Evaluation of Ten Egyptian Cultivated Rice Genotypes Tolerance to Drought Stress

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ABSTRACT

Drought is a significant limiting factor of rice growth and production, particularly in water scarce locations. To address drought impact on rice growth and development, ten of current cultivated Egyptian genotypes were assessed according to the morphological and physiological traits. Total chlorophyll contents drastically decreased to 100% except Giza 179 (9.66, 54.43% reduction) and Sakha 108 (2.46, 92.63% reduction). Meanwhile, Giza 182 and Sakha Super 300, exhibited minor decreases but remain resilient to stress. Considering growth attributes, drought significantly reduced plant height of all tested cultivars indicating that Sakha 102 is the most sensitive (70.9% reduction) and Sakha 108 is the most tolerant (26.9% reduction). Root fresh weight was drastically reduced in Sakha 102 (97.2%) and Sakha Super 300 (>90%), whereas Giza 178 maintained higher root biomass under stress. Shoot fresh weight also declined markedly, with Sakha 108 and Giza 179 showing the greatest sensitivity (>89%), while Sakha 101 and Sakha 103 exhibited improved performance under moderate stress. Root dry weight reductions were most pronounced in Sakha 102, Giza 177, and Giza 182 (>90%), whereas Sakha 103 and Sakha 104 sustained higher values. Similarly, shoot dry weight decreased in all genotypes, with Sakha Super 300 and Sakha 102 being most affected, while Giza 178 and Sakha 103 maintained relatively higher biomass. Collectively, Giza 178 and Sakha 103 demonstrated superior drought tolerance, highlighting their potential as promising candidates for breeding programs under water-limited conditions.

Keywords: Rice (*Oryza sativa* L.), Drought stress tolerance, Egyptian Rice genotypes and Growth attributes.

INTRODUCTION

Rice (*Oryza sativa* L.) is a globally cultivated staple crop, with an estimated area of over 160 million hectares, and leading producers including China, India, Indonesia, and Bangladesh, where it contributes significantly to food security and the national economy (Caplan *et al.*, 1990 and Margaret *et al.*, 2024). Rice cultivation in Egypt is mainly concentrated in the Nile Delta, with about 670,000 hectares (≈1.6 million feddans) grown in the 2024/2025 season (USID-IPAD, 2024). Average yields reached 8.4 t/ha, equivalent to nearly3.5t/feddan. This underscores the crop's strategic role in Egypt's agriculture despite water and climate challenges (USID-IPAD, 2025). Rice requires substantial amounts of water, approximately 1,200 to 2,500 mm per growing season, for optimal growth, particularly during the vegetative and reproductive stages. The water requirements of Egyptian rice genotypes are approximately 7,000 to 9,000 m^3 per feddan (FAO, 2021 and Wally, 2021). Because of rice high requirements, making drought a significant threat to yield consistency and quality particularly meeting notable climate changes aggravating water constraint, making efficient irrigation practices essential to sustain productivity under increasing water scarcity and understanding how drought affects Egyptian rice cultivars is critical for building resilient agricultural solutions (Hassan *et al.*, 2013; Li *et al.*, 2024 and Lu, 2024).

Drought has a negative impacts on rice's physiological, biochemical, and morphological processes, resulting in reduced germination, poor seedling establishment, stunted development, decreased biomass accumulation, and incomplete grain production depending on genotype, development stage, and level of drought stress (Caplan *et al.*, 1990; Xu *et al.*, 2021; Ahmad *et al.*, 2023 and Margaret *et al.*, 2024). Growth indicators, photosynthesis, and agronomic traits such as grain filling, spikelet fertility, and total grain production are drastically affected by water shortage, lowering rice productivity by 20-50%, depending on type and intensity (Zhang *et al.*, 2018).

Egyptian cultivated rice genotypes exhibited varied tolerance to drought conditions, affecting different types. While some cultivars are moderately to highly drought-tolerant, others experience severe production reductions when water-stressed. Egyptian rice genotypes, such as Sakha 101 and Giza 177, are highly sensitive, experiencing significant losses in biomass and yield under extreme drought conditions. In contrast, Sakha 108 and Giza 178 are more tolerant, sustaining root development while limiting water loss via stomatal management, unlike Sakha 102. Sakha Super 300 exhibited a moderate tolerance response, whereas Sakha 104 and Giza 182 were categorized as drought-resistant due to their effective water-use mechanisms (Hassan *et al.*, 2013). Drought stress causes oxidative damage by

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increasing the production of reactive oxygen species (ROS), which leads to cellular compartment disorganization and membrane damage (Sachdev *et al.*, 2021 and Tavu & Redillas, 2025).

