Egyptian Sugar Journal (2024), 23: 33 - 44
https://doi.org/10.21608/esugj.2025.344503.1074

RESEARCH ARTICLE

Heritability, genetic variability and performance of some sweet sorghum varieties for physiological, quality and yield parameters influenced by soil salinity

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Received: 14 December 2024\ Revised: 04 January 2025\ Accepted: 12 January 2025\ Published online: 15 January 2025

Abstract

Two field experiments were carried out at El-Sabahia Research Station (latitude 31° 12´N and longitude 29° 58´E), Alexandria Governorate, Egypt, in the two summer successive seasons of 2021 and 2022 for studying the responses of five sweet sorghum varieties (*Sorghum bicolor (L.) Mohlenbr.*) to soil salinity.

A split-plot design in a randomized complete block arrangement was used with three replications. Two types of soil (normal (3.48 dSm^{-1}) and saline soil (6.43 dSm^{-1}) were considered as main plots, while five sweet sorghum varieties, namely, GK Gaba, Brands, MN4508, SS301-1, and GK Ahron, were randomly planted in subplots.

The findings showed that there were notable variations between the varieties of sweet sorghum for every trait examined during the two seasons.

The GK Ahron variety recorded the highest significance for most studied traits such as proline content, stimulated stalk yield, and juice extraction % under saline soil.

Broad-sense heritability and genetic advancement expressed as a percentage of the grand mean were used to estimate the extent of genetic variability.

There were three promise varieties, Brands, GK Gaba, and GK Ahron, that surpassed the other varieties regarding juice extraction% and juice yield, indicating their magnitude as breeding materials that may be successfully used in breeding programs of sweet sorghum.

In the same context, high values of heritability accompanied by genetic advance percentage were observed in terms of juice extraction %, leaf area index, stalk yield (ton/fed), and juice yield (ton/fed), indicating that these traits were well heritable and can be improved through breeding programs.

Keywords: Sweet sorghum; Saline soil; Genetics parameters; Physiological traits

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Introduction

Due to the spread of saline soils in newly reclaimed areas in northern, southern, and western Egypt, it is necessary to search for tolerant varieties to soil salinity in different crops to overcome this problem.

In this goal, sweet sorghum is like grain sorghum in grain production and almost similar to sugarcane for sugar-rich stalks and high sugar accumulation (Gameh et al. 2020; Rao et al. 2004).

Moreover, salinity is one of the main abiotic stresses in agriculture worldwide, limiting the productivity of crops (Mubushar et al. 2024; Alharbi et al. 2023; Munns and Tester, 2008).

Limiting crop productivity in agriculture worldwide due to salinity stress, about 7% of the world's total land area is affected by salt, as is a similar percentage of its arable land (Ghassemi et al. 1995).

On the other hand, the adverse physiological effects may be attributed to the unavailability of water, reduction in photosynthesis through loss of turgidity, impeded nutrient uptake causing deficiency, and ion toxicity to plants (Niu et al. 2012; Netondo et al. 2004).

Sweet sorghum is characterized by high sugar content, mainly sucrose, fructose, and glucose, in the juice of the stalks, from which ethanol can be easily produced (Rajabi et al. 2024; Mastrorilli et al. 1999).

Additionally, sweet sorghum biomass is used for fiber, paper, syrup, and animal feed (Steduto et al. 1997). It grows in marginal areas because of its high tolerance to saline and drought conditions (Berenguer and Faci, 2001).

In addition, sorghum bicolor is an energy plant with a high biomass yield and wild varieties of ecological purposes. It has good adaptability to salt stress and belongs to C4 plants with a high photosynthetic rate, which is considered one of the most potential energy plants (Abu-Ellail et al. 2023a; Vasilakoglou et al. 2011).

The significant variances among sorghum varieties were considerable in growth characters and yield and its components, which were reported by many investigators: El-Gazzar (2003), Ahmed (2007), and Hassanein et al. (2010), who illustrated that four sorghum cultivars significantly differed in growth characters (plant height, plant diameter, leaf area index , relative growth rate, as well as yield and its components.

Consequently, Vasilakoglou et al. (2011) reported that sorghum plants grown in a soil salinity of 3.2 dS m^{-1} produced 42-48% greater dry biomass, juice, and total sugar yields than the yields of sorghum plants grown in a soil salinity of 6.9 dS m^{-1}.

Moreover, Ali et al. (2022) demonstrated that salinity stress had detrimental effects on plant height (cm), elongation percentage, leaf area, and chlorophyll A and B, which were gradually reduced with increased salinity. A crucial step in defining which traits are amenable to improvement through visual selection is the estimation of heritability and genetic advancement (Umakanthm et al. 2019; Zou et al. 2011).

According to Abu-Ellail et al. (2023b), if genetic advancement were not taken into account, heritability estimates would not be practically useful.

