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FRACTION OF INTERCEPTED RADIATION OF COTTON RESPONDS TO IRRIGATION AND INTEGRATED PLANT NUTRITION

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Abstract

Significant effect of different irrigation schedules and integrated nutrition levels was determined on fraction of intercepted radiation (Fi) in cotton. The treatments were four irrigation schedules viz. 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 i.e. control (N_0), 75-37.5–37.5 kg NPK ha^{-1} (N_1), 75-37.5-37.5 kg NPK ha^{-1} + FYM (farm yard manure) @ 20 t ha^{-1} (N_2), 75-37.5-37.5 kg NPK ha^{-1} + wheat straw@ 5 t ha^{-1} (N_3), 150-75-75 kg NPK ha^{-1} (N_4), 150-75-75 kg NPK ha^{-1} + FYM @ 20 t ha^{-1} (N_5), 150-75-75 kg NPK ha^{-1} + wheat straw @ 5 t ha^{-1} (N_6). Positive and linear relationships were established between Fi and total dry matter (TDM); and Fi and seed cotton yield. Significantly higher Fi values were attained when the crop was planted at N_5 with any of three irrigation schedules viz. I_1 or I_3 or I_4. The highest values of Fi (0.914 in first year and 0.913 in second year of study) were recorded with I_4N_5 which were followed by I_3N_5 and I_1N_5. The interactions I_4N_5, I_3N_5 and I_1N_5 harvested 23.51, 23.38 and 20.27 % greater Fi to I_2N_0.

Introduction

Total dry matter (TDM) per unit area is a pre-requisite to achieve higher crop 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). Irrigation use has a significant effect on light and radiation interception in improving seed cotton yield (Shafiq, 2002; Ahmad, 2003). Irrigation water applied less or more than the optimum requirement of a crop can adversely affect the yield and hence, there is an imperative need to determine suitable time or proper stage of crop in appropriate amounts for application of irrigation water to cotton (Saleem *et al*., 2008).

Integrated plant nutrition 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. Fertilizer is the most important component in an integrated nutrient supply system due to intensive cropping and because of 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 micro organisms; 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; Ahmad *et al.*, 2009).

Agriculture has, now, 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 era to use alternate sources of fuel in order to get advantage of these rich sources of nutrients particularly under irrigated conditions. Proper integration of two or more nutrient resources, taking into account balance fertilization, will ensure optimum nutrient supply to boost the crop productivity.

Cotton is an extremely valuable cash crop of Pakistan. The average seed cotton yield of Pakistan (2280 kg ha^{-1}) in 2005 was more than the world (1949 kg ha^{-1}) and some other countries such as India (850 kg ha^{-1}), Turkemanistan (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).

The objective of the present studies was to determine and analyze the effect of different irrigation schedules and integrated plant nutrition levels on fraction of intercepted radiation in cotton. Therefore the studies were planned considering the function of intercepted radiation in enhancement of total dry matter and economic yield of cotton by means of apposite scheduling of irrigation water application and optimal management of integrated plant nutrition.

Materials and Methods

Two years field experimentation was accomplished during 2003 and 2004 in 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.

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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 m x 6 m. The treatments were 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 crop was sown in the first week of June during both the years using recommended seed rate of 20 kg ha^{-1}. The crop was planted 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 the same for all the treatments.

Maximum potential soil moisture deficit (D) has been used as a criterion for irrigation application at 25mm and 50mm moisture deficit (French and Legg, 1979). Daily Penman's potential evapotranspiration (PET) is calculated by using standard programme of 'CROPWAT' developed by Anon., (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 is equal to the difference between potential evapotranspiration (PET) and rainfall + irrigation. Potential soil moisture deficit (D) is determined as under:

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

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

Potential evapotranspiration (PET) is determined using pan evaporation method. This method 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 is 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). Data on leaf area index (LAI), fraction of intercepted radiation (Fi), total dry matter (TDM) and seed cotton yield were recorded during the course of studies:

A net plot size measuring 1.5 m 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.

