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OPTIMUM IRRIGATION AND INTEGRATED NUTRITION IMPROVES THE CROP GROWTH AND NET ASSIMILATION RATE OF COTTON (*GOSSYPUM HIRSUTUM* L.)

MUHAMMAD SALEEM[1*], MUHAMMAD MAQSOOD[2], ASIF JAVAID[3], MAHMOOD-UL-HASSAN[4] AND TASNEEM KHALIQ[2]

[1]*Crop Sciences Institute, National Agricultural Research Centre (NARC), Islamabad, Pakistan*
[2]*Department of Agronomy, University of Agriculture, Faisalabad, Pakistan*
[3]*Plant Genetic Resources Institute, NARC, Islamabad, Pakistan*
[4]*Nuclear Institute for Agriculture and Biology (NIAB), Faisalabad, Pakistan*
[*]*Corresponding author email: drsaleemyousaf@gmail.com*

Abstract

The objective was to find out the impact of different irrigation schedules and integrated plant nutrition levels on the seasonal crop growth rate (CGR) and net assimilation rate (NAR) of cotton. The experiments were conducted using RCBD with split plot arrangement. The treatments were four irrigation schedules (main plot) i.e. six irrigations (I_1), three irrigations (I_2), irrigation at 25 mm deficit (I_3) and irrigation at 50 mm deficit (I_4), and seven integrated nutrition levels (sub plot) viz. control (N_0), 75-37.5-37.5 kg N-P_2O_5-K_2O ha^{-1} (N_1), 75-37.5-37.5 kg N-P_2O_5-K_2O ha^{-1} + FYM @ 20 t ha^{-1} (N_2), 75-37.5-37.5 kg N-P_2O_5-K_2O ha^{-1} + wheat straw @ 5 t ha^{-1} (N_3), 150-75-75 kg N-P_2O_5-K_2O ha^{-1} (N_4), 150-75-75 kg N-P_2O_5-K_2O ha^{-1} + FYM @ 20 t ha^{-1} (N_5), 150-75-75 kg N-P_2O_5-K_2O ha^{-1} + wheat straw @ 5 t ha^{-1} (N_6). Significantly higher seasonal CGR and NAR were attained at N_5 with any of two irrigation schedules viz., I_3 or I_4. Interaction I_3N_5 increased CGR and NAR by 145% and 20% in 2003 and 146% and 18%, respectively in 2004, however, I_4N_5 performed at par with I_3N_5 in 2003. Linear relationships between CGR and seed cotton yield; and NAR and yield were drawn. Subsequently, I_3N_5 and I_4N_5 resulted in better performance and higher seed cotton yield.

Introduction

The world uses cotton, more than any other crop for fibre (Saleem *et al.*, 2008). Pakistan's economy is mainly dependent on cotton and textile industry. Cotton is a significant source of foreign exchange earnings that accounts for 1.6% to GDP and 7.5% of value added in agriculture (Anon., 2007-08). In 2005, the average seed cotton yield of Pakistan (2280 kg ha^{-1}) was more than that of the world (1949 kg ha^{-1}) and some other countries such as India (850 kg ha^{-1}), Turkmenistan (1617 kg ha^{-1}), however, it was low comparing with many cotton producing countries for instance China (3379 kg ha^{-1}), USA (2305 kg ha^{-1}), Brazil (2972), Turkey (3817 kg ha^{-1}), Australia (4170 kg ha^{-1}), Greece (3375 kg ha^{-1}), Syrian Arabic Republic (4697 kg ha^{-1}) and Egypt (2603 kg ha^{-1}) (Anon., 2006-07).

Improvement in cotton yield can be attributed to many factors; however, irrigation scheduling and integrated plant nutrition management are of critical importance (Saleem *et al.*, 2008). Integrated plant nutrition system envisages the use of organic sources of plant nutrients along with chemical fertilizers (inorganic) so as to get maximum economic yield without any deleterious effect on physic-chemical and biological properties of soil. Major organic sources of plant nutrients are FYM, green manure, bio-fertilizer and crop residues. Proper integration of two or more nutrient resources can ensure optimum nutrient supply. Fertilizer is the most important component in an integrated nutrient supply system under intensive cropping and the role of chemical fertilizers has become obvious with the introduction of high yielding varieties (HYVs) responding to fertilizers. Unless the entire soil nutrient removed in harvested crops are replaced in proper amounts, both from organic and inorganic sources, crop production can not be sustained and soil fertility will decline (Malewar *et al*., 2000). Alternative fertility amendments enhance beneficial soil microorganisms, reduce pathogen populations, increase soil organic matter, total carbon and cation exchange capacity (CEC), and lower bulk density thus improving soil quality (Bulluck *et al*., 2002). Nutrient deficiencies, as a consequence of nutrient depletion over the years, have decreased seed cotton yields in treatments that received mineral fertilizer alone in comparison with manure-amended treatments. On a long-term basis, FYM application should, therefore, form an integral part of nutrient recommendation (Desouza *et al*., 2007).

