QUANTIFICATION OF GROWTH, YIELD AND RADIATION USE EFFICIENCY OF SUNFLOWER AT DIFFERENT IRRIGATION AND NITROGEN LEVELS UNDER SEMI-ARID CONDITIONS OF FAISALABAD

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ABSTRACT

An experiment was laid out in the Department of Agronomy, University of Agriculture, Faisalabad, Pakistan during the year 2012 under semi-arid climate conditions. Layout system was RCBD with split arrangement to quantify the effects of different irrigation and nitrogen levels on growth and yield of sunflower. Data on achene yield, total dry matter (TDM), leaf area index (LAI), leaf area duration (LAD), fraction of intercepted radiation (Fi) and radiation use efficiency (RUE) were taken. TDM pattern showed sigmoid growth curve for both irrigation and nitrogen levels and showed strong relationship ($R^2 = 0.96$) with LAD. Mean value of fraction of incident PAR (Fi) remained maximum (73%) at 80 days after sowing DAS due to maximum crop canopy development. Five irrigations at different crop growth stages produced 0.47 g/m of TDM for each MJ (mega joule) of accumulated PAR and nitrogen at 150 kg/ha statistically proved to be better in converting radiation into dry matter production.

KEYWORDS: Helianthus annuus L.; sunflower; quantification; radiation use efficiency; irrigation; nitrogen; Pakistan.

INTRODUCTION

Sunflower (Helianthus annuus L.) is a vital oilseed crop around the globe (16). It is also an important oilseed crop of Pakistan grown all over the country. Different factors control the yield of sunflower and are responsible for low yield of crop. However, poor water management is the most important because water has a direct relationship with the growth, development as well as crop yield (5, 12). Most critical period of sunflower yield determinants are anthesis and grain filling (6). Khan et al. (16) observed that head diameter,

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100-achene weight, number of achene's per head and achene yield per plant decreased when water stress increased from 100 to 25 percent of the field capacity. Ghani et al. (11) also evaluated the effect of different irrigation regimes (2, 4 and 6 irrigations) on growth and yield values of sunflower varieties Gimsun-94 and Gimsun-256. Head diameter, 1000-seed weight and number of seeds per head of both varieties were affected significantly by various irrigation frequencies. Six irrigations resulted in higher achene yield (3119 kg/ha) against two irrigations (2200 kg/ha). Moreover, nitrogen is also declared as growth limiting factor (25). In droughty sand, nitrogen at 224 kg/ha enhanced sunflower yield, but both irrigation and nitrogen were required to increase the yield of crop (4). Santalla et al. (27) concluded that quality of seeds not only depends on the genotype but also may be changed by environmental conditions during the fruit filling and by the interaction between environment and genotype, especially the intercepted radiation during the seed filling.

The aims of present study presented are:

1. To quantify the growth, yield and radiation use efficiency of sunflower under semi-arid conditions of Faisalabad.
2. To analyze sunflower hybrid performance using several irrigation schedules.

MATERIALS AND METHODS

This study was conducted in the Department of Agronomy, University of agriculture, Faisalabad, Pakistan under semi-arid conditions during spring season of 2012. The analysis of soil was carried out before crop sowing for physio-chemical characteristics and found sandy clay loam soil with pH 7.8;organic matter 0.87percent, total nitrogen 0.05 percent, available phosphorus 6.7 mg per kg, available and extractable potassium 189 mg per kg. Proposed study was conducted. The experiment was laid out in Randomized Complete Block Design (RCBD) in split plot arrangement with three replications having net plot size of 3.6 m × 5 m. Three irrigation levels (5, 4 and 3) were tested at three nitrogen levels (90, 120, 150 kg/ha) keeping irrigation levels in main plots and nitrogen levels in sub-plots. Line sowing at 60 cm spacing was done using 8 kg per hectare seed rate with hand-mounted seed drill (dibbler). Thinning was done keeping 25 cm plant-to-plant distance. All other cultural practices such as hoeing, irrigation and plant protection measures were kept normal according to general recommendations for the crop. The net plot size measuring 3.6 m × 5 m was
maintained for final yield and rest of the plot was used for random sampling regarding the crop growth. Randomly three plants from each plot were harvested with an interval of 10 days from each plot during the season.

