RESPONSES OF COTTON (*Gossypium hirsutum* L.) TO SUPPLEMENTARY IRRIGATION AND NITROGEN FERTILIZER RATES

BY

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DECLARATION

I hereby declare that this thesis has been written by me and that it is a record of my own research work. It has not been presented before in any previous application for a higher degree.

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CERTIFICATION

This thesis entitled "RESPONSES OF COTTON (Gossypium hirsutum L.) TO SUPPLEMENTARY IRRIGATION AND NITROGEN FERTILIZER RATES BY MUHAMMED JIKA, meets the regulations governing the degree of Master of Science of Ahmadu Bello University, Zaria and is approved for its contribution to scientific knowledge and literary presentation.

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DEDICATION

This work is dedicated to my grandmother Late Hajja Goggo Daso and my guardian Alhaji Muhammadu Yolde-Pate for their love and encouragement throughout my educational career.

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First of all, I am most grateful to Almighty Allah for giving me the strength, will and ability to write this thesis.

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ABSTRACT

Investigations to evaluate the response of cotton to supplementary irrigation at various stages of growth under different levels of nitrogen were carried out in 1987 at Kadawa Irrigation Research Station, Kano (lat. 11°30'N, Long. 8°30'E).

Supplementary irrigation was given as follows: Pre-sowing irrigation, pre-sowing plus pre-flowering, pre-sowing plus post-flowering and pre-sowing plus pre-flowering plus post-flowering irrigations each at nitrogen levels of 0, 40 and 80 kg/ha.

Growth characters, yield components and yield of cotton were all statistically similar in the irrigated crop but significantly higher than the control. Only one pre-sowing irrigation produced the highest! seed-cotton yield (3,770kg/ha) that was 54% more than the control. Further increase in irrigation levels resulted in reduction of seed cotton yield.

Nitrogen application positively increased vegetative characters, yield components and seed-cotton yield. Application of 40 kg N/ha yielded 3,189 kg seed-cotton per hectare which was 16% higher than the control. There was no significant yield advantage by increasing nitrogen level from 40 to 80kg/ha.

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Chapter 1

INTRODUCTION

The national annual production of cotton fell from as high as 500,000 bales* in 1970 to just over 50,000 bales in 1985, while the national demand is projected to be about 1,500,000 bales of lint by the year 2000 AD (Kumar et al., 1989). A bulk of the Nigerian cotton crop, which is mainly rainfed, is grown in the northern states, extending from 7° 30'N to 13° N latitude (Kumar and Ogunlela, 1982). The area is divided into three major cotton zones, namely: The northern zone comprising Sokoto, Kaduna, Katsina, Kano states and northern parts of Niger state. This zone produces about 60-65 percent of the national production. The eastern zone comprising Bauchi, Borno and Gongola states which produces about 30-35 percent. The southern zone comprising Plateau, Benue, Kwara states and southern parts of Niger state produces the rest.

Most of this area is characterized by pronounced fluctuations in local and seasonal weather conditions among which availability of moisture is by far the most serious constraint imposed on cotton production. Limited amount of rainfall and poor distribution, lack of fertilization coupled with the practice of planting cotton late in the season (July-August) are some of the problems responsible for low cotton

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* 1 bale = 181.4 kg lint net weight.

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yields in the country. Although experimental results from Samaru, Nigeria have established seed-cotton yields of 2.5 - 3.0 t/ha by adoption of recommended crop husbandry practices (Kumar et al., 1982a), average yield of the small farmers is less than 300 kg/ha.

It has been observed that in most cotton regions of the world, supplementary irrigation of rainfed cotton is the most obvious way of raising the ceiling for cotton productivity (Pearson, 1965; Prentice, 1972). This becomes even more important in regions of scanty annual rainfall such as in the sudan and sahel savanna zones. Supplementary irrigation can either be pre-sowing irrigation to boost early seedling growth and establishment, or rainfall can be supplemented by irrigation whenever a prolonged drought occurs.

Various irrigation schemes in the country, when fully developed by 1991, may irrigate about 345,000 hectares and approximately half of this land area will go for wheat production and the other half will be put to the production of vegetables, rice, cotton and sugar cane (Kumar and Owonubi, 1987). Cotton-wheat rotation is one of the cropping systems successfully tried under irrigation at Kadawa (Kumar et al., 1983; 1984). The recent emphasis on the integration of rainfed and irrigated agriculture to boost the country's total agricultural production therefore affords

a great potential for supplementary irrigation of rainfed cotton especially in the main irrigation schemes of the various River Basins. This provides a considerable potential for increasing cotton production to meet a higher proportion of the raw-cotton demand of the nation's textile industries as well as provide attractive financial returns to the farmers.

Several studies on response of early-sown and late-sown rainfed cotton to nitrogen fertilizaation have been conducted (Kumar et al., 1982a; Ogunlela et al., 1982) but no attempt was made on the nitrogen response of early-sown cotton under supplementary irrigation. There is therefore the need to study the effect of nitrogen and irrigation on productivity of cotton. The present investigation was undertaken with the following objectives:

i) To study the effects of supplementary irrigation at various stages of cotton growth on growth and yield of cotton.

ii) To study the effects of various ratesof nitrogen application on growth and yield of cotton.

iii) To investigate the interaction between supplementary irrigation at various stages and nitrogen levels on growth and yield of cotton.

Chapter 2

LITERATURE REVIEW

2.1 Role of Water in Plants

Several functions of water in plant have been established (Russell, 1959; Kramer, 1963). Water is a major constituent of plant tissue, a reagent in photosynthetic and hydrolytic processes and a solvent for and mode of translocation of metabolites and minerals within plants. Water also acts as heat sink during transpiration and cools plants. Water is responsible for maintaining sufficient turgidity for growth of cells and maintenance of form and position of leaves and new shoots (Kramer, 1963; Elliot et al., 1968).

According to Michael (1978) over 98% of the water absorbed by plants is lost in transpiration and failure to replace these losses in time results in loss of turgidity, cessation of growth and eventual death of the plant. Replacement of these losses may come from one or a combination of the following sources: (i) irrigation water, (ii) effective rainfall and (iii) soil profile contributions.

2.1.1 Cotton crop water requirement

Crop water requirement is defined as the quantity of water (regardless of its source) required by a given crop in a given period of time for its normal growth under field conditions at a place (Michael, 1978). This amount includes all losses due to evapotranspiration plus the losses during

application of irrigation water (unavoidable losses) and the quantity required for special operations (e.g. land preparation, leaching, transplanting, etc.)

Manning (1957) pointed out that under rainfed conditions at Samaru, only cotton sown between May and June had a reasonable expectation of a total seasonal water supply of between 765 mm and 667.5mm to satisfy optimum crop water requirement. Lea et al. (1965) gave the total average water requirement of irrigated cotton in Swaziland as about 30" (750mm) net. Wali and Hanif (1979) in Faisalbad, Pakistan found that planting cotton in mid-May and completion of its irrigation needs by the 1st week of October, appeared to be the best practice for obtaining the optimum yield of seed-cotton. Prolonging irrigation beyond this period was observed to be un-economical and a wasteful practice in regions receiving 250-500mm rainfall during its growing period.

