Water Use Efficiency and Yield Responses of Hybrid Sunflower (*Helianthus annuus* L.) under Different Irrigation Regimes in Dry Season of Myanmar

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ABSTRACT

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| Obtaining the maximum yield of the hybrid sunflower for the specific growing conditions is related to the optimum provision of water to plants from sowing until seed maturity. The pot and field experiments were conducted on clay loam soil of the dry season of Myanmar in 2024 to study plant growth and yield responses of the hybrid sunflower under different irrigation regimes. Two experiments were conducted in a randomized complete block design with four irrigation regimes by using Hybrid Sunflower (Yezin 1). The treatments were irrigated at 10 - 15% Soil Moisture Depletion (SMD) (I1), 20 - 25% SMD (I2), 40 - 45% SMD (I3), and 60 - 65% SMD (I4). In both experiments, the increase in irrigation frequency increased plant growth and crop yield. Similarly, yield had a positive correlation with water use efficiency. The Hybrid Sunflower (Yezin 1) gave a maximum plant growth and seed yield (1933.60 kg ha-1) and saved irrigation frequency at 40 - 45 % SMD. It is suggested that the Hybrid Sunflower (Yezin 1) withstands moderate water stress conditions in the study area. |

*Keywords: Hybrid sunflower, Water Use Efficiency, Plant growth, Seed yield*

1. INTRODUCTION

Water is essential for crop production, and the best use of available water must be ensured for efficient crop production and higher yields. Irrigation is most important in areas where climatic conditions are unfavorable, water and land resources are limited, and rainfall is scanty and sporadic. Therefore, agriculture under such conditions cannot be profitably practiced and farm water management must be improved to meet the present growing demands for increased food production. This requires a proper understanding of the effect of rainfall and irrigation on crop growth and yield under different growing conditions.

 Sunflower is a crop that consumes a significant amount of water to form a unit yield. Obtaining maximum yields for the specific growing conditions and the specific hybrid is related to the provision of water to be consumed by plants from sowing until the seeds mature. Irrigation practices are one of the agricultural technologies required to increase unit yields and oil yields to be obtained from the sunflower. Sunflower yield and oil quality responses to irrigation practices have been studied previously (Erdem and Delibas, 2003; Swain et al., 2019; Gocmen, 2021; Sher et al., 2022). Sezen et al. (2011) concluded that the amount and timing of irrigation are important for efficient use of the applied water and for maximizing the sunflower yield and oil content. Sunflowers consume plenty of water (650 mm or more) throughout the vegetation period (Jude, 2012).

 In recent years, sunflower has again become a favorite field crop for growing in Myanmar. This is a prerequisite experiment related to the optimization of irrigation of crops for obtaining the highest possible yields in the presence of limited water resources. This study also aims to study growth and yield responses of hybrid sunflower under optimum water regime in dry season.

2. material and methods

**2.1. Experimental site**

 The experiments were carried out at the Tatkon research farm, Department of Agricultural Research, Myanmar (20° 7' N and 96°12' E) with an elevation of 140 m above mean sea level. The Hybrid Sunflower Yezin 1 was planted in April, 2024 in the pot experiment and October, 2024 in the field experiment and harvested in June, 2024 and January, 2025. The soil was a clay loam soil having 50.39 mg kg-1 available nitrogen content, 76.78 mg kg-1 available phosphorus, 174.85 mg kg-1 available potassium, 2.81% organic matter, and a bulk density of 1.32 g cm-3 in the 0 - 0.40 m profile. The soil pH was 8.9. The average field capacity and permanent wilting point of the root zone soil in the crop field were 35.37 and 11.64%, respectively. Some weather parameters during the study are shown in Table 1 and 2. Evaporation amounts were measured from a Class A pan placed in the experimental area.

