EFFECT OF DIFFERENT IRRIGATION LEVELS ON THE YIELD AND RADIATION USE EFFICIENCY OF COTTON (Gossypium hirsutum) UNDER TWO SOWING METHODS

Muhammad Maqsood, Tariq Hussain, M. Tayyab and M. Ibrahim
Department of Agronomy, University of Agriculture, Faisalabad

An experiment to study the effect of different irrigation levels on the yield and radiation use efficiency of cotton (Gossypium hirsutum) under two sowing methods was conducted at the agronomic research area, University of Agriculture Faisalabad. The treatments were consist of (A) two sowing methods viz (i) flat sowing (ii) ridge sowing and (B) six irrigation viz: irrigation during vegetative growth (1 irrigation: missing last 5 irrigations), irrigation during vegetative growth (missing last two irrigations), irrigation from flowering till maturity (5 irrigation; missing first irrigation, irrigation from boll formation till maturity (3 irrigations; missing first 3 irrigations), irrigation at all stages (Normal 6 irrigation). The experiment was laid out according to RCBD in split plot arrangement with three replications and net plot size was 2.25x6 m. 

I_5 (irrigation at all stages) produced maximum (2406 kg ha^{-1}) seed cotton yield, which was significantly higher than all treatments. In treatment I_4 (irrigation from boll formation till maturity) seed cotton yield (2217kg ha^{-1}) was significantly higher than I_3 (irrigation up to boll formation 2098 kg ha^{-1}). I_5 irrigation from boll formation till maturity (1362kg ha^{-1}) was significantly minimum yield (887kg ha^{-1}) was recorded in I_1 (irrigation during vegetative growth).

Key words: Irrigation, Radiation use efficiency, Yield, cotton and Pakistan.

INTRODUCTION

Cotton (Gossypium hirsutum) is the most important cash crop and plays a significant role in the economic development of the country. The cotton crop not only meets the increasing demand of domestic agro-based industries but also fetches a substantial amount of foreign exchange (about 60%) through exportable surplus of cotton fiber and fiber made products (Anonymous, 2001). In addition cotton crop also provides livelihood to million of people that are engaged in the textile industry. Realizing the immense importance of cotton plant in building the economy of Pakistan, it has always been the objects of expansive research to improve the yield potential of the crop under the local environmental conditions. Irrigation of cotton at various growth stages leads to differential behavior of crop canopy development and the light use efficiency. More over different sowing patterns also allow differential light penetration into the crop canopy. The present study was conducted to see the effect of different irrigation levels on the light use efficiency of cotton crop grown at two planting methods. The irrigation water is the key factor in achieving higher yield because it is an important constituent of plants and plays a vital role in many metabolic processes. It increases leaf production expansion rate, leaf area duration which effects radiation interception consequently contributes towards final dry matter production (Waston, 1952).

The pre-requisite to achieve high yields is a high production of total dry matter (TDM) per unit area. 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 into TDM (Monteith, 1977). There is no considerable evidence that for other crops, yield at the end of season is proportional to the amount of radiation that the green leaves intercepted 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 crop. The objective of the study was to determine and analyse the effect of different irrigation levels on the growth, yield and radiation use efficiency of cotton crop and to investigate and quantify the effect of sowing method on growth and yield of cotton.

