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Evaluation of grain yield of some new bread wheat Cultivars under water stress conditions

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A R T I C L E I N F O

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A B S T R A C T

Five cultivars of bread wheat (*Triticum aestivum* L.) were used in this study at Fayoum University, Fayoum Governorate, during 2019/2020 and 2020/2021 growing seasons. The objective of the study was to assess the yield of newly developed bread wheat cultivars under conditions of water stress (drought indices). The experimental design was a split-plot in randomized complete block design with three replicates. The experiment consisted of two factors, which were three different water stress conditions and five different wheat cultivars. The results showed that skipping irrigations had a significant effect on grain yield, with the highest reduction of 42.9% observed when irrigations at the heading stage were skipped compared to full irrigation. The cultivar Sakha-95, Misr-3, exhibits a higher level of drought tolerance during the elongation and flowering stages. Stress susceptibility index (SSI) under drought stress conditions (skipping irrigation during the elongation stage and skipping irrigation during heading stages), the Sakha-95 performed better in the two irrigation skips on grain yield. Misr-3," followed by Sakha-95," are the top-performing cultivars in the yield index (YI) of drought tolerance during the flowering stages. Also, the Sakha-95" cultivar showed the highest stress tolerance index (STI) value of 1.08 when irrigation skips at the heading stage. While the cultivar "Sids-14" displayed the highest STI value (1.04), only irrigation at the elongation stage was skipped. The recommended of this study, Misr-3 is the most drought-tolerant cultivar, while Giza-171 is least tolerant. These traits highlight their resilience in water scarcity.

1. Introduction

Wheat (*Triticum aestivum* L.) is considered the most important cereal crop worldwide that yields more than a quarter of the total world cereals production [1,2]. In Egypt, wheat is the oldest and most important cereal crop and considered the first food grain for all societies and the main source of straw yield as feed for animals [3]. Currently, it holds the title of being the most extensively cultivated crop, occupying over 216 million hectares and yielding 766 million tons annually [4]. In Egypt, wheat cultivation covers 1.4 million hectares, resulting in a production of 9 million tons [5]. The use of new improved cultivars, new cultivation techniques, and modern irrigation techniques contributed to 97.0% of the increase in yield per unit area and 1.5% of the increase in yield was due to planting area expansion [6]. The threat of drought is a significant factor that affects crop production on a global scale. To enhance wheat production and productivity in regions prone to drought, an effective and sustainable strategy is the development of wheat cultivars specifically adapted to these challenging environments [7,8].

Drought indices, which quantify the impact of drought on crop yield in relation to normal conditions, have been widely employed for evaluating the performance of drought-tolerant genotypes [9–12]. These indices are typically developed based on the drought resistance or susceptibility of different genotypes [13,14]. Drought resistance, as defined by Yan et al., [15] , refers to the yield of a particular genotype relative to other genotypes exposed to identical drought stress conditions.

The present investigation aims to evaluate the tolerance levels of newly developed bread wheat cultivars towards drought stress in newly reclaimed soil.

2. Materials and Methods

Two field experiments were conducted during the consecutive seasons of 2019/2020 and 2020/2021 at the Experimental Farm of the Faculty of

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Agriculture (Demo) in Fayoum University, Fayoum Governorate, Egypt. The objective of the study was to assess the yield characteristics of newly developed bread wheat cultivars under conditions of water stress.

The experiment consisted of two factors, which were three different water stress conditions and five different wheat cultivars as follows: Water stress (skipping irrigation) treatments: I_1, Normal irrigation (control), I_2, Skipping irrigation during the vegetative stage (stem elongation), and I_3, Skipping irrigation during heading stage. Wheat cultivars: Misr-1, Misr-3, Sakha-95 and Sids-14, Giza-171. The pedigree of the tested five Egyptian bread wheat cultivars are presented in Table 1. Soil characteristics of the soil used in the current experiment in two seasons are presented in Table 2.