Furthermore, recent breeding projects have focused on introducing drought-responsive genes into Egyptian rice types to improve tolerance at the molecular level (Hassan *et al.*, 2013 and Hazman *et al.*, 2019). The development and adoption of drought-tolerant rice cultivars, along with improved agronomic methods, are critical for Egypt's long-term rice production. Future studies should focus on enhancing genetic resilience, optimizing irrigation systems, and employing molecular breeding approaches to promote drought tolerance in Egyptian rice varieties (Hazman *et al.*, 2019 and Hassanein *et al.*, 2021).

The current study aimed to evaluate the morphological and physicochemical features of cultivated Egyptian genotypes under drought stress and to identify the most tolerant and non-tolerant genotypes for future studies.

MATERIALS AND METHODS

Plant materials

The obtained ten (Sakha Super 300, Sakha 101, Sakha 102, Giza 182, Sakha 103, Sakha 104, Giza 177, Giza 178, Sakha 108 and Giza 179) genotypes were soaked in water and transplanted into plastic pots (25 cm) containing 3 kg of autoclaved clay soil. Rice grains were obtained from the Sakha agricultural research station, Kafr El-Sheikh, where ten various genotypes of rice (*Oryza sativa*) were grown and used in experiments.

Growth conditions

The rice genotypes were soaked for a week until the emergence of the coleoptile and radical, subsequently transferred to a prepared modified Hoagland's nutrient solution (Ali *et al.*, 2013). Seeds were treated with polyethylene glycol 6000 for 2 hours before being translocated to a hydroponic solution. Fifteen days later, the seedlings were transferred to the previously sterilized and prepared clay soil, ready for planting. Soil water capacity was calculated, and it was found that each 5 kg of soil requires 1 liter of water to reach 100% humidity.

Planting Experiment

The planting experiment began in the 2023 season, utilizing a factorial split-plot design. Each replicate consisted of forty treatments, replicated three times.

Drought Treatments

Each pot is filled with 2 kg of soil, so to provide a moisture content of 100%, we apply 400 ml of water to the soil. For 50% moisture, 200 ml of water were added, and for 30% moisture, 120 ml of water were added to each pot. A soil Tester was used to check water content constantly.

Chlorophyll measurement

The chlorophyll content in the flag leaf of rice plants was measured using the SPAD device, where total chlorophyll in the flag leaf was assessed for all studied varieties.

RESULTS

Effect of drought on chlorophyll measurements

Chlorophyll content determinations under 50% water holding capacity indicated that cultivars Sakha Super 300, Giza 182 exhibited a sharp decline in chlorophyll content, up to ~82%. On the contrary, the cultivars Sakha 104, Giza 177, Sakha 103 and Sakha 101, and Giza 178 exhibited increases in chlorophyll by 556.6, 447.8, 168.8, 29 and 20% respectively, suggesting potential adaptive or compensatory responses to drought stress (Table 1). Rice cultivars exposed to 30% holding capacity exhibited dramatic reduction in chlorophyll contents of all cultivars (100%) except Sakha 108 (2.46 mg/g FW) and Giza 179 (9.66 mg/g FW), indicating severe impairment of photosynthesis.

Growth characteristics of drought affected rice genotypes:

Plant heights

Screened rice genotypes exhibited varied responses to drought levels (Table 2). The majority of tested genotypes showed a reduction in plant height under moderate drought conditions (50%), where Sakha 102 exhibited severe reduction (54.33cm, 33.2%), followed by Sakha Super 300 (48 cm, 20%). The plant height reduction of the other genotypes ranged from 12.24% to 15.43% presented in Giza 179 and Giza 178, respectively. Sakha 103, Sakha 103 and Giza 177 exhibited slight increases or no change, indicating moderate tolerance. However, under severe drought stress (30% irrigation), all cultivars showed substantial reductions in height. Sakha 102 recorded the highest reduction (70.9%), highlighting its high sensitivity to water deficit. In contrast, Giza 178, Sakha 108, and Giza 179 maintained relatively higher plant heights with the least reduction percentages (26.28%, 26.09%, and 28.20%, respectively), suggesting these genotypes possess greater resilience to drought.

Fresh weights

Under moderate drought conditions at 50% of soil water holding capacity, most cultivars exhibited substantial reductions in root fresh weight (Table 3).

