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# Evaluation of full and deficit irrigation on two sunflower hybrids under semi-arid environment of Gezira, Sudan

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**ABSTRACT**

Afield study was conducted at Gezira Research Station Farm (GRSF) to investigate the influence of full and deficit irrigation (irrigation stoppage) on sunflower in semi-arid environment in 2011 and 2012 winter seasons. One full-irrigated treatment (T1) and three deficit irrigation (T2, T3 and T4) treatments were applied to Hysun-33 and Bohooth-1 hybrids planted on a clay soil. Results showed that irrigation treatments significantly affected yield and yield components, full-irrigated treatment, T4 and/or T3 exhibited the highest values of disc diameter, stem diameter, number of seed per disc, 1000 seed weight, oil yield and seed yield. The full-irrigated treatment had the heighest seed yield (1769 and 1752.8 kg/ha during the first and second seasons, respectively) while T2 had the lowest seed yield (832 and 1184 kg/ha, respectively) with 53 and 33% seed yield reduction, respectively. Bohooth-1 hybrid was significantly decreased the period to 50% flowering. The average values of applied water during the two seasons under full-irrigated treatment were 3747 and 3417 $m^3$/feddan for Hysun-33 and Bohooth-1, respectively. While average applied water of Hysun-33 for deficit irrigation treatments (T2, T3, and T4) were 2138, 2637, and 3214 $m^3$/feddan, respectively equivelent values for Bohooth-1 were 2078, 2543, and 2979 $m^3$/feddan, respectively. Results also indicated that exposing sunflower to continuous water stress during flowering stage hindered oil percentage and oil yield.

***Keywords:*** *Deficit irrigation, Water productivity. Sunflower, Yield.*


## INTRODUCTION

Under the semi-arid environment of the Sudan and the absence of rainfall during winter season, water remains the major constraint to crop production. In some regions, the available water supply is inadequate to produce the maximum yield on the irrigable area. Therefore, scarce water has to be handled in a manner that combines provision of irrigation requirements to crops and improvement of water use efficiency. Information concerning the inflluence of irrigations at critical growth stages of sunflower under Sudan' condition is not yet available.

Sunflower (Helianthus annuus L.) is one of the four most important oil crops globally and is grown on over 22 million hectaares worldwide and is produced mainly in Argentina, Russia, France, Ukraine, Spain, India, USA, China, Turkey, Romania and Hungary (FAO, 2010). Although sunflower is a temperate zone crop, it can perform well under wide spectrum of climatic and soil conditions. The crop is grown both as a summer and winter crop under irrigated system and as a summer crop under rainfed system.

The area under sunflower cultivation in the Sudan had shown an increasing manner in the last ten years (Mohamed, 2009). The rapidly increased areas is a consequence of farmers and private sector's interest, genetic improvement, wide adaptability and suitability to mechanization, low labor needs, short growth duration, higher yield potential as well as its good quality. Moreover, the increase of the areas under sunflower crop both in developed and in developing countries depend primary on the

productivity of newly created hybrids. In the Sudan, virtually 98% of oilseed sunflower production is with hybrid cultivars, which has intensified the interest of farmers and other producers to grow the crop.

Lack of adequate information about the crop under Sudan condition is cosidered as one of the major problems facing sunflower production. Crop water requirement is one of the main packages that is necessary for irrigation scheduling and water resources management. Doorenbos and Pruitt (1977) reported that the water requirements of crops vary substantially during the growing period mainly due to variations in crop canopy and climatic conditions. Anderson (1979) suggested three growth stages heading, flowering and milking in sunflower sensitive to water stress. Flowering stage is the most senstive stage to water stress causing considerable decrease in both yield and oil contenets. According to Schneiter and Miller (1981) sunflower growth stages can be divided into four physiological phases: vegetative, floral, seed filling and dry down phasse. Therefore, several reports in literature indicate better yields achieved with irrigation applied at the most critical stage i.e. flowering than irrigation at other growth stages (Connor, 1985; Unger, 1986). In the previous studies, water stresses at various growth stages have been shown to markedly influence yields, since maximum yields were generally obtained with full irrigation, nearly maximum yields were obtained when irrigations were made to provide adequate water during flowering and yield formation periods (Connor, 1985; Unger, 1986). Among various production factors, water deficit appears as most crucial factor that can reduce water use without causing significant yield reduction. The concept of deficit irrigation has been considered worldwide as a way of maximizing water use efficiency by eliminating irrigations that have little impact on yield (English and Raja, 1996; Kirda, 1999). Moreover, scientific ressults unveil that yield loss resulted from deficit irrigation is offset by the benefits of reduced water use (Kirnak, 2002). However, under Gezira climatic conditions, deficit irrigation is a neccessity for water resources are limited. Therefore, information on the influence of water deficit at different stages of plant growth in the form of recommedations based on local experimental studies is badly needed.