Table 1: Pedigree of the five Egyptian bread wheat cultivars under study

Cultivars	Pedigree
Misr-1	OASIS/SKAUZ//4*BCN/3/2*PASTOR
Misr-3	ROHF07*2/KIRITICGSS05B00123T-099T-0PY-099M-099NJ-6WGY-0B-0BGY0GZ
Sakha-95	PASTOR//SITE/MO/3/CHEN/AEGILOPSSQUARROSA(TAUS)//BCN/4/WBLLI
Sids-14	PASTOR//SITE/MO/3/CHEN/AEGILOPSSQUARROSA(TAUS)//BCN/4/WBLLI
Giza-171	Sakha 93 / Gemmiza 9 S.6-1GZ-4GZ-1GZ-2GZ-0S

Table 2. Mechanical and chemical analysis of experimental fields in two seasons

Seasons	2019/2020	2020/2021
Physical Properties		
Sand (%)	75.3	75.1
Silt (%)	12.1	12.0
Clay (%)	12.7	12.9
Soil texture class	Sandy Loam	
Chemical Properties		
Organic Matter (%)	1.07	1.09
ECe* (dS m^{-1}; soil paste extract)	3.2	3.3
PH (at a soil: water w/v ratio of	7.26	7.48
Total N %	0.04	0.05
$Caco_3$	6.50	6.93

The experimental design was a split-plot in randomized complete block design with three replicates. Water stress treatments assigned to the main plots. While five wheat cultivars laid out in the sub-plots. The experimental sub-plot area was 10.5 m^2 (3.5 long and 3.0 m wide). To protect against irrigation treatment effects, two meters were utilized to isolate the experimental units.

2.1. Agronomical parameters :

Grain yield (GY, Kg/ feddan) has been recorded in the current study.

2.2. Drought stress parameters

The calculation of drought tolerance indices to determine water stress levels or water deficits in different wheat cultivars is a common practice. Common indices, including the drought tolerance indices, were calculated as follows:

1. Stress susceptibility index (SSI); $SSI = 1 - (Ys / Yp) / SI$, while $SI = 1 - (\hat{Y}s / \hat{Y}p)$ [16]
2. Yield Index (YI); $YI = Ys / \hat{Y}s$ [17]
3. Stress tolerance index (STI); $STI = (Yp * Ys) / (\hat{Y}p)^2$ [14,18]
4. Reduction % = $(p - Ys/ Yp) \times 100$ [19]

Where: Yp and Ys were the yield of each cultivars, non-stressed and stressed, respectively. SI is stress intensity and $\hat{Y}s$ and $\hat{Y}p$ are the means of all genotypes under stress and well water conditions, respectively.

2.3. Statistical analysis:

All data obtained in both seasons were subjected to analysis using anova table in GenStat statistical computer software (edition 12). Treatment means were compared using the Least Significant Difference (LSD) test at the 5% level of significance [20].

3. Results

3.1. Mean performance of grain yield under water regimes, wheat cultivars, and their interactions

The mean performance of yield trait under different water regimes, various wheat cultivars, and their interactions refers to the average outcome or results observed concerning the growth and productivity, of wheat crops when subjected to different water availability conditions. This assessment takes into account the impact of diverse wheat cultivars and how they may interact with varying water regimes, ultimately influencing the overall performance of the grain yield trait.

The average performance of the grain yield skipping irrigation and wheat cultivars over two seasons are presented in Table (3). The study evaluated the impact of skipping irrigations and different wheat cultivars on grain yield over two seasons. The results showed that skipping irrigations had a significant effect on grain yield, with the highest reduction of 42.9% observed when irrigation at the heading stage was skipped compared to full irrigation. Similarly, skipping irrigation at the elongation stage resulted in a 24.1% decrease in yield compared to the control. Furthermore, the study found significant differences in grain yield among the tested wheat cultivars. Sids-14 exhibited the highest grain yield (2894.50 kg/fed), followed by Giza-171 (2860.94 kg/fed), and the lowest yield was observed for Miser-3 (2187.50 kg/fed) over the two seasons.

Table (3): Mean performance of the grain yield (kg/fed) as affected by skipping irrigation, wheat cultivars and their interaction over two seasons.

