.15	0.12
Na	2.80	2.30	2.58
Exchangeable acidity(H+ Al)	-	-	-
CEC	7.90	8.20	8.07

Analyzed at Soil Science Department, Faculty of Agriculture, A.B.U. Zaria.

Appendix 1: Some Meteorological data of the experimental site for 2007-2009 dry seasons

		Temperature (^{o}C)						**Relative humidity**					
		Maximum			**Minimum**			**Maximum**			**Minimum**		
Month	Days	**2007**	**2008**	**2009**	**2007**	**2008**	**2009**	**2007**	**2008**	**2009**	**2007**	**2008**	**2009**
January	1-10	31.3	33	24	10.0	16	15	69.3	50	65	19.6	NA	NA
	11-20	29.3	32	26	12.0	15	20	45.6	49	62	21.5	NA	NA
	21-31	NA	31	26	NA	13	18	NA	51	54	18.1	NA	NA
February	1-10	38.3	36.3	31.6	17.3	16.2	19.7	34.3	32.0	35.2	18.8	18.0	16.8
	11-20	34.7	35.9	31.6	15.6	19.7	18.2	30.8	34.1	36.4	16.8	19.8	17.6
	21-28	35.9	37.1	40.0	14.8	19.5	18.7	32.0	35.8	37.4	16.9	21.6	20.3
March	1-10	34.5	35.8	42.2	15.7	19.2	22.8	29.9	37.1	37.6	16.4	19.8	21.2
	11-20	32.3	38.3	37.6	18.9	19.4	21.4	32.3	36.1	34.9	18.2	21.7	18.1
	21-31	39.4	41.4	42.1	23.3	20.4	20.5	36.2	36.7	36.4	20.3	18.6	18.7
April	1-10	42.8	40.7	41.5	25.7	19.6	19.6	38.3	36.9	36.5	24.4	18.2	18.1
	11-20	41.1	39.1	43.9	23.9	18.6	23.8	36.9	37.5	38.3	21.6	18.7	22.1
	21-30	41.2	40.9	41.1	25.7	22.3	26.6	37.6	37.6	36.1	25.6	20.8	25.1
May	1-10	39.6	46.1	37.4	26.0	26.8	25.1	37.2	38.8	32.9	24.6	23.4	24.2
	11-20	38.4	39.4	41.7	26.6	25.2	25.3	34.8	39.3	37.2	23.7	23.8	24.7
	21-31	40.1	37.6	43.0	26.0	24.1	25.9	35.9	37.9	36.0	25.1	22.6	22.5
June	1-10	36.8	40	34	24.6	24	24	NA	NA	NA	43.1	NA	NA
	11-20	37.1	42	31	23.8	25	24	NA	NA	NA	44.1	NA	NA
	21-30	35.3	37	31	24.7	28	24	NA	NA	NA	50.7	NA	NA

Source: Meteorological Unit, IAR/ABU, Zaria

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