***Objectives***

The objectives of this study were to investigate the impact of full and deficit irrigation (T1, T2, T3 and T4) treatments on the growth, oil yield, seed yield and seed yield components of two sunflower's hybrids (Hysun-33 and Bohooth-1). The study also aims to evaluate water use efficiency under different irrigation treatments to provide an outline for sunflower irrigation under the semi-arid conditions of the Sudan.

## MATERIALS AND METHODS

Afield experiment was conducted for two consecutive winnter seasons (2011 and 2012) at Gezira Research Station Farm (GRSF), Wad Medani, Sudan (14 30° N, 33 29°E, 405m) to investigate the effect of one full-irrigated treaatment and three deficit irrigation (irrigation stoppage) treatments on the performance of two sunflower hybrids. The soil of the experimental area is characterized by relatively high clay content (average 56%) and low organic matter (0.03%). The experiment was laid out in a randomized complete block design (RCBD) with split plot arrangement. Full and Deficit irrigation treatments (T1= full-irrigated treatment, T2= stopping of irrigation after 60 days from planting, T3= stopping of irrigation after 75 days from planting and T4= stopping of irrigation after 90 days from planting) represent main plot while sunflower's hybrids (Hysun-33 and Bohooth-1) represent sub plot treatments. The experiment consisted of three replications with a plot size of 6.4 m x 10 m, having 10 rows spaced at 30 cm. Crop was sown during the second week of July using seed rate of 5 kg/fed. Three seeds per hole were placed at a depth of approx. 3 - 5 cm at the top of the ridge, then thinned out to one plant/hole two weeks later. Nitrogen fertilizer in the form of urea was added in two splits doses before the second irrigation and before flowering at the rate of 43 kg N/ha per dose as recommended. Irrigation water was applied followed the common practice of farmers in the Gezira Scheme (every 14 days). Other agronomic practices were followed throughout the season as recommended by Agricultural Research Corporation (ARC). Three random plants per treatment were opted to measure leaf area, stem diameter and disc diameter. Irrigations were applied as per treatments throuth out the season. Weed control was performed by hand and repeated when required to provide suitable condition for maximum crop growth and development. Harvesting was completed in the midddle of March. Irrigation water was measured each irrigation cycle using water flow meter device?.

At maturity an area of 9.6 $m^2$ (1.6 m x 9.0 m) was harvested on 15$^{th}$ March for both seasons. Final harvest data (grain yield, 1000 seed weight, empty seed and No. of seed per disc) were collected from the 9.6 $m^2$ harvested area. A sub-sample of 10 plants was randomly collected from each plot for the determination of the remaing parameters. Sunflower water productivity (WP) waas estimated using the following equation:

$$WP = Yield/TAW \quad (1)$$

Where yield in kg and TAW is total applied water in $m^3$. Sunflower economic water productivity (EWP) was calculated as the gross income in Sudanese Pounds (SDG) per gross water supplied in $m^3$. EWP was computed based on the following information obtained at the study site: the size of irrigable area, maximum obtainable yield and the gross income gained from the sale of grain (main product) and sunflower cacke considering the average seasonal local market price (SDG) as stated by the following equation:

EWP = GI/GIWR (2)

Where, GI is gross income from the sale sunflower seed (SDG) and GIWR is gross irrigation water requirement ($m^3$/ha). The gross income is the product of the average price of sunflower per kg for the season and the average grain yield per given irrigable area.

Data were subjected to analysis of variance according to the split plot design and treament means were compared based on least significant difference (LSD) at probability level of 0.05).