Table 1. SPAD contents of ten cultivated rice genotypes under 50% and 30% soil water holding capacity (SWHC) exposed rice genotypes.

Cultivars	Chlorophyll				
	Control	50% SWHC	Reduction %	30% SWHC	Reduction %
Sakha Super 300	11.30 ± 0.70cA	2.00 ± 1.74dB	-82.30	0.00 ± 0.00bC	100
Sakha 101	11.07 ± 1.36cA	14.37 ± 11.60cA	29.81	0.00 ± 0.00bB	100
Sakha 102	6.07 ± 3.82eB	11.30 ± 5.05cA	86.16	0.00 ± 0.00bC	100
Giza 182	23.57 ± 7.35bA	19.07 ± 6.35bA	-19.09	0.00 ± 0.00bB	100
Sakha 103	10.13 ± 1.21dB	27.23 ± 4.04aA	168.81	0.00 ± 0.00bC	100
Sakha 104	4.03 ± 2.51eB	19.83 ± 6.85bA	556.58	0.00 ± 0.00bC	100
Giza 177	4.83 ± 0.85eB	26.46 ± 2.16aA	447.83	0.00 ± 0.00bC	100
Giza 178	18.00 ± 5.66bB	21.60 ± 2.70bA	20.00	0.00 ± 0.00bC	100
Sakha 108	33.37 ± 1.55aA	20.77 ± 0.35bB	-37.76	2.46 ± 4.27aC	92.63
Giza 179	21.20 ± 4.35bA	12.63 ± 5.61cB	-40.42	9.66 ± 8.42aB	54.43

*Values are means of three replicates. Values of the same column followed by the same letter (s) are not significantly different at $P \leq 0.05$ of LSD. Values of the same row followed by the same letter (s) are not significantly different at $P \leq 0.05$ of LSD.

Table 2. The plant heights (cm) of 50% and 30% soil water holding capacity (SWHC) exposed rice genotypes.

Cultivars	Plant heights				
	Control	50% SWHC	Reduction %	30% SWHC	Reduction %
Sakha Super 300	60.00±22.65bA	48.00 ± 3.00aB	-20	32.66 ± 3.01bC	45.56
Sakha 101	59.33 ± 2.08bA	50.33 ± 8.08aA	-15.25	32.00 ± 13.86bB	46.06
Sakha 102	81.33 ± 2.52aA	54.33 ± 3.51aC	-33.20	23.67 ± 4.73cD	-70.90
Giza 182	49.00 ± 8.54cA	43.67 ± 5.51bB	0.11	32.00 ± 8.18bC	34.69
Sakha 103	53.67 ±17.62bB	54.00 ± 6.00aB	0.62	23.33 ± 8.51cC	56.53
Sakha 104	52.00 ±15.00bB	52.00 ± 2.00aB	0.00	23.00 ± 3.61cC	55.77
Giza 177	48.00 ±18.00cB	49.00 ± 4.00aA	2.08	25.33 ± 4.73cC	47.23
Giza 178	58.33±10.50bA	49.33 ± 7.51aB	-15.43	43.00 ± 4.36aB	26.28
Sakha 108	61.33 ± 7.51bA	53.00 ± 1.00aB	-13.58	45.33 ± 11.85aC	26.09
Giza 179	62.67±10.21bA	55.00 ± 9.85aA	-12.24	45.00 ± 9.00aB	28.20

*Values are means of three replicates. Values of the same column followed by the same letter (s) are not significantly different at $P \leq 0.05$ of LSD.

Table 3. Effect of water shortage 50% and 30% soil water holding capacity (SWHC) exposure on cultivated rice genotypes' root fresh weights.

Cultivars	Root fresh weights/plant (g)				
	Control	50% SWHC	Reduction %	30% SWHC	Reduction %
Sakha Super 300	5.46 ± 1.58bA	2.13 ± 1.86eB	-60.99	0.61 ± 0.35aB	-88.83
Sakha 101	6.41 ± 4.14bA	6.19 ± 1.79bA	-3.43	0.83 ± 0.18aB	-87.05
Sakha 102	9.79 ± 0.46aA	3.66 ± 0.69dB	-62.61	0.27 ± 0.02cC	-97.24
Giza 182	8.37 ± 3.17bA	4.61 ± 0.64bB	-44.92	0.94 ± 0.61aC	-88.77
Sakha 103	0.85 ± 1.25cB	1.92 ± 0.30eA	125.88	0.30 ± 0.09cC	-64.71
Sakha 104	3.23 ± 2.96cA	1.55 ± 0.43eA	-52.01	1.06 ± 0.51aA	-67.18
Giza 177	5.75 ± 1.49bA	4.12 ± 0.25cB	-28.35	0.52 ± 0.03bC	-90.96
Giza 178	5.94 ± 3.36bA	6.78 ± 1.87aA	14.14	0.95 ± 0.38aB	-84.01
Sakha 108	8.08 ± 1.65bA	8.75 ± 2.18aA	-8.29	1.02 ± 0.52aB	-87.38
Giza 179	7.87 ± 1.45bA	5.54 ± 0.49bB	-29.61	0.89 ± 0.71aC	-88.69