Number of irrigations and total amount of water applied depend largely on the time of the year and the evaporative demand of the environment. While Waheed et al. (1980) reported that upto four irrigations were required to mature a cotton crop successfully in Pakistan, only one pre-sowing irrigation is reported to have significant positive effect on seed-cotton yield of May-sown cotton crop at Kadawa, Nigeria (Kumar et al., 1983; 1984).

Tharp (1960) quoting work on cotton in Texas gave figures for water use(as less than 2.5 mm/day in the early stages of growth (up to day 45 from planting); 2.5 - 6.0mm/day from day 45-75, and 6-10 mm/day from day 75-120. Kumar and Ogunlela (1982) in a graphical representation of crop water use for cotton, estimated that the consumptive use of water for cotton between 0-47th day after planting was 1-3 mm/day; 3-5mm/day from 47th - 77th day; it then gradually increased to a maximum of 5-8 mm/day from day 78 -127th and rapidly dropped from 8 to less than 1 mm/day during the period 128th day to maturity.

2.1.2 Irrigation schedules and growth stages of cotton

Lea et al. (1965) gave five stages of cotton growth from planting to maturity as follows:- Germination stage (0-1 week), establishment stage (1-6 weeks), vegetative stage (6-12 weeks), boll development stage (12-17 weeks) and maturation stage (20-23weeks). He then referred to stages (iii) and (iv) as main growth stages comprising of (a) expansion in leaf area, and (b) elongation of stems, branches and flower bud formation.

Based on the above growth stages, he found that the peak demand for water by the crop was 13th-14th weeks after sowing (i.e. during heavy boll development) and suggested that soil available moisture at this period should not be allowed to go down below 50%.

For the purpose of irrigation scheduling, the growth stages of cotton include pre-planting (pre-sowing), pre-flowering and post-flowering (maturation).

2.1.2.1 Pre-sowing irrigation

Since early root development of cotton is extensive, irrigation at this stage is important unless rainfall has brought the soil to field capacity to a depth of one metre (Hagan et al., 1967). This will ensure good germination and rapid growth, it will also maintain a favourable salt balance in the soil. Moisture is also stored in the root zone for use later in the growing season (Christidis and Harrison, 1955; Elliot et al., 1968; Michael, 1978).

2.1.2.2 Pre-flowering irrigation

Rate of water use at this stage is very low, totalling about 10% of the total water use. Vegetative growth rate at this stage is slow, averaging about 20mm/day in terms of plant height (Hagan et al., 1967; Kumar and Ogunlela, 1982).

In the San Joaquin Valley of California, research results have shown that two irrigations may be required for normal growth at this stage (Hagan et al., 1967) while under Israeli conditions, Levin and Shmueli (1964) concluded that the first irrigation can be delayed until flowering provided the main portion of the root zone (0-76.2 cm depth)

did not fall below 50% available soil moisture. Michael (1978) contended that it is desirable to maintain available soil moisture above 50% in the upper 45-75 cm of root zone during this period.

2.1.2.3 Flowering stage irrigation

This is the period of most rapid growth and development, when root density is near maximum, leaf area is at maximum and air temperature is also high, so 50% or more of the total water use occurs during this period (Elliot et al., 1968). Irrigation at this stage is determined by soil water holding capacity, rooting depth, degree of plant cover and evaporative demand of the environment (Hagan et al., 1967). He suggested that irrigation be scheduled to control vegetative growth in relation to reproductive growth. Levin and Shmueli (1964) observed that moisture stress during this period from onset of flowering reduced yield more drastically than similar stress occuring after peak period of flowering.

El-Morshidy et al. (1981) in Egypt, obtained highest number of fruiting branches with irrigation at 50% field capacity during flowering. Mikosvki et al. (1971) reported positive correlation between water supply during the period between flowering and start of boll formation and number of bolls retained and subsequently harvested per plant.

2.1.2.4 Post-flowering irrigation

Water during this stage is only needed for fibre and seed development and therefore, about 16% of the total water use is required (Christidis and Harrison, 1955; Hagan *et al.*, 1967). Soil moisture levels maintained during previous period is usually adequate and if it becomes necessary to irrigate at this stage, irrigation intervals are increased (Micheal, 1978).

2.1.3 Effects of different norms of irrigation on growth, yield components and seed cotton yield.

Christidis and Harrison (1955) reviewed some work carried out at Sindos (Greece) in 1943 which showed that withdrawing water after a large number of bolls have formed, proved distinctively injurious to yield. Further experiments at Sindos in 1945 and 1946, led to similar conclusions. Datsur and Sinha (1943) in India reported that heavy watering of cotton on a light sandy soil neither affected the production of flowers nor number of bolls, however it increased significantly the height through the elongation of internodes, and yield through increment in boll size. Results of trials in Uzbekistan (USSR) gave highest yields of seed-cotton with 6,000 - 7,000 m^3 of water per hectare in seven irrigations (1-2 irrigations upto the budding stage, 4-5 irrigations upto the end of flowering and one irrigation during maturing (Domullodzhanov, 1976). Further increase in

number of irrigations or norms delayed maturation and reduced yield at first picking.

Aminov (1976) obtained highest yields on grey sernozem soils with irrigation norms in which pre-sowing moisture contents were maintained at 65% of field capacity upto flowering, 70% during flowering and 65% during maturation. In this treatment, one irrigation upto flowering, four irrigations during flowering and one irrigation during maturation were applied. In South Africa, highest yields of 2.62 t/ha seed cotton was obtained with only 2 irrigations (Dippenaar, 1977). Yields were 23-26% higher than that of rainfed cotton and equal to that of cotton irrigated four times, although the latter maintained highest growth rate and produced tallest plants.

Response of cotton yield to different moisture regimes was also reported by El-Nahal et al. (1979) in Egypt where irrigation at 60% available soil moisture depletion (AMD) was found to be most favourable to seed cotton yield; irrigation at 90% AMD was less favourable to seed cotton yield and irrigation at 30% AMD was most favourable to stalk yield.

2.2 Role of Nitrogen in Cotton Production

Cotton nutrient studies have shown that of the principal nutrient elements, cotton needs nitrogen the most, followed by potash and phosphorus in ratios ranging from 5:2:3 to 10:3:9 of NPK, respectively (Christidis and Harrison, 1955).

Nitrogen is a constituent of all amino acids and nucleic acids and hence of all protoplasm (Russell, 1973). Cotton also requires fairly large quantities of the secondary nutrient elements like calcium, magnesium and sulphur. Other trace elements like Cu, Mn, Zn, Fe, and B are also required by cotton for normal and healthy growth (Hayat et al., 1979).

Nitrogen in addition to its role in the formation of proteins is an integral part of the chlorophyll molecule (Tisdale and Nelson, 1975). According to Elliot et al.(1968) as much as 85% of the leaf nitrogen is translocated out of the leaves into the developing bolls as they approach senescence. Similarly Oosterhuis et al. (1983) reported that cotton seed and lint contained 42% of the total above ground nitrogen at maturity. Nitrogen application in cotton therefore encourages plant growth which leads to increase in flowering and fruiting sites, increase in the duration of peak fruiting period and net assimilation rate, all of which result in increased seed cotton yield (Gardner and Tucker, 1967; Elliot et al., 1968). The beneficial effects of nitrogen to cotton crop have also been reported by several workers (Mackenzie and Van Schaik, 1963; Hayat et al., 1979; Idem, 1984 and Anon., 1987). Excessive rates of nitrogen however, is reported to increase the susceptibility of crops especially

cotton to insect and pathogen damage thereby reducing yield and quality (Pearson, 1965).

