Advances in Bioresearch
Adv. Biores., Vol 10 (4) July 2019: 19-24
©2018 Society of Education, India
Print ISSN 0976-4585; Online ISSN 2277-1573
Journal's URL:http://www.soeagra.com/abr.html
CODEN: ABRDC3
DOI: 10.15515/abr.0976-4585.10.4.1924

Advances in Bioresearch

ORIGINAL ARTICLE

Water Deficit Effect on Sunflower (*Helianthus annuus* L.) Morphological Parameters, Yield and Yield Components under Algeria Conditions

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ABSTRACT
This study was carried out to evaluate the responses of 5 sunflower genotypes to water stress under Algerian pedoclimatic conditions. To achieve our purpose an experimental field was conducted during 2016 in Relizane where 5 genotypes sowed under two water supplies in a randomized complete block with 3 replications. Morphological parameters, yield and yield components were estimated. According to the results; water supply effect was significant for plant height, stem diameter, head diameter, head weight, seed yield and its components. However, it was not significant for the number of leaves. Genotype effect was not significant for all parameters except head weight. The genotype by water supply interaction was significant for some parameters and not significant for other. The results showed that the highest seed yield was obtained from water supply 2 (133.5g per plant). The lowest seed yield (92.7g per plant) was found in water supply1. In the other hand, seed yield exhibited a significant correlation with plant height, head diameter, head weight, 1000 grain weight and seed number per head.
Keywords: *Sunflower (Helianthus annuus L.), Water deficit, morphological parameters, yield.*

Received 14.05.2019 Revised 28.06.2019 Accepted 03.07.2019

How to cite this article:
H Lahouel, W Rezzoug, A Adda. Water Deficit Effect on Sunflower (*Helianthus annuus* L.) Morphological Parameters, Yield and Yield Components under Algeria Conditions. Adv. Biores., Vol 10 [4] July 2019. 19-24.

INTRODUCTION

Sunflower *(Helianthus annuus L.),* is the world's fourth largest oil-seed mainly produced by Russia, Ukraine, European Union and Argentina [1]. Although, the culture of sunflower is almost inexistent in Algeria [2], for that the resort to the importation of its seeds with a bill which price increase from one year to another. In order to overcome this situation alternative solutions are imperative among them, supplying the national market with local production which requires the rehabilitation of oil crops including sunflower which is a spring crop practiced in rained condition. Sunflower (*Helianthus annuus L.),* has an ecological flexibility and agronomic benefit in farming systems. Also the crop has a moderate auxiliary input requirement and an economic profitability given that it provides raw materials used in a number of food and oil-based non-food industrial sectors [3]. Sunflower oil is one of the most desirable oils in the world because its oil exhibits the fatty acid composition that is favourable for human consumption [4]. This potential substantiates the rising interest in sunflower particularly towards its inclusion in cereal-based crop rotations of Mediterranean environments, also promoting a connected industrial development [5]. The major constraint of this culture in North Africa is the water deficit which greatly penalizes the yield [6]. Previous investigation such as Anastasi et al. [5] Suggest that growing sunflower in a water limited Mediterranean type environment is possible to produce satisfactory grain and oil yields with an appropriate use of irrigation. Gö ksoy et al. [7] show that the results from three years period indicated that full and limited irrigation treatments at three growth periods (heading, flowering, and milking) increased seed yield, oil yield and other traits observed more than the non-irrigated and single irrigation applications. Erdem and Delibas [8] attest that sunflower *(Helianthus annuus L.),* is more sensitive to water deficit during flowering, total vegetative and yield formation periods than during early and late vegetative periods. Further, the research carried out by Iqbal et al. [9] showed that water stress at the vegetative or reproductive growth stage induced decline in achene yield /plant. In Algeria, the highlands and inland plains are the main areas where the different cultures are concentrated. They belong to the semi-arid bioclimatic stage where sudden thermal variations and drought are the main factors limiting the productivity of cultivated species [10]. According to this reality, the sunflower culture introduction into this agricultural landscape will inevitably face the constraints of these environmental stresses. Thus, all attempts to introduce sunflower cultivation in Algeria require an evaluation of behavior and productivity of this species under local conditions. The present study is part of this strategy; it treats the drought effects on sunflower (*Helianthus annuus L.)*, behavior and yield development. For this purpose, five sunflower genotypes of different origins were conducted in Relizane locality, representative of the semi-arid zones. Conducting trials under different water supply allows to studying the drought effects on the morphological behavior, yield and its components in this species.

