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Water Productivity as a Tool for Deficit Irrigation Strategy to Optimize Watering Requirements for the Production of Sunflower (*Helianthus annuus* L.) under Dry Land Conditions of the Northern State, Sudan*

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Abstract: A field experiment was carried out for two consecutive seasons (2015/16 and 2016/17) at the sandy loam soil of New Hamdab Research station with a view to investigate the effect of deficit irrigation induced at different growth stages of sunflower (*Helianthus annuusL.*) on yield and water productivity. Five irrigation treatments were conducted, I_1 (100% crop water requirement throughout the season was considered as control), I_2 and I_3 indicated 75% and 50% crop water requirements at crop vegetative growth stage, respectively, whereas I_4 and I_5 indicated 75% and 50% crop water requirements at crop ripening stage, respectively. The results showed that there were no significant differences between the treatments in yield and yield components. On the other hand the deficit irrigation treatment I_3 (Imposing 50% crop water requirement at vegetative stage) resulted in higher water productivity with no reduction in yield, therefore, it becomes evident that in order to save irrigation water while keeping high productivity of sunflower under such desert conditions, deficit irrigation of 50% crop water requirements at the crop vegetative stage of the crop should be applied.

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Key words: Crop water requirement**,** Deficit Irrigation, Water Productivity, Sunflower , Desert condition.

INTRODUCTION

Availability of water is the most limiting factor for food production in arid and semi-arid regions. Due to the growing population and competition for water by other users (i.e., industries, domestic, etc.) the amount of water allocated for agriculture is decreasing throughout the world (Molden, 2007). In northern Sudan water resources for irrigation are limited and become very expensive when it is to be pumped (Arneo, 2007). The application of water below the crop water requirement or actual crop evapotranspiration (ETa) is defined as deficit irrigation (Fereres and Soriano, 2007). Deficit irrigation (DI) and limited irrigation have been proposed as valuable strategies for arid regions (English, 1990; Pereira *et al.*,2002; Fereres and Soriano, 2007) where water is the limiting factor in crop production (Geerts and Raes, 2009). DI is an optimization strategy in which, irrigation is applied during drought –sensitive growth stages of a crop. Water restriction is limited to drought-tolerant phonological stages, often the vegetative stages and late ripening period. DI has the potential to maximize irrigation water productivity and it aims at stabilizing yields and has the potential to optimizing crop water productivity rather than maximizing the yield (Zhang and Oweis, 1999; Geerts and Raes, 2009).

Sunflower (*Helianthus annuus* L.) ranks as one of the four most important annul crops in the world with soybean, rapeseed and groundnut which are grown for edible oil. It is constitutes the second most important oil seed crop after soybeans, in the world production (Skoric, 1992 and Weiss ,1966).

The objective of this study was to investigating the effects of deficit irrigation (DI) strategy on sunflower yield and its water productivity.

MATERIALS AND METHODS

The soil of the research farm is non – saline, non – sodic, and has coarse texture (sandy loam) in top soil (0 – 40 cm), in which the percentages of

sand and clay were 65 and 18%, respectively. It is classified as Typic Haplocambids, fine loamy, mixed, hyperthermic and super active. It is correlated to Kelly soil series.

Table 1. Soil physical and chemical properties of the experimental site.

Characters	Soil depth				
	0-20 cm	20-40 cm	40-45 cm	45-85 cm	85-125 cm
CS (%)	52	52	55	55	52
FS (%)	14	13	14	15	12
Si (%)	18	12	15	8	13
C (%)	16	13	16	23	23
Bulk density (g cm^{-3})	1.73	1.49	1.86	1.85	1.71
Porosity (%)	35	44	30	30	35
Wilting point (%)	8.9	9.2	9.0	8.5	8.9
Field Capacity (%)	17.8	18.3	18.3	17.0	17.9
Saturation (%)	36	36	36	41	62
$CaCo_3$ (%)	2.4	2.4	2.0	6.6	19.2
CEC ((Cmol +)kg^{-1} soil)	13	10	12	17	18
EC (dsm^{-1})	0.45	0.86	0.55	1.08	1.47
PH paste	7.9	7.9	7.8	8.0	7.6

Where: CS = Coarse sand, FS = Fine sand, Si = silt, ECe = Electric conductivity, CEC = Cation exchange capacity and ESP = Exchangeable sodium percentage.