**Table 1. Some weather parameters during the sunflower cultivation in pot experiment**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Months** | **Temperature (°C)** | **RH****(%)** | **Sunshine****(hr)** | **Rainfall (mm)** | **Evaporation (mm day-1)** |
| **Max** | **Min** |
| 10th – 30th April, 2024 | 40.35 | 27.06 | 46.48 | 12.82 | 37.00 | 5.55 |
| May, 2024 | 37.38 | 25.97 | 67.32 | 13.06 | 117.00 | 3.95 |
| June, 2024 | 33.27 | 25.39 | 72.00 | 13.20 | 81.80 | 3.83 |

**Table 2. Some weather parameters during the sunflower cultivation in field experiment**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Months** | **Temperature (°C)** | **RH (%)** | **Sunshine (hr)** | **Rainfall (mm)** | **Evaporation (mm day-1)** |
| **Max** | **Min** |
| 28th-31st Oct,2024 | 34.95 | 23.58 | 83.00 | 12.34 | 17.00 | 4.31 |
| Nov, 2024 | 31.86 | 20.87 | 81.43 | 12.32 | 32.00 | 3.54 |
| Dec, 2024 | 32.67 | 17.83 | 78.19 | 12.32 | 0.00 | 3.88 |
| 1st-18th Jan, 2025 | 32.57 | 14.19 | 77.44 | 11.01 | 0.00 | 3.96 |

**2.2. Experimental design and treatments**

 The experiments were laid out in a randomized complete block design (RCBD) with five replications. The treatments were irrigated at 10 - 15% soil moisture depletion (SMD) (I1), 20 - 25% SMD (I2), 40 - 45% SMD (I3), and 60 - 65% SMD (I4). Soil moisture contents at each irrigation treatment were determined gravimetrically from the samples collected from different soil layers (0 - 20 and 20 - 40 cm). The volumetric method was used to measure the amount of irrigation water. The individual irrigation application depths were determined based on soil water storage depletion. Soil water contents from the plots of the treatments were monitored 1-2 days before each irrigation using the gravimetric method, and then these values were converted to volumetric water contents. According to the soil water contents measured, the plots of the treatments were irrigated from a deficit moisture content of 0 - 40 cm soil layer to available soil water at each irrigation using bulk density. In the field experiment, perforated PVC pipes were used to ensure uniform water distribution to reach the furrow in a plot.

 In the pot experiment, 20 plastic pots of about 50 cm height and 30 cm diameter with a capacity of 40 L were used. Each pot was filled with about 40 kg of soil in the upper part (0 - 20 cm) of a cultivated field, and 800 g of compost (equivalent to 2%) was incorporated. The soil was shredded, homogenized, sieved, and afterward dried in the air. After drying, the soil was characterized by its physicochemical properties as shown in Table 3. Three sunflower seeds were sown, and one plant was left 14 days after sowing.

 In the field experiment, the area of each plot was 3.7 m x 4.6 m (17.02 m2), consisting of 6 rows, 4.6 m long, and 0.60 m apart. Seeds were sown by hand and thinned to a target density of 9 plants m-2 (0.20 m x 0.60 m). The plots were surrounded by dykes, and a 2 m wide strip was left bare between adjacent plots to prevent water percolation. Weeds were manually controlled during the experiment. At planting, urea (30.36 kg ha-1) was applied (two-thirds of the application) and side-dressed at the reproductive stage (one-third of the application). Triple super phosphate fertilizer and potash fertilizer were applied at sowing with a rate of 10 and 12 kg ha-1, respectively. The amount of irrigation was identical for all irrigation regimes from the day of sowing (DAS) until the complete establishment of sunflower plants (after 8 leaves had formed; Chimenti and Hall, 1993). After this stage, the plots were irrigated according to the irrigation regimes.