MATERIAL AND METHODS

EXPERIMENTAL SITE

A field trial was conducted during 2016 in yelel Relizane region (35°44'N latitude, 0°33E longitude, 98m altitude) in the North West of Algeria. The soil was analyzed to determine the following physicochemical characteristics as granulometry, pH, electrical conductivity, organic matter was determined by Walkley and Black [11] method, total limestone was determined by Baize [12] method. The results of soil analyzes are represented in the following table (Table1)

Table1; Soil physicochemical characteristics of experimental field

pH	E.C(µs)	OM%	total limestone%	granulometry
7.94	227	2.27	23.93	Silty clay

Relizane belong to the warm Mediterranean climate with dry summer characterised by average annual precipitation of 407.6 mm and temperature of 19.9°C. Total monthly precipitation and mean air temperature data during 2015/ 2016 year are presented in Table2.

Table2; Mean air temperature and total monthly precipitation during 2015/2016 in Relizane region

Months	Temperature (°C)	Precipitation (mm)
September	27,3	8,13
October	22,8	21,59
November	16,7	56,39
December	13,5	0
January	14,4	13,96
February	14,9	46,24
March	14,9	110,7
April	18,8	41,39
May	23.1	12.46
June	28.9	3.05
July	32.2	0.5
August	31.4	0

EXPERIMENTAL FACTORS AND AGRONOMIC MANAGEMENT

Five sunflower genotypes include four hybrids oleic varieties from Syngenta France Seed Company (Nutrasol, N.K Ferti, Extrasol and Aurasol) and one local variety were used as plant material in our essay. Plants were submitted to two water supply; water supply 1 (WS1) and water supply 2 (WS2). In WS2 irrigation with field capacity was applied throughout the crop cycle whereas in WS1 it was applied from seedling until heading stage. In growing season all combinations of above factors were laid out in the field according to randomized complete block with three replications for each water supply where each repetition include the five genotypes and each genotype is represented by a plot of three lines, plot size was 4.14m^2(4.6m×0.90m), row spacing was 0.45m, plant-plant spacing was 0.25m. Both water supply 1 and water supply 2 devices were separated by a distance of 7m. The soil which previous crop was wheat had been managed uniformly, it was ploughed in autumn and a superficial soil work was carried out one week before sowing. After preparation of seed bed the plot area was hand sown on the first of May.

Diseases and insects are confined by the application of an insecticide and a fungicide. However, weeds were controlled by hand when necessary.

MEASUREMENT STAGE AND PARAMETERS STUDIED

Six plants were randomly selected for each genotype and from each water supply at the end of flowering stage for measurement of morphological parameters such as plant height (cm), number of leaves, stem diameter (cm); at maturity stage for measurement of head diameter (cm) and head weight (g). After plants' harvest; seed yield per plant (g/plant), thousand seeds weight (g), number of seeds per head were recorded.

STATISTICAL ANALYSIS

ANOVA was applied to analyze the effect of water supply, genotype and their interaction on morphological parameters, yield and yield components of five sunflower genotypes. Moreover, correlations between seed yield per plant, morphological parameters and yield components were studied. Both analysis ANOVA and correlations has been carried out using an SPSS program (version 16.0).

RESULTS AND DISCUSSION

MORPHOLOGICAL TRAITS

The results show that water supply significantly affect morphological parameters such as plant height, stem diameter, head diameter and head weight however the genotype has an insignificant effect for all parameters except head weight. Otherwise, genotype by water supply interaction was significant for some characters such as head diameter, stem diameter, head weight which indicated that genotypes responded distinctly to the water supply and non significant for other characters such as number of leaves and plant height (table 3).