Randomly 5 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 taken. These samples were dried under sun for 48 hours and then drying weight was determined at 65^0 C to a constant weight to determine the dry matter.

The leaf area was converted into total leaf area per unit area and the leaf area index was measured.

$$LAI = Leaf\ area/Land\ area$$

The fraction of intercepted radiation (Fi) was calculated from LAI using the exponential equation suggested by Monteith & Elston (1983).

$$Fi = 1- \exp(-K \times LAI)$$

where K is an extinction coefficient for total solar radiation, value of K is 0.77 which is used for cotton as suggested by Rosenthal & Gerik (1990).

Regression analysis was enforced to determine the relationship between Fi and TDM, and Fi and seed cotton yield.

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 data correspond to mean monthly values 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.

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

Month	2003				2004			
	Temp. (°C)	Rainfall (mm)	R.H. (%)	Net radiation (Mj m^{-2} day^{-1})	Temp. (°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
Aug.	32.9	143.6	66.7	12.4	32.5	86.8	67.1	13.0
Sep.	31.5	54	59.0	12.1	31.3	24.6	59	15.4
Oct.	26.7	0	55.3	10.5	26.6	4.3	61	10.1
Total		338.9				228.6		
Av.	32.08	67.78	56.56	12.56	31.76	45.72	57.04	13.76

where Aug. = August, Sep. = September, Oct. = October and Av. = Average

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.

Fraction of intercepted radiation (Fi) was established to be significantly affected by different irrigation schedules (Fig. 1 a, b). Fi values ranged from 0.129 to 0.878. Maximum fraction of intercepted radiation (0.878 in 2003 and 0.876 in 2004) was intercepted by I_4 (irrigation at 50 mm deficit), which were closely followed by I_3 (irrigation at 25 mm deficit) and I_1 (six irrigations). Least values of Fi were recorded in I_2 (three irrigations) (0.135 in 2003 and 0.129 in 2004). These conclusions are in unison with those affirmed by Hussain (2002), Shafiq (2002) and Ahmad (2003) who examined higher Fi values with a schedule of six irrigations in disparity to the schedules with less number of irrigations.

There was an increasing trend of Fi from sowing to 120 days and then Fi diminished at final harvest. Different integrated plan nutrition levels had a significant effect on Fi (Fig. 2 a, b). Maximum values (0.893 in 2003 and 0.872 in 2004) of Fi were recorded on 120 DAS in the treatment N_5 (150-75-75 kg N – P_2O_5 – K_2O ha^{-1} + FYM @ 20t ha^{-1}). The minimum values of 0.166 and 0.158 were experienced with N_0 (control). Fi was linearly increased with the increase in nutrition levels. These results are in conformity to the previous work on nitrogen performed by Cheema (2006) who recorded the increase in Fi values at higher nitrogen rates for different cotton cultivars. Similar findings have also been reported by Wajid *et al*., (2010) and Zahoor *et al*., (2010) on different crop plants.