## RESULTS AND DISCUSSION

### *Results*

### *Crop growth analyses*

### *Days to 50% flowering*

Days to 50% flowering was significantly affected by sunflowers' hybrids during the first seaason (2011), although results in the second season (2012) show no significant differences but Bohooth-1 required fewer days to reach 50% flowering compared with Hysun-33 (Table 1). In the first season Bohooth-1 has signnificantly shorter period to reach 50% flowering (68 days) compared to Hysun-33 which required 70 days to complete 50% flowering. In the second season the same trend was followed by the two hybrids, Bohooth-1 reached 50% flowering after 62 days compared with 64 days for Hysun-33. On the other hand, full and deficit irrigation treatments (T1, T2, T3 and T4) were in-significant in number of days to 50% flowering.

Table 1. Effect of hybrids and irrigation treatments on some growth parameters of sunflower during 2011 and 2012 seasons

| | Plant height (cm) | | Number of leaves/plant | | Head diameter (cm) | | Stem diameter (cm) | | Leaf Area Index (LAI) | | Days to 50% flowering | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Hybrids | | | | | | |
| | 2011 | 2012 | 2011 | 2012 | 2011 | 2012 | 2011 | 2012 | 2011 | 2012 | 2011 | 2012 |
| Hysun-33 | 149 | 139.8 | 35 | 23.8 | 13.5 | 12.3 | 1.82 | 1.66 | 3.1 | 1.93 | 70 | 64.4 |
| Bohooth-1 | 146 | 138.1 | 34 | 23.5 | 12.8 | 12.4 | 1.76 | 1.60 | 2.6 | 1.81 | 68 | 62.4 |
| SE ± | 1.68 | 2.16 | 0.32 | 0.45 | 0.24 | 0.32 | 0.33 | 0.68 | 0.15 | 0.73 | 0.31 | 0.89 |
| Irrigation treatments | | | | | | | | | | | | |
| | 2011 | 2012 | 2011 | 2012 | 2011 | 2012 | 2011 | 2012 | 2011 | 2012 | 2011 | 2012 |
| 60 days | 147.3 | 143.0 | 34.0 | 22.0 | 11.8 | 12.1 | 1.68 | 1.58 | 2.81 | 1.95 | 69.3 | 63.0 |
| 75 days | 152.8 | 137.5 | 36.5 | 24.8 | 13.4 | 12.7 | 1.83 | 1.63 | 2.99 | 1.98 | 69.0 | 63.5 |
| 90 days | 144.8 | 137.3 | 34.8 | 24.3 | 13.4 | 12,2 | 1.73 | 1.57 | 2.87 | 1.67 | 69.3 | 63.7 |
| 105 days | 145.0 | 137.8 | 33.8 | 23.5 | 14.0 | 12.2 | 1.92 | 1.73 | 2.76 | 1.88 | 69.2 | 63.5 |
| SE± | 3.85 | 2.79 | 1.74 | 1.42 | 0.53 | 0.85 | 0.88 | 0.79 | 0.81 | 0.61 | 0.23 | 0.58 |
| CV% | 4.0 | 5.4 | 3.2 | 6.6 | 6.3 | 9.0 | 6.4 | 14.4 | 18.2 | 13.6 | 1.6 | 5.3 |

### *Plant height and number of leaves per plant*

Results of plant height and number of leaf per plant show in-significant difference among different irrigation treatments as well as sunflowers' hybrids (Table 1). Hysun-33 and Bohooth-1 obtianed similar heights of 149 and 146 cm in the first season, respectively Equivalent values in the second season were 139.8 and 138.1cm, respectively. On the other hand, full and deficit irrigation treatments did not affect plant height and number of leaves per plant.

### *Disc and stem diameters and LAI*

Table (1) shows that in the first season (2011) T1 (full-irrigated treatment) gave significant higher values of disc diameter (14.0 cm) compared with deficit irrigation treatments of T2. Other deficit irrigation treatments of T3 and T4 scored 13.4 and 13.4 cm, respectively. However, in the second season irrigation treatments revealed similar values. Disc diameter values with sunflower hybrid were in-significant. Differences in values of stem diameter and LAI were also found in-significant for both irrigation treatments and sunflower hybrids (Table 1).