Fundamental to any targeted genetic intervention is the existence of genetic variability among the targeted varieties.

Enhancement of the breeding regimen because the plant breeder can identify diverse parents for successful hybridization with the help of knowledge about the type and level of genetic variability (Naoura et al. 2020; Mulima et al. 2018).

This study aimed to evaluate the performance of different sweet sorghum varieties under saline conditions, assess genetic variability and heritability for key traits, and identify promising varieties for breeding salt-tolerant cultivars.

Materials and Methods

Two field experiments were carried out at El-Sabahia Research Station (latitude 31º12´N and longitude 29º58´E), Alexandria Governorate, Egypt.

In the two summer successive seasons of 2021 and 2022 for studying the responses of some varieties of sweet sorghum (*Sorghum bicolor var. saccharatum (L.) Mohlenbr.)* under saline soil.

A split-plot design in a randomized complete block arrangement was used with three replications. Two levels of soil salinity (normal (3.48 dSm^{-1}) and saline soil (6.43 dSm^{-1}) were considered as main plots, while five sweet sorghum varieties, namely, GK Gaba, Brands, MN4508, SS301-1, and GK Ahron, were randomly planted in subplots.

The preceding winter crop was clover (*Trifolium alexandrinum L.*) in both seasons. Sweet sorghum varieties were sown on the 24th and 18th of May in the 1st and 2nd seasons, respectively.

Phosphorus fertilizer was added as calcium super phosphate (15% P_2O_5) at the rate of 30 kg P_20_5/fed, during seedbed preparation.

On the 21st day after sowing, plants were thinned to secure one plant per hill. Nitrogen was added in ammonium sulfate (20%) at a rate of 90 kg N/fed, which was added in two equal doses, the 1st after thinning and the 2nd after about one month, while potassium was added as potassium sulfate (48%) at the rate of 48 kg K_2O/fed, which was added after about 60 days after sowing.

Other cultural practices, such as hoeing, irrigation (surface), etc., were maintained at levels to assure optimum production.

Some physical and chemical characteristics of the experimental soil were determined according to the method of Black (1965) as shown in Table (1), monthly weather data at Alexandria as an average for the two growing seasons of study are presented in Figure 1.

Table 1. Mechanical analysis, physical and chemical properties of the experimental soil site

Saline Soil Site Physical properties particle size			pH	EC (ds/m)	Soil chemical properties										
Clay %	Silt %	Sand %			Soluble cations (meq/l)				Soluble anions (meq/l)				Available Nutrient (mg/kg soil)		
Texture: Clay					K^+	Na^+	Mg^{++}	Ca^{++}	SO_4^{--}	Cl^-	HCO_3^-	CO_3^{--}	N	P	K
							Season (2021)								
40.3	36.5	23.2	7.87	6.64	1.8	88.3	34.4	45.5	5.4	162.1	2.5	-	31.2	0.61	95.8
							Season (2022)								
41.6	38.3	20.1	7.99	6.22	1.5	74.2	31.1	38.2	6.0	136.8	2.2	-	24.3	0.89	98.4
									Season (2021)						
Normal Soil Site															
43.2	34.4	21.4	7.66	3.44	2.6	48.٤	2٦.7	35.6	18.4	87.16	6.3	1.44	22.6	2.68	85.7
								Season (2022)							
43.6	35.2	21.2	7.42	3.52	2.8	44.2	21.1	27.2	19.3	67.52	٧.4	1.08	26.8	3.97	88.6