Now, agriculture has been transformed to mechanized farming. In Pakistan, a lot of wheat growers harvest the wheat crop with the combine harvester before sowing cotton crop, but, instead of incorporating wheat residue / straw into the soil to improve its fertility status, people generally burn it which results in the wastage of crop nutrients. Similarly, FYM is being burnt as fuel by many farmers. This is the need of the time to motivate the people to use alternate sources of fuel and get advantage of these rich sources of nutrients. There is, for such reasons, an imperative need to integrate organic sources of nutrients along with the chemical fertilizers (inorganic). Crop growth rate (CGR) and relative growth rate (RGR) of cotton are significantly influenced by the application of recommended dose of NPK through inorganic source and 50% of N through sun hemp + 50% of N through vermin compost (Mohan & Ghandaragiri, 2007). The balanced fertilization is, therefore, required to boost the crop productivity.

Water stress to cotton crop at any stage during its growth decreases total dry matter production (TDM) (Jogev, 1988). The growth parameters like dry matter production (DMP), CGR and relative growth rate (RGR) of cotton are significantly influenced by the use of recommended dose of NPK through inorganic sources and 50% of N through organic sources (Mohan & Ghandaragiri; 2007).

Without water, there is no perception of life. So, to give a vigorous life to cotton crop, proper irrigation scheduling is essentially required which can save water and energy, boost up crop yield and production. Water is an important constituent of plant tissue. It is an essential solvent for cell turgidity which is related to photosynthesis, growth of cells, tissues and organs (Reddi & Reddi, 1995). It plays a key role in many metabolic processes. A high production of TDM per unit area is a pre-requisite to achieve high yield which may be caused by better CGR and NAR. For many crops, the rate of TDM is directly proportional to the amount of intercepted radiation and the efficiency with which the light energy is converted to TDM. Thus, the agronomic aim, in the quest for greater yield, should be to ensure maximum light interception by green leaves of the crops. The irrigation water use efficiency is higher for the well watered treatment than either of the delayed-irrigation treatments (Vories *et al*., 2007). The prime consideration with reference to water need of the crop is to decide the time and amount of irrigation. Irrigation water, applied less or more than the optimum requirement of a crop, adversely affects NAR and yield. It is, consequently, crucial to determine suitable time or proper stage of crop for application of irrigation water in appropriate amounts.

An assortment of growth characteristics of cotton can be manipulated by certain agronomic factors (Saleem *et al*., 2009). Optimum irrigation scheduling and integrated crop nutrition can positively affect CGR and NAR of cotton that in turn may result into an improved seed cotton yield.

The present study was, for such motives, undertaken with the objective to determine and analyze the effect of different irrigation schedules and integrated plant nutrition levels on the seasonal mean crop growth and net assimilation of cotton.

Materials and Methods

Two field experiments were conducted during 2003 and 2004 growing seasons on the Agronomic Research Area, Postgraduate Agricultural Research Station, University of Agriculture, Faisalabad (31.25° N, 73.09° E, 184.0 m), Pakistan. The soil was sandy clay loam in texture with the available NO_3 – N 11.8 ppm, available P 6.33 ppm and available K 107 ppm. Meteorological data were collected during the growing seasons from the Observatory of Department of Crop Physiology, University of Agriculture, Faisalabad.

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 3 x 6m. The treatments comprised of (A) four irrigation schedules (I) viz., six irrigations (I_1), three irrigation (I_2), irrigation at 25 mm potential soil moisture deficit (I_3) and irrigation at 50 mm potential soil moisture deficit (I_4), and (B) seven integrated plant nutrition levels (N) ; control (N_0), 75-37.5-37.5 kg N-P_2O_5-K_2O ha^{-1} (N_1), 75-37.5-37.5 kg N-P_2O_5-K_2O ha^{-1} + FYM @ 20 t ha^{-1} (N_2), 75-37.5-37.5 kg N-P_2O_5-K_2O ha^{-1} + Wheat straw @ 5 t ha^{-1} (N_3), 150-75-75 kg N-P_2O_5-K_2O ha^{-1} (N_4), 150-75-75 kg N-P_2O_5-K_2O ha^{-1} + FYM @ 20 t ha^{-1} (N_5), 150-75-75 kg N-P_2O_5-K_2O ha^{-1} + Wheat straw @ 5 t ha^{-1} (N_6).

The cotton crop was sown in the 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. Row-to-row distance of 75cm and plant to plant distance of 30cm were maintained. P_2O_5 and K_2O were applied in accordance with the treatments at the time of sowing while nitrogen (N) was applied in three split doses according to the treatments viz., at sowing, flowering and peak flowering stages. Urea, single super phosphate (SSP) and sulphate of potash (SOP) were used as sources of N, P and K, respectively. Irrigations were applied according to the treatments. The other cultural practices were kept uniform for all the treatments.

Potential soil moisture deficit (PSMD) is the drought index which is based on physical quantities like irrigation, rainfall and potential evapotranspiration (PET). Potential soil moisture deficit (D) has been used as a criterion for irrigation application at 25mm and 50mm moisture deficit (French & Legg, 1979). Daily Penman's potential evapotranspiration (PET) was calculated by using standard programme of 'CROPWAT' developed by FAO (Anon.,1992). Daily summation of PET values over time gives a cumulative potential soil moisture deficit (D) as suggested by French & Legg (1979). The amount of water applied is equal to the difference between potential evapotranspiration (PET) and rainfall + irrigation. Potential soil moisture deficit (D) was determined as under:

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

where PET is potential evapotranspiration, I is irrigation and R is rainfall.