### *Crop yield analyses*

### *Grain yield (kg/ha)*

Compared with the deficit irrigation treatment (T2), other irrigation treatments increased seed yield significantly. Full-irrigated treatment (T1) had the highest seed yield (1769 and 1752.8 kg/ha during the first and second seasons, respectively) followed by T4 and T3 deficit irrigation treatments with 1477.6 and 1540.9 kg/ha, respectively, during the first seaason and 1412.2 and 1641.4 kg/ha, respectively, during the second season. The deficit irrigation treatment (T2) produced 53 and 33% lower seed yield than the T1 irrigation treatment during the first and second season, respectively. However, T3 and T4 had 6.4 – 16.5% less seed yield compared with treatment T1 (Table 2). These findings are in agreement with Brevedan and Egli (2003) who reported that the yield of plants exposed to continuous water stress was significantly less (39%) than the full-irrigated (non-stressed) treatment. A decreased sunflower yield under water deficit or drought-stress conditions was also reported by earlier researchers (Murriel 1975, Talha and Osman 1975, Unger 1982). Sunflower hybrids, Hysun-33 and Bohooth-1 obtained

similar yield of 1414.1 and 1396.2 kg/ha during the first season, respectively and 1532.9 and 1462.3 kg/ha during the second season, respectively (Table 2).

Table 2. Effect of hybrids and irrigation treatments on yield and yield components of sunflower during two seasons (2011 and 2012)

| | Seed Yield (kg/ha) | | Oil percentage (%) | | Oil yield (kg/ha) | | Number of seeds/head | | Empty seed (%) | | 1000-seed weight (g) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hybrids | | | | | | | | | | | | |
| | 2011 | 2012 | 2011 | 2012 | 2011 | 2012 | 2011 | 2012 | 2011 | 2012 | 2011 | 2012 |
| Hysun-33 | 1414.1 | 1532.9 | 38.4 | 40.9 | 543.01 | 626.95 | 1461 | 1427 | 3.27 | 1.99 | 55.5 | 54,2 |
| Bohooth-1 | 1396.2 | 1462.3 | 38.9 | 41.0 | 543.12 | 599.54 | 1457 | 1428 | 2.74 | 1.77 | 60.6 | 54.3 |
| SE ± | 70.0 | 75.9 | - | - | - | - | 56.3 | 59.63 | 0.27 | 0.18 | 2.57 | 0.69 |
| Irrigation treatments | | | | | | | | | | | | |
| | 2011 | 2012 | 2011 | 2012 | 2011 | 2012 | 2011 | 2012 | 2011 | 2012 | 2011 | 2012 |
| 60 days | 832.6 | 1184.0 | 37.1 | 39.2 | 308.89 | 464.12 | 1190 | 1306 | 4.20 | 2.4 | 50.4 | 50.1 |
| 75 days | 1477.6 | 1412.2 | 38.5 | 39.5 | 568.87 | 557.81 | 1676 | 1427 | 3.10 | 1.5 | 52.9 | 53.1 |
| 90 days | 1540.9 | 1641.4 | 40.1 | 40.2 | 617.90 | 659.84 | 1473 | 1475 | 2.80 | 1.9 | 63.5 | 57.4 |
| 105 days | 1769.1 | 1752.8 | 41.1 | 41.4 | 727.10 | 725.65 | 1479 | 1551 | 1.97 | 1.8 | 65.3 | 56.5 |
| SE± | 107.2 | 137.9 | - | - | - | - | 121.9 | 72.1 | 0.64 | 0.27 | 2.12 | 1.73 |
| CV% | 17.3 | 17.5 | - | - | - | - | 13.4 | 14.5 | 30.8 | 33.2 | 15.3 | 4.4 |

***Number of seed per disc and 1000 seed weight***

The number of seed per disc and 1000 seed weight components are shown in Table (2). The 1000 seed weight component had a similar response to irrigation treatments like seed yield. Deficit irrigation treatment (T2) significantly scored lower values than the full-irrigated and deficit irrigation (T4) treatments in both seasons. The deficit irrigation treatment (T3) was significantly lower than T1 and T4 in the first season. It has been found that 1000 seed weight significantly increased with increasing amount of irrigation, while other scholars emphasised that 1000 seed weight increased with irrigations applied at flowering and milking periods (Murriel 1975, Talha and Osman 1975, Jana et al. 1982 and Karaata 1991). Like seed yield, sunflower hybrids did not affect 1000 seed weight component. The two hybrids (Hsysun-33 and Bohooth-1) obtained similar values of 1000 seed weight in both seasons (Table 2).

