IMPACT OF INTEGRATED PLANT NUTRITION AND IRRIGATION SCHEDULING ON THE YIELD AND QUALITY OF COTTON

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Irrigation schedules I_1 (six irrigations), I_3 (irrigation at 25 mm potential soil moisture deficit) and I_4 (irrigation at 50 mm potential soil moisture deficit) increased seed cotton yield by 79.23%, 80.26% and 81.70%, respectively over I_2 (three irrigations) during 2003 and 79.19%, 80.20% and 81.65%, respectively during 2004. It was mainly due to the increase in total dry matter production (TDM) in former than the later. Increasing rate of integrated plant nutrition levels significantly enhanced seed cotton yield and TDM over control and lower rates of integrated plant nutrition. Integrated plant nutrition level N_5 (150-75-75 kg NPK ha^{-1} + FYM @ 20 t ha^{-1}) increased seed cotton yield by 53.63% in 2003 and 53.69 % in 2004 over control that was followed by N_6 (150-75-75 kg NPK ha^{-1} + wheat straw @ 5 t ha^{-1}) which gave higher seed cotton yield (35.49% in 2003 and 35.50% in 2004 over control) in comparison to the rest of integrated plant nutrition levels. The seed cotton yield was strongly dependent and related to the total dry matter production since there was a positive and linear relationship between them. Higher TDM production in I_4 (irrigation at 50 mm potential soil moisture deficit) or in other higher integrated plant nutrition levels was due to higher crop growth rate in these treatments. Analyzing crop growth and yield in terms of leaf area duration (LAD) and yields, a strong and positive linear relationship was found.
Keywords: Plant nutrition, irrigation, scheduling, cotton, Pakistan

INTRODUCTION

Cotton plays a significant contribution to the economy of Pakistan. Pakistan is one of the ancient homes of cultivated cotton, 4th largest producer of cotton, the 3rd largest exporter of raw cotton and a leading exporter of yarn in the world (Anon., 2006). Pakistan is, by and large, a mono crop economy as cotton contributes nearly 10 percent in the agriculture GDP and a source of 60 percent foreign exchange earnings. Cotton is not only an export-earning crop but also provides raw material to local textile industry. A profound investment in the form of over 1000 ginning factories, over 400 textile mills heavily depends upon cotton (Economic Survey, 2005-06).

The world uses more cotton for fibre than any other crop. Cotton is a leading cash crop. This stimulates business activities for factories and enterprises throughout the country. Without water, there is no concept of life. So, to give a healthy life to cotton crop, proper irrigation scheduling is essentially required which saves water and energy, boosts up yield and production. Water is an important constituent of plant tissue in more than 80% herbaceous plants. Water is essential for cell turgidity which is related to photosynthesis, growth of cells, tissues and organs (Reddi and Reddi, 1995).Water need of the crop is the prime consideration to decide the time and amount of irrigation. Irrigation water applied less or more than the optimum requirement of a crop adversely affects the yield. It is, therefore, imperative to determine suitable time or proper stage of crop in appropriate amounts for application of irrigation water.

Water plays a key role in achieving higher yields because it is an important constituent of plants and plays a vital role in many metabolic processes. It increases leaf production and expansion rate, leaf area duration which affects radiation interception and consequently contributes towards final dry matter production (Watson, 1952). A high production of total dry matter (TDM) per unit area is a pre-requisite to achieve high yields. For many crops, the rate of dry matter production is directly proportional to the amount of intercepted radiation and the efficiency with which the light energy is converted to TDM (Monteith, 1977). For cotton and other crops, yield is directly proportional to the amount of intercepted radiation that green leaves intercept throughout the season. Thus, the agronomic aim in the quest for greater yield should be to ensure maximum light interception by green leaves of the crops. Irrigation of cotton at various growth stages leads to differential behavior of crop canopy development and the light use efficiency.

Objectives

To determine and analyze the effect of different irrigation schedules on the growth, radiation interception and its efficiency of use, and yield of cotton.

To investigate and quantify the impact of different integrated plant nutrition levels on the growth and yield of cotton.