Table3; Results of variance analysis of morphological traits, seed yield and yield components of sunflower hybrids under two water supplies in 2016 at Relizane region

SV	NLP	PH	SD	HD	HW	NSH	SW	SYP
Genotype	2.206	1.474	0.402	0.680	3.633*	1.318	0.606	1.783
Water supply	0.583	23.860***	7.786**	38.720***	66.982***	4.724*	12.863***	35.302***
Interaction	0.338	0.862	4.059	2.920*	4.876**	0.960	0.269	3.419**

SV: Source of variation, **NLP**: Number of leaves per plant, **PH**: Plant height, **SD**: Stem diameter, **HD**: Head diameter, **HW**: Head weight, **NSH**: Number of seed per head, **SW**: 1000 seed weight, **SYP**: Seed yield per plant

* Significant, ** highly significant, *** very highly significant

Growth reduction under salinity or drought stresses could be due to interference in processes in energy production such as photosynthesis, respiration and change in hormonal balance [13]. Poormohammad Kiani et al, [14] indicate that water deficit decreases plant growth by slowing the rate of cell division and expansion, mainly due to loss of turgor. Our results indicate that water deficit significantly decreased plant height in sunflower where water supply 2(WS2) produced the tallest plants in Extrasol and Local variety respectively. The shortest plant was obtained from WS1in N.K Ferti (Table 4). According to Maury et al. [15] the vegetative development of sunflower grown under water deficit conditions is strongly disturbed, they note mainly an important decrease in size. Our results were in agreement with the results reported by various researches such as Gö ksoy et al. [7] who study the effect of fourteen irrigation treatments on yield, yield components and morphological sunflower traits found that irrigation treatments significantly affected all characters except the number of leaves per plant. Shafi et al. [16] found that irrigation practice had a significant effect on plant height of sunflower hybrids. Hussain et al. [17] and Poormohammad Kiani et al. [14] conclude that drought stress significantly decreased plant height. Otherwise, stem diameter of well irrigated plants are bigger than that of stressed plants (Table 4). Also, the interaction between the genotype by water supply showed that the different genotypes have a distinct response to the water supply for this trait.

Table 4; Mean of morphological traits, seed yield and yield components of sunflower hybrids under two water supplies in 2016 at Relizane region

WS	GEN	NLP	PH (cm)	SD (mm)	HD (cm)	HW(g)	NSH	SW(g)	SYP(g)
	Nutrasol	30,3	134,3	22,7	19,5	142,3	1352,2	68,0	92,7
	N,Kferti	32,8	132,5	21,4	18,3	120,7	1190,2	71,4	83,1
WS1	Local	32,5	133,5	24,3	19,2	113,7	1096,7	71,0	75,8
	Extrasol	32,2	138,7	21,1	18,3	113	1138,7	63,5	71,8
	Aurasol	30,0	135,7	24	17,7	97	1133,3	59,0	63,2
	Nutrasol	32,3	144,7	24,3	21,5	184,7	1385	80,9	112,1
	N, Kferti	33,3	150,5	26,3	22	188,7	1305	81,0	105,8
WS2	Local	32,8	153,2	24	19,5	129	1125,3	86,0	86,8
	Extrasol	33,8	160,2	27,8	22	181,7	1393,8	77,0	108,6
	Aurasol	29	142,3	22,1	23	214	1579,8	84,0	133,5

NLP: number of leaves per plant, **PH**: plant height, **SD**: stem diameter, **HD**: head diameter, **HW**: head weight, **NSH**: number of seeds per head, **SW**: 1000 seed weight , **SYP**: seed yield per plant. **WS**: Water supply, **GEN**: Genotype.

In our investigation, water supply induce a significant reduction of head diameter where the maximum average head diameter was observed with WS2 in Aurasol, while the minimum was obtained from WS1 in the same genotype (Table 4) which is also accounted by Kaya and Kolsarici [18] who indicated that head diameter of sunflower cultivars was considerably influenced by irrigation. Drought stress drastically decreased head diameter, number of achenes per head, thousand achene weight and achene yield as compared to without drought stress. This decrease was more severe when the crop faced drought at early flowering than at bud initiation [17].

In the other side, significant differences in head weight were observed between both water supplies. In the same genotype "Aurasol" the highest head weight was obtained from WS2 (214.0g) whereas, the lowest by WS1 (97.0g). The genotype factor, genotype by water supply interaction had a significant effect on head weight.