Potential evapotranspiration (PET) was determined using pan evaporation method. Pan evaporation provides a measurement of all the integrated effects of radiation, temperature and wind on evaporation from a scientific open water space (evaporation pan). Then, PET was calculated according to the following formula:

$$PET = Kp.\ E_{pan}$$

where E_{pan} = mean daily value of pan evaporation

Kp = pan co-efficient

Three irrigations (first irrigation at the commencement of sympodial branches, second at flowering and third at boll development stage) and six irrigations (one irrigation at the commencement of sympodial branches, one at squaring, three at flowering from white bloom to peak bloom and one during boll development stage) were applied according to different growth stages as described by Kerby *et al*., (1987).

Observations: Following data on the growth and net assimilation characteristics of cotton were recorded during the course of studies:

1. Leaf area and total dry matter (TDM)
2. Seasonal mean crop growth rate (CGR)
3. Net assimilation rate (NAR)
4. Seed cotton yield relationship with CGR and NAR

Procedure for recording observations: A net plot size measuring 1.5 x 6.0 m was retained for random sampling regarding the crop growth consideration and the rest of the plot was used for final seed cotton yield.

1. Leaf area and total dry matter (TDM): Randomly five plants were taken from each plot monthly. These plants were cut at ground level and leaves were separated from the plants. The fresh weight of each fraction (leaf, stem and boll etc.) was measured on an electronic balance. Then two sub-samples of 5 g green foliage were taken from each sample. The leaf area of these sub samples was measured with leaf area meter and average was computed. These samples were dried under sun and then drying weight was measured after keeping the samples in oven at 65^{o}C to a constant weight to determine the dry matter.

2. Crop growth rate: Crop growth rate (CGR) was calculated as proposed by Hunt (1978):

$$CGR = (w_2 - w_1) / (t_2 - t_1)$$

where w_1 and w_2 are the final dry matter at times t_1 and t_2, respectively.

3. Net assimilation rate (NAR): Net assimilation rate (NAR) was estimated using the formula of Hunt (1978):

$$NAR = TDM / LAD$$

here, TDM and LAD are the final total dry matter and leaf area duration respectively.

4. Seed cotton yield relationship with CGR and NAR: Regression analysis was enforced to determine the relationship between CGR and seed cotton yield, and NAR and seed cotton yield.

Statistical analysis: Data collected were analyzed to evaluate the different irrigation schedules in combination with integrated plant nutrition treatments applying the MSTATC statistical computer software package. When a significant F-value was obtained then applying Least Significance Difference (LSD) test at 5% probability level (Steel *et al*., 1997) compared the treatment means.

Results and Discussion

Weather: Weather data represents mean monthly value for the crop growth period during both the years (Table 1). Mean air temperature of June, July, August, September and October were 35.8, 33.5, 32.9, 31.5 & 26.7^o C in 2003 and 33.9, 34.5, 32.5, 31.3 & 26.6^o C during 2004. The month wise maximum average temperature was recorded in the month of June (35.8^{o}C) in 2003 and 34.5^{o}C during the month of July in 2004. The minimum average temperature was observed in the month of October (26.7^{o}C) during 2003 and 26.6^{o}C in the month of October during 2004. The range of average solar radiation from 10.5 to 14.1 Mj m^{-2} day^{-1} was observed during 2003 and 10.1 to 15.2 Mj m^{-2} day^{-1} in 2004.

The average humidity increased from June to August (maximum 66.7% in 2003 and 86.8% in 2004). But after August it decreased to 55.3% in 2003 and 59% in 2004. The maximum average rainfall was recorded in the month of August (143.6 mm) in 2003 and 98.1 mm in 2004. Total rainfall throughout the growing seasons was 338.9 mm in 2003 and 228.6 mm in 2004.

2. Crop growth rate (CGR) (g m^{-2} d^{-1}): The effect of treatments on the average seasonal CGR is shown in Table 2. Irrigations schedules produced significant results in all the harvests. The maximum seasonal CGR (9.38 in 2003 and 9.01 g m^{-2} d^{-1} in 2004) were shown by I_3 (irrigation at 25 mm potential soil moisture deficit). The least seasonal CGR values of 5.82 and 5.59 g m^{-2} d^{-1} were recorded in 2003 and 2004, respectively with I_2 (three irrigations). CGR is directly proportional to the intercepted light provided leaf area index is optimum and crop is not deficient of water.

Table 1. The meteorological data on temperature, rainfall, relative humidity and net radiation for the growing seasons during 2003 and 2004.