Table (2) also shows that irrigation treatments in the first seeason (2011) significantly affected number of seed per disc. Treatment T3 resulted in the highest number of seed per disc 1676 compared with 1479, 1190 and 1473 for T1, T2 and T4, respectively. In the second season full-irrigated treatment (T1) obtained 16% higher number of seed per disc compared with T2 while T3 and T4 scored lower values that ranged between 5 and 7% comparred with full-irrigated treatment. Like 1000 seed weight and seed yield, sunflower hybrids had more congruence with number of seed per disc in both seasons.

***Empty seed %***

Table (2) shows that empty seed% was in-significant among irrigation treatments as well as sunflower hybrids in both seasons. However, deficit irrigation treatment (T2) scored the highest value 4.2% and 2.4% during the first and second seasons, respectivley. Average values of empty seed% for Hysun-33 and Bohooth-1 were not significant, however, Hysun-33 slightly obtained higher empty seed% compared with Bohooth-1.

***Oil percentage and oil yield***

The oil percentage and yield, are important quality measurements in sunflower. These components followed similar trends of yield and 1000 seed weight. The parameters were greatly affected by the irrigation treatments, however, sunflower hybrids obtained similar values. The oil content increased parallel to the increasing amounts of irrigation in the treatments, where the largest oil content were obtained from the full-irrigated treatment T1 (41.1 and 41.4%) and deficit irrigation treatment, T4 (40.1 and 40.2%) in both seasons. Deficit irrigation treatment (T2), yielded the least oil content (37.1 and 39.2%). Hybrids show a small difference in oil content, Bohooth-1 was higher by 0.1 and 0.5% than Hysun-33 during the first and second seasons, respectively (Table 2). These findings indicated that oil percentage of sunflower seeds decreased as the amount of water supplied decreased. These results asserted many researchers who reported an increase in the oil percentage with the increased use of irrigation water (Kadayifci and Yildirim 2000 and Flagella, 2002).

Sunflower oil yield was mainly affected by irrigation treatments in both growing seasons (Table 2). The average oil yield was obtained by full-irrigated treatment, T1 (727.1 and 725.7 kg/ha) and defict irrigation treatment, T4 (617.9 and 659.8 kg/ha) in both growing seasons. The lowest oil yield was recorded by deficit irrigation treatment, T2 that yielded 308.9 and 464.1 kg/ha during the two growing years (Table 2). Treatments T1 and T4 scored 50 and 58% higher oil yield than treatment T2 during the first season, respectively, while during the second season equivelent values were 30 and 36%, respectively.

***Applied water and water use efficiency***

***Irrigation applied water***

Results show that total applied water for the full-irrigated treatment (T1) along the entire season was 3747 and 3417 $m^3$/feddan for Hysun-33 and Bohoot-1, respectively. Hysun-33 was 9% higher compared with Bohooth-1. The deficit irrigation treatments, T2, T3 and T4 applied to Hysun-33 scored average values of 2142, 2637 and 3214 $m^3$/fed, respectively. The corresponding values for Bohooth-1 were 2078, 2543 and 2979 $m^3$/fed, respectively (Figs 1 and 2). In all irrigation treatments, Bohooth-1 slightly required less amount of water compared with Hysun-33 (Figs. 1 and 2).

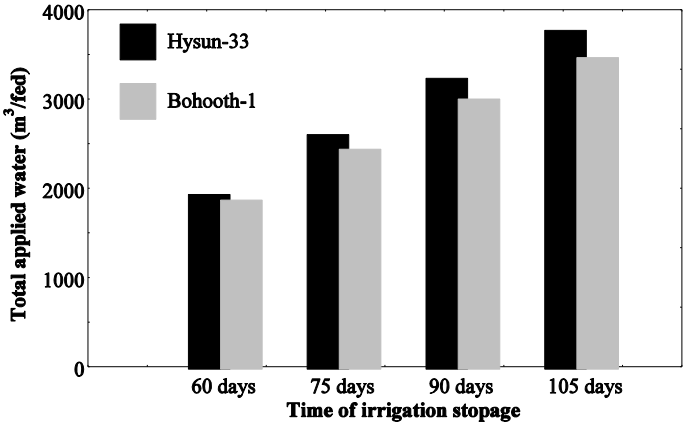


Figure 1. Total applied water of two sunflower hybrids under different irrigation treatments during 2011 season

