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Water use efficiency of sunflower genotypes under drip irrigation

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This investigation was conducted to determine the productivity and water use efficiency (WUE) for new sunflower genotypes obtained from selfing and induced mutation. Ten sunflower genotypes were evaluated under drip irrigation using two treatments of irrigation (100 and 75% from water requirement of sunflower). Statistical analysis showed that there were significant differences among genotypes, as well as between irrigation treatments and the interaction between them. Results indicate that decreasing the amount of irrigation water from 1500 to 1130 (mm/ha) significantly reduced all studied traits. Mutation ($M_{2,1}$-63) surpassed all the other genotypes in seed yield and WUE. Lines which gave the highest yield of the seed have WUE under drought conditions higher than WUE under normal irrigation. The lowest depression in seed yield due to drought conditions compared to the seed yield under normal irrigation has been registered for Line 20, Line $M_{2,1}$-63, and Sakha 53 genotypes (11, 18, and 16%, respectively), but the highest depression recorded for Line 48, Line $M_{2,3}$-63, and Line $M_{2,4}$-63 (49, 46, and 43%, respectively). The genotypes (Line 20, Line $M_{2,1}$-63 and Sakha 53) are more tolerant to drought than others and we can used its in breeding program to develop sunflower hybrids suitable for cultivation under drought condition.

Key words: Sunflower genotypes, water use efficiency, mutation, inbred lines.

INTRODUCTION

Available water is a limited factor for the expansion of agriculture in the desert which occupied about 93% of the total area in Egypt. The development of new genotypes of crops having the ability to be tolerant to drought is the useful way to expand in the desert cultivation using modern irrigation systems.

Sunflower (*Helianthus annuus* L.) is one of the four most important oil crops in the world (Demir et al., 2006). Because of its moderate cultivation requirements and high oil quality, its acreage has increased in both developed and developing countries (Skoric, 1992). In Egypt, great emphasis must be given towards this crop to decrease the gap in oil production. Sunflower oil is highly demanded not only for human consumption, but also for chemical and cosmetic industries. In respect of total yield produced, water requirements of sunflower are relatively high as compared to most crops. Despite its high water use, the crop has the ability to withstand short periods of

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Table 1. The genotypes evaluated in this investigation.

Genotype	Source
Line 20	S_5 (selfing of Maiak variety)
Line 48	S_5 (selfing of Maiak variety)
Line 61	S_5 (selfing of Maiak variety)
Line 63	S_5 (selfing of Maiak variety)
$M_{2,1}$-63	Mutation from Line 63
$M_{2,2}$-63	Mutation from Line 63
$M_{2,3}$-63	Mutation from Line 63
$M_{2,4}$-63	Mutation from Line 63
Maiak	Parent of above genotypes
Sakha 53	Commercial variety (as a check variety)

severe soil water deficit of up to 15 atmosphere tensions. Long periods of severe soil water deficit, particularly, at water-sensitive growth stages cause significant reduction in seed yield (Beyazgul et al., 2000) by limiting evapotranspiration (ET) through stomata closure, reduced assimilation of carbon and decreased biomass production (Demir et al., 2006).

It has been shown that, sometimes, periods of reduced growth may trigger physiological processes that actually increase yield (Smith et al., 2002). Severe water deficits during the early vegetative growth result in reduced plant height, but may increase root depth. Adequate water during the late vegetative period is required for proper bud development. The flowering period is the most sensitive to water deficits which cause considerable yield decrease since fewer flower come to full development (Beyazgul et al., 2000; Ali and Shui, 2009). Seed formation is the next most sensitive period to water deficit, causing severe reduction in both yield and oil content (Doorenbos and Kassam, 1979). Although sunflower is known to be a drought tolerant crop or grown under dry land conditions, substantial yield increases can be achieved by supplementary irrigation, which is one of the most effective strategies to mitigate the effects of dry spells in crop production (Fox and Rockstrom, 2000; Xiao et al., 2007).

The objective of this study was to determine the productivity and water use efficiency (WUE) for new sunflower genotypes obtained from selfing and induce mutation.