	2003				2004			
Month	Temp. (^{o} C)	Rainfall (mm)	R.H. (%)	Net radiation (Mj m^{-2} day^{-1})	Temp. (^{o} C)	Rainfall (mm)	R.H. (%)	Net radiation (Mj m^{-2} day^{-1})
June	35.8	7.6	38.3	14.1	33.9	98.1	45.4	15.2
July	33.5	133.7	63.5	13.7	34.5	14.8	52.7	15.1
August	32.9	143.6	66.7	12.4	32.5	86.8	67.1	13.0
September	31.5	54	59.0	12.1	31.3	24.6	59	15.4
October	26.7	0	55.3	10.5	26.6	4.3	61	10.1
Total		338.9				228.6		
Average	32.08	67.78	56.6	12.56	31.76	45.72	57.0	13.76

Table 2. Effect of irrigation schedules and integrated plant nutrition levels on seasonal CGR (g m^{-2} day^{-1}) and NAR (g m^{-2} d^{-1}).

Treatment	Seasonal CGR		NAR	
	2003	2004	2003	2004
Irrigation levels				
I_1 = 6 irrigations	8.86 c	8.51 c	4.89 c	4.73 c
I_2 = 3 irrigations	5.82 d	5.59 d	4.63 d	4.50 d
I_3 = irrigation at 25 mm deficit	9.38 a	9.01 a	5.10 a	4.93 a
I_4 = irrigation at 50 mm deficit	9.35 b	8.98 b	5.03 b	4.87 b
LSD Value at 5%	0.0076	0.0076	0.034	0.0239
Integrated nutrition levels				
N_0 = Control	6.92 g	6.64 g	4.74 e	4.60 f
N_1 = 75-37.5-37.5 kg N-P_2O_5-K_2O ha^{-1}	7.28 f	6.98 f	4.76 e	4.62 f
N_2 = 75-37.5-37.5 kg N-P_2O_5-K_2O ha^{-1} + FYM @ 20 t ha^{-1}	8.30 d	7.86 d	4.93 c	4.78 d
N_3= 75-37.5-37.5 kg N-P_2O_5-K_2O ha^{-1} + Wheat straw@5 t ha^{-1}	7.79 e	7.48 e	4.85 d	4.69 e
N_4 = 150-75-75 kg N-P_2O_5-K_2O ha^{-1}	8.80 c	8.44 c	4.97 c	4.81 c
N_5 = 150-75-75 kg N-P_2O_5-K_2O ha^{-1} + FYM @ 20 t ha^{-1}	10.18 a	9.77 a	5.13 a	4.96 a
N_6 = 150-75-75 kg N-P_2O_5-K_2O ha^{-1} + Wheat straw @ 5 t ha^{-1}	9.22 b	8.85 b	5.02 b	4.86 b
LSD Value at 5%	0.008	0.008	0.052	0.026

Means in a column not sharing a letter in common differ significantly at ($p \leq 0.05$)

Integrated plant nutrition also significantly affected the CGR. CGR showed the increasing trend with the increasing integrated plant nutrition levels. CGR increased up to 90 DAS then decline occurred in all the treatments. Among different integrated plant nutrition levels; N_5 (150-75-75 kg N – P_2O_5 – K_2O ha^{-1} + FYM @ 20t ha^{-1}) resulted in the maximum seasonal CGR values of 10.18 and 9.77 g m^{-2} d^{-1} in 2003 and 2004, respectively. The minimum seasonal CGR values of 6.92 and 6.64 were recorded in 2003 and 2004, respectively with N_0 (control). There were linear and positive relationships between Fi and TDM and Fi and seed cotton yield. The common regression for the pooled data accounted for 95.9 and 96.63% of the variability for Fi and TDM and Fi and seed cotton yield, respectively (Fig. 3a, b).

The interaction between irrigation schedules and integrated plant nutrition levels was significant (Table 3). The treatment combination I_3N_5 (irrigation at 25 mm deficit × 150-75-75 kg N – P_2O_5 – K_2O ha^{-1} + FYM @ 20t ha^{-1}) showed maximum seasonal CGR of 11.51 in 2003 (Fig. 1) and 11.05 in 2004 (Fig. 2). Then the treatment combination of I_4N_5 (irrigation at 50 mm deficit × 150-75-75 kg N – P_2O_5 – K_2O ha^{-1} + FYM @ 20t ha^{-1}) gave the higher crop growth rate of 11.45 in 2003 and 11.00 in 2004, which was followed by CGR values of 10.63 in 2003 and 10.20 in 2004 with the treatment combination of I_1N_5 (six irrigation × 150-75-75 kg N – P_2O_5 – K_2O ha^{-1} + FYM @ 20t ha^{-1}). The minimum CGR values of 4.70 in 2003 and 4.52 g m^{-2} d^{-1} in 2004 were shown with the treatment combination of I_2N_0 (three irrigations x control). Similar CGR trend was reported by Cheema (2006), and Hussain (2002). Mauney *et al*., (1978) reported similar pattern that the CGR of cotton not only increased during the Juvenile stage (10d-30d) but even after juvenile stage cotton plants maintained their larger size and greater absolute growth.

3. Net Assimilation Rate (NAR) (g m^{-2} d^{-1}): Irrigation schedules affected NAR significantly in both the years (Table 2). The treatment I_3 (irrigation at 25 mm potential soil moisture deficit) resulted in NAR of 5.1 in 2003 and 4.93 in 2004. The minimum values of 4.63 in 2003 and 4.50 in 2004 were recorded in I_2 (three irrigations).

Table 3. Interaction between irrigation schedules and integrated plant nutrition levels affecting the seasonal CGR and NAR.