*Values are means of three replicates. Values of the same column followed by the same letter (s) are not significantly different at $P \leq 0.05$ of LSD.

Cultivars Sakha 102 and Sakha Super 300 exhibited high significant reduction of root fresh weight by 62.61% and 60.99%, respectively, followed by cultivars Sakha 104 (52.01%) and Giza 182 (44.92%) meanwhile, Sakha 101 and Sakha 108 (8.29%) exhibited a moderate tolerant response. On the contrary, Giza 178 and Sakha 101 exhibited slightly improved root biomass and enhanced root proliferation, which may serve as a potential drought adaptation mechanism. Under severe drought conditions (30% irrigation), all genotypes showed significant reductions. Sakha 102 and Giza 177 showed the highest reduction % by 97.24% and 90.96%, respectively. Cultivars Sakha 103 (64.71%) and Sakha 104 (67.18%) displayed the least significant reduction compared to the corresponding controls.

The shoot fresh weight of screened rice genotypes was significantly affected by water shortage, particularly at 30% irrigation, with a maximum reduction of 89.35% and 89.22% observed in Sakha 108 and Giza 179 genotypes, respectively (Table 4). Sakha Super 300, Sakha 102, and Giza 177 experiencing reductions of over 84% at 30%, indicating high sensitivity. Interestingly, some cultivars, such as Sakha 101 and Sakha 103, displayed negative reduction percentages at 50% irrigation, suggesting improved biomass, possibly due to adaptive responses under mild stress. However, under 30% drought, even these cultivars suffered substantial losses, highlighting the limited sustainability of such responses under severe stress. The most drought-tolerant cultivars, in terms of fresh shoot weight, were Giza 178 and Sakha 108, which showed the least reduction at both stress levels. These results highlight the variability in drought responses among rice genotypes and the potential of specific cultivars for breeding programs aimed at enhancing drought resilience.

Investigating root dry weights of drought-exposed rice genotypes displayed a dramatic reduction, particularly at 30% saturation (Table 5). All tested genotypes showed severe reductions up to 96.8% in Sakha 102, followed by Giza 177 (94.59%) and Giza 182 (90%). Sakha 103 and Sakha 104 exhibited the lowest rates at 72.4% and 68.6%, respectively. The reduction in root dry weights of the remains ranged from 76.44% with Sakha 108 to 88.3% with Sakha Super 300. These results highlight the effect of genotypic differences in drought tolerance, with some cultivars maintaining root biomass better than others. Exposure to 50% field capacity conditions resulted in considerable reductions in dry root biomass, ranging from 47% to 83%, with Sakha 104 and Sakha 102 being the most affected. Interestingly, Sakha 103 and Giza 178 exhibited less reduction or even slight increases, suggesting a potential adaptive response through enhanced root development to maintain water uptake.

The data presented in Table (6) indicate the effect of 50% and 30% exposure to field capacity on the dry weights of screened rice shoots. The genotypes Sakha Super 300 and Sakha 102 showed the highest significant reduction (68.51% and 47.42%, respectively), while Sakha 101, Giza 179, Giza 177, and Giza 182 exhibited moderate reductions (25.76%, 29.34%, 37.67%, and 42.58%, respectively). The cultivar Sakha 104 showed a slight reduction, estimated by 8.04%. On the contrary, genotypes Sakha 108, Sakha 103, and Giza 178 showed an increase in shoot dry weights, ranging from 5.1% to 59.9%, with the maximum increase observed in Giza 178. Under 30% saturation conditions, all genotypes experienced substantial reductions in dry weight.

Table 4. Shoot fresh weights of 50% and 30% soil water holding capacity (SWHC) irrigation exposure on the shoot fresh weights of cultivated rice genotypes.