**Table 3. Some physico-chemical properties of soil in the experiments**

|  |  |  |  |
| --- | --- | --- | --- |
| **Soil parameters** | **0-20 cm depth** | **Units** | **Method** |
| Textural class | Clay loam |  | Pipette method |
| Available N | 50.39 | mgkg-1 | Alkaline permanganate method |
| Available P | 76.78 | mgkg-1 | Olsen՚s method |
| Available K | 174.85 | mgkg-1 | 1N Ammonium acetate extraction method |
| Soil bulk density | 1.32 | gcm-3 | Gravimetric method |
| Soil moisture content at field capacity (θfc) | 35.37 | % | Gravimetric method |
| Soil moisture content at Permanent wilting point (θwp) | 11.64 | % | Gravimetric method |
| Plant available water content (PAW) | 23.73 | % | Gravimetric method |
| Organic matter content | 2.81 | % | Walkley and Black method |
| Electrical conductivity | 3.36 | dSm-1 | 1:5 Soil water suspension |
| pH | 8.9 |  | 1:5 Soil water suspension |

**2.3 Irrigation application**

 The irrigation water was applied to each pot under depletion of soil moisture content at field capacity. The depth of irrigation water was calculated by the following formula (Soomro et al., 2001):

**D = SMD/(100 ) x ƿb x dr**

where, D = depth of water required (cm), SMD = soil moisture deficit level, ƿb = bulk density (g cm-3), dr = root depth (cm). The following formula was used to identify soil moisture deficit level:

**SMD = θfc – θ0**

where, θfc = moisture content at field capacity (%), θ0= moisture content before irrigation (%). Daily pan evaporation value was collected and multiplied by a pan coefficient to obtain reference evapotranspiration (ETo) and then by coefficients (kc) to estimate ETcrop. Some climatic data was taken from a Meteorological Station at the Tatkon farm site.

 **ETcrop = ETo x kc**

 **ETo = Epan x kpan**

 **ETcrop = Epan x kpan x kc**

where, ETcrop = Crop evapotranspiration, kc= Crop coefficient, kpan = Pan coefficient, Epan = Pan evaporation value/period, ETo = Reference evapotranspiration.

**The amount of irrigation water = ETcrop - Effective rainfall**

Effective rainfall = 0.8 p – 25 if p>75mm/period

Effective rainfall = 0.6 p – 25 if p<75mm/period

p = rainfall of precipitation (mm/period)

 Epan value was obtained from pan; kpan was 0.75 because it was class A pan. The crop coefficients (kc) value used those suggested by Food and Agriculture Organization of the United Nations (FAO, 2002), with mean values of 0.35,0.75,1.10,0.75, and 0.40 for the initial, vegetative, flowering, grain filling, and physiological maturity stages, respectively.

**2.5. Data collection**

 Crop measurements (plant height, leaf area, dry biomass) were performed at 10-day intervals. The plants were randomly sampled by collecting two representative plants from each plot. Dry biomass was measured after drying in an oven at 85°C for 48 hr until biomass reached constant weight. Leaf area per plant (cm2) was calculated according to Schneiter (1978) at 50% anthesis. It was determined by the following formula.

**LA= [ (LxW) x 0.6683] – 2.45**

where, L = Maximum length of the leaf,

 W = Maximum width of the leaf

 Yield components were recorded on ten randomly selected plants from the inner two rows in each plot. Seed yield was measured by harvesting the plants from 4.6 m2 in the center of each plot. Water use efficiency (kgm-3) was calculated as the ratio of total seed yield (kgha-1) and the total amount of water added to the field (m3ha-1) (Eltaeef and Al-Hadithi, 1988).

**2.6. Statistical analysis**

 The data were analysed by using the Analysis of Variance (ANOVA) through the 'F' test at the level of p < 0.01 and p < 0.05 probability, and means were compared at a probability level of 5% when the effect of the treatment was significant. All the data were analyzed by using Statistix (version 8).