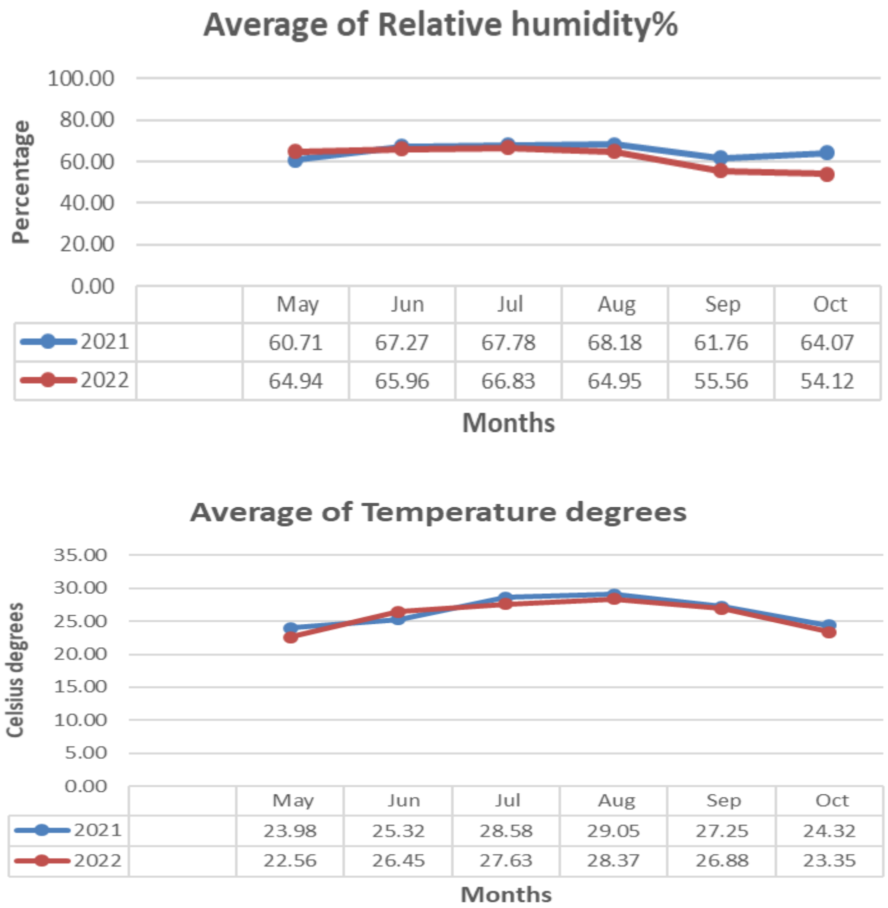

Figure 1. Average of temperature and relative humidity in Alexandria through two seasons (2021/2022).

Data recorded

Morphological characters

Harvest time was carried out for each variety at the dough stage (90 to 120 days from sowing).

The three middle-guarded rows of each plot were used to determine

Days to 50% flowering

Stalk diameter (cm): was measured at mid stalk.

Stalk height (cm): was measured from the land level until visible dewlap.

Stripped-stalks yield (ton/fed), was calculated on a plot basis kg/ plot then converted to ton/fed.

Quality characters

Stalks free from leaves and husks were crushed through a three-roller mill to extraction the juice. Raw juice was filtered, weighed, and the following traits were measured for each variety

TSS% (percent soluble solids) was determined with a hand refract meter.

Sucrose percentage of clarified juice was determined by using automated saccharimeter according to A. O. A. C. (2005).

Juice extraction % (JEP) = (juice weight/stalk weight) x 100.

Juice yield (ton/fed.) (fed = 4200 m^2) = stripped stalk yield × JEP /100

Physiological characters

The physiological growth analyses used in this trial were calculated according to (Watson, 1952, Hall et al. 1993, and Hunt, 1978 (as follows:

Germination ratio: At the age of 10 days from sowing.

Leaf area index = (leaf area / plant) / (soil area / plant), at 65 days after planting.

Crop growth rate (CGR) (g/cm²/day) = (W2-W1) / (T2-T1).

Net assimilation rate (g/m2/day) = (W2-W1) (LogA2-logA1) / (A2-A1) (T2-T1)

Where: W1 and W2, respectively, refer to dry weight at time T1 and T2 in 40 and 65 days, respectively, after planting.

Determination of free proline:

The leaf's proline content was determined after 60 DAP: Proline was determined according to the method of (Bates et al. 1973).

Estimation of Genetic parameters

Estimation of genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were evaluated according to the methods as follows (Chaudhary, 2001)

Genotypic coefficient of variation (GCV) = $\sqrt{\frac{\sigma_g^2}{\bar{x}}} * 100$

Phenotypic coefficient of variation (PCV) = $\sqrt{\frac{\sigma_p^2}{\bar{x}}} * 100$

Where, $\sigma 2g$ is genotypic variance $\sigma 2p$ is phenotypic variance and is general mean.

Estimation of broad-sense heritability ($h2$) was calculated following the formula described by (Allard, 1999 and Johnson et al. 1955)

Heritability ($h2b$) = ($\sigma 2g/\sigma 2p$) * 100

Where, $\sigma 2g$ is genotypic variance and $\sigma 2p$ is phenotypic variance

Statistical analysis

All data were subjected to the proper statistical analysis according to the procedures outlined by Gomez and Gomez (1984). Means of treatments were compared at the probability level of 5% using the Least Significant Difference (LSD).

Results and Discussion

Mean performance

Plant growth indicators play a crucial role in assessing the responses of various varieties to both normal and stressful conditions. Salinity is an important non-living element that affects agricultural yield.

The results of the present study clearly show that saline soil adversely affects the growth characteristics, quality components, and yield of the varieties, along with their interactions, during the two study seasons (Tables 2, 3 and Figure 2).

Statistical data indicate a significant and notable reduction in germination percentage (31.1%) and stalk yield (27.3%) under saline soil conditions when compared to the control.

Additionally, there were reductions in stalk diameter (14.35%) and stalk height (11.67%).