Cultivars	Shoot fresh weight (g)/plant				
	Control	50% SWHC	Reduction %	30% SWHC	Reduction %
Sakha Super 300	10.59 ± 2.07bA	4.47 ± 3.88fB	-57.79	1.35 ± 0.96bB	-87.25
Sakha 101	6.47 ± 3.20cB	11.08 ± 1.56bA	71.25	2.19 ± 0.67aC	-66.15
Sakha 102	9.76 ± 2.28bA	8.50 ± 0.91dB	-12.91	1.26 ± 0.04bC	-87.09
Giza 182	9.21 ± 1.95bA	9.95 ± 0.80cA	8.03	2.06 ± 0.24aB	-77.63
Sakha 103	2.32 ± 2.30dB	6.53 ± 0.29eA	181.47	0.69 ± 0.27bB	-70.26
Sakha 104	4.80 ± 3.38cB	6.32 ± 0.31eA	31.67	1.55 ± 0.24aC	-67.71
Giza 177	5.81 ± 1.16cA	6.43 ± 0.46eA	10.67	0.91 ± 0.05bB	-84.34
Giza 178	10.90 ± 4.54bA	10.93 ± 1.94bA	0.28	1.66 ± 0.22aB	-84.77
Sakha 108	15.30 ± 2.57aA	16.77 ± 1.35aA	-9.61	1.63 ± 0.22aB	-89.35
Giza 179	12.25 ± 3.70bA	11.27 ± 0.94bA	-8	1.32 ± 0.48bB	-89.22

*Values are means of three replicates. Values of the same column followed by the same letter (s) are not significantly different at $P \leq 0.05$ of LSD. Values of the same row followed by the same letter (s) are not significantly different at $P \leq 0.05$ of LSD.

Table 5. Effect of water shortage 50% and 30% soil water holding capacity (SWHC) exposure on cultivated rice genotypes' root dry weights.

Cultivars	Root dry weights (g)/plant				
	Control	50% SWHC	Reduction %	30% SWHC	Reduction %
Sakha Super 300	1.88 ± 1.07aA	0.74 ± 0.65dB	-60.64	0.22 ± 0.15aB	-88.30
Sakha 101	2.35 ± 0.52aA	1.24 ± 1.04cB	-47.23	0.28 ± 0.10aB	-88.09
Sakha 102	3.45 ± 0.32aA	0.92 ± 0.13cB	-73.33	0.11 ± 0.02bC	-96.81
Giza 182	3.53 ± 1.95aA	1.50 ± 0.69cB	-57.51	0.35 ± 0.21aC	-90.08
Sakha 103	0.29 ± 0.42bA	0.38 ± 0.19dA	31.03	0.08 ± 0.03cB	-72.41
Sakha 104	1.18 ± 1.13bA	0.20 ± 0.04dA	-83.05	0.37 ± 0.25aA	-68.64
Giza 177	2.22 ± 1.00aA	0.60 ± 0.06dB	-72.97	0.12 ± 0.02aC	-94.59
Giza 178	2.16 ± 1.71aB	2.82 ± 0.40aA	30.56	0.31 ± 0.19aC	-85.65
Sakha 108	2.25 ± 0.14aA	3.19 ± 0.94aA	41.78	0.53 ± 0.39aB	-76.44
Giza 179	2.08 ± 0.67aA	2.07 ± 0.49bA	-0.48	0.74 ± 0.62aB	-64.42

*Values are means of three replicates. Values of the same column followed by the same letter (s) are not significantly different at $P \leq 0.05$ of LSD. Values of the same row followed by the same letter (s) are not significantly different at $P \leq 0.05$ of LSD.

Table 6. Effect of water shortage (50% and 30%) exposure on cultivated rice genotypes' shoot dry weights.

Cultivars	Shoot dry weights (g)/plant				
	Control	50%	Reduction %	30%	Reduction %
Sakha Super 300	7.24 ± 0.80aA	2.28 ± 1.98eB	-68.51	0.87 ± 0.46bC	87.98
Sakha 101	4.97 ± 2.34bA	3.69 ± 0.60cA	-25.76	1.21 ± 0.50aB	75.65
Sakha 102	7.57 ± 1.82aA	3.98 ± 0.65bB	-٤٧.42	0.63 ± 0.12bC	91.68
Giza 182	7.61 ± 1.36aA	4.37 ± 0.56cB	-42.58	1.58 ± 0.37aC	79.24
Sakha 103	1.45 ± 1.67cA	2.25 ± 0.88eA	55.17	0.41 ± 0.31bB	71.72
Sakha 104	3.36 ± 2.60cA	3.09 ± 0.07cA	-8.04	0.87 ± 0.23bA	74.11
Giza 177	4.46 ± 1.35bA	2.78 ± 0.30dB	-37.67	0.42 ± 0.05bC	90.58
Giza 178	4.04 ± 2.20bB	6.46 ± 0.50 aA	59.90	1.40 ± 0.16aC	65.35
Sakha 108	٦,٢٨ ± 2.41bA	6.60 ± 0.53aA	5.10	1.04 ± 0.44bB	83.44
Giza 179	8.35 ± 1.40aA	5.90 ± 0.95bA	-29.34	1.12 ± 0.73bB	86.59