3. results and discussion

**3.1. Pot experiment**

**3.1.1. Yield and yield components**

 The data presented in Table 4 shows the effect of water irrigation regime treatments on yield and yield components. The result indicated a significant effect of different water regimes on sunflower yield and head diameter, filled seeds per head, seed yield (kg ha-1), and seed setting (%). The highest seed yield was possible when the irrigation level was high (i.e., I3 and I4) (Table 5), which could be attributed to an increase in both filled seed and head diameter. Irrigation at 40 - 45% SMD gave the highest significant value of head diameter (10.15cm), seed yield (1304.25 kg ha-1), and filled seeds per head (341.50). Ghani et al. (2000) reported that irrigation at 60% of the depletion of available water is optimum for better sunflower production. In this study, irrigation did not significantly affect the 1000 seed weight of the sunflower crop. Similarly, Khot and Patil (2002) concluded that 1000 seed weight was not significantly affected by irrigation. However, higher seed setting (91.65% and 89.10%) was attained at irrigation with 60 - 65% SMD and 40 - 45% SMD, respectively. Chaniara et al. (1989), Ali et al. (1998), Mahender et al. (2000), and Kakar and Soomro (2001) indicated that an increase in the seed yield of sunflower depended on genotype and irrigation intervals.

Table 4. Yield and yield components of sunflower as affected by irrigation regimes in pot experiment

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Treatment** | **Head diameter (cm)** | **Filled seeds per head** | **1000 seed****weight****(g)** | **Seed setting** **(%)** | **Seed yield** **(kg ha-1)** |
| I1 | 8.49 b | 210.52 b | 45.84 | 78.40 b | 729.03 b |
| I2 | 8.91 ab | 206.50 b | 44.72 | 86.98 a | 744.05 b |
| I3 | 10.15 a | 341.50 a | 48.24 | 89.10 a | 1304.25 a |
| I4 | 10.00 a | 308.95 ab | 52.04 | 91.65 a | 1243.41 a |
| **Mean** | **9.39** | **266.87** | **47.71** | **86.53** | **1005.2** |
| **CV%** | **10.63** | **28.95** | **18.03** | **4.99** | **32.58** |
|  **LSD 0.05** | **0.63** | **48.86** | **5.44** | **2.73** | **207.11** |
| **F test** | **\*** | **\*** | **ns** | **\*\*** | **\*** |

Means of the same category followed by different letters are significantly different at LSD test (p≤ 0.05)

**3.1.2. Water use efficiency**

 Water use efficiency (WUE) is a common expression of plant productivity. It may represent the ratio of total above-ground dry biomass or dry seed weight to the seasonal evapotranspiration (ET). Water use efficiency expressed as (kg m-3) of seeds as affected by the different water treatments is presented in Table 5. The amount and number of irrigations are two important aspects that determine the efficient use of applied water and maximize crop yields. There are significant differences among irrigation treatments in water use efficiency; the irrigation at 40 - 45%SMD gave the highest WUE (0.1992 kg m-3). This may be because irrigation at 40 - 45%SMD responded by raising water use efficiency with the lower number of irrigations as their efficiency in using water increased by a very high rate. In general, WUE values were found to be higher in stressed treatments than in abundantly irrigated treatments (García-López et al., 2016).

Table 5. Water use efficiency under different irrigation regimes in pot experiment

|  |  |  |  |
| --- | --- | --- | --- |
| **Treatment** | **Amount of water****(m3ha-1)** | **WUE** **(kg m-3)** | **Irrigation frequency** |
| I1 | 5404.0 b | 0.1285 b | 13 a |
| I2 | 5533.8 b | 0.1210 b | 12 a |
| I3 | 5977.7 a | 0.1992 a | 9 b |
| I4 | 6243.1 a | 0.1629 ab | 8 b |
| **Mean** | **5789.7** | **0.1529** | **10.85** |
| **CV%** | **4.09** | **26.62** | **10.51** |
|  **LSD 0.05** | **149.77** | **0.026** | **0.721** |
| **F test** | **\*\*** | **\*** | **\*\*** |

Means of the same category followed by different letters are significantly different at LSD test (p≤ 0.05)