MATERIALS AND METHODS

Site and soil

Two field experiments to evaluate the effect of different levels of integrated plant nutrition and irrigation scheduling on the growth, radiation use efficiency and yield of cotton during 2003 and 2004 growing seasons. The experiments were conducted at the Agronomic Research Area, Postgraduate Agricultural Research Station (PARS), University of Agriculture, Faisalabad, (31.25^o N, 73.09^o E, 184.0 m) Pakistan. The soil was sandy clay loam in texture with available (NO_3 – N) 11.8 ppm, available (P) 6.33 ppm and available K 107 ppm.

Experimental design and treatments

The experiments were laid out in Randomized Complete Block Design (RCBD) with split plot arrangement using three replications keeping the irrigation schedules in main plots and integrated plant nutrition levels in sub-plots. The net plot size was 3m x 6m. Experiments comprised of the following treatments.

a. Irrigation schedules (I) (Main plots)

I_1 =Six irrigations (one irrigation at the commencement of sympodial branches, three at flowering and two during boll development stage). I_2 =Three irrigation, (first irrigation at the commencement of sympodial branches, second at flowering and third at boll development stage). I_3 = Irrigation at 25 mm potential soil moisture deficit. I_4 = Irrigation at 50 mm potential soil moisture deficit.

b. Integration plant nutrition levels (N) (Sub plots)

N_0=Control, N_1=75-37.5–37.5 kg N-P_2O_5–K_2O ha^{-1}
N_2=75-37.5–37.5 kg N P_2O_5–K_2O+FYM @ 20 t ha^{-1}
N_3=75-37.5–37.5 kg N P_2O_5–K_2O+Wheat straw @ 5 t ha^{-1}
N_4=150–75–75 kg N P_2O_5–K_2O t ha^{-1}
N_5=150–75–75 kg N P_2O_5–K_2O+FYM @ 20 t ha^{-1}
N_6=150–75–75 kg N P_2O_5–K_2O+Wheat straw @ 5 t ha^{-1}

Crop husbandry

The cotton variety NIAB-999 was sown in first week of June during 2003 and 2004 using recommended seed rate of 20 kg ha^{-1}. The crop was sown with a single row hand drill having row-to-row distance 75cm. Plant to plant distance 30cm was maintained. P_2O_5 and K_2O were applied at the time of sowing while nitrogen (N) was applied in three split doses at sowing, flowering and peak flowering stages. Urea, SSP and SOP were used as sources of N, P and K, respectively. Irrigations were applied according to the schedule. The crop was sprayed with confidor, Lorsban, Steward, Acetamiprid and Tracer to control the insect pest attack.

Irrigation scheduling

Maximum potential soil moisture deficit (D) was used as a criterion for irrigation application at 25mm and 50mm moisture deficit (French and Legg, 1979). Daily Penman's potential evapotranspiration (PET) was calculated by using standard programme of 'CROPWAT' developed by FAO (1992). Daily summation of PET values over time gives a cumulative potential soil moisture deficit (D) as suggested by French and Legg (1979). The amount of water applied was equal to the difference between potential evapotranspiration (PET) and rainfall +irrigation.

$$D = \sum PET - \sum (I + R)$$

Where **I** is irrigation and **R** is rainfall.

Observations

Yield and yield components

Number of bolls plant^{-1}, Number of bolls matured plant^{-1}, 100-cotton seed weight (g), Seed cotton yield (kg ha^{-1})
Quality characteristics Ginning out-turn (%), Fibre fineness (μ g inch^{-1}).

Procedure for recording observations

A net plot size measuring 1.5 x 6.0 m was retained for final yield and yield components from each plot and the rest of the plot was used for random sampling regarding the crop growth.

100-cotton seed weight

After ginning 100-cotton seed weight was taken from each plot sample and weighed through an electronic balance.

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

Seed cotton was collected in two picks in paper bags separately from each plot. Seed cotton yield per plot was weighed and converted into yield tha^{-1}.