Deficiency of nitrogen in cotton according to Memon et al. (1975) becomes evident by the stunted growth of the crop with chlorotic leaves and poor root system. Sawhney and Sikka (1960) reported that 22.4 kg N/ha was optimum for rainfed cotton and 45-67 kg N/ha for irrigated cotton. Garg (1964) also gave 45 kg N/ha as optimum dose for cotton, while Hayat et al. (1979) in Pakistan noted that yield of cotton increased with each successive increment of 33.6 kg N/ha upto 101 kg N/ha after which a fall in yield was observed.

In Nigeria, Kumar and Ogunlela (1982) reported that an early planted cotton crop grown under improved management, yielding 1.5 - 2.0 t/ha of seed cotton requires 80-100 kg N/ha. Part of this quantity is met from the soil and the remaining N needs is to be added as fertilizers and manures. Ogunlela et al. (1982) reported significant yield response upto 52 kg N/ha by cotton in the Nigerian Savanna.

2.2.1 Nitrogen uptake by cotton at different growth stages

Olson and Bledsoe (1942) in Georgia found that the cotton crop on one acre of land cotains 130 lbs of nitrogen. They gave the percentage of total nitrogen utilized at each of the four growth stages as 4.4% from planting to seedling stage; 12.8 % from seedling to early square; 43.3% from early square to boll formation stage; and 39.5 % from early boll stage to

maturity. In a similar analysis, Kumar and Ogunlela (1982) gave figures of 20% from seedling to early square stage; 45% from flowering to early boll stage and 35% from early boll stage to maturity. These two studies therefore indicate that around 80% of the total nitrogen uptake by cotton occurs during the reproductive phase (i.e. at 8-25 weeks after sowing).

2.2.2 Effects of nitrogen levels on growth, yield and yield components of cotton

Increase in plant height, total dry matter production/plant, seed cotton yield and yield components such as number of bolls/plant, seed cotton weight/boll and number of seeds/boll with increase in nitrogen application have been reported. Ogunlela et al. (1982) reported increase in yield and yield components of cotton with increasing nitrogen rates in which seed cotton yield was mainly influenced through increase in boll number/plant. Working with normal and okra leaf type cottons in the northern and southern cotton growing zones of Nigeria, Idem (1984) obtained positive and significant influence of nitrogen on yield and yield components such as number of bolls/plant, average boll weight and number of seeds/boll.

Anon (1987) reported significant yield response upto 60kg N/ha in Samaru, where seed-cotton yield of 2110, 2401, 2514 and 2543 kg/ha were obtained with 0, 30, 60 and 90 kg N/ha, respectively. Yield components such as seed cotton yield/plant, number of bolls/plant and weight/boll responded similar to seed

cotton yield/ha. Hayward (1972) working on late sown cotton in Nigeria however, reported that nitrogen application to July sown cotton may even decrease yield, probably as a result of pest damage and moisture stress.

A combination of high nitrogen levels, frequent irrigation or excess rainfall and high temperatures result in excessive rank growth in cotton with longer internodes and fewer bolls/plant (Eaton and Ergle, 1957). Rank growth according to Pearson (1965) will encourage crop lodging and boll rot, and at the same time render the crop more difficult in pest control and less efficient in harvesting.

Differences in climate, soils, varieties and crop management practices may be responsible for the differences in response of cotton to irrigation and fertilizer nitrogen in the various literature cited.

Chapter 3

MATERIALS AND METHODS

3.1 Experimental Site and Soil

The experiment was conducted during the 1987 wet season at Irrigation Research Station, Kadawa, Kano state (8°30'E and 11°30'N) in the Sudan Savanna ecological zone of Nigeria. The soil of the site varies with depth from sandy loan in the top 20 cm to sandy clay loam from 21-40 cm. The soil reaction is slightly acidic with a pH of 6.0, moderate supply of potassium and phosphorus; low in nitrogen and organic matter.

The field which received normal rainfall (748 mm) in 1987, was cropped with tomatoes during the 1986 rainy season and fallowed during the 1986/87 dry season. Details of the physico-chemical properties of the soil and meteorological data for the site are presented in tables 1 and 2,respectively.

3.2 Treatments

There were 15 treatments combinations tested comprising of five irrigation treatments and three nitrogen levels as shown below:

Table 1 Physico-chemical properties of the top 40cm of soil of the experimental site at Kadawa, May 1987.

Physical Properties	0-20cm	21-40cm
Particle size		
Clay %	19	23
Silt %	28	28
Sand %	53	49
Textural class	sandy loam	sandy clay loam
Chemical Properties		
pH (1:2.5 H_2O)	6.10	6.00
pH (0.01M $CaCl_2$)	5.80	5.70
% Organic Carbon	0.25	0.28
% Nitrogen	0.021	0.021
Available P (ppm)	4.20	3.07
Exchangeable bases (meq/100gm soil)		
Ca	3.19	3.83
Mg	0.65	0.85
K	0.20	0.20
Na	0.115	0.115
C.E.C. (meq/100gm soil)	6.50	8.30
Water Relations		
Field capacity (-0.3 bar)	26.62% W/W	
Permanent wilting percentage (-15 bar)	13.44% W/W	

Table 2 Meteorological data for Irrigation Research Station Kadawa, 1987

Month	Rainfall (mm)	Windspeed (km/hr)	Pan Evap. (mm/day)	Temperature (°C) max.	Temperature (°C) min.	Relative Humidity (%)
January	-	134	6.8	29.8	12.2	48.6
February	-	132.2	7.9	32.1	15.7	47.6
March	-	144.1	8.9	34.6	19.7	52.1
April	-	176.6	11.1	36.4	21.1	41.0
May	35.0	214.3	12.3	39.3	23.7	54.3
June	76.1	189.8	6.6	34.3	22.9	76.9
July	285.9	171.1	5.9	31.8	21.8	79.7
August	233.2	128.1	6.0	30.0	21.7	85.7
September	69.1	108.5	5.5	32.2	21.3	82.1
October	49.3	100.8	6.1	33.1	19.5	69.9
November	-	115.1	6.2	32.6	13.6	57.3
December	-	131.4	5.4	28.7	12.6	50.1
Total	748.6mm					

Source: Meteorological Section, IAR/ABU, Samaru Zaria.

3.2.1 Irrigation treatments

I_0 = Rainfed (planted on 4th July, 1987).

I_1 = Pre-sowing irrigation only (155mm water depth applied on 26-5-87).

I_2 = Pre-sowing irrigation (as in I_1) + one pre-flowering irrigation (106mm applied on 9-7-87).

I_3 = Pre-sowing irrigation (as in I_1) + one post-flowering irrigation (100mm applied on 9-9-87).

I_4 = pre-sowing + one pre-flowering + one post-flowering irrigation.

3.2.2 Nitrogen levels (kg/ha)

N_0 = 0

N_1 = 40

N_2 = 80

Each of the above rates was split applied in two equal doses at 3 and 8 weeks after sowing.