Growth parameters were recorded from measurements of leaf area and dry weight. Leaf area index (LAI) was calculated as the ratio of leaf area to land area (LAI = Leaf area / land area) proposed by Hunt (14) and Leaf area duration (LAD) was estimated as suggested by Hunt (14). LAD = LAI_1 + LAI_2 \times (t_2 - t_1) / 2, where LAI_1 and LAI_2 are the leaf area indices at time t_1 and t_2, respectively. The fraction of intercepted radiation (Fi) by the green surfaces of sunflower crop canopy was measured from Beer’s law (18) as under:

\[ Fi = 1 - \exp (-k \times LAI) \]

Here k is extinction coefficient for total solar radiation equal to 0.85 for sunflower (23). Radiation use efficiency for TDM (RUE_{TDM}) and TDM (RUE_{GY}) was calculated as the ratio of total biomass and grain yield to cumulative intercepted PAR (\(\sum Sa\)) as proposed by Monteith (20).

\[ RUE_{TDM} = \frac{TDM}{\sum Sa} \]
\[ RUE_{GY} = \frac{GY}{\sum Sa} \]

Statistical analysis: Data recorded on growth, yield and radiation use efficiency were statistically analyzed using Fisher’s analysis of variance technique and least significant difference (LSD) test at 5% probability was applied to compare significance of treatments means (28).

RESULTS AND DISCUSSION

Weather: Mean monthly weather data for the crop growth period (Table 1) indicated that average air temperature of March, April, May and June was 18.8°C, 25.3°C, 32.7°C and 34.8°C, respectively. Maximum air temperature was recorded in the month of June (34.8°C) and minimum average was in the month of March (18.8°C). Average relative humidity first increased from March to April (maximum 59.1%) but after April it decreased to its minimum (43.3%) in May. Maximum average rainfall was recorded in the month of June (23.6mm) and no rain fall in the month of May. Total rainfall throughout crop growing season was 35.6 mm. Maximum net radiations were received in the month of May.

Table 1. Meteorological data for cropping season 2012.

<table>
<thead>
<tr>
<th>Month</th>
<th>Mean temp. (°C)</th>
<th>Mean RH (%)</th>
<th>Rainfall (mm)</th>
<th>Net radiation (MJ/d)</th>
<th>ETo (mm)</th>
<th>Wind speed (km/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>March</td>
<td>18.8</td>
<td>58.2</td>
<td>1.5</td>
<td>8.3</td>
<td>2.9</td>
<td>4.9</td>
</tr>
<tr>
<td>April</td>
<td>25.3</td>
<td>59.1</td>
<td>10.5</td>
<td>9.2</td>
<td>3.8</td>
<td>4.7</td>
</tr>
<tr>
<td>May</td>
<td>32.7</td>
<td>43.3</td>
<td>0</td>
<td>10.4</td>
<td>6.5</td>
<td>3.5</td>
</tr>
<tr>
<td>June</td>
<td>34.8</td>
<td>44.1</td>
<td>23.6</td>
<td>9.38</td>
<td>7.2</td>
<td>6.5</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>35.6</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Source: Agro-meteorological data collected at University of Agriculture, Faisalabad-Pakistan.

Achene yield

Achene yield is a combined effect of individual yield components under particular environmental conditions. The data (Table 2) show that achene yield was significant among various irrigation levels. Five irrigations at different growth stages produced higher achene yield (2532 kg/ha) it was 28 and 4 percent higher over four and three irrigations, respectively. Five and four irrigation levels did not differ significantly. Three irrigations produced the lowest achene yield (1813 kg/ha) due to limited growth by deficit of water.