Wheat cultivars (V)	Irrigation treatments (I)			Mean
	Control (I_1)	Skipping (I_2)	Skipping (I_3)	
Giza-171	3787.83	2751.00	2044.00	**2860.94**
Misr-1	3405.50	2877.00	2009.00	**2763.83**
Misr-3	2768.50	2135.00	1659.00	**2187.50**
Sakha-95	3200.40	2499.00	2257.50	**2652.30**
Sids-14	4042.50	2793.00	1848.00	**2894.50**
Mean	**3440.95**	**2611.00**	**1963.50**	**2671.82**
LSD at 5 % level for:				
I		12.94		
V		4.96		
I × V		18.30		

Regarding the interaction between skipping irrigations and wheat cultivars, it was found that the effect of skipping irrigations on grain yield varied among the different cultivars. Sids-14 showed the highest yield (4042.50 kg/fed) under normal irrigation conditions, while Misr-3 had the lowest yield (1659.00 kg/fed) under two skipped irrigations. Sakha-95 was identified as the most drought-tolerant cultivar, with a yield of 22257.00 kg/Fed less than two skipped irrigations and 2793.00 kg/Fed for Sids-14 under one skipped irrigation.

Regarding the reductions in grain yield (kg/Fed) under skipped irrigation at the elongation stage was 15.52% for Misr-1 and 21.92 and 29.46% for Sakha-95 in both stages, respectively. On the other hand, Sids-14 and Giza-171 experienced the highest reductions in grain yield during both the elongation and heading stages with 30.91, 27.37, 54.29 and 46.04%, respectively (Figure 1).

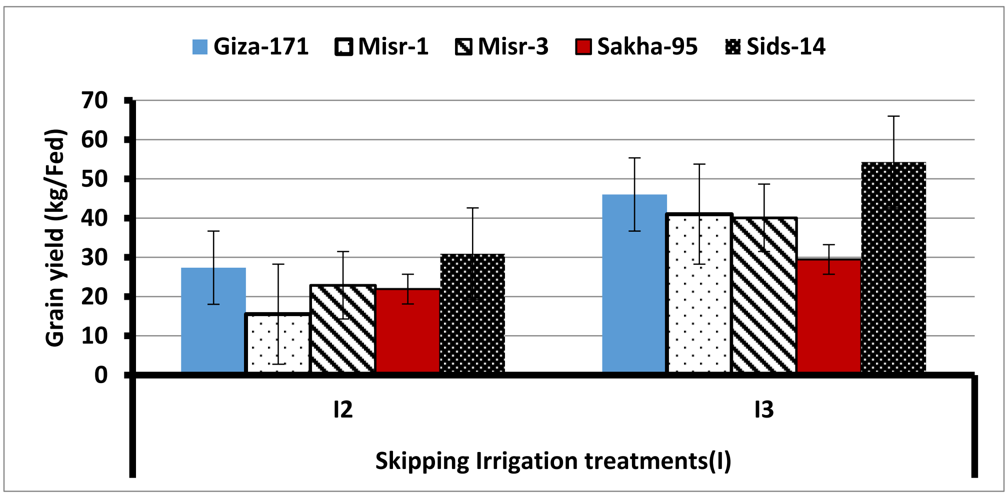

Fig.1. The impact of skipping irrigation, wheat cultivars, and their interaction on the reduction percentage of the grain yield (kg/fed) over two seasons.

3.2. Effect of water stress on wheat cultivars

Drought resistance indices are mathematical tools or formulas used to assess the ability of plants or crops to withstand and recover from drought conditions. Drought resistance indices are quantitative measures used to assess the performance and tolerance of crop cultivars under drought stress conditions. These indices help in identifying crops or cultivars that are better adapted to water-limited environments. Also, these indices help researchers, agronomists, and farmers to understand the impact of drought on plants, compare different genotypes or cultivars for drought tolerance, and make informed decisions regarding water management and crop selection.

Here's an explanation of some commonly used drought resistance indices: SSI is a measure of the relative decrease in performance (e.g., yield) of a crop cultivar under drought stress compared to optimal conditions. A lower SSI value indicates higher resistance to drought stress. STI: evaluates the ability of plants to tolerate drought stress by considering various yield parameters under normal and drought conditions. It quantifies the performance of different genotypes or cultivars under water-limited conditions. It is calculated by multiplying the yield under drought stress with the SSI value. Higher STI values indicate greater tolerance to drought stress. Yield Index (YI) represents the overall yield potential of a crop cultivar under optimal growing conditions. This index provides a reference point for comparing the yield performance of different cultivars, including their response to drought stress.