The least significant decrease was recorded in the trait of days to 50% flowering, which was 6.67%, as shown in Table 3. Also, there were significant variations in germination and growth characteristics across different sorghum varieties.

The observed decline in germination percentage, in reaction to this stress, can be linked to the diminished osmotic potential of the germination media resulting from salt presence.

This situation impedes water absorption and leads to Na^+ toxicity, which adversely affects enzymatic activities, even in salt-tolerant species (Roy et al. 2018).

Salinity has been shown to decrease relative growth rates while simultaneously increasing the concentration of soluble carbohydrates, particularly in the leaves of salt-sensitive varieties (Lacerda et al. 2005).

The GK-Gaba varieties exhibited superior performance in terms of net assimilation rate (NAR), the number of days to reach 50% flowering, and germination percentage when compared to the other varieties, while the Brands variety excelled in yield, CGR, stalk diameter, and stalk height, as shown in

Table 3, salt stress leads to a reduction in the leaf area of plants, facilitating osmotic adjustment by promoting the accumulation of carbohydrates within the tissues (Kotagiri and Kolluru, 2017). Similarly, the results of the interaction between saline soil and varieties presented in Table 3 showed a significant effect at P ≤ 0.05 on the all-studied parameters during both growing seasons. Varieties (GK Gaba, SS301-1, and GK Ahron), showed better adaptation as compared to others, in the first season. The observed rates of decline in germination percentage for these varieties were 5.33, 19.53, and 35.19, respectively, while their days to 50% flowering were 11.39, 11.11, and 5.63, and their leaf area index were 7.84, 7.04, and 6.96%, respectively when compared to the control. These results are in agreement with those of earlier studies, indicating that all parameters experienced a decline because of salinity stress. Dehnavi et al. (2020) also indicated that the variations observed in the germination characteristics of different sorghum varieties are primarily attributed to genetic factors and the inheritance variability present among the varieties. Furthermore, Kusvuran et al. (2021) noted that salinity serves as a significant environmental factor that restricts crop plants from achieving their full genetic potential; consequently, salt stress in plants leads to numerous growth limitations.

Table 2. Mean of germination%, days to 50% flowering, leaf area index, stalk diameter, stalk height (cm) and stalk yield (ton/fed) of five sweet sorghum varieties under saline soil during two seasons (2021 and 2022).

Measurement		*Physiological and yield parameters*											
		Germination%		Days to 50% flowering		Leaf area index		Stalk diameter (cm)		Stalk height (cm)		Stalk yield (ton/fed)	
Year Treatment (T)		2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022
Control		76.95	61.94	67.40	62.00	2.85	2.74	2.09	2.06	201.31	212.20	10.00	9.67
Saline		53	37.87	60.20	56.60	2.66	2.60	1.79	1.86	177.81	177.24	7.27	6.94
LSD at 0.5% (T)		3.36	3.11	2.13	1.98	0.84	0.75	0.23	0.11	3.22	3.42	1.12	0.98
Varieties													
GK Gaba		70.99	60.12	74.50	65.50	2.45	3.37	1.95	1.85	176.81	187.53	10.06	9.92
Brands		64.7	60.79	58.50	53.50	2.58	3.45	2.27	2.25	212.13	197.61	11.03	10.09
MN4508		59.11	61.18	57.50	61.50	2.81	3.65	1.97	1.95	191.46	203.51	6.51	7.25
SS301-1		63.1	67.45	59.50	56.50	2.88	2.90	1.80	1.98	198.69	207.70	9.31	8.81
GK Ahron		66.99	66.62	69.00	59.50	3.05	2.73	1.74	1.77	168.73	177.25	6.30	5.46
LSD at 0.5% (V)		2.11	2.41	3.26	4.14	0.61	0.51	0.25	0.19	5.06	3.10	1.43	1.35
Treatment vs. Varieties													
Control	GK Gaba	72.93	82.62	79.00	67.00	2.55	3.47	2.14	1.90	182.33	198.61	11.52	11.38
Saline		69.04	37.62	70.00	64.00	2.35	3.26	1.76	1.80	171.28	176.45	8.59	8.45
Control	Brands	83.93	72.62	64.00	57.00	2.64	3.55	2.50	2.33	225.30	230.61	12.49	11.55
Saline		45.47	48.95	53.00	50.00	2.51	3.35	2.03	2.16	198.95	164.61	9.56	8.62
Control	MN4508	76.38	65.62	60.00	66.00	2.90	3.73	2.10	2.00	201.61	214.61	7.97	8.71
Saline		41.83	56.74	55.00	57.00	2.71	3.57	1.83	1.90	181.31	192.41	5.04	5.78
Control	SS301-1	69.93	88.84	63.00	59.00	2.98	2.96	1.90	2.20	217.72	229.11	10.77	10.27
Saline		56.27	46.06	56.00	54.00	2.77	2.84	1.70	1.76	179.66	186.28	7.84	7.34
Control	GK Ahron	81.6	78.62	71.00	61.00	3.16	2.79	1.83	1.86	179.61	188.05	7.26	6.42
Saline		52.38	54.62	67.00	58.00	2.94	2.67	1.65	1.67	157.85	166.44	5.33	4.49
LSD V×S		5.09	5.14	4.42	5.33	1.02	1.06	0.46	0.36	6.12	7.05	2.31	1.96