Table 2. Effect of irrigation and nitrogen levels on achene yield, TDM, and other growth parameters.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Achene yield (kg/ha)</th>
<th>TDM (g/m)</th>
<th>LAI</th>
<th>LAD</th>
<th>FI</th>
<th>RUE (TDM) (MJ/g)</th>
<th>RUE (GY) (MJ/g)</th>
</tr>
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<tr>
<td>Irrigation Levels</td>
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<tr>
<td>I1= 5-Irrigations</td>
<td>2532.2a</td>
<td>912.08a</td>
<td>4.60a</td>
<td>156.98a</td>
<td>0.755a</td>
<td>1.696a</td>
<td>0.472a</td>
</tr>
<tr>
<td>I2=4-Irrigations</td>
<td>2430.2a</td>
<td>901.23b</td>
<td>4.51b</td>
<td>140.47b</td>
<td>0.741b</td>
<td>1.678a</td>
<td>0.465b</td>
</tr>
<tr>
<td>I3=3-Irrigations</td>
<td>1813.5b</td>
<td>754.48c</td>
<td>3.86c</td>
<td>123.90c</td>
<td>0.699c</td>
<td>1.61b</td>
<td>0.409c</td>
</tr>
<tr>
<td>LSD 5%</td>
<td>143.36</td>
<td>2.57</td>
<td>0.028</td>
<td>1.10</td>
<td>0.0027</td>
<td>0.042</td>
<td>0.003</td>
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<tr>
<td>Significance</td>
<td>**</td>
<td>**</td>
<td>**</td>
<td>**</td>
<td>**</td>
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<td>Nitrogen levels</td>
<td></td>
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<tr>
<td>N1=90 kg/ha</td>
<td>1985.0b</td>
<td>818.42c</td>
<td>4.18c</td>
<td>132.29c</td>
<td>0.72c</td>
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<td>N2=120 kg/ha</td>
<td>2381.0a</td>
<td>855.08b</td>
<td>4.32b</td>
<td>140.18b</td>
<td>0.73b</td>
<td>1.670b</td>
<td>0.461a</td>
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<tr>
<td>N3=150 kg/ha</td>
<td>2409.9a</td>
<td>896.27a</td>
<td>4.48a</td>
<td>148.88a</td>
<td>0.75a</td>
<td>1.751a</td>
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<tr>
<td>LSD 5%</td>
<td>100.53</td>
<td>1.68</td>
<td>0.036</td>
<td>1.53</td>
<td>0.0028</td>
<td>0.051</td>
<td>0.44</td>
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<tr>
<td>Significance</td>
<td>**</td>
<td>**</td>
<td>**</td>
<td>**</td>
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<td>Interaction</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Mean</td>
<td>2558.63</td>
<td>856.26</td>
<td>4.325</td>
<td>140.45</td>
<td>0.735</td>
<td>1.66</td>
<td>0.448</td>
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</tbody>
</table>

Means having different letters differ significantly from each other (p = 0.05), *Significant, **Highly significant, NS = Non-Significant

Similarly different N doses linearly increased achene yield. N @ 150 kg/ha produced maximum yield (2409 kg/ha) followed by 120 kg N (2381 kg/ha). Minimum N fertilization (90 kg/ha) produced the lowest achene yield (1985 kg/ha). Overall Napplication at optimum rate (150 kg/ha) enhanced yield by

18 percent over low dose of N (90 kg/ha). An increase in achene yield of sunflower in response to N fertilization has also been reported by Munir et al. (22) and Ozer et al. (24). While studying sunflower yield under skip irrigation they found that yield was maximum at optimum irrigation level because more water was available for plant to transpire for photosynthesis process which ultimately enhanced yield Ghani et al. (11), Erdem et al. (9) and Kakar and Soomro (15) reported similar results.

**Total dry matter**

Seven harvests for TDM were recorded with an interval of ten days starting from 20 days after sowing (DAS) to physiological maturity. TDM accumulation was less at first harvest (20 DAS) then it linearly increased till 80 DAS. Early harvest had slower vegetative growth and canopy development which yielded less dry matter. However, as the developmental stages progressed, DM accumulation response to N application became linear. Perusal of data (Table 2) shows that five irrigations level remained superior over other levels in case of dry matter accumulation (912.08 g/m²) due to its more available water. Four Irrigations level showed close value of TDM (901.23 g/m²) to five irrigation level and 17 percent less value by three irrigations level. These results validate the findings of Ghani et al. (11), Erdem et al. (9) showing positive effects of irrigation on TDM sunflower crop. Each increment of N application had significant effect on TDM which ranged between 727-959 g/m. TDM was 24 percent higher with 150 kg N comparative to low dose of 90 kg N. The enhancement in TDM with increasing rate of nitrogen was due to better crop growth rate, which facilitated maximum photosynthates, LAI and ultimately produced more biological yield. These results agree to those of Hassan et al. (13), Dordas et al. (8), Ahmad et al. (1) and Dordas and Siolas (7).