Treatment	Seasonal CGR		NAR	
	2003	2004	2003	2004
I_1N_0	7.36 t	7.06 t	4.71 no	4.55 up
I_1N_1	7.86 q	7.55 q	4.80 lmn	4.64 mn
I_1N_2	8.83 k	8.48 k	4.92 hijk	4.76 k
I_1N_3	8.38 n	8.04 n	4.86 jklm	4.69 lm
I_1N_4	9.33 I	8.96 I	4.94 hij	4.78 jk
I_1N_5	10.63 c	10.20 c	5.06 efg	4.88 gh
$I1N_6$	9.67 h	9.28 h	4.97 ghi	4.81 ij
I_2N_0	4.70 [	4.52 [	4.51 q	4.38 t
I_2N_1	5.09 z	4.89 z	4.56 pq	4.43 st
I_2N_2	5.77 x	5.54 x	4.64 op	4.50 r
I_2N_3	5.32 y	5.11 y	4.60 pq	4.47 rs
I_2N_4	6.17 w	5.92 w	4.65 op	4.51 qr
I_2N_5	7.12 u	6.83 u	4.77 mn	4.62 no
I_2N_6	6.57 v	6.31 v	4.71 no	4.58 op
I_3N_0	7.82 r	7.51 r	4.93 hijk	4.77 jk
I_3N_1	8.08 o	7.76 o	4.88 ijkl	4.72 kl
I_3N_2	9.32 I	8.95 I	5.11 de	4.95 ef
I_3N_3	8.74 l	8.39 l	5.01 fgh	4.84 hi
I_3N_4	9.86 f	9.46 f	5.17 cd	5.00 de
I_3N_5	11.51 a	11.05 a	5.39 a	5.19 a
I_3N_6	10.34 d	9.93 d	5.22 bc	5.06 c
I_4N_0	7.79 s	7.48 s	4.83 klm	4.69 lm
I_4N_1	8.07 p	7.74 p	4.83 klm	4.68lm
I_4N_2	9.29 j	8.92 j	5.06 efg	4.90 fg
I_4N_3	8.71 m	8.36 m	4.93 hijk	4.77 jk
I_4N_4	9.82 g	9.43 g	5.10 def	4.94 f
I_4N_5	11.45 b	11.00 b	5.31 ab	5.13 b
I_4N_6	10.30 e	9.89 e	5.18 cd	5.00 d
Overall mean	9.75	9.36	4.92	4.76
LSD at 5%	0.01642	0.01642	0.1038	0.05191

Means in a column not sharing a letter in common differ significantly at ($p \leq 0.05$)

The integrated plant nutrition levels showed significant effect on NAR that showed the increasing tendency with increasing integrated plant nutrition levels. Among integrated plant nutrition levels, N_5 (150-75-75 kg N – P_2O_5 – K_2O ha^{-1} + FYM @ 20t ha^{-1}) gave the maximum NAR of 5.13 in 2003 and 4.93 g m^{-2} d^{-1} in 2004. Least values of NAR (4.74 in 2003 and 4.73 g m^{-2} d^{-1} in 2004) were recorded in N_0 (control). Seed cotton yield was significantly and positively correlated with the NAR. The common regression accounted for 84.72% variability in data (Fig. 6). These results are in line to those reported by Saleem *et al*., (2008) who also found an analogous linear relationship. Variation in NAR in response to agronomic treatments may be accounted for by differences in crop growth.

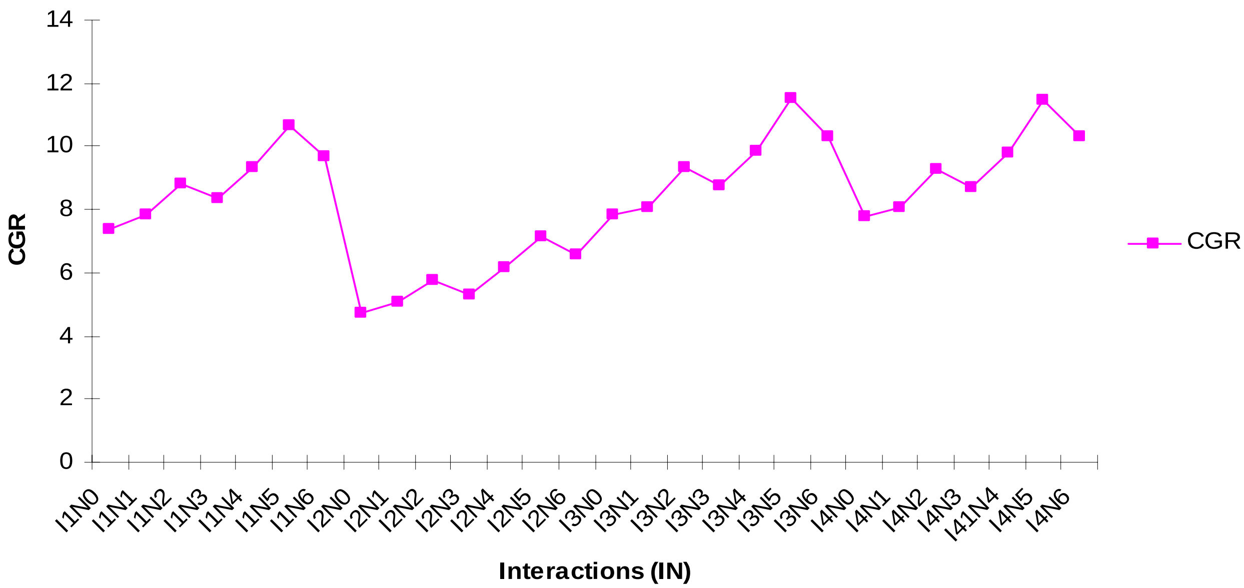

Fig. 1. Interactions between irrigation schedules and integrated plant nutrition levels affecting the seasonal CGR during 2003.