MATERIALS AND METHODS

Investigations to study the growth, yield and radiation use efficiency of cotton at different irrigation levels and sowing methods were conducted at the Agronomic Research Area, University of Agriculture Faisalabad during the year 2003. The cotton variety FH 900 was sown on June 9, 2003 using recommended seed rate of 20 kg ha^{-1}. The soil was sandy clay loam in texture Meteorological data collected during the growing season of the crop from the Department of Physiology, University of Agriculture, Faisalabad. The experiment was laid out in a Randomized Complete block Design (RCBD) with split Plot arrangements using three replications, keeping the sowing method in main plots and irrigation levels in subplots. The net plot size was 2.25 m X 6 m. Experiment comprised of the following treatments. The sowing methods used were flat sowing (S1) and Ridge...
sowing (S2) and six irrigation levels viz. irrigation during vegetative growth (1 irrigation; missing last 5 irrigations), irrigation during vegetative growth and flowering (3 irrigations; missing last three irrigations), irrigation up to boll formation (4 irrigation; missing last 2 irrigations), irrigation from flowering till maturity (5 irrigations; missing first 1 irrigation), irrigation from boll formation till maturity (3 irrigation; missing first 3 irrigations), irrigation at all stages (Normal 6 irrigations) were used. Investigations were carried out to study the growth, yield and light use efficiency of cotton at different irrigation levels and sowing methods. The cotton variety FH 900 was sown in the first week of June 2003 using recommended seed rate of 20kg ha\(^{-1}\). The crop was sown with a single row hand drill on flat seedbed and manually on ridges having row to row distance of 75cm. In both sowing methods plant to plant distance of 30cm was maintained. A basal dose of 115kg ha\(^{-1}\) Nitrogen and 56kg ha\(^{-1}\) P\(_2\)O\(_5\) was applied. Irrigation was applied according to the treatments at various crop growth stages. All other Agronomic practices were kept normal and uniform for all the treatments. The crop was sprayed with Methamedaphos, Cypermethrin, Talstar and Karate to check the insect pest.

**Leaf Area Index:** To calculate leaf area index three plant were taken from each plot monthly. Plants were cut at ground level and leaves were separated from the plants. The fresh weight of the leaves was recorded and then two sub samples of 5g were taken from each sample. The leaf area of these samples were measured with leaf area meter and average was taken. The leaf area of sub-sample was converted into total leaf area per unit area, then leaf area index was measured.

**Radiation use efficiency:** The fraction of intercepted radiation (Fi) was estimated from LAI using the exponential equation suggested by Monteith and 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 Gallagher and Biscoe (1978). Photosynthetically active radiation (PAR) was assumed to equal to half (50%) of total incident radiation (Szcziez, 1974). Multiplying these totals by appropriate estimates of Fi gave the amount of intercepted radiation (Sa). Radiation use efficiency (RUE) of TDM was calculated as under:

\[
RUE = \frac{TDM}{\sum Sa}
\]

Data recorded on different growth and yield parameters were subjected to Finisher's analysis of variance techniques and LSD at 0.05 level of probability was applied to compare the significant means (Steel and Torrie, 1984).

**RESULTS AND DISCUSSION**

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

The final cotton yield is the function of combined effect of all the yield component under a particularly set of environmental condition. It is evident that two sowing methods differed from each other in seed cotton yield. Similarly the differences due to different irrigation levels were also highly significant. The interaction between irrigation levels and sowing methods was non-significant Table 1. The results show that I6 (irrigation at all stages) produce maximum (2406 kg ha\(^{-1}\)) seed cotton yield which was significantly higher than all other treatments. In treatment, I4 (irrigation from boll formation till maturity) seed cotton yield (2217 kg ha\(^{-1}\)) was significant higher than I3 (irrigation up to boll formation) 2098 kg ha\(^{-1}\) and I5 (irrigation from boll formation till maturity) 1362 kg ha\(^{-1}\). The significantly minimum seed cotton yield (887.8kg ha\(^{-1}\)) was noted in I1 (irrigation during vegetative growth) Table 1.

<table>
<thead>
<tr>
<th>Irrigation Levels</th>
<th>Leaf Area Index</th>
<th>Seed cotton yield Kg ha(^{-1})</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Flat sowing</td>
<td>Ridge sowing</td>
</tr>
<tr>
<td>I(_1)</td>
<td>0.72g</td>
<td>0.74g</td>
</tr>
<tr>
<td>I(_2)</td>
<td>1.09f</td>
<td>1.30e</td>
</tr>
<tr>
<td>I(_3)</td>
<td>1.94d</td>
<td>2.23bc</td>
</tr>
<tr>
<td>I(_4)</td>
<td>2.08cd</td>
<td>2.37ab</td>
</tr>
<tr>
<td>I(_5)</td>
<td>1.27ef</td>
<td>1.27ef</td>
</tr>
<tr>
<td>I(_6)</td>
<td>2.46a</td>
<td>2.38ab</td>
</tr>
<tr>
<td>Means</td>
<td>1.59</td>
<td>1.72</td>
</tr>
</tbody>
</table>