Quality characteristics

Ginning out-turn (GOT) (%)

The representative samples of seed cotton each of 50 g were taken from each plot. These samples were cleared, sun dried and then ginned by using single roller electric ginning machine. The lint was weighed and GOT was calculated by using the following formula:

$$GOT = \frac{\text{Weight of lint in sample}}{\text{Weight of seed cotton in total sample}} \times 100$$

Fibre fineness (u g inch^{-1}) = Fibre fineness was determined with a micronare meter by taking representative samples of cotton lint from each plot.

Statistical analysis

Data collected were tabulated and subjected to Fisher's Analysis of Variance Technique. When a significant F-value was obtained then applying Least Significance Difference (LSD) test at 5% probability level compared the treatment means (Steel *et al.*, 1984).

RESULTS AND DISCUSSION

Number of bolls plant^{-1}

Irrigation schedules I_1 (six irrigations), I_3 (irrigation at 25mm potential soil moisture deficit) and I_4 (irrigation at 50 mm potential soil moisture) produced significantly greater number of bolls plant^{-1} (30.22, 30.39 and 30.33 in 2003 and 26.68, 29.85, 29.79 in 2004, respectively). The minimum number of bolls plant^{-1} was 19.21 and 18.87 during 2003 and 2004, respectively with I_2 treatment (three irrigations). These results are in line with the findings of (Hussain, 2002) who reported that two weeks irrigation intervals after first irrigation resulted in higher number of bolls. These finding are also in agreement with those of (Milkovski, 1971) who reported that application of irrigations at optimum levels markedly increased boll formation. Marani, 1973) also observed that boll number, boll retention, boll weight, lint yield and fibre length decreased by water stress at the end of flowering. Integrated plant nutrition levels also significantly enhanced the number of bolls plant^{-1} in both the years. In both the season, the treatment N_5 produced maximum number of bolls (32.05 in 2003 and 31.48 in 2004). The minimum number of bolls plant^{-1} was 23.24 and 22.83 with N_0 (control) during 2003 and 2004, respectively. Similar results were also presented by (Khaliq *et al.,* 2006) who reported the increase in number of bolls with the application of NPK along with organic matter.

100-Cotton Seed Weight (g)

Irrigation at 25 mm deficit gave the highest 100-cotton seed weight of 7.58 g in 2003 and 7.49 g in 2004 as compared to all the other irrigation treatments. Integrated plant nutrition level N_5 produced the maximum 100-cotton seed weight of 7.65 in 2003 and 7.56 in 2004 as compared to all other treatments. The minimum 100-cotton seed weight (7.32 in 2003 and 7.23 in 2004) was found in N_0 (control). The interaction between irrigation schedules and integrated plant nutrition levels affecting 100-cotton seed weight was also significant (Table.1). In 2003, the treatment combination of irrigation at 25 mm potential soil moisture deficit and N_5 resulted in the maximum 100-cotton seed weight 7.78 g as compared to all other treatment combinations where the minimum 100-cotton seed weight at 6.98 g was recorded with the treatment combination of I_2N_0 (three irrigations x control). Similar pattern of interaction affecting 100-cotton seed weight was also noted in 2004 where maximum 100-cotton seed weight (7.68 g) was recorded with irrigation at 25 mm potential soil moisture deficit and N_5. The minimum 100-cotton seed weight of 6.98 was observed in treatment combination of three irrigations and control. Bhutta (1996) also concluded from his results that with the increasing nutrition levels there was significant increase in 100-cotton seed weight. Similar results have also been reported by (Hussain, 1999) who showed that six irrigation levels resulted in highest boll weight. Water stress enhanced the partitioning of assimilates to reproductive growth which accelerated boll development and thus enhanced crop maturity which caused less boll weight in water stress conditions as also reported by (Orgaz *et al.,*1991).