3.2.1. Stress susceptibility index (SSI)

Stress susceptibility index (SSI) under drought stress conditions (skipping irrigation during the elongation stage (I_2) and skipping irrigations during heading stages (I_3)) on grain yield (kg/Fe) over two seasons are depicted in Figure 2. The results from two seasons showed that Giza-171 had the highest SSI value of 2.26 for grain yield when irrigation skipped the vegetative stage and 3.55 when irrigation skipped the heading stage (I_3). Sakha-95 and Sids-14 also showed some level of tolerance, with Sakha-95 performing better in the two irrigation skips and Sids-14 in the irrigation skip on the elongation stage.

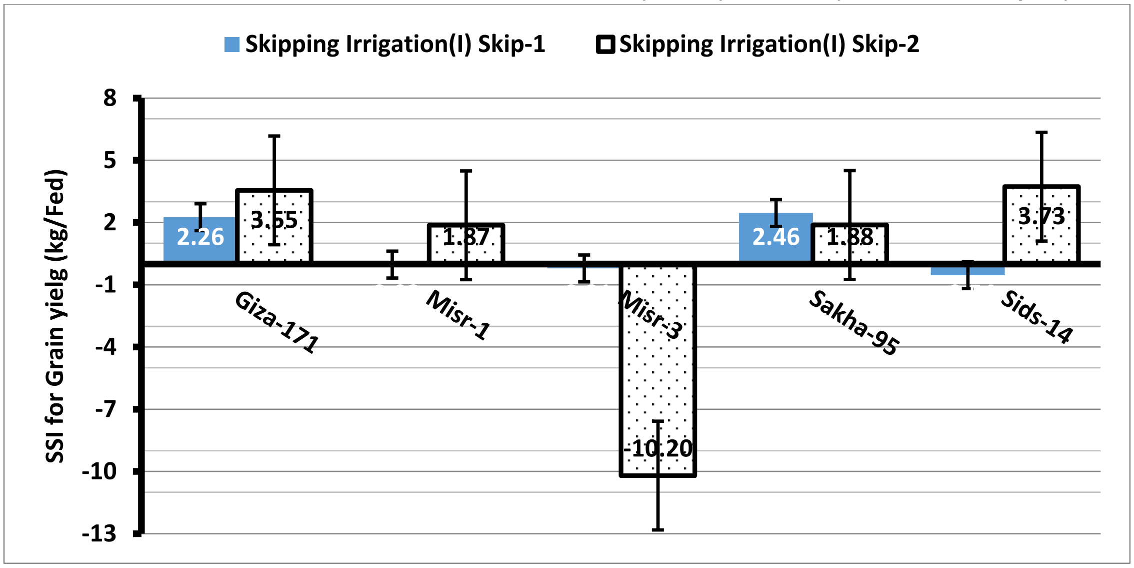

Fig.2. Stress susceptibility index (SSI) values for grain yield (kg/Fed) on some wheat cultivars under water stresses over two seasons.

3.2.2. Yield Index (YI)

Figure 3 show the YI under drought-stress conditions for grain yield (kg/Fe) over two seasons. The results indicated significant variations in the yield index for grain yield. The yield index ranged from 1.5 to 0.84, with the "Misr-3" cultivar displaying the highest values when irrigation skips at the heading stage were considered. Similarly, the "Sids-14" cultivar exhibited the highest values when considering only irrigation at the elongation stage skip for grain yield. Therefore, Misr-3," followed by Sakha-95," are the top-performing cultivars in terms of drought tolerance during the flowering stages. Conversely, "Sids-14" followed by "Misr-1" performed exceptionally well when considering only irrigation at the elongation stage skip during the elongation growth stage.