3.3 Experimental Design and Plot Size

The 15 treatment combinations were laid out in a split plot design with irrigation as main plots and nitrogen levels as sub-plots. The treatments were replicated 4 times giving a total of 60 plots. The main, sub and net plot sizes were 48.6m^2, 16.2m^2 and 8.1m^2, respectively.

3.4 Cultural Practices

3.4.1 Land preparation

The land was ploughed and harrowed once. Soil samples were taken before ploughing at two depths of 0-20cm and 21-40cm. The field was then ridged 90cm apart. Sixty plots of 4 ridges (4.5m long) each were marked out.

3.4.2 Sowing

Dressed cotton seed of the recommended variety Samaru 71 was sown manually on the shoulders of the ridges at the rate of 5-6 seeds per hill 45 cm apart. Seedlings were then thinned to two plants per stand at three weeks after emergence.

3.4.3 Fertilizer application

Boronated superphosphate (19% P_2O_5; 0.53% B) fertilizer was incorporated at the rate of 25 kg P_2O_5 + 0.7 kg B/ha before ridging. Nitrogen fertilizer in the form of calcium ammonium nitrate (CAN) (26% N) was split applied as per the treatments. The fertilizer was applied 5 cm away from the seed in grooves and covered with hoe.

3.4.4 Irrigation

The furrow method of irrigation was used in this trial. Water was released from the field channel into the furrows of

plots to be irrigated according to treatment. Remoulding of ridges and clearing of furrows was maintained at each weeding operation in order to facilitate smooth irrigation and drainage of excess water out of the field.

Soil samples were taken at 0-20, 21-40 and 41-60cm depths before and after irrigation for determination of soil moisture content.

3.4.5 Weed control

Weed control was done by handpulling and hoe-weeding as and when necessary. The types of weeds most prevalent during the season are presented in Table A2.

3.4.5 Pest control

Cymbush super ED (Cypermethrin with dimethoate) was sprayed at the rate of 0.5 l/ha using Electrodyn sprayer from the on-set of flowering to maturity depending upon observed field situation (Table A2). Bool-worm larvae (*Earias* spp) were the first early season pests observed in the cotton field followed by cotton leaf rollers (*Sylepta derogata*) in the late season.

No incidence of diseases were noted in any of the plots throughout the season.

3.4.7 Harvesting

First picking was done at 20 weeks after sowing(WAS) for the irrigated crop and 18 WAS for the control crop when an estimated 60-70% of the bolls were opened. Harvesting was completed with two additional pickings at 2 and 4 weeks after the first picking.

3.5 Data Collcetion

Five plants were tagged randomly from each plot for the measurement of various parameters such as plant height; number of nodes; number of seeds/boll; lint weight/ boll; seed weight/boll and 1,000 seed weight. Other observations taken earlier include stand count at thinning; days to 1st flowering; days to 50% flowering; days to 1st boll opening and days to 50% boll opening.

3.6 Data Analysis

The data were subjected to statisticaly analysis and the means were compared using Duncan Multiple Range Test (DMRT) (Duncan, 1955) at 5% level of probability. Correlation was also done on selected parameters.

Chapter 4

RESULTS

4.1 Growth Characters

4.1.1 Stand count at thinning

Plant population was fairly uniform irrespective of irrigation, with average of about 37,000 plants/ha (60 plants/plot) for the irrigated crop and 32,700 plants/ha (53 plants/plot) for the control (Table A1). These counts were taken before the nitrogen treatments were applied, and nitrogen levels had therefore no effect on stand count at thinning as would be expected. The low number of plants per plot recorded was as a result of poor germination obtained even after gap filling.

4.1.2 Days to flowering and maturity

The irrigated crop did not flower until 49 days after planting but the control flowered in 45 days. Similarly, days to first boll opening were 107 and 98 days after planting for the irrigated and the control treatments, respectively. Nitrogen levels had no effect on days to flowering or days to first boll opening.

4.1.3 Plant height

Plant height at first picking is presented in table 3. Although plant height increased with increasing irrigation levels, the only significant difference in height was between

Table 3 Effects of supplementary irrigation at various stages of growth and nitrogen levels on plant height and total dry matter/plant at first picking of cotton at Kadawa,1987.

Treatments	Plant height (cm)	Total dry matter/plant (gm)
Irrigation		
Control	76.17b[1]	133.38b
Pre-sowing	127.92a	249.46a
Pre-sowing + pre-flowering	130.75a	213.54a
Pre-sowing + post-flowering	131.50a	212.74a
Pre-sowing + pre-flowering + post-flowering	132.17a	231.12a
SE (±)	4.21	15.02
Nitrogen (kg/ha)		
0	113.20b	169.15b
40	120.20a	216.48a
80	125.70a	238.50a
SE (±)	2.17	13.68

[1]Means followed by the same letter(s) within a column are not significantly different at 5% level.

the control and the other irrigation treatments.

Nitrogen application significantly influenced plant height at first picking. Plant height was significantly increased with the application of 40 and 80 kg N/ha. Increase in plant height resulting from increase in N rate from 40 to 80 kg/ha was however, not significant.

Interaction between irrigation and nitrogen levels was not significant on plant height at first picking.

4.1.4 Total dry matter per plant

Total dry matter production/plant was significantly higher (by 70%) in the irrigated crop than the control (Table 3). The differences in total dry matter/plant among the irrigated treatments were not statistically significant, although plots that received only pre-sowing irrigation produced more dry matter/plant.

Nitrogen application significantly increased total dry matter production. Application of 40 and 80 kg N/ha increased total dry matter/plant by 28 and 41%, respectively over the control. Increase in total dry matter/plant between 40 and 80kg N/ha was not significant.

Interaction between irrigation and nitrogen levels was not significant on total dry matter production/plant at first picking.

4.1.5 Number of green leaves/plant

Number of green leaves/plant at first picking is presented in Table 4. Plants that received supplementary irrigation (I_1- I_4) had significantly more green leaves per plant at first picking than the control (I_0). Irrigation levels had no significant influence on the number of green leaves/plant.

Nitrogen application significantly increased number of green leaves/plant at first picking. Application of 40 and 80 kg N/ha significantly increased leaf number/plant by 40 and 33%, respectively, over the control. No significant difference in leaf number per plant was observed between 40 and 80 kg N/ha.

Interaction between irrigation and nitrogen levels was not significant on number of green leaves/plant at first picking.

4.1.6 Number of nodes/plant

Number of nodes/plant at first picking followed a similar trend as in number of green leaves/plant (Table 4). While number of nodes/plant in the control was significantly lower than the irrigated crop, there were no significant difference among the irrigation levels.

Nitrogen application significantly increased mean node number per plant. An increase of 12% over the control was produced with 40 kg N/ha, but increase in nitrogen rate from

Table 4 Effects of supplementary irrigation at various stages of growth and nitrogen levels on number of green leaves/plant and number of nodes/plant (at 1st picking) of cotton at Kadawa, 1987.