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

Irrigation at 50 mm potential soil moisture deficit produced maximum seed cotton yield (2642 kg ha^{-1} in 2003 and 2621 kg ha^{-1} in 2004) which was followed by irrigation at 25 mm deficit that produced 2621 kg ha^{-1} in 2003 and 2485 kg ha^{-1} in 2004 (Table.1). Irrigation schedules I_1 (six irrigations), I_3 (irrigation at 25 mm potential soil moisture deficit) and I_4 (irrigation at 50 mm potential soil moisture deficit) increased seed cotton yield by 79.23%, 80.26% and 81.70%, respectively over I_2 (three irrigations) during 2003 and 79.19%, 80.20% and 81.65%, respectively during 2004. It was mainly due to the increase in total dry matter production (TDM) in former than the later. The minimum seed cotton yield (1454 kg ha^{-1} in 2003 and 1379 kg ha^{-1} in 2004) was recorded in the treatment I_2 (3 irrigations). Integrated plant nutrition levels also had a significant effect on seed cotton yield in both the seasons. During both the years, the treatment N_5 yielded significantly higher (2922 kg ha^{-1} and 2770 kg ha^{-1} in 2003 and 2004, respectively) than rest of the treatments, which also differed significantly from one another. The results further indicated that integrated plant nutrition levels enhanced the seed cotton yield significantly over control as a result of improving various yield attributes. The nutrient N_5 was followed by the treatment N_6 that produced more seed cotton yield (2577kg ha^{-1} in 2003 and 2443 kg ha^{-1} in 2004) as compared to the remaining treatments. Hence, integrated plant nutrition level N_5 increased seed cotton yield by 53.63% in 2003 and 53.69 % in 2004

Table 1. Effect of different irrigation scheduling and integrated plant nutrition on yield and yield components and quality of cotton

Treatments	Seed cotton yield (Kg ha^{-1})		Ginning out turn (%)		Fibre Fineness (µg inch^{-1}).		Number of bolls plant-1		100-seed cotton weight (g)	
Irrigation Schedules	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004
I_1 6 irrigations	2606 b	2471 b	35.61 c	35.32 c	4.60	4.64	30.22a	29.68a	7.55 c	7.46 c
I_2=3 irrigations	1454 c	1379 c	34.97 d	34.93 d	4.67	4.69	19.21b	18.87b	7.21 d	7.12 d
I_3=irrigations at 25mm deficit	2620ab	2485ab	37.01 a	36.70 a	4.60	4.59	30.39 a	29.85 a	7.58 a	7.49 a
I_4=irrigations at 50mm deficit	2642 a	2505 a	36.29 b	35.98 b	4.60	4.63	30.33 a	29.79 a	7.57 b	7.47 b
LSD at 5%	25.14	23.82	0.00761	0.214	NS	NS	0.2162	0.2122	0.00755	0.00755
Integrated plant nutrition levels										
N_0 = Control	1902 g	1803 g	35.98 NS	35.75 NS	4.65	4.70	23.24g	22.83g	7.32 g	7.23 g
N_1 = 75-37.5-37.5 kg N-P_2O_5-K_2O ha^{-1}	2035 f	1930 f	35.98	35.73	4.64	4.62	24.48f	24.05f	7.39 f	7.30 f
N_2 = 75-37.5-37.5 kg N-P_2O_5-K_2O ha^{-1} + FYM @ 20 t ha^{-1}	2286 d	2168 d	35.96	35.73	4.62	4.60	27.51d	27.02d	7.46 d	7.36 d
N_3= 75-37.5-37.5 kg N-P_2O_5-K_2O ha^{-1} + Wheat straw @ 5t ha^{-1}	2167 e	2054 e	35.97	35.73	4.62	4.65	26.00e	25.54e	7.42 e	7.33 e
N_4 =150-75-75 kg N-P_2O_5-K_2Oha^{-1}	2428 c	2302 c	35.96	35.73	4.61	4.67	28.98c	28.46c	7.52 c	7.42 c
N_5 = 150-75-75 kg N-$_2O_5$-K_2O ha^{-1} + FYM @ 20 t ha^{-1}	2922 a	2771 a	35.96	35.72	4.58	4.59	32.05a	31.48a	7.65 a	7.56 a
N_6 = 150-75-75 kg N-P_2O_5-K_2O ha^{-1} + Wheat straw @5tha^{-1}	2577 b	2443 b	35.96	35.74	4.60	4.62	30.49b	29.95b	7.58 b	7.49 b
LSD Value at 5%	28.34	26.87	NS	NS	NS	NS	0.3744	0.368	0.0082	0.0083