**3.2. Field experiment**

**3.2.1. Plant height**

 The highest plant height was recorded with 10 - 15% SMD (I1) treatment while the minimum height was attained in plants at 60 - 65% SMD (I4) (Figure 1). The individual effects of irrigation regimes on plant height were found non-significant during 40 DAS. It is due to the development of the root system, where water uptake in the soil profile was more homogeneous, and differences between treatments were reduced. The plant height was significantly different among the irrigation treatments in the hybrid sunflower after 40 DAS. Based on the results of the analysis of variance of plant height, the effect of irrigation regimes was significant at the level of 5%. The results related to plant height of different treatments showed that with increasing irrigation intervals based on evaporation rate and increasing frequency, growth increases along the growth season. It can be concluded that the effects of irrigation regimes applied in crops was not significant for the plant growth especially during the vegetative period (till 40 DAS). It is suggested that the reduction in plant height due to stress at the stem elongation stage was due to the loss of turgor resulting in a reduction in cell division and elongation. These results were confirmed by El-Hafez et al. (2002) who indicated that reduced irrigation intervals led to a decreased plant height. Abdel-Gawad et al. (1987) concluded that differences in sunflower plant height persisted throughout the growth season and the crop was irrigated at different intervals. Likewise, several researchers (Nandagopal et al., 1996, and Tomar et al., 1997) reported the significant and positive influences on sunflower plant height with adequate water supply at different crop growth stages.

I1=10-15%SMD I2=20-25%SMD I3=40-45%SMD I4=60-65%SMD

**Figure 1. Mean plant height of sunflower as affected by different water regimes**

**3.2.2 Number of leaf per plant**

 The number of leaf per plant was also significantly affected by different irrigation regimes. The number of leaf per plant (30.61) was the highest in the plants irrigated at 10-15 % SMD (I1) followed by those at 20 - 25% SMD (I2) (28.80) and 40-45 % SMD (I3) (26.80) (Figure 2). Minimum leaf number (23.20) was obtained in the case of plants irrigated at 60-65 % SMD (I4). The leaf is the most affected member by the lack of water; the reduction of leaf area is also one of the mechanisms that withstand drought stress by reducing the number of stomata, thus reducing the water loss through transpiration. Reduction in chlorophyll contents due to dehydration under water deficit situations, especially in older leaves, could be another reason for reduced photosynthesis under water deficit situations (David et al.,1998).

I1=10-15%SMD I2=20-25%SMD I3=40-45%SMD I4=60-65%SMD

**Figure 2.** **Number of leaf per plant as affected by different water regimes**

**3.2.3 Leaf area per plant**

 There were significant differences among irrigation treatments in the leaf area. The plants that were irrigated at 10-15% SMD (I1) gave the highest mean leaf area (79304 cm2) compared with the plants that were irrigated at 60-65 % SMD (I4) that had a lowest leaf area (43112 cm2) at 50 DAS (Figure 3). These results showed that increasing irrigation intervals maintained existing leaf area and this crop retained green leaves for the longest period until maturity. The sensitivity of leaf area development is shown by the behavior of the water deficits in 60-65 % SMD (I4) treatment. Issa (1990) stated that the leaf area is one of the important indicators in knowing the representative efficiency of the plant and the extent of the possibility of converting the products of photosynthesis to plant growth.

I1=10-15%SMD I2=20-25%SMD I3=40-45%SMD I4=60-65%SMD

**Figure 3. Leaf area per plant as affected by different water regimes**

**3.2.4. Head diameter and stem girth**

 The data on head diameter and stem girth showed that irrigation frequencies had a significant effect on these parameters. I1 gave a significantly larger head diameter (18.02 cm) against the minimum (14.91 cm) recorded in I4 irrigation (Figure 4). Then, there were significant differences in stem girth among irrigation treatments, the plants that were irrigated in the I1 treatment had the highest mean (6.16 cm) compared with the plants that were irrigated in the I4 treatment that had the lowest (4.69 cm). This increase could be attributed to higher net assimilation due to better utilization of the available water, which ultimately led to better development of the head.On the other hand, it has been approved that the stem can play an important role as the source of mobile non-structural carbohydrate translocation to seeds after flowering (Angadi and Entz, 2002).