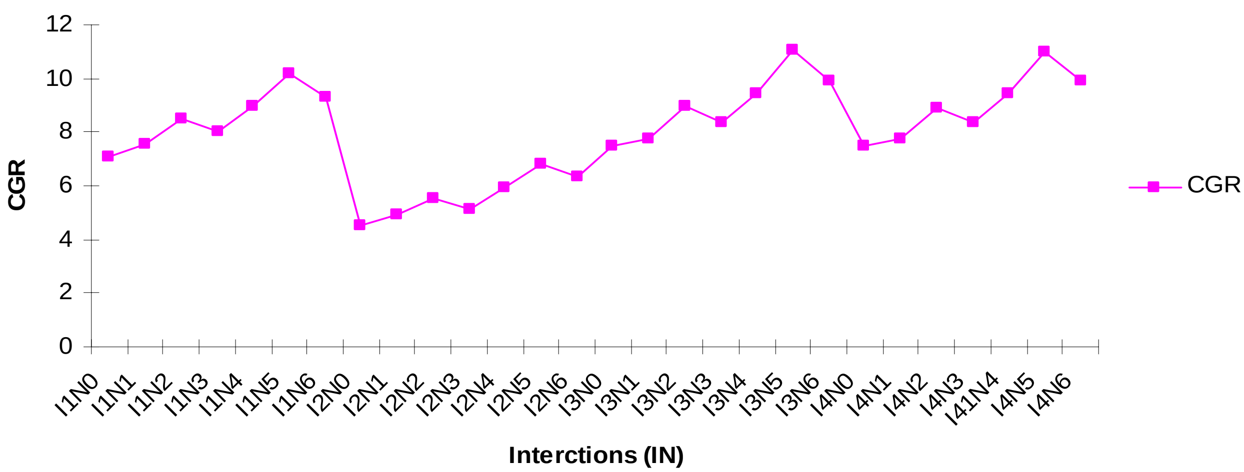

Fig. 2. Interactions between irrigation schedules and integrated plant nutrition levels affecting the seasonal CGR during 2004.

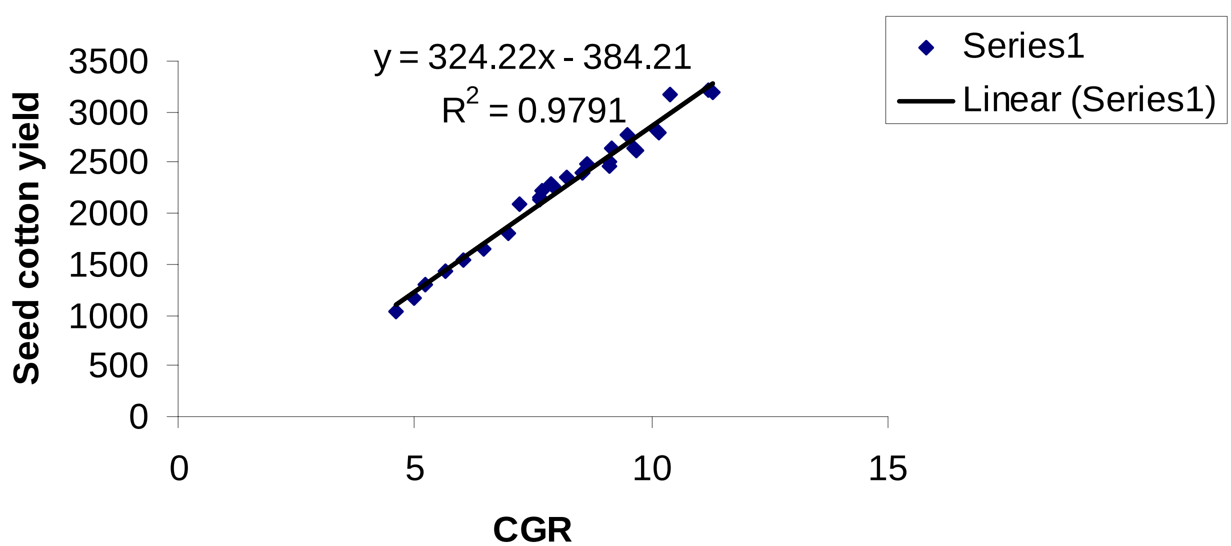

Fig. 3. Regression between CGR and seed cotton yield.