over control that was followed by N_6 which gave higher seed cotton yield (35.49% in 2003 and 35.50% in 2004 over control) in comparison to the rest of integrated plant nutrition levels. Seed cotton yield was significantly and positively correlated with the total dry matter. There was also a linear relationship between leaf area duration (LAD) and seed cotton yield. The final seed cotton yield was significantly and linearly related with the final LAD. The common regression accounted for 98.88 % variability in the data (Fig. 1).

Quality parameters

Ginning Out Turn (GOT %)

Irrigation schedules affected significantly ginning out turn (GOT %) but integrated plant nutrition levels did not affect GOT (%). The maximum GOT of 37.01% in 2003 and 36.70% in 2004 was observed with I_3 (irrigation at 25 mm deficit). The minimum GOT (34.97% in 2003 and 34.93% in 2004) were recorded with the treatment I_2 (three irrigations). The ginning out turn (GOT %) was not affected by different integrated plant nutrition levels during both the seasons. In both the years, the interaction between irrigation schedules and integrated plant nutrition levels was found to be non-significant. (Elayan, 1992) concluded that lint percentage remained unaffected with the increase in nutrition. These results are contradictory to the results of (Tobert and Ravees, 1994) who concluded that increasing nitrogen rates significantly decreased the lint percentage. These results are also in line with those of (Cheema, 1976) and (El-Rehman *et al.,* 1980) who reported the significant effect of irrigation levels on GOT values in cotton.

Fibre Fineness (µg inch^{-1})

Irrigation schedules and integrated plant nutrition levels showed the non-significant results on fibre fineness because this character may be genetically controlled and less influenced by the environmental conditions.

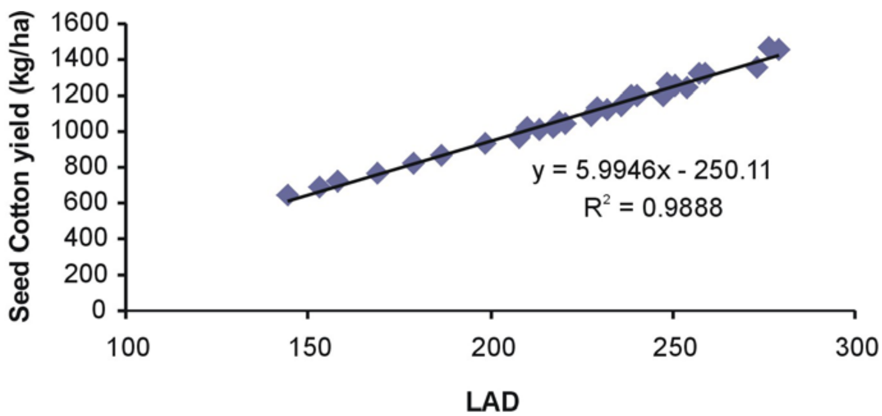

Fig. 3. Relationship between leaf area duration (LAD) and seed cotton yield

The fibre fineness varied from 4.60 to 4.67 in 2003 4.59 to 4.69 in 2004 among various irrigation schedules. The values among different integrated plant nutrition levels ranged from 4.58 to 4.65 in 2003 and 4.59 to 4.70 in 2004. The interaction of irrigation schedules and integrated plant nutrition levels was also found to be non-significant. These findings are in conformity with those of (Palomo and Quirate, 1975); who reported that fibre quality remained unaffected with different irrigation schedules. These results are also in agreement with the prior reports where the effect of N on fibre properties was reported non-significant (Phipps *et al.,* 1997), (Elayan, 1992), (Sawan *et al.,* 1997) and (Brar *et al.,* 1993). In contrast, some studies showed that the poor quality of fibre was observed for plants grown under low N concentrations and the high quality of fibre at optimum N concentrations (Pettigrew, 2001), (Tewolde and Fernandez, 2003).

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