The field experiment was conducted at New Hamdab Research Station farm, which is located in the desert plain of El Multaga area, Northern Sudan for two consecutive winter seasons (2015/16 and 2016/17) with a view to investigate the effects of deficit irrigation (DI|) strategy on sunflower yield and its water productivity. Four DI irrigation treatments at crop non critical stages were tested together while a full irrigation treatment was taken as control. The treatments were as follows:

1- 100% Crop water requirement (CWR) throughout the season as full irrigation (control)

2- 75% Crop water requirement (CWR) at crop vegetative stage.
3- 50% Crop water requirement (CWR) at crop vegetative stage.
4- 75% Crop water requirement (CWR) at crop ripening stage.
5- 50% Crop water requirement (CWR) at crop ripening stage.

The optimum crop water requirement of sunflower was predetermined as 712 mm/season at field condition during three consecutive previous seasons.

The treatments were arranged in randomized complete block design (RCBD) with four replicates. The plot size was 28.8 m^2 (8 ridges each 6m long). The experimental plots were separated from each other by a 1m wide buffer zone to prevent surface and lateral movement of water. The predetermined quantities of irrigation water were applied in 10 days intervals using calibrated Parshall flume and 90^o V-notch weir appropriately installed in series.

Sunflower (variety Hysun33) was grown on November 18^{th} during both seasons following Agricultural Research Corporation (ARC) standard practices.

Phosphorus fertilizer in the form of triple super phosphate (TSP) was applied at sowing at the rate of 1P(43 Kg P_2O_5/ha) while Nitrogen in the form of Urea was applied in two equal doses at the rate of 1N (43 Kg N/ha), the first dose was applied after 2-3 weeks from sowing and the second dose was applied before flowering. Other cultural operations were performed according to the standard practices and the data collected included plant growth parameters and yield attributes.

Data collection:
Yield and yield components:
were collected based on ARC standard practices and presented in table (2).

Leaf area index (LAI):
Equation (1) was used as suggested by Nur,1971; Jovanka, *et al*., 1999 and Amin, 2006. As follows;

$$LAI = length \times width\ at\ \frac{1}{4} length \times \frac{No\ of\ leaves}{plant} \times 0.779 \times \frac{No\ of\ plant}{m^2}$$ **(1)**

Water productivity:

Was calculated using the formula suggested by Zwart and Bastiaanssen (2004); Greets and Reas (2009) and Khan(2013) as follows:

$$(2) \quad CWP(\text{kg/m}^3) = \frac{\text{grain yield (kg/ha)}}{\text{total water applied (m}^3\text{/ha)}}$$

Deficit irrigation stress index (DISI):

The equation used was proposed by Pandey, *et al*. (2000) and Dajman (2011) as follows;

$$(3)\ DISI = \frac{(yield\ of\ un\ stressed\ treatment - yield\ of\ stressed\ treatment)}{yield\ of\ un\ stressed\ treatment}$$

The statistical analysis was performed using SAS and MSTAT statistical package. The tested data were analyzed using the analysis of variance (ANOVA) procedure and the treatments were compared using the means separation procedure Duncan Multiple Range.

RESULTS AND DISCUSSION

Effect of full and deficit irrigation on grain yield and yield components:

The statistical analysis (Table 2) indicated that there were no significant differences between the full and deficit irrigation treatments on grain yield and other measured parameters of yield component (the plant height, stem diameter, head diameter, No of seed/head and 1000 seed weight) over the two seasons. This result is in line with those reported by Todorovic, *et al*., 2007; who stated that there were no significant variation have been noticed with increasing irrigation regime in sunflower, never the less, they also reported that the excellent result have been reached in the treatment irrigated by deficit irrigation method. This result also agree with those stated by Karaa, *et al*., 2007; the variety of crop such as Sunflower have been found to benefit from deficit irrigation.

Table 2. Effect of full and deficit irrigation treatments on sunflower grain yield and yield components during 2015-2016 and 2016-2017 seasons.

Tr	Plant height (cm)	Stem diameter (cm)	head diameter (cm)	No of seed/head	1000 seed weight (g)	Grain yield (Kg/ha)
Season 2015-2016						
I_1	145.0	1.7	18.8	1434	68.3	4969
I_2	141.3	1.5	17.2	1168	63.8	4160
I_3	143.2	1.7	18.0	1312	64.2	4477
I_4	143.2	1.6	17.7	1195	64.3	4518
I_5	142.1	1.6	17.8	1258	63.8	4318
CV	5.54	8.54	6.64	13.58	6.45	14.78
S.L	NS	NS	NS	Ns	NS	NS
SE ±	31.3202	0.0689	0.5932	86.4597	2.0926	331.5536
	Season 2016-2017					
I_1	161.4	1.8	18.9	1475	65.1	4976
I_2	160.1	1.8	18.3	1476	63.3	4828
I_3	159.0	1.8	18.7	1428	62.4	4859
I_4	160.5	1.8	18.6	1460	62.2	4868
I_5	159.0	1.8	18.3	1455	62.4	4833
CV	3.32	3.80	3.69	5.27	4.92	1.49
S.L	NS	NS	NS	NS	NS	NS
SE ±	2.6594	0.0345	0.3417	38.4238	1.5530	36.3920