MATERIALS AND METHODS

This work started in 2009 at the Farm of Plant Production Department, El-Kufra City, Garyonus University, Libya by planting the open pollinated cultivar "Maiak" (*H. annuus* L.) on 20th March, 2009. A total of 500 plants were grown in a non-replicated experiment in rows set of 60 cm apart with 20 cm between plants within a row. Just before flowering, the 100 plant were selected, selfed, and tagged. After harvest, the best (S_1) heads were saved and regrown in a non-replicated experiment on 1st July, 2009 to obtain S_2 achene. Selfing and selection were repeated twice in 2010 and 2011 until the S_5-generation. Four inbred lines (S_5) were thus recovered from the open pollinated cultivar "Maiak", namely (Line 20, Line 48, Line 61, and Line 63). In addition, four new mutants, namely, $M_{2,1}$-63, $M_{2,2}$-63, $M_{2,3}$-63, and $M_{2,4}$-63 were obtained from treating the seeds of inbred line-63 (S_3) with gamma rays (Co^{60} source) at three doses, namely, 70, 100, and 150 Gy and the seeds were planted in the field a day after irradiation to obtained M_1-63. The phenotypical observations and biometrical measurements were made during the vegetation period. Part of the plants, produced from treatment with gamma rays were isolated in paper bags and self-pollinated in order to obtain M_2. The four inbred lines, four new mutant forms along with the base population Maiak, and a check cultivar Sakha-53 were evaluated under drip irrigation using two treatments of irrigation (100 and 70% from water requirement of sunflower). The experiment was conducted in Randomized Complete Block Design using split-plot arrangement with three replications at EL Wady EL Assiuty Farm, Faculty of Agriculture, Assiut University where the soil is sandy calcareous. Drip irrigation was used in this farm. Irrigation has been placed in the main plot and genotypes in the sub plot. Date of planting was on 13th June, 2012. The experiment unit was one row, 5 m long, and set 50 cm apart with 25 cm distance between plants within a row. Days to 50% flowering were recorded on plot mean basis. At harvest, ten random plants/plot from each genotype were collected to record the following traits: plant height (cm), head diameter (cm), achene yield/plant (g), and weight of 100 seed (g).

Seed oil content was determined by Soxhlet apparatus using petroleum ether (40 to 60°C) as a solvent according to AOAC (1995). Seed yield (kg/ha) calculated from all plants in row then WUE value was calculated according to the equation:

$$WUE(kglmm) = -\frac{Seed\ yield\ \ (kg/ha\ )}{Applied\ \ water\,(mm/ha)}$$

Genotypes and irrigation treatments

Ten genotypes of sunflower were evaluated under two treatments of irrigation: (1) I_1 = Application of 100% from water requirements (1500 mm/ha)/season; (2) I_2 = Application of 75% from water requirement (1130 mm/ha)/season (Table 1).

All other agronomic practices were done according to the recommendations for growing sunflower production in Egypt under sandy soil. Statistical analysis was done according to Gomez and Gomez (1984) for all of the studied traits.

Table 2. Studied traits for sunflower genotypes under normal and drought conditions.

Genotypes	Plant height (cm)			Head diameter (cm)			Achene yield (g/plant)			100-Achene weight (g)		
	Irrigation		Mean	Irrigation		Mean	Irrigation		Mean	Irrigation		Mean
	1_1	I_2		1_1	I_2		1_1	I_2		1_1	I_2	
Line 20	184.0	179.0	181.5	17.7	16.3	17.0	41.0	35.3	38.2	7.3	6.7	7.0
Line 48	139.0	130.7	134.8	16.3	13.3	14.8	42.3	31.0	36.7	7.9	6.6	7.3
Line 61	171.7	160.0	165.8	17.3	14.7	16.0	43.0	35.3	39.2	7.5	7.1	7.4
Line 63	100.0	75.0	87.5	7.0	5.7	6.3	9.7	7.3	8.5	3.0	2.7	2.9
$M_{2,1}$-63	160.0	158.3	159.2	18.0	15.7	16.8	44.7	36.3	40.5	6.2	5.7	6.0
$M_{2,2}$- 63	153.0	117.7	135.3	13.3	11.7	12.5	18.7	14.0	16.3	4.4	5.2	4.8
$M_{2,3}$-63	156.0	144.3	150.2	15.3	11.3	13.3	35.7	19.3	27.5	5.9	4.2	5.1
$M_{2,4}$-63	145.0	115.0	130.0	13.3	11.0	12.2	39.7	22.7	31.2	6.7	4.5	5.6
Sakha53	157.3	161.3	159.3	16.7	15.7	16.2	36.0	30.0	33.0	7.2	6.5	6.9
Maiak	168.3	161.7	165.0	17.7	16.3	17.6	35.0	33.3	34.2	7.5	6.8	7.2
Mean	153.4	140.3	-	15.3	13.2	-	34.6	26.5	-	6.4	5.6	-
$L.S.D_{0.05}$												
G	-	-	4.8	-	-	1.1	-	-	1.6	-	-	0.2
G×I	-	-	6.8	-	-	n.s	-	-	2.3	-	-	0.3