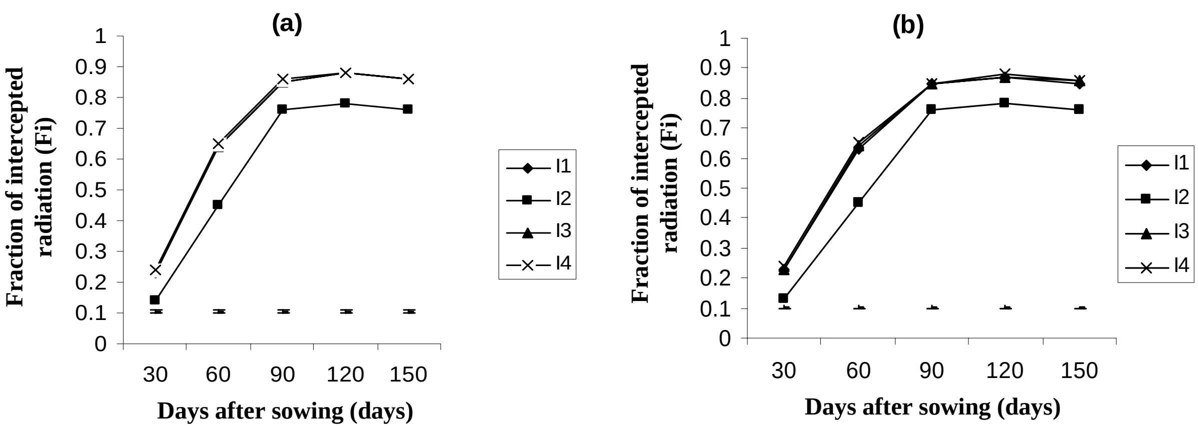


Fig. 1 (a, b). Effect of irrigation schedules on fraction of intercepted radiation (Fi) of cotton during 2003 (a) and 2004 (b), Bars are LSD at 5%.

The interaction between irrigation schedules and integrated plant nutrition levels was non-significant on 30 DAS but it was significant on 60, 90, 120 and 150 DAS (Table 2). The highest values of Fi (0.914 in 2003 and 0.913 in 2004) were recorded with I_4N_5 (irrigation at 50 mm deficit × 150-75-75 kg N–P_2O_5–K_2O ha^{-1} + FYM @ 20 t ha^{-1}) which were followed by I_3N_5 (irrigation at 25 mm deficit × 150-75-75 kg N–P_2O_5–K_2O ha^{-1} + FYM @ 20 t ha^{-1}) and I_1N_5 (six irrigations × 150-75-75 kg N–P_2O_5–K_2O ha^{-1} + FYM @ 20t ha^{-1}). The three treatment combination, I_4N_5, I_3N_5 and I_1N_5, harvested 23.51, 23.38 and 20.27 %, respectively greater Fi to I_2N_0 (three irrigation x control / no nutrition). The total dry matter and seed cotton yield were strongly dependent and related to Fi, as there were positive and linear relationships between them. 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. 3 a, b). The domino effect is in concurrence to the ending of Monteith (1977) who exemplified that the rate of dry matter production was directly proportional to the amount of intercepted radiation and the efficiency with which the light energy was converted to TDM (Monteith, 1977). Improved dry matter accumulation and seed cotton production in I_4N_5, I_3N_5 and I_1N_5 was due to higher Fi.

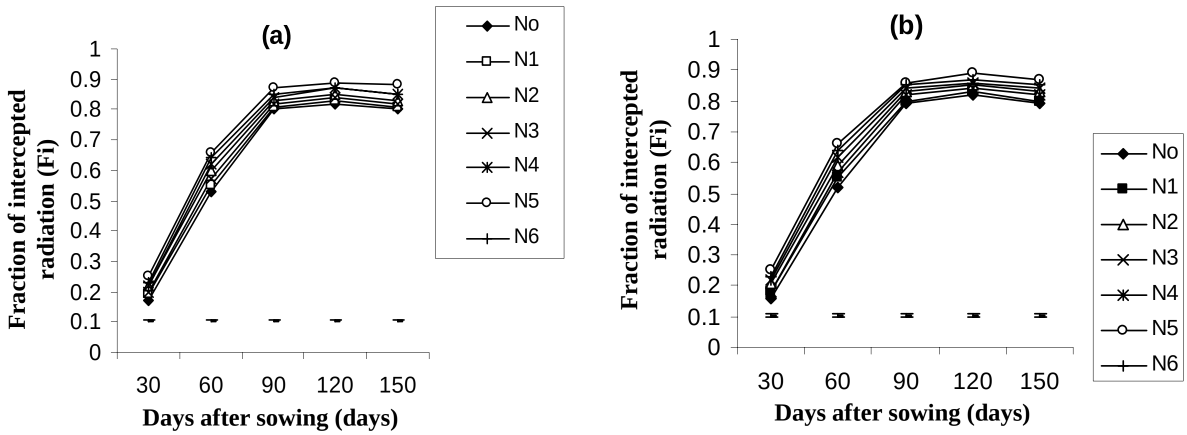


Fig. 2 (a, b). Effect of integrated plant nutrition levels on fraction of intercepted radiation (Fi) of cotton during 2003 (a) and 2004 (b), Bars are LSD at 5%.