Based on the statistical data presented in Figure 2, Brands exhibited the highest significant mean value for the CGR parameter, measuring 27.55 mg/day, when compared to all other varieties analyzed. Furthermore, in the 2021 season, both varieties (GK Gaba and MN4508) demonstrated the highest significant mean values for the NAR parameter among the varieties investigated. Conversely, in 2022, SS301-1 achieved the highest mean values for both CGR at 30.16 mg/day and NAR at 5.29 g m^{-2} day^{-1} when compared to the other varieties.

The interaction between varieties and saline soil exhibited that there were no significant differences observed among all examined varieties regarding NAR parameters in saline soil when compared to their respective controls during the second season. Furthermore, SS301-1 showed no significant difference in the CGR parameter when compared to all studied varieties in control soil in 2022. The findings align with those of Saberi and Aishah (2013) who indicated that sorghum varieties grown under conditions of soil salinity exhibited reduced dry matter, leaf area index (LAI), net assimilation rate (NAR), and ultimately a decline in dry matter yield. Mubushar et al. (2024) found that salinity stress led to a significant decline in all measured traits and growth indices, while simultaneously increasing the relative growth rate, net assimilation rate and specific leaf weight in four varieties and 36 recombinant inbred lines.

Additionally, principal component analysis identified three main groups of traits and plant growth indicators, highlighting the close association of RGR, NAR, and specific leaf area with grain yield and harvest index. Conversely, leaf area duration demonstrated a strong correlation with green leaf area, plant dry weight and leaf area index.

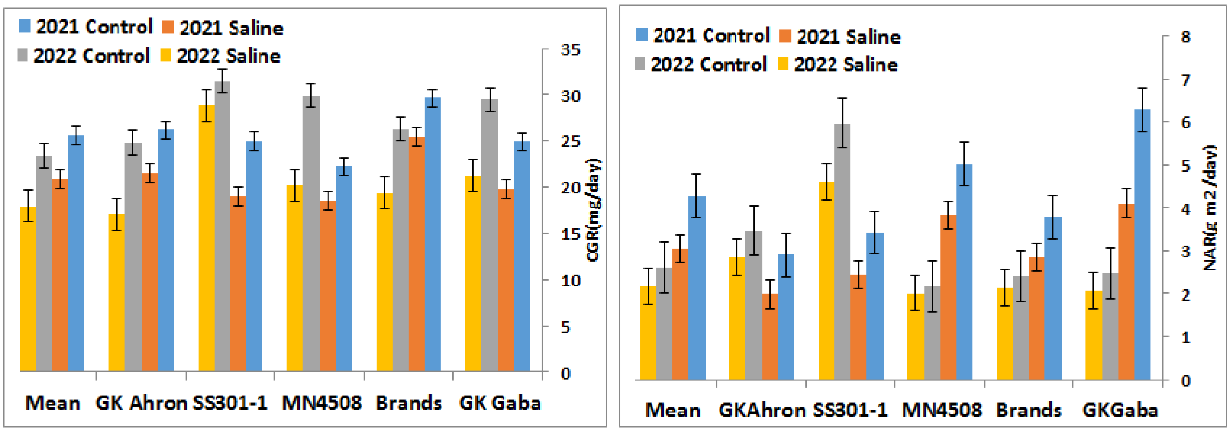

Figure 2. Mean of growth rate parameters crop growth rate, net assimilation rate of five sweet sorghum varieties under saline soil during two seasons (2021 and 2022).

Proline serves an essential function as an osmoprotectant in plants. During both study periods, proline levels consistently increased, indicating a significant main effect of saline soil, as shown in Table 3. The variety SS301-1 exhibited the highest proline concentration at 5.4 µM g^{-1} FW, which was statistically similar to that of varieties, MN4508 and GK Gaba in the 2021 season. No significant differences were observed among the varieties in saline soil during the second study season.

The mean performance results of the interaction between the sorghum varieties and treatments under study are presented in Table 2. All varieties exhibited no significant differences in saline soil, with the exception of the GK Ahron variety.

The SS301-1 variety recorded the highest cumulative rate at 37.98%, followed by variety MN4508 at 36.97%, GK Gaba at 33.49%, Brands at 24.25, and GK Ahron at 10.44% during the 2021 season.