Interactive effects of irrigation schedules and integrated plant nutrition levels showed significant influence upon NAR. In 2003, I_3N_5 (irrigation at 25 mm potential soil moisture deficit × 150-75-75 kg N – P_2O_5 – K_2O ha^{-1} + FYM @ 20t ha^{-1}) gave maximum NAR of 5.39, which was followed by I_4N_5 (irrigation at 25 mm deficit × 150-75-75 kg N – P_2O_5 – K_2O ha^{-1} + FYM @ 20t ha^{-1}) that showed 5.31 NAR value (Fig. 4). In 2004, the highest NAR value of 5.19 was recorded with I_3N_5 (irrigation at 25 mm deficit × 150-75-75 kg N – P_2O_5 – K_2O ha^{-1} + FYM @ 20t ha^{-1}) (Fig. 5). The minimum values of 4.51 in 2003 and 4.39 in 2004 were recorded with I_2N_0 (three irrigations × control). In present experiments, the comparatively superior performance of the treatments may be associated with higher LAI, especially early in the growing seasons. Increasing rate of nutrition in N_5 (150-75-75 kg N – P_2O_5 – K_2O ha^{-1} + FYM @ 20t ha^{-1}) enhanced seed cotton yield over control because of higher LAI and higher CGR. Many researchers have reported similar effects (Ahmad, 2003; Hussain *et al*., 1985). Saleem *et al*., (2009) attained significantly higher leaf area duration and total dry matter cotton yields with the interaction of apposite irrigation schedule and integrated nutrition that might be attributed to the increase in CGR and NAR.

Conclusion

The treatment combinations of I_3N_5 (irrigation at 25 mm potential soil moisture deficit and 150-75-75 kg N-P_2O_5-K_2O ha^{-1} + FYM @ 20 t ha^{-1}) and I_4N_5 (irrigation at 50 mm deficit and 150-75-75 kg N-P_2O_5-K_2O ha^{-1} + FYM @ 20 t ha^{-1}), significantly enhanced CGR compared to all the other interactions. Interaction I_3N_5 increased CGR and NAR by 145 % and 20 %, respectively in 2003 and 146 % and 18 %, respectively in 2004, however, I_4N_5 performed at par with I_3N_5 in 2003. Analyzing crop growth and yield in terms of NAR and yields, a strong and positive linear relationship was found. The interactions between irrigation schedules and integrated plant nutrition levels affecting seed cotton yield and CGR were significant in both the years. The interactions of I_3N_5 and I_4N_5 resulted in higher TDM, CGR, NAR and consequently improved seed cotton yield. The seed cotton yield was strongly dependent and related to CGR and NAR, as there were positive and linear relationships between them. Higher seed cotton production was attributed to higher crop growth rate and net assimilation in these treatments.

In conclusion, better cotton yield and greater CGR and NAR can be attained, under Faisalabad, Pakistan conditions, when cotton crop is planted at 150-75-75 kg N-P_2O_5-K_2O ha^{-1} + FYM @ 20 t ha^{-1} along with any of two irrigation schedules viz., irrigation application when there is 25 or 50 mm potential soil moisture deficit since the said two irrigation schedules performed statistically at par. After 150-75-75 kg N-P_2O_5-K_2O ha^{-1} + FYM (farm yard manure) @ 20 t ha^{-1}, the second sustainable substitute of integrated plant nutrition level may be 150-75-75 kg N-P_2O_5-K_2O ha^{-1} + wheat straw @ 5 t ha^{-1} to have optimum returns in terms of yield, CGR and NAR. In general, optimum use of organic manures along with the chemical fertilizers in conjunction with the judicious irrigation water application when applied in compliance with the concluded rates can enhance cotton yields by affecting CGR and NAR.

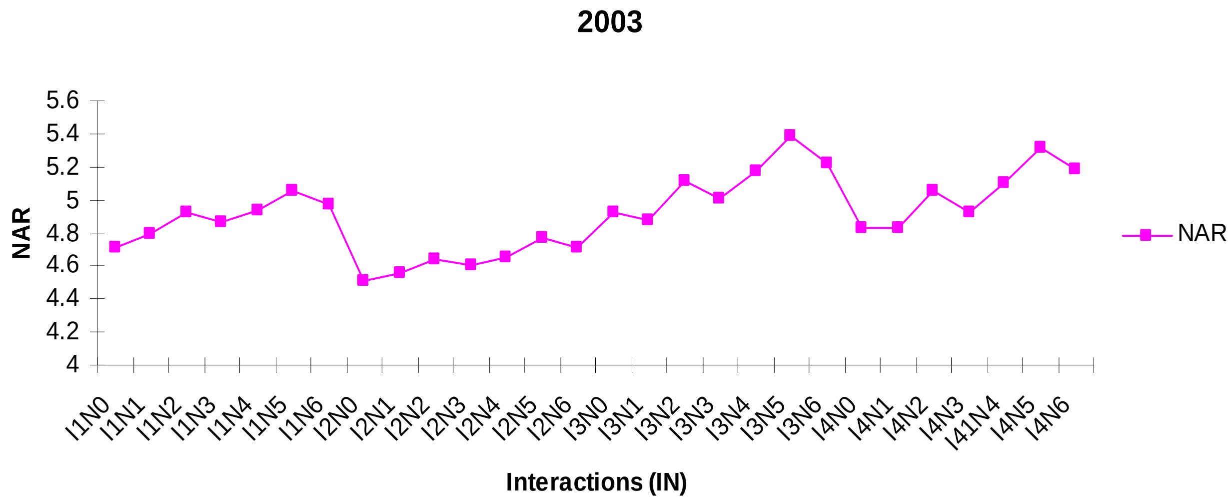

Fig. 4. Interactions between irrigation schedules and integrated plant nutrition levels affecting the net assimilation rate (NAR) during 2004.