*Values are means of three replicates. Values of the same column followed by the same letter (s) are not significantly different at $P \leq 0.05$ of LSD. Values of the same row followed by the same letter (s) are not significantly different at $P \leq 0.05$ of LSD.

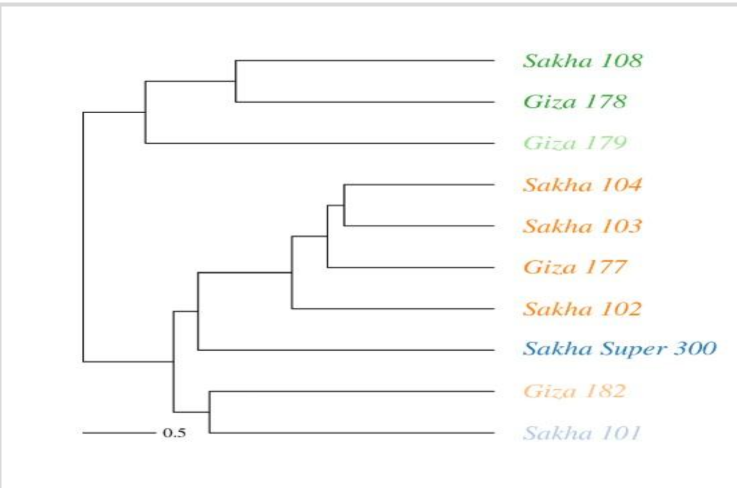

Figure 1. The clustering of genotypes clearly separated tolerant and sensitive cultivars. Sakha 108, Giza 178, and Giza 179 formed a distinct tolerant group, showing superior drought performance. Sakha 101 stood apart at the bottom of the dendrogram, indicating the highest sensitivity to drought stress. Intermediate responses were seen in Sakha 104, Sakha 103, and Giza 177, forming a separate group. Sakha 102, Sakha Super 300, and Giza 182 showed moderate tolerance behavior.

Sakha 102 and Giza 177 showed the highest sensitivity (91.68% and 90.58% reduction), indicating poor adaptability to severe drought. In contrast, Giza 178 and Sakha 103 demonstrated the lowest reductions (65.35% and 71.72 %, respectively), suggesting better drought tolerance. Overall, dry weight data reinforce the impact of water deficit on plant biomass and highlight the variability among cultivars, with Giza 178 emerging again as a promising genotype for drought-prone conditions due to its relatively stable performance (Figure 1).

DISCUSSION

The current study was designed to evaluate the response of ten cultivated Egyptian rice cultivars to 30% and 50% and 100% holding water capacity, with a focus on determining growth traits and chlorophyll content. The obtained data revealed that drought stress triggered a cascade of physiological alterations in rice genotypes affecting key photosynthetic pigment contents, whereas 30% water holding capacity significantly reduced chlorophyll content of all cultivars except Giza 179 and Sakha 108 in agreement with previous studies (Hashem, 2019). Chlorophyll contents positively correlate with photosynthetic rate under optimal water conditions, meanwhile drought exposure negatively affect chlorophyll contents by abscisic acid accumulation, stomatal closure, reactive oxygen species accumulation and subsequent photo-oxidative stress that damage chloroplast membranes the end result is conversion of leaf color from green to yellow, resulting in reduced radiation absorption (Ahmadikhah & Marufinia, 2016 and Moonmoon *et al.*, 2017).

Plant height of all screened genotypes was significantly decreased, meanwhile cultivar Sakha 102 is the most sensitive exhibiting reduction by 33.2% and 70.9% after 50 and 30% of soil water holding capacity, respectively, while cultivars Giza 179, Giza 178 and Sakha 108 were more tolerant under both 30 and 50% soil water holding capacity compared to control, our findings in harmony previous published reports explaining robust hormonal regulation and nutrient availability promote vigorous tillering and elongation; however, as water availability decreases to 50% and further to 30%, disruptions in cytokinin and gibberellin pathways result in significant reductions in these growth parameters (Ahmadikhah & Marufinia, 2016 and Hassanein *et al.*, 2021).