The variety MN4508 exhibited the highest cumulative rate of 47.54%, followed closely by variety SS301-1 at 46.77%, GK Ahron at 46.55%, and Brands at 38.98%. In contrast, variety GK Gaba recorded the lowest cumulative rate of 27.27% for the 2022 season.

Proline accumulation in response to salt stress has been identified by Sabir et al. (2011) as a mechanism that can lower water potential and assist in preserving water content within leaves. Under conditions of salt stress, numerous plant species exhibit a notable increase in proline levels, as indicated by El Omari and Nhiri (2015).

De Freitas et al. (2019) further noted that proline buildup is a common reaction to saline conditions. Moreover, the introduction of proline was found to mitigate membrane degradation without leading to an increase in relative water content.

Plants subjected to salt stress and treated with proline exhibited heightened levels of proline, a response that was regulated by specific modulation of proline synthesis.

In general, salinity had a considerable adverse effect on all chemical parameters during the study period in both seasons. Table (3) illustrates the effectiveness of saline soil in reducing the quality characteristics of sorghum juice, which varied significantly between the seasons.

In the 2022 season, all varieties exhibited lower average values for Brix value, sucrose, juice extraction, and juice yield compared to the sorghum crop of the previous year.

The Brands variety achieved the highest average values for all quality parameters, showing a significant similarity with variety SS301-1, followed by variety MN4508 in both seasons. In contrast, variety GK Gaba and GK Ahron consistently recorded the lowest quality parameters throughout the two seasons examined (Table 3).

The sucrose content in various plant parts serves as a marker for salt tolerance (Juan et al. 2005). It has been observed that significant water or salt stress in sorghum correlates with elevated sugar levels in embryos, which may play a role in osmoregulation during stressful conditions (Gill et al. 2003).

Similarly, the interaction between varieties and soil conditions resulted in a decline in all quality parameters when exposed to saline soil.

The Brands variety demonstrated markedly superior mean values across all quality parameters compared to its control.

This includes a TSS% level of 18.11%, a sucrose content of 9.15%, a juice extraction% of 33.54%, and a juice yield of 5.79 tons / fed under saline conditions, which showed reduction rates in comparison to the control soil at 11.18%, 11.93%, 8.48%, and 27.35% respectively, during the 2021 season.

Conversely, the GK Ahron variety showed both significant and minimal mean values compared to its control for all quality parameters in saline soil throughout both seasons.

The observed variations among cultivars in plant traits can be attributed to genetic differences among the cultivars and their respective responses to environmental conditions.

Research has shown that, sorghum plant under salt stress experiences a decline in physiological and yield parameters, including a decrease in germination rates.

This decline results in reduced plant densities and lower overall yields. Additionally, the total soluble sugar content in sorghum sap increases with elevated salinity levels, as noted by Hassouni and Nasser (2021). All sorghum varieties exposed to salty settings showed declines in a number of important indices, according to Rajabi et al. (2024).

These declines influenced both biochemical and growth indicators, ultimately resulting in a reduction in total yield.

The researchers also indicated that the intricate interaction between salinity levels and the responses of different varieties highlights the complex genetic adaptations that enable each variety to address challenges effectively.

The distinctions among varieties are distinctly demonstrated through their individual physiological and biochemical responses to salt stress, providing important insights into the mechanisms that regulate salt tolerance in sorghum.

Finally, salinity had a significant adverse effect on all physiological, yield, and chemical parameters during the study period in both seasons.

There were two promise varieties, Brands and SS301-1, which surpassed the other varieties, demonstrating markedly higher mean values across all quality parameters compared to their control and among physiological parameters, indicating their magnitude as breeding materials that may be successfully used in breeding programs of sweet sorghum under saline soil.

While the GK Ahron variety recorded the lowest mean values among all parameters compared to its control

Table 3. Mean of chemical parameters Brix soluble content %, sucrose%, juice extraction%, juice yield (ton/fed) and proline contents of five sweet sorghum varieties under saline soil during two seasons (2021 and 2022).