Treatments	Number of green leaves/plant	No. of nodes/plant
Irrigation		
Control	8.17b[1]	21.00b
Pre-sowing	41.58a	24.25a
Pre-sowing+pre-flowering	33.83a	24.33a
Pre-sowing+post flowering	33.25a	23.25a
Pre-sowing+pre-flowering+ post-flowering	33.83a	23.50a
SE (±)	4.14	0.508
Nitrogen (kg/ha)		
0.0	24.60b	22.10b
40.0	34.40a	24.70a
80.0	32.60a	23.00ab
SE (±)	2.25	0.571

[1]Means followed by the same letter(s) within a column are not significantly different at 5% level.

40 to 80 kg N/ha produced no significant increase in node number/plant. Interaction between irrigation and nitrogen levels was not significant on number of nodes/plant at first picking.

4.2 Yield Components and Yield

4.2.1 Number of bolls/plant

Number of bolls/plant at first picking is presented in table 5. Number of bolls/plant in all the plots that received supplementary irrigation were significantly higher than the control by a margin of 87%. No significant differences in number of bolls/plant were observed among the irrigation levels.

Number of bolls/plant responded significantly to nitrogen application. Increase of 29 and 35% in boll number/plant were recorded with 40 and 80 kg N/ha, respectively, over the control. The difference in boll number/plant between 40 and 80 kg N/ha was however not significant.

Interaction between irrigation and nitrogen levels was significant on number of bolls/plant (Table 5). Plants that received no nitrogen showed steady increase in boll number/plant with increasing levels of irrigation upto I_4. Plots that received 40 kg N/ha produced highest number of bolls/plant with only one pre-sowing irrigation

Table 5 Effects of supplementary irrigation at various stages of growth and nitrogen levels on number of bolls/plant of cotton at Kadawa, 1987.

Irrigation	Nitrogen rate (kg/ha)			
	0	40	80	Mean
Control	8.75h[1]	11.75gh	14.75e-h	11.75b[2]
Pre-sowing	14.25e-h	28.50a	24.50abc	22.40a
Pre-sowing+pre-flowering	17.00d-g	19.75c-f	20.25cde	19.00a
Pre-sowing+post-flowering	19.00c-f	23.00a-d	21.50bcd	21.16a
Pre-sowing+pre-flowering+ post-flowering	20.25cde	19.00c-f	26.25ab	21.83a
SE (±)		1.19		1.5
Mean	15.85b[3]	20.40a	21.45a	

1 Nitrogen x irrigation means, 2 Irrigation means, and 3 Nitrogen rates means followed by the same letter(s) within a group are not significantly different at 5% level.

(I_1) and showed a downward trend with further increase in irrigation levels. Plots that received the highest rate of nitrogen (80 kg/ha), however, produced more bolls/plant with the highest irrigation levels. I_1N_1 produced the highest number of bolls/plant.

4.2.2 Mean boll weight

Boll weight was not significantly influenced by irrigation treatments (Table 6). There was no clear trend in the response of boll weight to nitrogen application.

While the 80 kg/ha rate produced heavier bolls than both the control and the 40 kg N/ha rate, the difference between the 80 kg N/ha and the control was not significant. Interaction between irrigation and nitrogen levels was not sitnificant at boll weight.

4.2.3 Seed-cotton weight/boll

Mean seed cotton weight/boll is presented in table 6. Seed cotton weight per boll was significantly higher in the supplementary irrigated crop than the control, but there were no significant difference among the irrigation levels.

Seed-cotton weight/boll did not respond significantly to nitrogen application.

Interaction between irrigation and nitrogen levels was not significant on seed-cotton weight/boll.

Table 6 Effects of supplementary irrigation at various stages of growth and nitrogen levels on boll weight and seed cotton weight/boll of cotton at Kadawa, 1987.

Treatments	Weight/boll (gm)	Seed cotton weight/boll (gm)
Irrigation		
Control	5.96	4.38b[1]
Pre-sowing	6.47	4.91a
Pre-sowing + pre-flowering	6.63	4.94a
Pre-sowing + post-flowering	6.56	4.86a
Pre-sowing + pre-flowering+ post-flowering	6.45	4.95a
SE (±)	0.170	0.12
Nitrogen (kg/ha)		
0.0	6.41ab[2]	4.81
40.0	6.20b	4.63
80.0	6.72a	4.99
SE (±)	0.13	0.116

[1]Means followed with the same letter(s) within a column are not significantly different at 5% level.

4.2.4 Lint weight/boll

Lint weight/boll as shown in table 7, was similar to seed cotton weight/boll. There were no significant differences among the irrigation levels but these were significantly higher than the control.

Lint weight/boll did not respond significantly to nitrogen application.

4.2.5 Cotton seed weight/boll

Cotton seed weight/boll is presented in table 7. Neither the treatments nor their interaction had any significant influence on cotton seed weight/boll.

4.2.6 Number of seeds/boll

Number of seeds/boll remained fairly similar among the irrigated plots (irrespective of irrigation levels) but these were significantly higher than the control (Table 8).

When averaged over irrigation levels, nitrogen application had no significant influence on number of seeds/boll.

Interaction between irrigation and nitrogen levels was significant on number of seeds/boll, although only irrigated plots that received pre-sowing plus post-flowering irrigation (I_3) maintained a steady increase in seed number/boll and produced significantly more seeds/boll (38.5) with 80 kg N/ha.

Table 7 Effects of supplementary irrigation at various stages of growth and nitrogen levels on lint weight/boll and cotton seed weight/boll of cotton at Kadawa, 1987.

Treatments	Lint weight/ boll (gm)	Cotton seed weight/boll (gm)
Irrigation		
Control	1.49 b[1]	2.89
Pre-sowing	1.72a	3.19
Pre-sowing + Pre-flowering	1.75a	3.19
Pre-sowing + Post-flowering	1.72a	3.18
Pre-sowing + Pre-flowering+ post-flowering	1.73a	3.14
SE (±)	0.0356	0.083
Nitrogen (kg/ha)		
0.0	1.68	3.13
40.0	1.60	2.99
80.0	1.76	3.23
SE (±)	0.05	0.081

[1]Means followed by the same letter(s) within a column are not significantly different at 5% level.

Table 8 Effects of supplementary irrigation at various stages of growth and nitrogen levels on number of seeds/boll of cotton at Kadawa, 1987.

Irrigation	Nitrogen (kg/ha)			
	0	40	80	Mean
Control	29.15ef[1]	22.75g	27.70f	26.53b[2]
Pre-sowing	34.75b-e	33.60b-e	34.58b-e	34.31a
Pre-sowing + Pre-flowering	36.15abc	32.65def	35.25bcd	34.68a
Pre-sowing+Post-flowering	34.15b-e	34.80b-e	38.50a	35.82a
Pre-sowing+Pre-flowering+ post-flowering	32.90c-f	36.60ab	33.43b-e	34.31a
SE (±)		1.096		0.74
Mean	33.42	32.08	33.90	

1 Nitrogen x irrigation means, and 2 Irrigation means followed by the same letter(s) within a group are not significantly different at 5% level.

4.2.7 Ginning out turn (G.O.T.)

Ginning out turn (ginning percentage) is presented in table 9. Ginning out turn was significantly higher in the irrigated crop than the control, but there were no significant differences among the irrigated treatments.

Nitrogen application had no significant influence on ginning out turn.

Interaction between irrigation and nitrogen levels was not significant on G.O.T.