Table 2. Interaction between irrigation schedules and integrated plant nutrition levels affecting the Fi

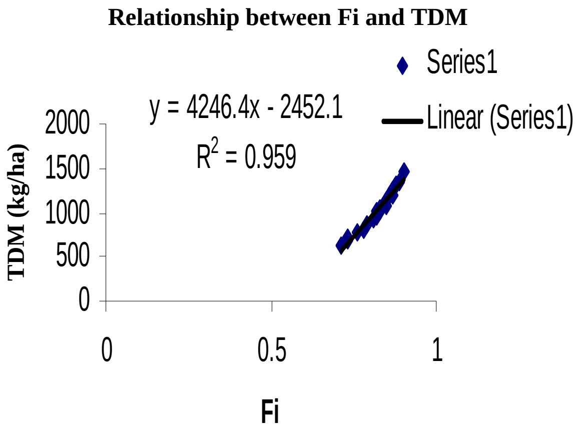
Treatment	60 DAS		90 DAS		120 DAS		150 DAS	
	2003	2004	2003	2004	2003	2004	2003	2004
I_1N_0	0.58 r	0.57 r	0.82 mn	0.82 k	0.84 jk	0.84 jk	0.82 jk	0.82 ij
I_1N_1	0.60 pq	0.59 pq	0.83 klm	0.83 ijk	0.85 ij	0.85 ij	0.83 ij	0.83 hi
I_1N_2	0.64 jkl	0.63 jkl	0.85 fghij	0.85 fgh	0.87 fgh	0.87 efg	0.85 fg	0.85 ef
I_1N_3	0.62 mno	0.61 mno	0.84 ijkl	0.84 hij	0.87 hi	0.86 ghi	0.85 ghi	0.84 fgh
I_1N_4	0.66 jhi	0.65 ghi	0.86 defgh	0.86 defg	0.89 cdefg	0.88 cdef	0.87 cdef	0.87 bcde
I_1N5	0.69 abc	0.69 abc	0.88 abc	0.88 abc	0.91 ab	0.91 ab	0.89 ab	0.89 a
$I1N_6$	0.68 def	0.67 def	0.87 def	0.86 def	0.89 cde	0.89 cd	0.87 cd	0.87 bc
I_2N_0	0.36 y	0.36 y	0.72 s	0.72 p	0.74 o	0.73 o	0.71 o	0.71 n
I_2N_1	0.39 x	0.39 x	0.73 rs	0.73 op	0.76 n	0.75 n	0.73 n	0.73 m
I_2N_2	0.46 v	0.46 v	0.76 q	0.76 n	0.78 m	0.78 m	0.76 m	0.75 l
I_2N_3	0.42 w	0.42 w	0.75 r	0.74 o	0.76 n	0.76 n	0.74 n	0.73 m
I_2N_4	0.49 u	0.48 u	0.78 pq	0.78 mn	0.80 l	0.80 l	0.78 l	0.77 k
I_2N_5	0.54 s	0.54 s	0.80 no	0.80 l	0.83 k	0.83 k	0.81 k	0.81 j
I_2N_6	0.51 t	0.51 t	0.79 op	0.79 lm	0.81 l	0.81 l	0.79 l	0.79 k
I_3N_0	0.58 r	0.58 r	0.82 m	0.82 k	0.84 jk	0.84 jk	0.82 jk	0.82 ij
I_3N_1	0.60 opq	0.60opq	0.83 klm	0.83 ijk	0.85 ij	0.85 hij	0.83 hij	0.83 ghi
I_3N_2	0.64 ijk	0.64 ijk	0.85 fghi	0.85 fgh	0.88 efgh	0.87 defg	0.86 efg	0.85 def
I_3N_3	0.62lmn	0.62 lmn	0.84 hijk	0.84 hi	0.87 hi	0.87 gh	0.85 gh	0.85 fg
I_3N_4	0.66 fgh	0.66 fgh	0.86defg	0.86 def	0.89 cdef	0.89 cde	0.87 cdef	0.87 bcde
I_3N_5	0.70 ab	0.70 ab	0.89 ab	0.88 ab	0.91 a	0.91 a	0.90 a	0.90 a
I_3N_6	0.68 cde	0.68 cde	0.87 cde	0.87 cde	0.89 bcd	0.89 c	0.88 bc	0.88 b
I_4N_0	0.59 qr	0.58 qr	0.83 lm	0.82 jk	0.85 jk	0.84 jk	0.83 jk	0.82 ij
I_4N_1	0.61 nop	0.61 nop	0.84 jklm	0.83 ijk	0.85 ij	0.85 hij	0.83 hij	0.83 ghi
I_4N_2	0.65 hij	0.64 hij	0.86 efghi	0.85 efgh	0.88 defgh	0.88 defg	0.86 defg	0.86 cdef
I_4N_3	0.63 klm	0.63 klm	0.84 ghijk	0.84 ghi	0.87 gh	0.87 fg	0.85 g	0.85 f
I_41N_4	0.66 efg	0.66 efg	0.86 def	0.86 def	0.89 cdef	0.89 cde	0.87 cde	0.87 bcd
I_4N_5	0.71 a	0.70 a	0.89 a	0.89 a	0.91 a	0.91 a	0.90 a	0.90 a
I_4N_6	0.68 bcd	0.69 bcd	0.87 bcd	0.87 bcd	0.90 bc	0.89 bc	0.88 bc	0.88 b
Overall mean	0.59	0.59	0.83	0.83	0.85	0.85	0.83	0.83
LSD at 5%	0.0164	0.0164	0.0164	0.0164	0.0164	0.0164	0.0164	0.0164