Root fresh weight of all screened genotypes was significantly reduced under drought stress, with Sakha 102 and Sakha Super 300 showing the greatest sensitivity, recording reductions of 62.6% and 61.0% at 50% soil water holding capacity, respectively, and further declines of 97.2% and over 90% at 30% irrigation. In contrast, Sakha 101, Sakha 108, and particularly Giza 178 exhibited more tolerant responses, with some genotypes even displaying enhanced root biomass under moderate stress, suggesting adaptive root proliferation. These results are consistent with previous reports indicating that drought stress alters root development through changes in assimilate partitioning and hormonal regulation, particularly reduced cytokinin transport and altered auxin signaling, which influence root growth and biomass allocation. However, under severe stress (30%), these compensatory mechanisms collapse, leading to drastic root biomass reductions across all cultivars (Kim *et al.*, 2020).

The shoot fresh weight of all screened rice genotypes was markedly reduced under drought stress, with the most pronounced reductions recorded at 30% irrigation. Cultivars Sakha 108 and Giza 179 were highly sensitive, showing reductions of 89.35% and 89.22%, respectively, while Sakha Super 300, Sakha 102, and Giza 177 also exhibited severe sensitivity with losses exceeding 84%. On the contrary, Sakha 101 and Sakha 103 displayed improved biomass at 50% irrigation, suggesting mild stress-induced adaptive responses; however, these responses were unsustainable under severe drought, as both cultivars later suffered considerable reductions. Comparatively, Giza 178 and Sakha 108 demonstrated the greatest tolerance, showing lower reductions at both stress levels, aligning with previous reports where genotypic differences in shoot biomass under drought were attributed to enhanced osmotic adjustment, hormonal regulation, and improved water-use efficiency (Mostajeran and Rahimi-Eichi, 2009).

Root dry weight of all screened rice genotypes was significantly reduced under drought stress, particularly at 30% soil water holding capacity, where Sakha 102, Giza 177, and Giza 182 recorded the highest sensitivity with reductions of 96.8%, 94.59%, and 90%, respectively. In contrast, Sakha 103 and Sakha 104 displayed the least reduction (72.4% and 68.6%), suggesting relatively better drought tolerance. At 50% irrigation, considerable reductions were observed across genotypes, ranging from 47% to 83%, with Sakha 102 and Sakha 104 being most affected, whereas Giza 178 and Sakha 103 showed improved or sustained root biomass, possibly reflecting adaptive responses through enhanced root development and water acquisition strategies. These findings align with previous reports indicating that genotypic variation in root biomass under drought is strongly linked to deeper rooting ability, osmotic adjustment, and hormonal regulation of root architecture (Henry *et al.*, 2011 and Hassan *et al.*, 2013).

Shoot dry weight of the tested rice genotypes was significantly reduced under drought stress, with the highest sensitivity observed in Sakha Super 300 and Sakha 102, showing reductions of 68.5% and 47.4% at 50% field capacity, while Sakha 104 exhibited only a slight reduction (8.0%). Interestingly, some cultivars such as Giza 178, Sakha 103, and Sakha 108 even showed increases in dry weight under moderate stress, suggesting possible adaptive biomass allocation. However, under 30% saturation, severe reductions occurred across all genotypes, with Sakha 102 and Giza 177 being the most sensitive (91.7% and 90.6%), whereas Giza 178 and Sakha 103 maintained relatively higher dry weights, highlighting their superior drought resilience. These results align with previous studies reporting that drought stress drastically limits biomass accumulation through reduced carbon assimilation, impaired translocation, and accelerated senescence, while tolerant genotypes exhibit improved water-use efficiency and altered biomass partitioning under stress (Hassan *et al.*, 2013 and Fahad *et al.*, 2017).