I1=10-15%SMD I2=20-25%SMD I3=40-45%SMD I4=60-65%SMD

**Figure 4. Head diameter and stem girth as affected by different water regimes**

**3.2.5 Plant biomass**

 The effects of irrigation regimes on above-ground dry biomass were not significant until 40 DAS (Figure 5). The restriction to water supply affected in the post-anthesis period (during 80 DAS) had a large effect on final biomass (I3 and I4). Although not significantly different among treatments during the anthesis period and post-anthesis period (50 DAS,60 DAS,70 DAS), the crop still can grow rapidly and accumulate substantial biomass at 80 DAS for the treatments of I1 (928 g plant -1) and I2 (824 g plant -1). The results suggested that soil moisture should be maintained at least 20 - 25 % depletion of available soil water until post-anthesis. Thus, it can retain the capacity to respond with high growth rates during their prolonged growth and have a more favorable allocation of biomass to seed growth. Nobre et al. (2010) also confirmed that the soil water content exerted a positive effect on the biomass of the sunflower plants.

I1=10-15%SMD I2=20-25%SMD I3=40-45%SMD I4=60-65%SMD

**Figure 5. Above ground dry biomass as affected by different water regimes**

**3.2.6. Yield and yield components**

 The number of seeds per head is one of the most important yield components in sunflower. Irrigation regimes showed significant effects on the number of seed head-1, 1000 seed weight, and head diameter (Table 6). In this study, the number of filled seed head-1 was decreased by increasing water deficit, with the minimum average value of 558 seeds observed for I4. The maximum and minimum 1000 seed weight were obtained at I1 and I4, respectively. A significant reduction in the number of filled seed head-1 resulted from a reduced head diameter and an increase in the unfilled seed percentage with an increase in water shortage (data not shown). The highest seed yield was possible when the irrigation level was high (i.e., I1), which could be attributed to an increase in both the number of seeds and 1000 seed weight in I1. Deficit irrigation had a pronounced effect on crop yield and yield attributes such as head diameter and 1000 seed weight, both of which decreased progressively as the water deficit increased and ultimately reduced the seed yield.Mahendra *et al*., (2000) reported that seed yield was enhanced with an increase in the number of irrigations. Taha *et al*., (2001) and Khot & Patil (2002) reported that 100 seed weight was linearly related to the amount of irrigation.

 The seed setting % is evident in the response of irrigation treatments (I1, I2, and I3) that led to a better yield in comparison with late irrigation (I4).The size of the sunflower head, i.e., its diameter, is an important factor that affects the seed yield by influencing the number of seeds per head and the size of the seed itself (Balalic *et al.,* 2016). Other studies have shown that the number of irrigations increases sunflower head diameter (Rauf *et al.,* 2012; Gholinezhad *et al*., 2016).

**Table 6. Yield and yield components of sunflower as affected by irrigation regimes**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Treatment** | **Head diameter****(cm)** | **Filled seeds per head** | **1000****seed weight** **(g)** | **Seed setting (%)** | **Seed yield** **(kgha-1)** |
| I1 | 18.02 a | 830.00a | 43.44 a | 88.36 a | 2398.20 a |
| I2 | 16.59 ab | 723.28ab | 43.40 a | 89.07 a | 2093.80 a |
| I3 | 15.73 b | 668.52ab | 38.76 b | 89.05 a | 1933.60 a |
| I4 | 14.91 b | 557.82b | 36.76 b | 80.63 b | 1365.80 b |
| **Mean** | **16.31** | **694.91** | **40.59** | **86.78** | **1947.80** |
| **CV%** | **8.95** | **18.15** | **4.78** | **4.49** | **18.76** |
| **LSD0.05** | **0.92** | **73.91** | **1.23** | **2.46** | **231.12** |
| **F test** | **\*** | **\*** | **\*\*** | **\*** | **\*\*** |