Measurement		*Chemical and proline parameters* TSS%		Sucrose%		Juice extraction%		Juice yield (ton/fed)		Proline (µM g-1 FW)	
Year		2021	2022	2021	2022	2021	2022	2021	2022	2021	2022
Treatment (T)											
Control		18.43	18.64	9.11	10.35	29.82	27.88	6.74	6.42	3.63	2.66
Saline		16.84	17.64	8.05	8.16	26.71	24.97	4.94	5.41	5.26	4.52
LSD at 0.5% (T)		0.11	0.08	0.19	0.18	1.15	1.43	0.16	0.24	1.07	1.35
Varieties											
GK Gaba		16.54	18.33	8.16	8.84	29.56	25.01	5.26	4.81	5.05	3.80
Brands		19.25	19.91	9.77	10.39	35.10	30.96	6.88	7.58	4.10	4.75
MN4508		18.00	16.04	8.84	9.81	25.53	27.04	5.40	6.32	4.70	4.65
SS301-1		18.54	17.93	9.59	10.10	28.95	25.62	6.55	6.03	5.40	4.75
GK Ahron		15.85	18.49	6.56	7.16	22.21	23.54	5.14	4.85	3.00	4.45
LSD at 0.5% (V)		0.14	0.16	0.43	0.35	1.75	1.14	0.39	0.56	1.06	1.75
Treatment vs. Varieties											
Control	GK Gaba	17.05	18.72	8.64	10.39	31.11	26.56	6.35	5.39	4.03	3.20
Saline		16.03	17.94	7.67	7.28	28.00	23.45	4.17	4.39	6.06	4.40
Control	Brands	20.39	20.84	10.39	11.72	36.65	32.51	7.97	8.17	3.53	3.60
Saline		18.11	18.98	9.15	9.64	33.54	29.40	5.79	6.98	4.66	5.90
Control	MN4508	18.61	18.05	9.39	11.05	27.08	28.09	5.87	6.86	3.63	3.20
Saline		17.39	17.80	8.28	8.57	23.97	25.98	4.92	5.77	5.76	6.10
Control	SS301-1	19.70	19.39	10.06	10.55	30.50	27.17	7.76	6.45	4.13	3.30
Saline		17.38	17.59	9.11	9.06	27.39	24.06	5.33	5.60	6.66	6.20
Control	GK Ahron	16.39	16.18	7.06	8.06	23.76	25.09	5.76	5.24	2.83	3.10
Saline		15.30	15.90	6.05	6.26	20.65	21.98	4.51	4.30	3.16	5.80
LSD V×S		0.76	0.64	1.12	1.03	2.45	2.71	0.68	0.71	2.28	2.97

Genetic variability and heritability

Data in Fig. 3 revealed that genetic variability varied between sweet sorghum varieties for germination%, days to 50% flowering, stalk diameter, stalk height, stalk yield, TSS%, sucrose%, juice extraction%, juice yield, and proline contents. The differences between phenotypic coefficient of variation (PCV%) and genotypic coefficient of variation (GCV%) were small for most studied traits.

The small differences between GCV% and PCV% indicated the possibility of genetic improvement in these traits. High to low estimates of (GCV %) were obtained, i.e., 6.73, 12.23 and 13.14% for days to 50% flowering, TSS% and sucrose%, respectively. Abu-Ellail et al. (2023a), who found that genotypic, Coefficient of variation (GCV) decreased from plant cane crop to second ratoon crop for cane yield while they increased slightly for number of stalks Per feddan.

Broad-sense heritability estimates were highest recorded (93.84, 91.64, 91.13, and 90.12%) for traits juice extraction%, leaf area index, stalk yield (ton/fed), and juice yield (ton/fed), respectively. While, lowest recorded (71.22, 83.12, and 87.63%) for traits days to 50% flowering, germination%, and TSS%, respectively.

The highest expected genetic gain was recorded in proline contents and stalk yield (ton/fed) (66.81 and 49.89 %), while, days to 50% flowering and germination % was (12.69 and 13.64 %) which was low genetic gain than that of stalk yield. Similar results were reported by Yücel et al. (2022) and Maruthamuthu et al. (2022), who found that the heritability and the excepted genetic advance obtained by stem yield followed by juice yield indicate the importance of these traits for sweet sorghum selection.