***Water productivity***

Crop water productivity (CWP) and economic water productivity (EWP) are the essential indicators of efficiency of water use. Evaluation of crop productivity per unit water aspect should be analyzed along with economic aspect because increasing crop productivity per unit of water does not necessarily increase the farmer's income due to the non-linearity of crop yield with the price of products (Araya et al. 2010). Therefore, sunflower water productivity was calculated on montary and water supply basis. In the first season, Hysun-33 WP under full and deficit irrigation treatments, T1, T2, T3 and T4 was 0.16, 0.25, 0.19 and 0.21 kg/$m^3$, respectively, the corresponding values of Bohooth-1 were 0.20, 0.24, 0.22 and 0.20 kg/$m^3$, respectively (Fig.1). While in the second season, Hysun-33 WP values were 0.20, 0.23, 0.21 and 0.22 kg/$m^3$, respectively, equivalent values for Bohooth-1 were 0.23, 0.22, 0.24 and 0.19 kg/$m^3$, respectively (Fig. 2). It is clear that values of WP in T3 and T4 treatments are always higher compared with T1 and T2 treatments which could be attributed to higher water supply and lower yield obtained in T1 and T2, respectively.

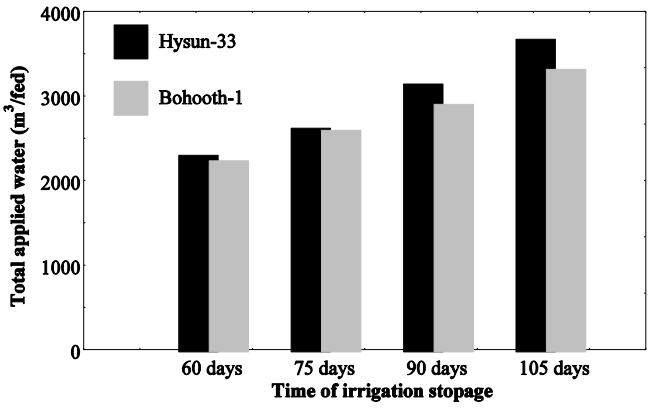


Figure 2. Total applied water of two sunflower hybrids under different irrigation treatments during 2012 season

The two seasons average economic water productivity (EWP) values obtained from growing Hysun-33 hybrid under each irrigation treatments (T1, T2, T3 and T4) 059, 0.80, 0.66 and 0.72 SDG/$m^3$, respectively, whereas the corresponding EWP for Bohooth-1 were 0.71, 0.76, 0.77 and 0.65 SDG/$m^3$, respectively. For both sunflower hybrids (Hysun-33 and Bohooth-1), deficit irrigation treatment (T3) obtained the highest EWP (0.80 and 0.0.76 SDG/$m^3$, for both hybrids, respectively) followed by T4 and T1, whereas deficit irrigation treatment (T2) and full-irrigated treatmets (T1) scored the lowest EWP 0.59 and 0.62

SDG/$m^3$ for Hysun-33 and Bohooth-1, respectively. The respective higher and lower values of EWP for T3 and T2 could be attributed to less irrigation water applied and low yield obtained, respectively.

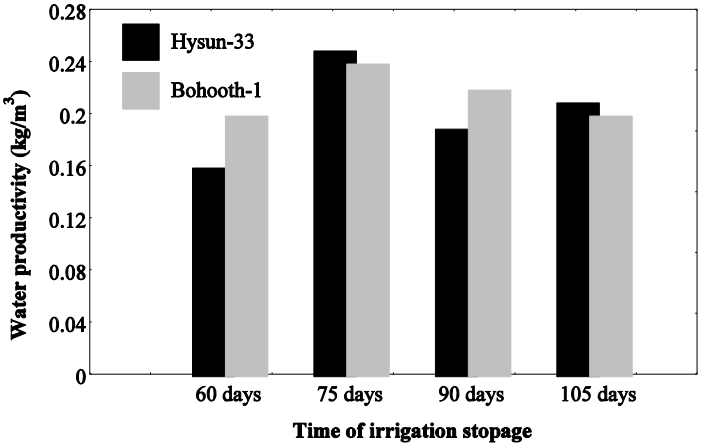


Figure 3. Water productivity (kg/$m^3$) for sunflower hybrids and irrigation treatments during 2011 season