4.2.8 Lint index

Lint index is presented in table 9. Lint index remained statistically similar among the irrigated treatments, but significantly lower than the control.

Lint index did not respond significantly to nitrogen application. Similarly, interaction between irrigation and nitrogen levels was not significant on lint index.

4.2.9 1,000 seed weight

Weight of 1,000 seeds is presented in table 10. Significantly heavier seeds were produced by the control crop as compared to the irrigated crop. There were no significant differences in the weight of 1,000 seeds among the irrigated treatments.

Nitrogen application did not significantly influence the weight of 1,000 seeds.

Interaction between irrigation and nitrogen levels was not significant on weight of 1,000 seeds.

Table 9 Effects of supplementary irrigation at various stages of growth and nitrogen levels on ginning out turn (G.O.T.) and lint index of cotton at Kadawa, 1987.

Treatments	G.O.T. (%)	Lint index(%)
Irrigation		
Control	34.02b[1]	5.67a
Pre-sowing	35.08a	5.02b
Pre-sowing + Pre-flowering	35.52a	5.09b
Pre-sowing + Post-flowering	35.15a	4.84b
Pre-sowing + Pre-flowering+ post-flowering	34.88a	5.04b
SE (±)	0.26	0.15
Nitrogen (kg/ha)		
0.0	34.89	5.05
40.0	34.64	5.11
80.0	35.25	5.24
SE (±)	0.417	0.165

[1]Means followed by the same letter(s) within a column are not significantly different at 5% level.

Table 10 Effects of supplementary irrigation at different stages of growth and nitrogen levels on 1,000 - seed weight of cotton at Kadawa, 1987.

Treatments	1,000 seed weight (gm)
Irrigation	
Control	110.05a[1]
Pre-sowing	92.84b
Pre-sowing + Pre-flowering	92.27b
Pre-sowing + Post-flowering	88.80b
Pre-sowing + Pre-flowering+ post-flowering	93.85b
SE (±)	3.35
Nitrogen (kg/ha)	
0 (control)	94.11
40	96.62
80	95.95
SE (±)	2.10
Interation	
I x N	4.70

[1]Means followed by the same letter(s) within a treatment are not significantly different at 5% level.

4.3 Seed Cotton Yield

4.3.1 Seed cotton yield/plant

Seed cotton yield/plant is presented in table 11. The irrigated crop produced seed-cotton yield/plant that was 96% more than the control on the average. Highest seed cotton yield/plant was produced with only one pre-sowing irrigation (I_1) and further increase in irrigation levels resulted in reduced seed-cotton yield/plant although the reduction was not significant.

Seed cotton yield/plant responded significantly to the application of nitrogen. Application of 40 and 80 kg N/ha increased seed-cotton yield/plant by 20 and 41%, respectively, over the control, but the difference in yield/plant between 0 and 40 kg N/ha was not significant. Similarly the difference in yield/plant between 40 and 80 kg N/ha was not significant.

4.3.2 Seed cotton yield/ha

Seed cotton yield/ha which is presented in table 11 followed a similar trend as seed cotton yield per plant. The irrigated crop produced seed cotton yield/ha that was 119% more than the control. Highest seed-cotton yield/ha (3,770 kg) was produced with only one pre-sowing irrigation and further increase in irrigation levels resulted in reduction of seed cotton yield/ha, although the reduction was not significant.

Table 11 Effects of supplementary irrigation at various stages of growth and nitrogen levels on seed cotton yield (gm/plant and kg/ha) at Kadawa, 1987

Treatment	Seed cotton yield (gm/plant)	Seed cotton yield (kg/ha)
Irrigation		
Control	51.92b[1]	1586b
Pre-sowing	108.50a	3770a
Pre-sowing + Pre-flowering	93.97a	3533a
Pre-sowing + Post-flowering	102.56a	3244a
Pre-sowing + Pre-flowering+ post-flowering	102.09a	3345a
SE (±)	8.78	187.7
Nitrogen (kg/ha)		
0.0	76.22b	2755b
40.0	91.54ab	3189a
80.0	107.67a	3345a
SE (±)	5.47	139.4

[1]Means followed by the same letter(s) within a column are not significantly different at 5% level.

Nitrogen application significantly increased seed cotton yield by 16 and 21% over the control with the application of 40 and 80 kg N/ha, respectively.

Interaction between irrigation and nitrogen levels was not significant on seed-cotton yield/ha.

4.4 Correlation

Results of correlation revealed a significant and positive association between seed cotton yield and some growth and yield characters of cotton (Table 12). A highly significant positive correlation was observed between seed cotton yield and plant height ($r = 0.76$); total dry matter/plant ($r = 0.43$) and number of nodes/plant ($r = 0.37$) all at first picking.

Yield components such as number of bolls/plant; seed cotton weight/boll; and number of seeds/boll were also highly significantlynand positively correlated with seed cotton yield. A highly significant but negative correlation was observed between seed cotton yield and 1,000 seed weight ($r = 0.39$).

Table 12 Correlation between seed-cotton yield, and yield components of cotton (Gossypium hirsutu at Kadawa, 1987.

	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11
V1	1										
V2	.627**	1									
V3	.767**	.436**	1								
V4	.466**	.480**	.375**	1							
V5	.678**	.644**	.655**	.470**	1						
V6	.420**	.166	.433**	.208	.184	1					
V7	.454**	.158	.427**	.255*	.237	.935**	1				
V8	.690**	.352**	.621**	.360**	.435**	-.589**	.559**	1			
V9	.250	.017	.165	.213	.219	.194	.513**	.148	1		
V10	-.512**	-.315*	-.392**	-.261*	-.386**	.148	.079	.216	-.175	1	
V11	.707**	.623**	.696**	.481**	.960**	.434**	.467**	.377**	.239	-.286*	1

Key

V1 Plant height at first picking (cm)
V2 Total dry matter/plant at first picking (gm)
V3 Seed cotton yield (kg/ha)
V4 Number of nodes/plant at first picking
V5 Number of bolls/plant
V6 Seed cotton weight/boll (gm)
V7 Lint weight/boll (gm)
V8 Number of seeds/boll
V9 Ginning percentage
V10 1,000 seed weight (gm)
V11 Seed cotton weight/plant (gm)
* Significant at 5% level
**Significant at 1% level

Chapter 5

DISCUSSION

5.1 Effects of Supplementary Irrigation

Total annual rainfall received at Kadawa in 1987 was 748.6 mm falling between May 31st and October. Of this total amount, 69% was recorded between July and August, 16% between September and October, and only 15% from May 31st to the end of June (Table 2). As such, a long favourable growing season resulting from well distributed rains and supplementary irrigation generally increased growth, yield components and seed cotton yield in this study.

The observed increase in plant height at first picking with increase in irrigation levels agrees with report by Datsur and Sinha (1943) and Dippenaar (1977) who reported that heavy watering of cotton produced tallest plants. This is expected since water generally plays an important role in cell expansion and plant growth (Elliot et al., 1968). Datsur and Sinha (1943) also reported that heavy watering in cotton produces taller plants particularly through the elongation of internodes. The general superiority of crop growth in the irrigated treatments over the control could be as a result of the long favourable growing season with adequate moisture which resulted in the production of vigorous plants. This is similar to the findings of Kumar et al. (1983) and Kumar et al. (1984).