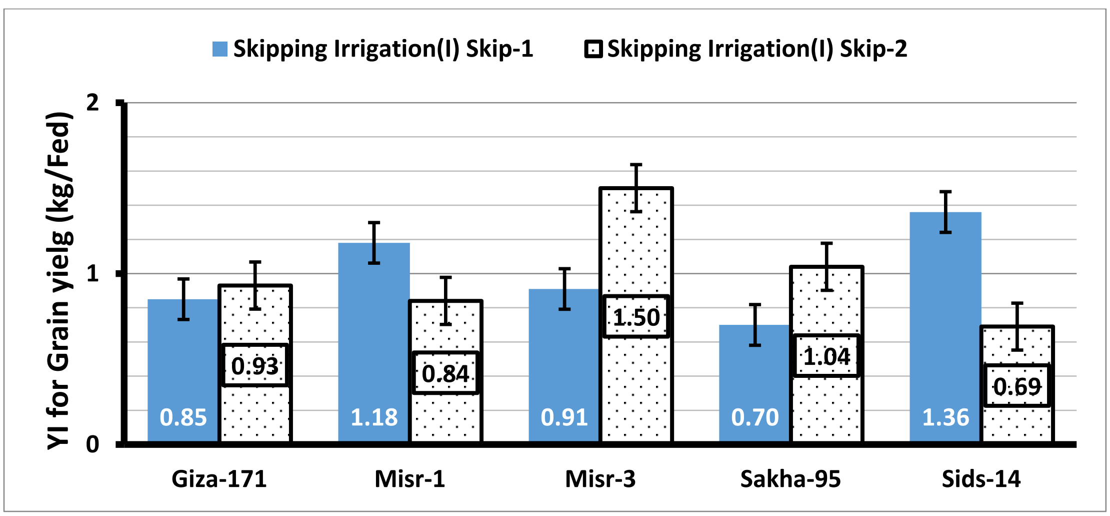

Fig. 3. Yield index (YI) values for grain yield on some wheat cultivars under water stresses over two seasons.

3.2.3. Stress tolerance index (STI)

Figure 4 show the STI under drought-stress conditions for grain yield (kg/Fe) over two seasons. The STI varied between 0.49 and 1.08. Among the cultivars considered, "Sakha-95" demonstrated the highest STI value (1.08) during irrigation skips at the heading stage, closely followed by Giza-171 (1.07). Likewise, for grain yield and harvest index trait, the cultivar "Sids-14" displayed the highest STI value (1.04) when only irrigation at elongation stage skip was taken into account during the elongation stage. Based on the information provided, it can be concluded that the "Sakha-95" cultivar showed the highest STI value of 1.08 when irrigation skips at the heading stage were considered. This was followed by the "Giza-171" cultivar with a STI value of 1.07. Additionally, the "Sids-14" cultivar displayed the highest STI value of 1.04 when considering only irrigation at vegetative stage skip at the vegetative stage for grain yield and harvest index traits.

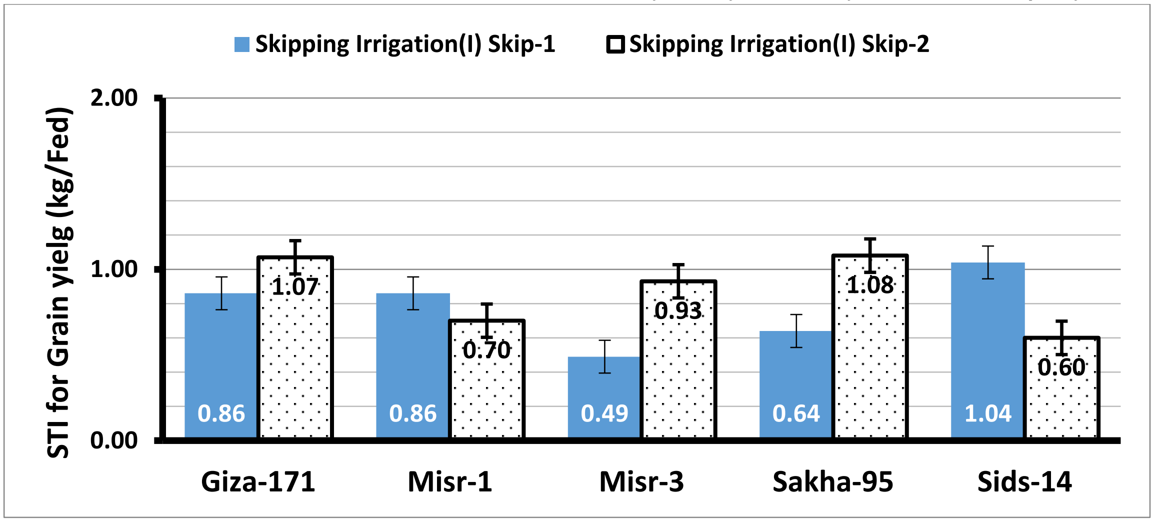

Fig.4. Stress tolerance index (STI) values for grain yield (kg/Fed) on some wheat cultivars under water stresses over two seasons.