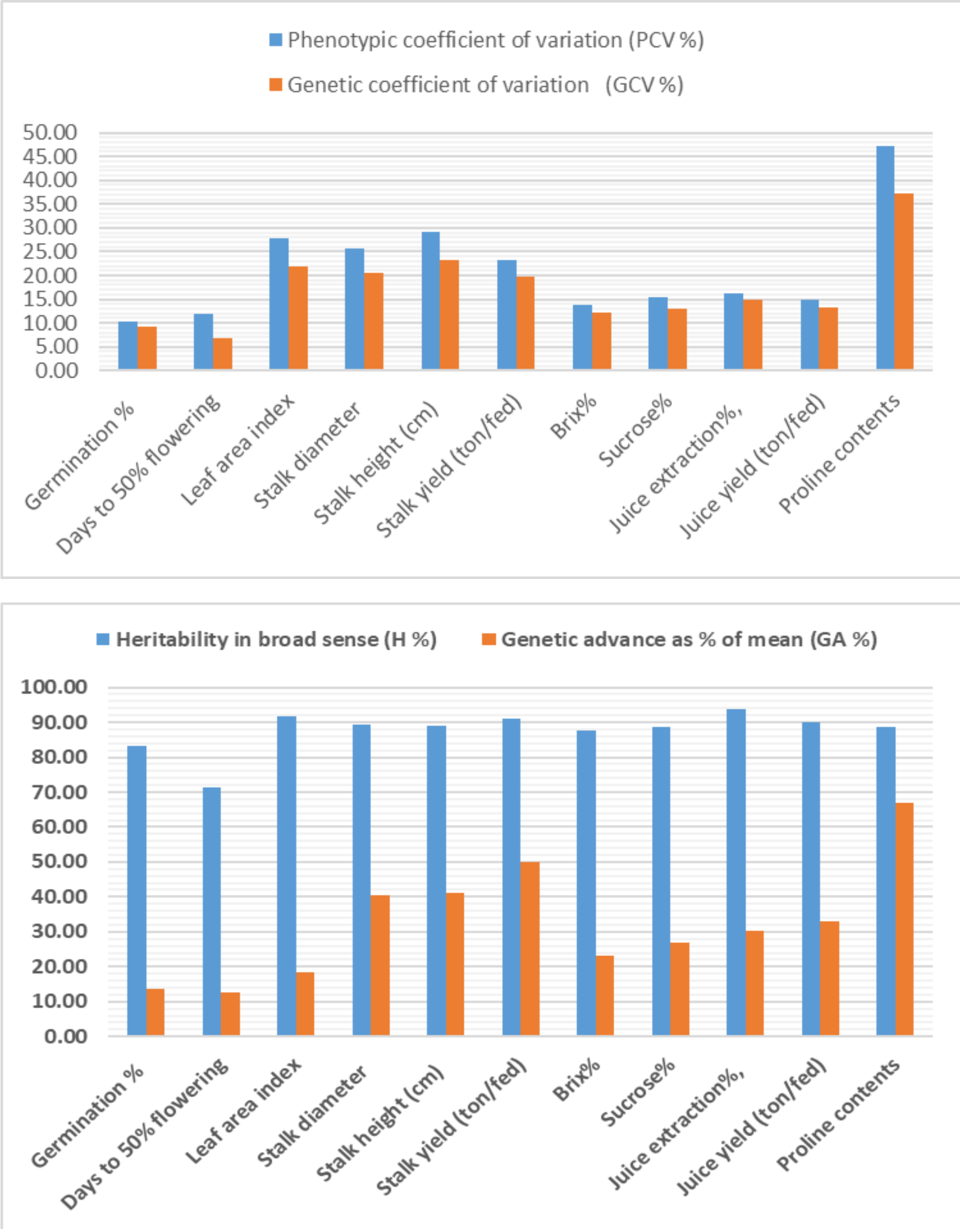

Figure 3. Genetic variability for studied traits during combined two seasons (2021-2022).

Phenotypic correlation

The correlation coefficients between all pairs of the studied characters across seasons are presented in Table 4. Juice yield showed positive and highly significant correlations with each of stalk diameter, stalk height, stem yield, TSS%, sucrose% and juice extraction %. A strong positive correlation was recorded between proline contents and germinations, TSS%, sucrose %, and juice yield.

These results are in agreement with those found by Abu-Ellail et al. (2023b), who showed significant positive genotypic correlations between juice yield and each stem yield, TSS% and sucrose%. Our results are in agreement with those mentioned by Tesfamichael et al. (2015) and Al-Aaref et al. (2016), who found that the juice yield, considered as the most important character of sweet sorghum, was positively and significantly correlated with juice extraction, and stem yield.

Table 4. Correlation coefficients among the studied traits of five sweet sorghum during combined seasons.

Traits	G	DF	SD	SH	SY	TSS	S	JE	JY
G	1.000								
DF	0.631	1.000							
SD	0.257*	0.248	1.000						
SH	0.845**	0.661	0.513**	1.000					
SY	0.245**	0.230	0.364*	0.514**	1.000				
TSS	0.331	0.378	0.129	0.218	0.289*	1.000			
S	0.165	0.199	0.461*	0.467	0.124*	0.334*	1.000		
JE	0.743	0.691	0.413 *	0.361	0.769**	0.414*	0.612**	1.000	
JY	0.610	0.334	0.392*	0.411*	0.678**	0.708**	0.316**	0.285*	1.000
PC	0.536**	0.262	0.443	0.265	0.181*	0.612**	0.241*	0.217*	0.307*
Abbreviations	Germination % (G), Days to 50% flowering (DF) , Stalk diameter(SD) , Stalk height(SH) , Stalk yield (SY) , TSS% , Sucrose% (S) , Juice extraction%(JE), Juice yield (JY), Proline contents (PC).								

, Significant at 5% and 1% probability levels respectively*

Conclusions

According to the study's findings, three promising varieties—Brands, GK Gaba, and GK Ahron—seem to be more tolerant of saline soil and showed stable values for the most heritable traits with a high genetic advance percentage. This suggests that these varieties could be important breeding materials for sweet sorghum breeding programs.

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