**3.2.7. Water use efficiency**

 Water use efficiency (WUE) is another basic indicator to evaluate the performance of irrigation methods. As a result, water consumptionof crops has improvedin seed yield and WUE, with a unit volume of soil moisture in each treatment, had a similar trend (Table 7 and Figure 6).For water volume and WUE parameters, the ANOVA analysis showed highly significant differences among treatments (*P <* 0.05).The I1 treatment was significantly higher in water volume and WUE (2399.20 m3ha-1 and 1.00 kgm-3, respectively) (Table 7).The highest water use efficiency of the sunflower was found in the I1 and I2 treatments.Similarly, the WUE value in the I3 treatment did not show a significant difference from I1 and I2. There were significant differences among irrigation treatments for the irrigation frequency. Irrigation frequency of I3 indicated a relatively low level in comparison to I1 and I2. It is suggested that regarding the above, stressing the sunflower crop and letting the available soil moisture depleted to 60 % can be an alternative to increase water use efficiency, furthermore, it is an ideal practice in areas that suffer from frequent periods of water deficit. Steduto et al. (2012) indicated that the total available water in the root zone should not exceed 40 % to obtain higher yields. Ghazy and Abu Ghazala, (1999) found that seed yield and WUE increase in proportion to the increase in the amount of irrigation given to sunflowers.

**Table 7. Water use efficiency of sunflower under different irrigation regimes**

|  |  |  |  |
| --- | --- | --- | --- |
| **Treatment** | **Water volume (m3 ha-1)** | **WUE (kg m-3)** | **Irrigation frequency** |
| I1 | 2399.20 a | 1.00 a | 5.80 a |
| I2 | 2367.40 ab | 0.90 a | 5.40 a |
| I3 | 2181.60 bc | 0.79 ab | 3.80 b |
| I4 | 2053.50 c | 0.66 b | 3.00 c |
| **Mean** | **2250.40** | **0.84** | **4.50** |
| **CV%** | **6.74** | **18.71** | **7.31** |
| **LSD0.05** | **95.89** | **0.10** | **0.21** |
| **F test** | **\*** | **\*** | **\*\*** |

**Figure 6. Correlation between seed yield and WUE of sunflower under different irrigation regimes**

**4. Conclusion**

 According to the results obtained, it is concluded that the effect of irrigation regimes had a significant effect on plant growth characteristics (i.e plant height, number of leaf per plant, leaf area per plant, head diameter, stem girth, above-ground biomass) and yield performance (i.e head diameter, filled seeds, 1000 seed weight, seed yield). This study concluded that an increase in irrigation can increase plant growth and crop yield. Hybrid cultivars gave the highest yield only when irrigated (Flagella *et al*., 2002). Similarly, yield had a positive correlation with WUE. In this result, sowing Hybrid Sunflower (Yezin 1) irrigation at 10 - 15 % SMD (I1), 20 - 25 % SMD (I2), and 40 - 45% SMD (I3) achieved maximum value in sunflower growth and seed yield. If it was considered to achieve better growth and seed yield, Hybrid Sunflower (Yezin 1) in the study area should be sown in 40-45 % SMD, and it can save irrigation frequency. It is suggested that the Hybrid Sunflower (Yezin 1) withstands moderate water stress conditions in the study area.

References

Abdel-Gawad, A.A., M.A., Ashoud, S.A., Salh and M.M. El-Gazzar (1987). Vegetative characteristics of some sunflower cultivars as affected by irrigation intervals. Annals of Agricultural Science. 32:1197-1211.

Angadi, S.V., M.H., Entz (2002). Water relations of standard height and dwarf sunflower cultivars. Crop Science,42: 152 – 159.

David, M.M., D. Coelho, I. Barrot, and M.J., Correia (1998). Leaf age effects on photosynthesis activity and sugar accumulation in droughted and rewatered Lupinus albus plants. *Australian Journal of Plant Physiology* 25: 299–306.

Demir, A.O., A.T., Göksoy, H., Büyükcangaz, Z.M., Turan and E.S., Köksal (2006). Deficit irrigation of sunflower (*Helianthus annuus* L.) in a sub-humid climate. Irrigation Science, 24, 4, 279 - 289.

Domuţa C. (2000). Irigarea culturilor. Ed. Universităţii din Oradea.

Domuta C. (2009). Irigarea culturilor. Ed. Universităţii din Oradea.