4. Discussion

In summary, this study highlights the significant impact of skipping irrigations on grain yield, with the highest reduction observed when irrigation at the heading stage was skipped. Additionally, different wheat cultivars demonstrated varying levels of drought tolerance, with Msir-3 and Sakha-95 exhibiting higher resilience under skipped irrigations. These findings emphasize the importance of proper irrigation management and the selection of appropriate wheat cultivars to optimize grain yield in water-limited conditions. Bashir etal., [21] and Khan et al., [22] reported that decreasing the number of irrigations and amount of water decreased wheat grain yield at the different growth stages. The performance variations of wheat genotypes have been studied by various authors, specifically focusing on the number of grains per spike [2,8,22–27]. The previous discussions regarding the yield components have revealed a consistent trend that is also observed in the case of the cultivar Misr-3. Similar to the cultivar Sakha-95, Misr-3 exhibits a higher level of drought tolerance during the elongation and flowering stages. This further emphasizes the significant influence of the active genetic composition in determining the drought-tolerant capabilities of these cultivars.

The findings from the study highlight distinct levels of drought stress susceptibility index (SSI) among the examined cultivars. Giza-171 emerges as the least tolerant to drought stress, underscoring its susceptibility to adverse conditions. On the contrary, Misr-3 stands out as the most drought-tolerant cultivar, showcasing resilience in the face of water scarcity. Sakha-95 and Sids-14 also exhibit noteworthy levels of drought tolerance. Sakha-95 and Sids-14 also exhibit noteworthy levels of drought tolerance. Sakha-95 demonstrates effectiveness in situations involving two irrigation skips, showcasing its adaptability to specific stress conditions. Meanwhile, Sids-14 excels when irrigation is skipped during the elongation stage, indicating a specialized tolerance mechanism during this critical growth phase. These distinctions in drought tolerance among cultivars emphasize the importance of targeted selection for specific stress conditions. Misr-3, with its overall resilience, could serve as a valuable resource for breeding programs aimed at enhancing drought tolerance in crops. Meanwhile, the nuanced performances of Sakha-95 and Sids-14 suggest the potential for tailored approaches depending on the nature and timing of drought stress.

In summary, the study provides valuable insights into the drought tolerance of different cultivars, offering a foundation for informed agricultural practices and breeding strategies to mitigate the impact of water scarcity on crop yield [16,27–31]. This was commonly used in earlier studies to detect tolerant genotypes for water stress. The study revealed significant variations in the yield index for grain yield, notably that the "Misr-3" cultivar displayed the highest values during irrigation skips at the heading stage, while "Sids-14" showed peak performance with irrigation skips at the elongation stage, emphasizing their resilience to drought conditions. In terms of drought tolerance during flowering stages, "Misr-3" and "Sakha-95" emerged as the top-performing cultivars. Conversely, during the elongation growth stage with irrigation skips at the vegetative stage, "Sids-14" and "Misr-1" demonstrated exceptional performance. The elevated values observed across these traits suggest a predominant influence of additive gene action, pointing towards potential opportunities for selective breeding to enhance yield under varying conditions. Desiccation appears to be a crucial factor in understanding and optimizing these cultivars for improved agricultural outcomes. These results are in line with the pervious reported [32–34]. The consistent findings across various studies, including this one, underscore the robustness of the observations regarding the superior stress tolerance of "Sakha-95," "Giza-171," and "Sids-14" cultivars. This aligns closely with previous research which contribute to a comprehensive understanding of genotype responses to stress conditions [1,35–39]. In conclusion, this discussion underscores the significance of the study's findings, contributing to a broader body of knowledge that informs agricultural practices, crop management, and breeding programs aimed at ensuring food security in the face of environmental challenges.

5. Conclusions

The study reveals that "Misr-3," "Sakha-95," and "Sids-14" show significant variations in grain yield under drought conditions. Misr-3 is the most drought-tolerant cultivar, while Giza-171 is the least tolerant. These traits highlight their resilience in water scarcity.

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Author Contributions

All authors contributed to this work. Zainab S. Mohamed prepared the samples and completed the experimental measurements. Both K.H. Ghallab and S.A. Abd El-Megeed shared writing and followed the performance of the experiments. K.H. Ghallab helped the last author complete the sample preparation. K.H. Ghallab with S.A. Abd El-Megeed completed the paper writing, analyzing the data, and validation K.H. Ghallab followed the revision and submission of the manuscript for publication.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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