Genotype	Seed yield (kg/ha)			WUE (Kg/mm)			Oil (%)		
	Irrigation		Mean	Irrigation		Mean	Irrigation		Mean
	I_1	I_2		I_1	I_2		I_1	I_2	
Line 20	1721.7	1540.0	1630.8	1.15	1.35	1.25	42.3	34.3	38.3
Line 48	1779.7	908.0	1343.8	1.19	0.80	0.99	30.3	38.3	34.3
Line 61	1813.0	1148.0	1480.5	1.21	1.01	1.11	30.7	39.7	35.2
Line 63	405.7	310.3	358.0	0.27	0.27	0.27	45.3	44.0	44.7
M_1-63	1820.7	1488.0	1654.3	1.22	1.34	1.27	32.7	37.7	35.2
M_2- 63	784.0	588.0	686.0	0.52	0.52	0.52	39.7	36.7	38.2
M_3-63	1497.7	812.0	1154.8	1.00	0.71	0.86	45.3	30.0	37.7
M_4-63	1665.7	951.7	1308.7	1.11	0.83	0.97	39.7	40.7	40.2
Sakha53	1512.0	1267.3	1389.7	1.03	1.11	1.07	34.3	33.0	33.7
Maiak	1552.7	1228.0	1390.3	1.04	1.08	1.06	41.3	40.3	40.8
Mean	1455.3	1024.1		0.97	0.91		38.2	37.5	-
$L.S.D_{0.05}$									
G	-	-	125	-	-	0.08	-	-	0.8
G × I	-	-	177	-	-	0.11	-	-	1.2

RESULTS AND DISCUSSION

Statistical analysis showed that there were significant differences among genotypes, as well as between irrigation treatments and the interaction between them.

The results in Table 2 indicate that decreasing the amount of irrigation water from 1500 to 1130 mm/ha significantly reduced all studied traits. It seems evident that subjecting sunflower plants to water deficit, through reducing the amount of irrigation water reduced all growth parameters, probably due to impairing photosynthetic process which could have been decreased by the drastic decrease of leaf relative water content. In this concern, Khalilv and Yarnia (2007) reported that drought stress conditions increased stomatal resistance as a result of relative closing of stomata; consequently, this condition increases the total resistance of the given plant against its H_2O movement in comparison to CO_2. Afkari (2010) showed that the application of water deficit stress decreased significantly plant height, seed number per head, leaf water potential, leaf area index, leaf relative water content, stomatal resistance, and harvest index.

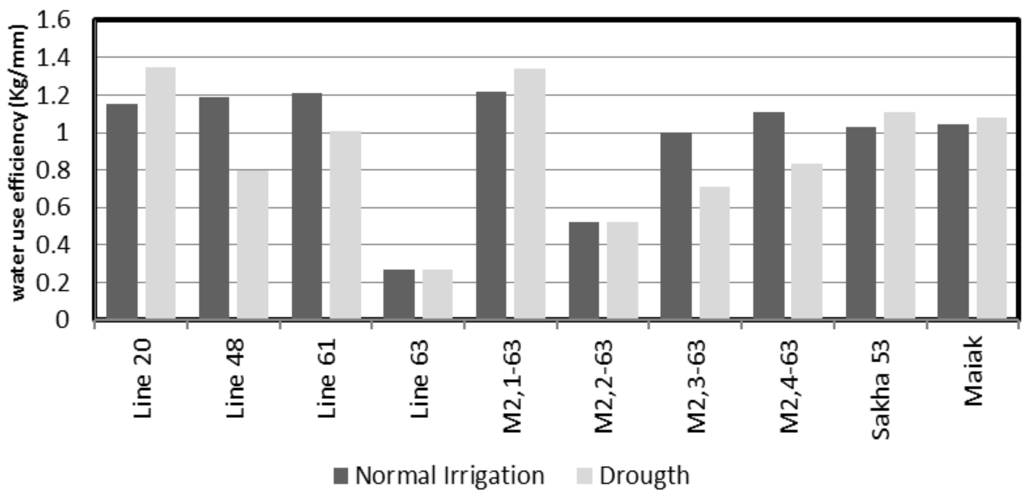

Figure 1. Water use efficiency for sunflower genotypes under drought and normal conditions.