NS = not Significant

Effect of full and deficit irrigation on water productivity and leaf area index:

The statistical analysis in (Table 3) showed that there were no significant differences between full and deficit irrigation treatments on leaf area index during the both seasons. The only significant difference between the full and deficit irrigation treatments resulted by water productivity ($P \leq 0.001$) in the second season, while the water productivity in the first season was not significant.

Table 3. Effect of full and deficit irrigation treatments on deficit irrigation stress index, water productivity and leaf area index during 2015-2016 and 2016-2017 seasons

Tr	DISI (%)	Water productivity (Kg/m^3)	Leaf area index
	Season 2015-2016		
I_1	0.00	0.70	4.61
I_2	16.28	0.62	3.57
I_3	9.90	0.72	4.54
I_4	9.08	0.66	4.05
I_5	13.10	0.66	3.57
CV		14.83	15.02
S.L		NS	NS
SE±		0.0498	0.1732
	Season 2016-2017		
I_1	0.00	0.70 d	4.48
I_2	2.97	0.72 bc	4.42
I_3	2.35	0.78 a	4.47
I_4	2.17	0.71 c	4.48
I_5	2.87	0.74 b	4.42
CV		1.52	2.46
S.L		***	NS
SE±		0.0055	0.0549

**** and NS = Significant at $P \leq 0.001$ and not significant.*

Means followed by the same letter(s) within each column are not significantly different according to Duncan's Multiple Range Test.

The deficit irrigation treatment I_3 recorded the higher water productivity (0.72 and 0.78) in the first and second season respectively, with a deficit irrigation stress index of (9.90% and 2.35%) in the first and second season respectively. When there was no significant difference in grain yield beside higher water productivity make the sunflower crop well suited to deficit irrigation practices with reduced evapotranspiration imposed through the predetermined growth stage as reported by Kirda, 2002.

CONCLUSIONS

- The full and deficit irrigation treatments have the same effect on grain yield, yield components and LAI.
- The deficit irrigation treatment **I_3** (imposing 50% CWR at vegetative stage) resulted in higher water productivity with no reduction in yield.

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مؤشر الانتاجية المائية لأستراجية الري الناقص لترشيد الاحتياجات المائية لانتاج محصول زهرة الشمس (*Helianthus annuus* L.) تحت ظروف الاراضى الجافة با لولاية الشمالية، السودان*

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المستخلص: اجريت التجارب خلال موسمين متتالين (2016/2015 -2017/2016) في محطة ابحاث الحامداب ذات التربة السهل الصحراوي الرملية الطمية لدراسة تاثير الري الناقص المسحث على الانتاج وانتاجية الماء (WP) لمحصول زهرة الشمس خلال مراحل النمو المختلفة. اشتملت التجربة على خمسة معاملات؛ الري الكامل **I_1** (100% من الاحتياج المائي خلال كل الموسم) والذي يمثل الشاهد، **I_2** (75% من الاحتياج المائي عند مرحلة النمو الخضري)، **I_3**(50%من الاحتياج المائي عند مرحلة النضج)، **I_4** (75% من الاحتياج المائي ``عند مرحلة النمو الخضري) و **I_5** (50% من الاحتياج المائي عند مرحلة النضج). اظهرت النتائج انه ليس هنالك اي فرق معنوي بين المعاملات في الانتاجية و كل مكونات الانتاجية ؛ ومن ناحية اخرى اتضح ان معاملة الري الناقص **I_3** (50%من الاحتياج المائي عند مرحلة النمو الخضري) قد نتج عنها اعلى زيادة ملحوظة في الانتاجية المائية (WP) للمحصول ؛ وعليه لتوفيرمياه الري مع المحافظة على زيادة الانتاجية فان الدراسة توصي باستخدام الري الناقص 50% من الاحتياج المائي عند مرحلة النمو الخضري لمحصول زهرة الشمس في الظروف البئية المشابهة.

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