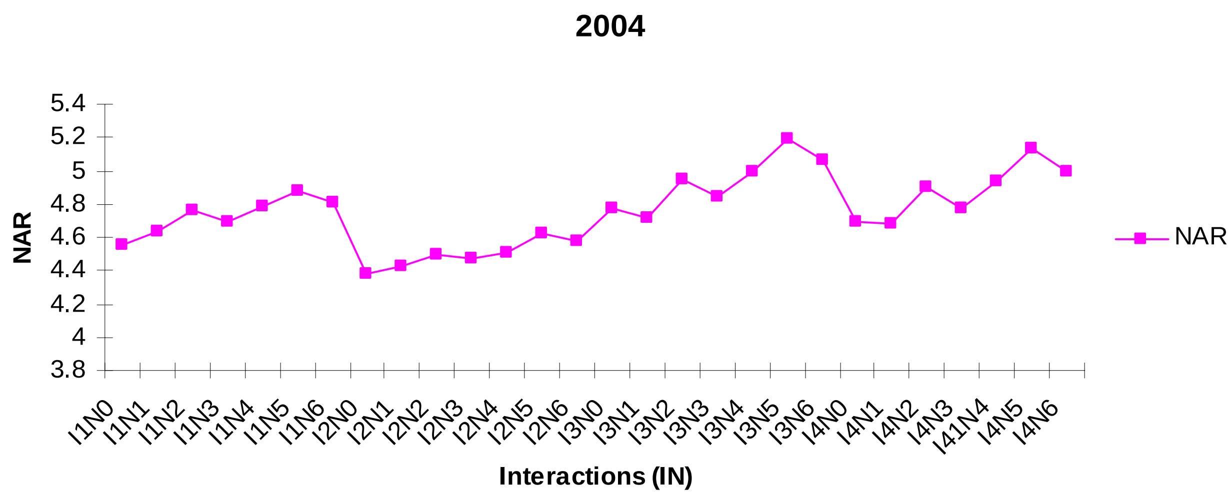

Fig. 5. Interactions between irrigation schedules and integrated plant nutrition levels affecting the net assimilation rate (NAR) during 2004.

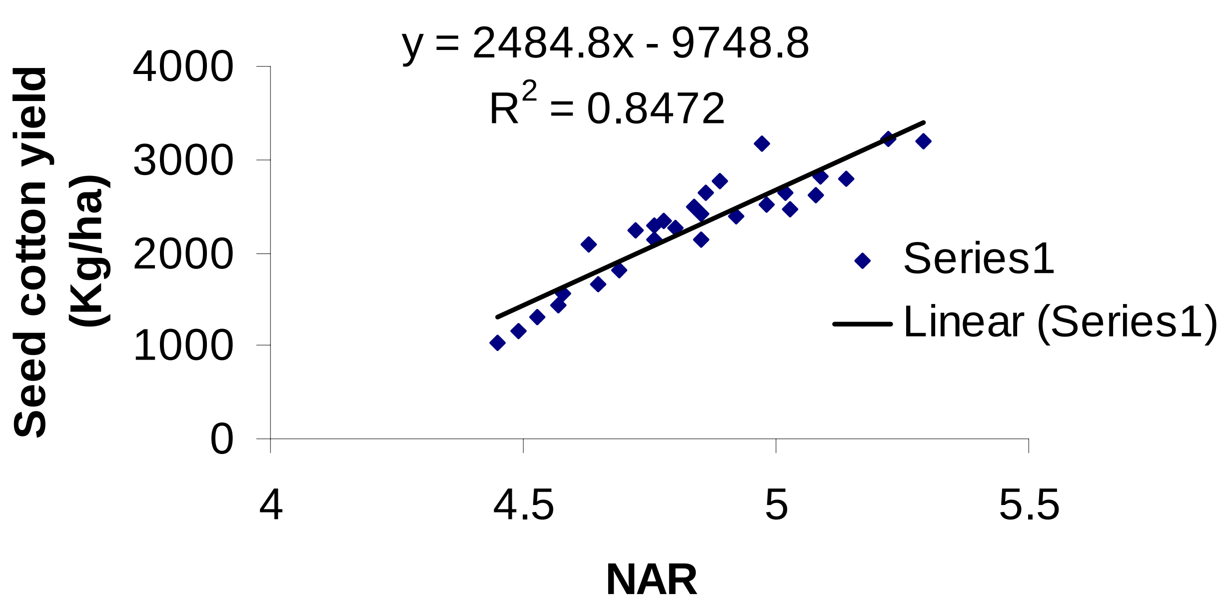

Fig. 6. Regression between NAR and seed cotton yield.

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