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

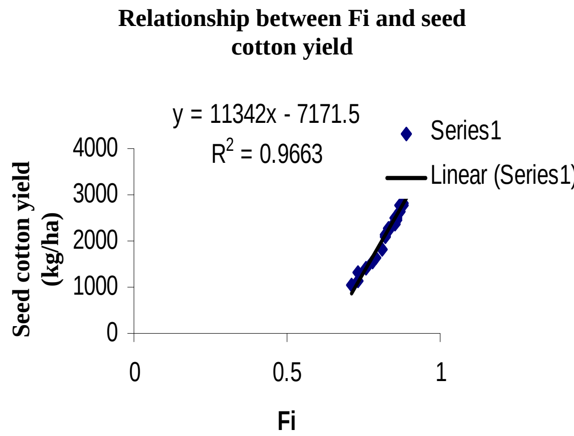
Conclusion

The three interactions of I_1N_5 (six irrigation and 150-75-75 kg N-P_2O_5-K_2O ha^{-1} + FYM @ 20t ha^{-1}), 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 potential soil moisture deficit and 150-75-75 kg N-P_2O_5-K_2O ha^{-1} + FYM @ 20 t ha^{-1}) resulted in higher fraction of intercepted radiation (Fi), total dry matter production (TDM), and consequently seed cotton yields. It was mainly due to the increase in Fi in former than the later. In conclusion, results of this study suggest that higher fraction of intercepted radiation and cotton yields 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 (farm yard manure) @ 20 t ha^{-1}

along with any of three irrigation schedules viz. six irrigations or irrigation application when there is 25 or 50 mm potential soil moisture deficit. After 150-75-75 kg N-P_2O_5-K_2O ha^{-1} + FYM (farm yard manure) @ 20 t ha^{-1}, the second sustainable alternative 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} in turn of Fi.



(a)



(b)

Fig. 3. Relationships between Fi and TDM (a) and Fi and seed cotton yield (b).

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