In our study leaves number were not influenced by water treatment (Table3). This result is confirmed by the study of Hall [19] who indicates that number of leaves is genetically fixed trait and it is slightly affected by environmental factors.

SEED YIELD AND YIELD COMPONENTS

According to Anova analysis, differences between water supplies were significant for seed yield and its components while genotype factor had an insignificant effect in these parameters in one hand. On the other hand genotype by water supply interaction was significant for yield and non significant for number of seed per head and 1000 seed weight (Table3).

Grain yield is a function of genetics, environment, management and their interaction [20], [21]. It is mainly driven by the grain number per head and their weight, which are genetically determined but they may be affected to different extent by environmental factors that could highly vary during the crop cycle [22].

Our results indicated that water stress induce a regression of seed yield per plant where the highest seed yield was found in Aurasol (133.5g/plant) with WS2 while the lowest was found in the same genotype (63.2g/plant) with WS1.Our finding were in agreement with Husain et al. [23] who conclude that drought stress at different growth stages hampers yield components, which ultimately lead to wards lower achene yield in sunflower. The yield reduction is the result of disturbed physiological and morphological attributes

According to the results presented in (Table 4), the application of water stress during the reproductive stage of sunflower plant results a decrease in seed number per head which reduced from1579.8 in Aurasol under WS2 to 1096.7 in local variety under WS1. These results are in agreement with [7], [24], [17] and [25]. This effect may be explained according to Elsheikh et al, [24] that under water deficit conditions the seeds are more or less unfilled also the head diameter decreased causing a decrease of filled grain number. In the other hand photosynthates partitioning to the head is of major importance for the determination of seed number. A decline in the amount of carbon partitioned to the head is one of the factors that may induce a reduction in seed number due to water stress [25].

In our study, thousand seeds weight (TSW) was influenced by water supply where the highest mean values were obtained from WS2 in local variety and the lowest from WS1in Aurasol (Table 4) which can be explained according to Asch et al. [26] and Khan et al. [27] that the translocation of photosynthates to reproductive organs was hampered by drought leading to reductions in thousand achene weights of sunflower.

SEED YIELD CORRELATION WITH MORPHOLOGICAL TRAITS AND YIELD COMPONENTS

Correlations coefficients between the seed yield and morphological traits in one side and the seed yield and yield components in the other one are given in table5. According to the results, seed yield was found to be in positive significant correlation with plant height and1000 grain weight (0.405**, 0.401**respectively), height positive significant correlation with head diameter and seed number per head (0.809**, 0.787** respectively) and very height positive significant correlation with head weight (0.928**). These results are in agreement with [28], [29], [30], [31], [32], who found a positive correlation between seed yield and head diameter, plant height, seed number per head and 1000 seeds weight.

Table5; Simple correlation coefficients of seed yield with morphological traits and seed yield components

	LN	PH	SD	HW	HD	SW	NSH
Yield	-0.111	0.405**	0.172	0.928**	0.809*	0.401**	0.787**

LN: Leaves number, **PH**: Plant height, **SD**: Stem diameter, **HW**: Head weight, **HD**: Head diameter, **SW**: 1000 Seed weight, **NSH:** Number of seed per head

*the correlation is significant at 0.05; **the correlation is significant at 0.01

In the other hand, correlations analysis showed that no relationship existed between stem diameter and seed yield in one side and between total leaves number per plant and seed yield in the other side (table 5) which is in accordance with [30].

CONCLUSION

Our results indicated that irrigation at vegetative growth, flowering and grain filling stages increased seed yield, their components and other traits observed more than irrigation only in vegetative stage. The highest seed yield per plant was obtained under optimal water supply. According to this study, it is concluded that there was a significant effect of water supply on plant height, stem diameter, head diameter, head weight, number of seed and thousand seed weight however it was non-significant on the number of leaves per plant. The effect of genotype was non-significant on all parameters except head weight. The effect of water supply by genotype interaction was significant on some parameters such as stem diameter, head diameter, weight head and yield and non-significant on the other, 1000 seed weight, seed number, plant height and number of leaves.

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