LSD for irrigation = 0.13 Interaction = 0.19 LSD for irrigation = 47.36 S.Methods = 19.44
The results indicate that there was a trend of reduction in yield with decreased amount of water used. The results further indicated that reduction in yield was more when irrigation was missed after vegetative stage and at flowering or boll formation stage. There was a significant progressive increase in seed cotton yield in each increase in irrigation level. Sowing methods also affected the seed cotton yield significantly. Ridge sowing produced significantly higher seed cotton yield than flat sowing. The highest seed cotton yield in case of $I_6$ treatment could be attributed to the increase in main yield component like number of mature bolls per plant and seed cotton weight per boll. These results are in line with the findings of Sarwar and Qureshi (1999), and Millhollon (2000) they reported that six irrigation produced the highest seed cotton yield.

**RADIATION USE EFFICIENCY**

**Leaf area index (LAI)**

Leaf area index (LAI) is the main physiological determinant of crop yield. Effect of treatments on LAI development during the season among different irrigation levels. The effect of irrigation levels on LAI was significant while the effect of sowing method and their interaction was non-significant. Maximum value of LAI in all the treatments was recorded on 20-09-2003. Maximum LAI reached to value of 2.42 on 21-09-2003 in $I_6$ treatment. In treatment $I_2$ (irrigation during vegetative growth and flowering), $I_3$ (irrigation up to boll formation) and $I_4$ (irrigation from flowering till maturity) the LAI increase rapidly till 21-9-2003 as compared with $I_1$ (irrigation during vegetative growth) and $I_5$ (irrigation from boll formation till maturity) on 21-07-2003 irrigation levels. Sowing methods also significantly affected the LAI. Their interaction was also significant. The maximum value of LAI was recorded in $I_6$ followed by $I_4$ (Table 1). The treatment $I_6$ produced maximum LAI (2.38 and 2.46) in ridge sowing and flat sowing, respectively and it was also at par with each other and also with $I_5$. Lowest value of LAI was recorded in $I_1$ (flat and ridge sowing, i.e. 0.72 and 0.74 respectively. Thereafter, LAI decline on 21-10-2003 and reached to value of 2.26, 0.70, 1.64, 1.77, and 0.83 in case of $I_6$, $I_5$, $I_4$, $I_3$, and $I_2$ respectively. Lowest value was recorded in $I_1$. These results are supported by Pace et al. (1999), Begonia et al. (1999) and Silva et al. (1998) they found that leaf area index was greater in irrigated than water stressed plants.

**Total dry matter (TDM)**

The effect of different irrigation levels and sowing methods on final total dry matter production is presented in Table 1. Irrigation treatments significantly affected the TDM production. $I_6 \times $ ridge sowing enhanced TDM 1304gm$^{-2}$ compared with all other treatments. $I_6$ (Flat sowing) and $I_4$ (ridge sowing) were at par. All other treatments differed significantly. $I_1$ (Flat sowing) treatment produced the lowest TDM i.e. (378.6 gm$^{-2}$). Sowing methods also affected the dry matter production. Ridge sowing significantly increased TDM (866.7gm$^{-2}$) compared with flat sowing i.e. (805gm$^{-2}$). These results are in line with Jogeiv (1988) and Carmi et al. (1993) they reported that water stress decreased total dry matter production.

There was a positive and linear relation between seed cotton yield and TDM accumulation, and the regression accounted for 99.3% of the variation in data.

**Accumulated Light Interception**

The amount of PAR intercepted differs significantly between irrigation levels $I_6$ significantly enhanced PAR interception compared with $I_4$, $I_5$ and $I_6$ respectively. Similarly $I_4$ enhanced intercepted PAR over $I_2$ and $I_1$ during the season. The average value of accumulated intercepted PAR was 829.1, 1104, 1141, 1340, 785.1, and 1416MJm$^{-2}$ in $I_1$, $I_2$, $I_3$, $I_4$, $I_5$ and $I_6$ respectively. A positive and linear relationship was noted between accumulated intercepted radiation and seasonal TDM accumulation, and the regression accounted for 92% variation in the data Table 2.