**Leaf area index**

Leaf area index (LAI) is the ratio of leaf area per unit land area. It is unitless quantity due to the ratio of same units. LAI is the main physiological determinant of crop yield. LAI development was less early in the season because of slow growth then it progressed faster and reached its peak value at 60 DAS and then declined in both irrigation and N application at less than 1.42 by 80 DAS due to leaf senescence. The data (Table 2) indicate that five irrigations treatment developed its canopy at much faster rate than other treatments. So, more LAI could be attributed to significant developments in leaf expansion. For example, length and breadth of leaves depend upon high
N rates. The greater leaf expansion in sunflower was attributed to higher rate of cell division and cell enlargement as described by Andrade (2) and Bange et al. (3).

**Leaf area duration (LAD)**

Leaf area duration is the persistence of leaf canopy to remain photosynthetically active. A regression equation was derived between LAD and TDM. (Fig. 1) which shows positive and linear relationship between seasonal TDM and LAD ($R^2 = 0.96$). It also shows that more days (156 days) were taken by five irrigations levels to stay green comparative to four and three irrigations (Table 2). Persistency of leaves to remain active for CO$_2$ assimilation increased with nitrogen application. At higher doses of N (150 kg/ha) leaf tissues remained green for an extended period of 96 days over low dose of 80 kg N (Table 2). During this period more assimilates were manufactured by the crop which ultimately accumulated more DM.

![Fig. 1. Relationship between TDM and LAD](image-url)
Fraction of radiation interception (Fi)

Abundant sunshine remains available during the growth season of sunflower crop in Pakistan. An analytical approach shows that well husbanded crop can harvest more light during the season. The results indicated that five irrigations application showed maximum Fi (0.755 MJ/m²) over two other irrigation levels (0.741 MJ/m² and 0.699 MJ/m²) (Table 2). Higher N dose (150 kg) also gave more fraction of radiation interception (0.75 MJ/m²) followed by 120 kg N (0.73 MJ/m²) and 90 kg N (0.71 MJ/m²). LAI value of 4 is sufficient to intercept more than 90% incident radiation to attain maximum growth rate (21).

Radiation use efficiency (RUE)

A crop canopy with greater LAI intercepts more radiation, which enhances RUE (26). In this study sufficient availability of water proved to be more efficient in converting light into carbohydrates than other deficit irrigation. Five irrigations level produced 0.472 g of achene yield for each MJ/m² of intercepted radiation. As regards N, higher dose (150 kg/ha) gave more value of RUE (0.464 g) for each MJ/m² and this treatment was 25 percent more efficient in converting radiation into seed cotton yield than N applied at low dose of 80 kg. Milroy and Bange (19) explained that leaf N and light intensity directly relates to photosynthesis and, in turn intercepts more radiation, as a result higher radiation use efficiency is obtained. They concluded that RUE increases up to 35 percent due to more accumulation of light.

CONCLUSION

The results conclude that achene yield of sunflower among various irrigation regimes and nitrogen doses related to photosynthetic activity. It revealed that there is considerable scope to exploit the yield potential of different sunflower varieties with different irrigation deficit levels and nitrogen rates, depending upon the prevailing climatic conditions. The study suggests that five irrigations at different growth stages of sunflower crop and 150 kg N per hectare are recommended for achieving high yield under semi-arid conditions of Faisalabad, Pakistan.
REFERENCES


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**CONTRIBUTION OF AUTHORS:**

<table>
<thead>
<tr>
<th>Name</th>
<th>Contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Muhammad Naveed Arshad</td>
<td>Conducted the experiment, took observations, analysed data and concluded results.</td>
</tr>
<tr>
<td>Ashfaq Ahmad</td>
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</tr>
<tr>
<td>Aftab Wajid</td>
<td>Supervisor</td>
</tr>
<tr>
<td>Fahd Rasul</td>
<td>Computed calculation of radiation use efficiency of crop</td>
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<tr>
<td>Tasneem Khaliq</td>
<td>Helped in assigning experimental sites</td>
</tr>
<tr>
<td>Muhammad Awais</td>
<td>Helped in weather data acquisition</td>
</tr>
<tr>
<td>Hafiza Naheed Fatima</td>
<td>Made graphs of different outputs</td>
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