The fact that only pre-sowing irrigation has shown consistent though insignificant superiority in yield components such as number of bolls/plant, seed cotton weight/boll, and seed number/boll and in seed cotton yield/ha, indicates that additional irrigation at any stage in the growing season in the absence of an extended drought spell, as in 1987, has no yield advantage in supplementary irrigated cotton. Dippenaar (1977) also reported lack of yield response of cotton to more than two irrigations in South Africa. This result is also in conformity with the findings of Kumar et al. (1983) at Kadawa where 40% seed cotton yield increase was obtained from May-sown crop with only one pre-sowing irrigation over the rainfed June-sown crop. Additional irrigation given at four weeks stage, however, decreased the yield.

The yield decrease resulting from additional irrigation in this study though non-significant, could be attributed to over irrigation, since excepting the pre-sowing irrigation given on 26th May, all other irrigations were given when the rains were well established (Table 2). Apart from the adequate rainfall during this period, depth to water table had also been within 46-60 cm range in mid-August at Kadawa. This may have created an unfavourable root environment as a result of excess water in plots that received additional irrigation above the pre-sowing level. Similar results were reported by Cull et al. (1981) in a two year study on cotton

crop water requirements and response to irrigation. In the first year of their study, no additional yield benefits accrued from subsequent irrigations following a pre-emergence irrigation due to above average rainfall (550 mm) throughout the grow ing season. In the second year, a similar rainfall amount (502 mm) fell but significant increase due to irrigation resulted because of uneven distribution of the rainfall. They concluded that the main effect was associated with later rains which influenced the number of bolls set.

The remarkable superiority in seed-cotton yield and yield components of the irrigated crop over the control in this study, was again mainly due to the relatively longer and favourable growth period with adequate moisture enjoyed by the irrigated crop compared to the shorter growth period with inadequate soil moisture for the control. Similar trends have been reported by Kowal and Faulkner (1975) who observed that the period between the time to first flower and when evapotranspiration exceeds rainfall controls the number of bolls/plant which are eventually retained and harvested. This period they added, is strongly dependent on sowing date and the later the sowing date the shorter the period. Similarly, Milkosvki et al. (1971) reported positive correlation between moisture supply (especially during the period between flowering and start of boll formation) and number of bolls retained on a plant.

Days from first flower to 50% boll opening in this study were 70 and 68 for the irrigated and the control crop, respectively. Out of these days, all the 70 days for the irrigated and only 44 days for the control crop were under adequate moisture conditions (Table 2). Hence fewer bolls were produced and retained by the control crop.

Supplementary irrigation lengthened this crucial period and pushed it into the time of most abundant water supply and optimum mean temperature for growth (Table 2) which resulted in rapid early vegetative and root growth followed by heavy boll production. This rapid vegetative growth and early close of canopy allowed for efficient utilization of solar radiation and acted as an effective means of controlling weeds. As a result, the yield components and seed cotton yield were higher.

During flowering and boll development, the irrigated crop experienced day temperatures of between 30-32°C. This is within the optimum range for cotton during the reproductive phase. Sikka and Datsur (1960) reported day temperature of between 27-32°C and cool nights (18-20°C) as the optimum for cotton during the fruiting period. Similarly, Kumar et al. (1982b) reported that during the reproductive stage, day temperatures of 26-32°C are desirable adding that nights should be cool (18-20°C). While optimum day temperatures promote high photosynthetic rates, cool

nights increase rate of translocation and reduce respiration rates, thus enhancing productivity. Tharp (1960) analysing the role of temperature in enhancing productivity, concluded that yield increase caused by temperature comes mainly from increase in number of bolls produced per unit area. Extension of this period by supplementary irrigation coupled with adequate soil moisture and nutrients, timely weed and pest control (Table A2) resulted in high seed cotton yields in the study area.

The irrigated crop was more efficient in water use than the control (Table A4), with the crop receiving only pre-sowing irrigation having the highest water use efficiency of 4.97 kg seed-cotton per hectare - cm of water.

5.2 Effects of Nitrogen Levels

Cotton vegetative growth characters, yield and yield components all responded to application of nitrogen. The positive response of plant height, number of nodes/plant, number of green leaves/plant and total dry matter/plant at first picking due to nitrogen application was no doubt as a result of nitrogen's role in plantgrowth. Nitrogen being part of the plant protoplasm is particularly associated with meristematic activities and cell differentiation in cotton (Crowther, 1934; Elliot et al., 1968).

Response to applied nitrogen by the cotton crop is also expected with the low soil nitrogen status of the site (Table 1) compared to the average N-value of 0.051% for the Savanna soils (Jones, 1973).

Although plant growth characters increased significantly with nitrogen application over the control, increase in nitrogen rate from 40 to 80 kg/ha did not significantly increase these characters.

Yield and yield components such as number of bolls/plant and seed-cotton/plant were significantly increased by nitrogen application. Increasing N-rate from 40 to 80 kg/ha however, had no significant yield advantage. This could be attributed to the fact that nitrogen rate of 40 kg/ha in addition to the small amount of soil nitrogen at the site was adequate to meet the nitrogen requirement for optimum seed cotton yield. These findings are in line with those of Ogunlela et al. (1982), Kumar et al. (1982a) and Ogunlela et al. (1986) who reported optimum yields with nitrogen rates of between 40-60 kg/ha.

The yield differential observed between the control crop and the two nitrogen rates reflect fertilizer response rates of about 10.85 and 7.37kg seed-cotton per unit kg of N applied, for 40 and 80 kg/ha, respectively. Similar response rates of 9.72 and 8.82 for 50 and 100 kg/ha were reported by Gomase and Patil (1987) in India. At Samaru, Nigeria, Anon (1987) reported that application of 90 kg N/ha produced a response rate of only 4.8 kg seed cotton/kg nitrogen.

The increase in yield components and seed cotton yield recorded in response to nitrogen application in this study conforms with results obtained earlier by Ogunlela et al. (1982) in which yield and yield components of cotton increased with increasing levels of nitrogen at least upto 52kg N/ha. They found that seed cotton yield was influenced by nitrogen mainly through increase in boll number/plant. Similarly, Idem (1984) recorded yield increase of 54.1% with 40 kg N/ha over the control (0 kg N/ha). He further observed that nitrogen positively and significantly influenced many cotton plant characters and seed cotton yield.

The significant response in growth, yield components and yield of cotton with application of nitrogen in this study and indeed in the various studies cited further illustrate the important role nitrogen plays in seed cotton yield by producing vigorous plants with better developed assimilatory area as well as increase in productive flowering and fruiting sites.

5.3 Interactions

Of all the cotton parameters studied, only number of bolls/plant and number of seeds/boll showed significant irrigation and nitrogen levels interaction. While unfertilized plants produced more bolls as the level of irrigation increased, fertilized plants (40 kg N/ha) produced highest

number of bolls with only one pre-sowing irrigation and showed a downward trend with additional irrigation (Table 5). Crowther (1934) in the Sudan, had conclusively shown that increasing water duty, resulted in greater efficiency of nitrogen uptake giving more yield, height, number of flowers and bolls, but had no appreciable effect on the ginning percentage.