**RUE for total dry matter (TDM)**

The treatment under study has significant effect on radiation use efficiency of cotton (Table 2). $I_6$ and $I_2$ treatments were statistically at par for radiation use efficiency by TDM over $I_3$, $I_5$, $I_6$ and $I_1$. Average value of radiation use efficiency by TDM was 0.884g MJ$^{-1}$ in $I_6$, 0.877 g MJ$^{-1}$ in $I_4$, 0.81 g MJ$^{-1}$ in $I_3$, 0.720 g MJ$^{-1}$ in $I_5$, 0.659 g MJ$^{-1}$ in $I_2$ and 0.503 g MJ$^{-1}$ in $I_1$, respectively. Sowing methods had no significant effect on radiation use efficiency to TDM. The interactions between irrigation levels and sowing methods were also non-significant. There was a positive and linear relation between radiation use efficiency and TDM accumulation, and the regression accounted for 75.95% variation in the data.

**RUE for seed cotton yield (SCY)**

Irrigation levels significantly affected radiation use efficiency for seed cotton yield (Table 1). The treatment $I_6$ was superior in radiation use efficiency (0.19gMJ$^{-1}$) for seed cotton yield than $I_5$ (0.16g MJ$^{-1}$), $I_3$ (0.17gMJ$^{-1}$), and $I_2$ (0.15gMJ$^{-1}$). $I_6$ was statistically at par with $I_4$ (0.18gMJ$^{-1}$). The treatments $I_4$ and $I_2$ were at par with each other but significantly enhanced radiation use efficiency for seed cotton yield over $I_2$ and $I_1$. The lowest value of RUE was recorded in case of $I_1$ (0.12gMJ$^{-1}$) treatment. Results emphasize that different
Table 2. Effect of different irrigation levels and sowing methods on yield and radiation use efficiency of cotton

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Accumulated light interception (TDM)</th>
<th>Total dry matter (TDM)</th>
<th>Radiation use efficiency for TDM (g MJ⁻¹)</th>
<th>Radiation use efficiency for seed cotton yield (g MJ⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Sowing methods</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flat</td>
<td>1078.10NS</td>
<td>805.8b</td>
<td>0.727NS</td>
<td>0.16NS</td>
</tr>
<tr>
<td>Ridge</td>
<td>1126.68</td>
<td>866.7a</td>
<td>0.765</td>
<td>0.16</td>
</tr>
<tr>
<td>B. Irrigation Levels</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I₁</td>
<td>829.1e</td>
<td>390.95f</td>
<td>0.503 e</td>
<td>0.11 d</td>
</tr>
<tr>
<td>I₂</td>
<td>1104 d</td>
<td>715.15 d</td>
<td>0.654 d</td>
<td>0.15 c</td>
</tr>
<tr>
<td>I₃</td>
<td>1141 c</td>
<td>913.45 c</td>
<td>0.810 b</td>
<td>0.17 b</td>
</tr>
<tr>
<td>I₄</td>
<td>1340 b</td>
<td>1174.5 b</td>
<td>0.877 a</td>
<td>0.18 a</td>
</tr>
<tr>
<td>I₅</td>
<td>785.1f</td>
<td>571.15 e</td>
<td>0.720 c</td>
<td>0.16 b</td>
</tr>
<tr>
<td>I₆</td>
<td>1416 a</td>
<td>1252.5 a</td>
<td>0.884 a</td>
<td>0.19 a</td>
</tr>
</tbody>
</table>

treatments increased yield by enhancing growth (LAI), which resulted incomplete canopy cover. The higher interception enhanced crop growth rate and thus increasing TDM production in these treatments. The effect of sowing methods and there interaction was non significant (Table 2). These results are in line with those of Muchow (1992) who reported that RUE decreased under water deficit. Seed cotton yield was also linearly related with RUE, and the regression accounted for 79.5% variation in the data.

REFERENCE


Muchow, R.C. 1992. Effect of water and nitrogen supply on radiation interception and biomass accumulation of Kenaf (Hibiscus cannabinus) in a semi-arid tropical environment. Field Crops Res.28(40;281-293 [Irrigation and Drainage Absts. 19(1);364:1993].