Domuţa C. (2012). Agrotehnica. Ed. Universităţii din Oradea

El-Hafez S.A.A., A. A., El-Sabbagh, A. Z. El-Bably & A. Abou-El (2002). Evaluation of sprinkler irrigated sunflower in North Delta, Egypt. Alexandria. J. Agric. Res. 47, 147-152.

Eltaeef NI and Al-Hadithi EK (1988). Irrigation, Principles and Applications. Ministry of Higher Education and Scientific Research, University of Baghdad.

Erdem T., L., Delibas (2003). Yield response of sunflower to water stress under Tekirdag conditions. Helia, 26(38): 149-158.

FAO (2000). Crops and Drops, Land and Water Development Division, FAO, Rome, Italy, p. 24.

FAO (2002). Crop water management. Sunflower. Retrieved from http://www.fao. org/ nr/water/ cropinfo\_sunflower.html

Flagella, Z., T., Rotunno, R., Tarantino, R., Di Caterina and A., De Caro (2002). Changes in seed yield and oil fatty acid composition of high oleic sunflower (*Helianthus annuus* L.) hybrids in relation to the sowing date and the water regimes. *Eur. J. Agron*., 17: 221-230.

Ghazy, M.A. and M.E., Abu Ghazala (1999). Intercropping sunflower with soybean under water regime and nitrogen fertilizer levels.*J. Agric. Res. Minsoura Univ*., 29(1): 323-336.

Gholinezhad, E., R., Darvishzadeh, I., Bernousi (2015). Evaluation of sunflower grain yield components under different levels of soil water stress in Azerbaijan. Genetika, *47* (2): 581–598.

Gocmen E. (2021). The effect of different irrigation applications on oil and fatty acids contents of sunflower. Fresen Environ Bull, 30(7 A): 8861-8866.

Göksoy A.T., A.O., Demir, Z.M., Turan and N., Dagüstü (2004). Responses of sunflower (*Helianthus annuus* L.) to full and limited irrigation at different growth stages. Field Crops Research, 87, 2-3, 167-178.

Issa T.A. (1990). (Translator) Directorate of Baghdad *Crop Physiology* University Press. pp: 496.

Jude E. (2012). Ecologie generală, Ed. Universităţii din Oradea

Majumdar, D.K. (2002). Irrigation Water Management, Principles and Practices. Prentice Hall of India, Pvt. Ltd. New Delhi, pp: 487.

Nandagopal, A., K.S., Subramanian, A.Gopalan, and A. Balasubramanian (1996). Influence of irrigation at critical stages on yield and quality of sunflower. Madras Agricultural Journal. 85(3): 152-154.

Rauf, A., M., Maqsood, A., Ahmad, A.S., Gondal. (2012). Yield and oil content of sunflower (*Helianthus annuus* L.) as influenced by spacing and reduced irrigation conditions. eSci J. Crop Prod., *1*: 41–45.

Sezen S.M., A.Yazar, S.Tekin (2011). Effects of partial root-zone drying and deficit irrigation on yield and oil quality of sunflower in a Mediterranean environment. Irrigation and Drainage, 60: 499-508.

Sher A., M.Suleman, A. Sattar, A.Qayyum, M. Ijaz, S.U.Allah, R.Al-Yahyai, Al- A.Hashimi, M.S. Elshikh (2022). Achene yield and oil quality of diverse sunflower (Helianthus annuus L.) hybrids are affected by different irrigation sources. J King Saud Univ Sci, 34(4): 102016.

Swain O.S., P., Mohatpara, B., Digal, A.P., Sahu (2019). Water use efficiency of sunflower under deficit drip irrigation in east and south-east coastal plain agro-climatic zone of Odisha, India. Int J Curr Microbiol Appl Sci.

Tomar, H.P.S., H.P., Singh, and K.S., Dadhwal (1997). Effect of irrigation, nitrogen, and phosphorus on growth and yield of spring sunflower. Indian Journal of Agronomy. 42: 169-172.