Irrigation and fertilization (especially nitrogen) are for long known as the two potent factors increasing the yields of many crops and each of these factors conditions the effectiveness and profitability of the other (Viets, 1962).

The lack of significant irrigation and nitrogen interaction on most of the parameters studied was possibly due to the masking effects of rainfall on the irrigation treatments.

5.4 Correlation

Seed cotton yield is shown in this study to have strong association in positive direction with plant height, total dry matter, and number of nodes/plant at first picking (Table 12). Thus for every unit increase in any of these characters, there happen to be a certain increase in seed cotton yield, the amount of increase varying with the character under study. This agrees with the earlier findings of Patel (1969) and Alves (1970), who reported

positive correlation of seed cotton yield with number of leaves and total dry matter per plant. Number of bolls per plant, seed cotton weight per boll and number of seeds per boll were also shown to have significant positive effects of seed cotton yield, while weight of 1,000 seeds showed significant negative effect on seed-cotton yield.

The observation made in this study that number of seeds per boll rather than seed size is positively correlated with seed-cotton yield, could be that a fully developed healthy boll of Gossypium hirsutum consists of 4-5 locules with 32-45 seeds per boll (Purseglove, 1968; Chapman and Carter, 1976), thus fewer seeds/boll only result from poorly developed bolls with fewer locules or from bolls that suffered from insect or other damages.

Chapter 6

SUMMARY AND CONCLUSION

Cotton (Gossypium hirsutum L.), variety Samaru 71 was grown in 1987, under supplementary irrigation at the Irrigation Research Station, Kadawa (8°30'E and 11°30'N) in the Sudan Savanna ecological zone of Nigeria. Treatments tested cosist of five irrigation levels (main plot treatments) (a) rainfed control (b) pre-sowing irrigation, (c) pre-sowing plus pre-flowering irrigations, (d) pre-sowing plus post-flowering irrigation, and (e) pre-sowing plus pre-flowering plus post-flowering irrigations each at nitrogen levels of 0, 40 and 80 kg per hectare (sub plot treatments). The experiment was laid out in a split plot design replicated four times.

One pre-sowing irrigation to the May-sown crop resulted in 5½ weeks earlier sowing and produced the highest seed cotton yield of 3,770 kg/ha compared to 1,586 kg/ha for the rainfed control crop. Additional post sowing irrigation at any stage during the growing season, resulted in decrease in seed cotton yield/ha, although the decrease was not significant.

Plant height, total dry matter per plant, number of nodes/plant, number of bolls/plant, seed cotton weight/boll, seed number/boll and ginning out turn were all statistically the same in the irrigated crop but significantly higher than the control.

Supplementary irrigation of May-sown cotton lengthened the period of flowering and boll formation of cotton resulting in higher seed cotton yield and water use efficiency than the control.

Application of nitrogen significantly increased vegetative growth characters of cotton such as plant height, total dry matter, number of green leaves per plant and also yield components such as number of bolls/plant and seed cotton yield/plant. Fertilized plots produced significantly higher seed cotton yield/ha than the control. Application of 40 kg N/ha yielded 3,189 kg seed cotton/ha which is 16% higher than the control (2,755 kg/ha). There was no significant yield advantage in increasing N-rate from 40 to 80 kg/ha.

Correlation between seed cotton yield (kg/ha) and yield components such as number of bolls/plant, seed-cotton weight per boll, number of seeds/boll and seed cotton yield/plant were positively significant.

The study has therefore, shown that in a year of normal and well distributed rainfall (748.6 mm) at Kadawa as experienced during the 1987 season, only pre-sowing irrigation is needed to grow an early season cotton crop yielding more than twice the yield of rainfed (July-sown) cotton crop. Additional irrigation at any stage during the growing season, in the absence of an extended drought spell may be a wasteful practice.

With the low nitrogen status of the experimental site (0.021%), nitrogen application was beneficial to growth and yield of cotton whether irrigated or rainfed, and application of 40 kg N/ha appeared to be adequate.

By November 21st, the irrigated crop was out of the field. This duration of harvest could be reduced to NOvember 7th by the use of defoliants (harvest aid) so as to allow enough time for land preparation and planting of dry season rotation crops such as wheat and tomatoes.

The average improvement of the soil nitrogen (0.056%) status at harvest is an indication that the rotation crop will normally benefit from the residual nitrogen from that applied to cotton crop.

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Table A1 Effects of supplementary irrigation on plant count at thinning, days to flowering and maturity of cotton at Kadawa, 1987.

	Irrigated (I_1 - I_4)	Control (I_0)
Plant counts (plants/plot) at thinning	60	53
Days at first flowering	49	45
Days to 50% flowering	78	73
Days to first boll opening	107	98
Days to 50% boll opening	119	113
Days to first picking	139	127
Days to last picking	181	147

I_0 = cotton planted 4th July as rainfed

I_1 - I_4 = cotton planted on 26th May with pre-sowing irrigation and supplementary irrigation at various stages of growth during the growing season.

Table A2 Weeds and insect pests at the experimental site and the control measures employed.

a) Number and periods of hoe-weeding.

	1st weeding	2nd	3rd	4th	5th
i) I_1-I_4	Wk 2	Wk 4	Wk 6	Wk 11	Wk 17
ii) I_0	Wk 3	Wk 6	Wk 11	-	-

b) Number and periods of sprays (Cymbush Super ED)

	1st spray	2nd	3rd	4th	5th
i) I_1-I_4	Wk 9	Wk 12	Wk 16	Wk 18	Wk 19
ii) I_0	Wk 8	Wk 10	Wk 12	-	-

c) Most Prevalent weed species encountered in the site during 1987 wet season:

i) Cyperus spp
ii) Acanthospermum hispidum
iii) Amaranthus spinosus
iv) Tribolus terrestris

d) Important Insect Pests:

i) Earias insulana (pre-flowering)
ii) Sylepta derogata (during boll maturity)

Table A3 Treatments and total amount of irrigation water applied (mm).

	26/5	9/7	9/9	Total
Control	x	x	x	x
Pre-sowing irrigation	155.2	x	x	155.2
Pre-sowing + pre-flowering irrigations	155.2	106.3	x	261.5
Pre-sowing +post-flowering irrigations	155.2	x	99.5	254.7
Pre-sowing + pre-flowering + post-flowering irrigation	155.2	106.3	99.5	361.0

Table A4 Crop water use-efficiency

Treatment	Rainfall[1] (mm) + irrigation	Evapo-trans-piration[2]	Seed cotton yield (kg/ha)	Water use efficiency (kg/ha) mm
Control	637.50	710.87	1,586	2.23
Pre-sowing irrigation	903.80	758.74	3,770	4.97
Pre-sowing+pre-flowering irrigations	1,010.10	758.74	3,533	4.66
Pre-sowing+post-flowering irrigations	1,003.30	758.74	3,244	4.28
Pre-sowing+pre-flowering+post-flowering irrigations	1,109.60	758.74	3,346	4.41

[1] Rainfall for $I_1 - I_4$ = 748.60 mm

Rainfall for I_0 - = 637.50 mm

[2] Mean crop coefficient (K_c) for cotton used = 0.68 (adopted from A.M. Michael, 1978).

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