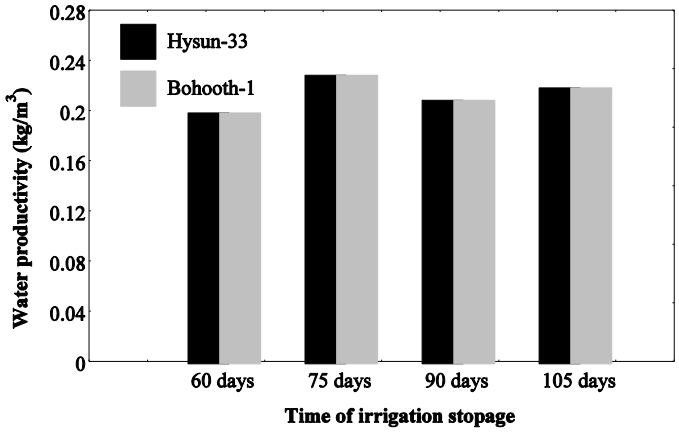


Figure 4. Water productivity (kg/$m^3$) for sunflower hybrids and irrigation treatments during 2012 season

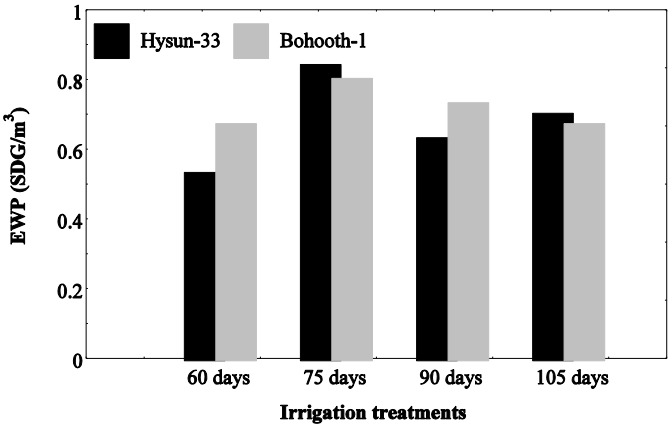


Figure 5. Economic Water productivity (SDG/$m^3$) for sunflower hybrids and irrigation treatments during 2011 season

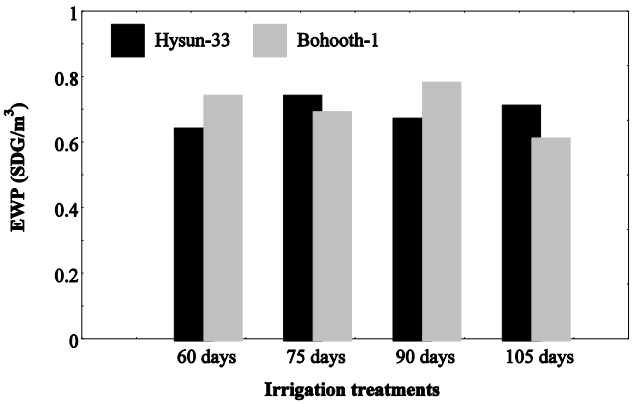


Figure 6. Economic Water productivity (SDG/$m^3$) for sunflower hybrids and irrigation treatments during 2012 season

***Discussion***

***Conclusions***

Based on the findings obtained during two consecutive winter seasons under semi-arid condition (Gezira, Sudan). The maximum yields were obtained with full irrigation (T1) and deficit irrigation treatment (T4), nearly maximum yields were also scored when irrigation were made to provide adequate water during flowering (T3), the authors therefore beleave that sunflower should be fully irrigated (8 irrigations per season) or adequate water should be added during seed filling (7 irrigations per season) otherwise, under limited irrigation water stopping of irrigation after flowering (6 irrigations per season) can also be acceptable under optimum sowig date.

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