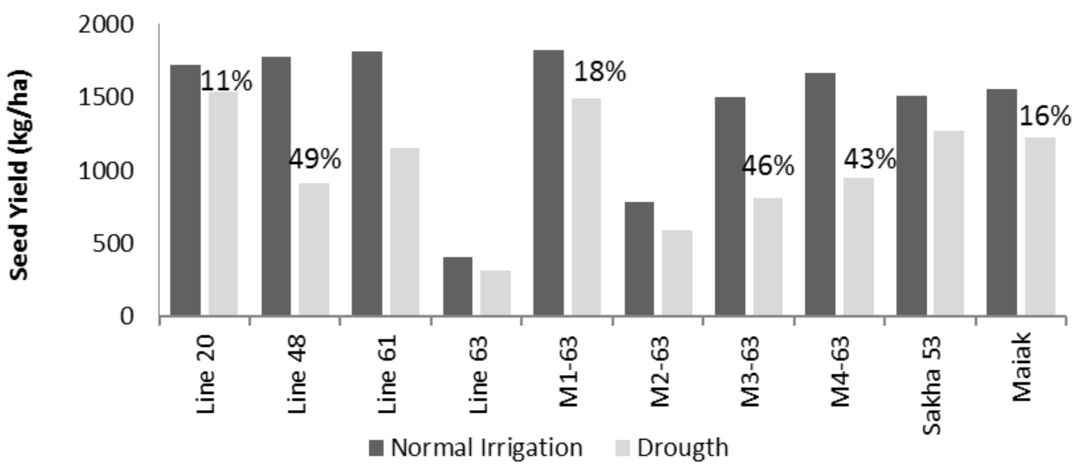

Figure 2. Seed yield (kg/ha) and percentage of yield shortage due to drought for sunflower genotypes under drought and normal conditions.

These results are in agreement with those obtained by Mehrpouyan et al. (2010), Kassab et al. (2012), and Öner et al. (2014).

The present data in Table 2 clearly show differences among the sunflower genotypes under study with respect to all studied traits. In this regard, Mutation ($M_{2,1}$-63) surpassed all the other genotypes in seed yield and WUE. The conspicuous differences among the genotypes suggest the presence of genetic differences and this illustrates the use of selfing and inducing the mutations in the creation of new recombination differ significantly from its parents. The results obtained by Encheva et al. (2008) and Alahdadi et al. (2011) confirm our findings.

The interaction between irrigation treatments and genotypes was significant in all studied traits except for head diameter. It is evident from Table 2 and Figures 1 and 2 that the lines which gave the highest yield of the seed (Line $M_{2,1}$-63 and Line 20) have WUE under drought conditions higher than WUE under normal irrigation. This observation was also in commercial variety (Sakha 53). The lowest depression in seed yield (Figure 2) due to drought conditions as compared to the seed yield under normal irrigation has been registered for Line 20, Line $M_{2,1}$-63, and Sakha 53 genotypes (11, 18, and 16%, respectively), but the highest depression recorded for Line 48, Line $M_{2,3}$-63 and Line $M_{2,4}$-63 (49, 46, and 43%, respectively). So, the genotypes (Line 20, Line $M_{2,1}$-63, and Sakha 53) are more tolerant to drought than others and it can be used in breeding program to develop sunflower hybrids suitable for cultivation under drought condition. Kassab et al. (2012) found that variety Sakha 53 gave WUE under drought condition higher than its under normal irrigation.

Conclusion

Self-pollination and mutagenesis are effective ways to get the new genetic differences in sunflower. Genotypes Line 20, Line $M_{2,1}$-63, and Sakha 53 are more tolerant to drought than others and it can be used in breeding program to develop sunflower hybrids suitable for cultivation under drought condition.

Conflict of Interests

The authors have not declared any conflict of interests.

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