This aligns with the broader literature, which shows that drought stress accelerates chlorophyll degradation and inhibits photosynthetic function. Similarly, reductions in plant height are widely reported and are attributed to impaired cell elongation and hormonal imbalance, particularly reduced gibberellin and cytokinin activity. In the case of root fresh weight, several studies confirm that drought alters assimilate partitioning and hormone signaling, which may initially stimulate adaptive root proliferation under moderate stress but collapse under severe stress, leading to drastic biomass. For shoot fresh weight, genotypic differences under drought have been linked to osmotic adjustment, efficient water use, and hormonal regulation, explaining why some cultivars sustain higher shoot weights under moderate water deficit. Likewise, variation in root dry weight among genotypes has been consistently attributed to differences in rooting depth, osmotic regulation, and adaptive changes in root architecture, enhancing water uptake under drought conditions. Finally, decreases in shoot dry weight are well-documented and primarily result from reduced carbon assimilation, impaired assimilate translocation, and premature senescence, with tolerant cultivars maintaining relatively higher biomass due to improved water-use efficiency and adaptive allocation strategies.

CONCLUSION

The responses of diverse rice genotypes to drought demonstrate how hormones, water-saving measures, and plant energy utilization all work together to cope with stress. While adequate water helps plants grow, severe drought can disrupt important growth processes such as tillering, plant height, and photosynthesis. This reduces the number of panicles and grain weight, resulting in decreased yields. However, other genotypes, such as Sakha 108 and Giza 179, have performed better under stress, making them promising candidates for breeding projects aimed at enhancing drought resistance. These findings provide an important starting point for enhancing rice varieties and managing resources more effectively in locations where water is becoming scarce.

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الملخص العربي

فحص تحمل عشرة أصناف منزرعة من الأرز المصري للجفاف

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يعد الجفاف أحد أهم العوامل الرئيسية التي تحد من نمو الأرز وإنتاجه، وخاصة في المناطق التي تعاني من ندرة المياه. ولمعالجة تأثير الجفاف على نمو الأرز وتطوره، تم تقييم عشرة من الأصناف المصرية المنزرعة حاليًا بناءًا على صفاتها المورفولوجية والفسيولوجية. بالنسبة لمحتوى الكلوروفيل الكلى، انخفض محتوى الكلوروفيل الكلى بشكل كبير بنسبة تصل إلى ١٠٠% في معظم الأصناف، ولكن اختلفت النتائج في صنف جيزة ١٧٩ حيث والذي سجل انخفاضًا بنسبة (٩،٦٦، ٥٤،٤٣ %) وصنف سخا ١٠٨ والذي سجل انخفضاً بنسبة (٢،٤٦، ٩٢،٦٣ %) مقارنة بالكنترول. بينما أظهرت الأصناف جيزة ١٨٢ وسخا سوبر ٣٠٠ انخفاضًا طفيفًا، مما يشير إلى قدرتها على التحمل. وبالنظر إلى صفات النمو مثل طول النبات انخفضت أطوال النباتات بشكل ملحوظ في جميع الأصناف التي تم اختبارها. حيث كان صنف سخا ١٠٢ هو الأكثر حساسية للجفاف (بانخفاض ٧٠،٩%)، في حين كان صنف سخا ١٠٨ هو الأكثر تحملاً (بانخفاض ٢٦،٩%). الوزن الرطب للجذر انخفض بشكل كبير في صنف سخا ١٠٢ (٩٧،٢ %) وسخا سوبر ٣٠٠ (>٩٠%)، بينما حافظ صنف جيزة ١٧٨ على كتلة حيوية أعلى للجذر تحت ظروف الإجهاد. الوزن الرطب للساق انخفض أيضًا بشكل ملحوظ، حيث أظهرت الأصناف سخا ١٠٨ وجيزة ١٧٩ أكبر حساسية (>٨٩%)، بينما أظهرت الأصناف سخا ١٠١ وسخا ١٠٣ نمو أفضل في ظل تواجد ظروف الإجهاد المعتدل. اما بالنسبة للوزن الجاف للجذر كان الانخفاض في الوزن الجاف للجذر أكثر وضوحاً في أصناف سخا ١٠٢ وجيزة ١٧٧ وجيزة ١٨٢ (>٩٠%)، في حين حافظت أصناف سخا ١٠٣ وسخا ١٠٤ على قيم أعلى لأوزان الجذور الجافة. وبالمثل الوزن الجاف للساق انخفض في جميع الأصناف، حيث كانت الأصناف سخا سوبر ٣٠٠ وسخا ١٠٢ الأكثر تأثراً، بينما حافظت أصناف جيزة ١٧٨ وسخا ١٠٨ على كتلة حيوية أعلى نسبياً واللذان يعتبران من الأصناف المتحملة للجفاف، مما يُبرز إمكاناتهما كمرشحين واعدين لبرامج التربية في ظل ظروف ندرة المياه.

الكلمات المفتاحية: الأرز، تحمل الجفاف، أصناف الأرز المصرية، مقاييس النمو.