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GERMINATION PARAMETERS AND GRAIN MORPHOLOGY OF SOME SORGHUM GENOTYPES

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Abstract

Sorghum (Sorghum bicolor (L.) Moench) stands as the world's fifth major crop, following wheat, rice, maize, and barley. The current study conducted to study the germination and seedling parameters of some sorghum genotypes as well as the morphological grain. The studied genotypes were differed significantly in the studied morphological, germination and seedling parameters. The genotype number 4 (PI574598) characterized by the heights values of morphological grain parameters ie, L, W, A, P and GW, which were 4.3mm, 4.05 mm, 13.69 mm^2, 13.92 mm and 34 mg. the highest GP (100%) recorded in the genotypes Giza-15 and Giza-113. Furthermore, they recorded highly MDG (16.67 & 16.87 %) as well as the speed of germination (4.17 & 3.98 seed/day) comparing with the others. Regarding the seedling parameters, Giza-15 was more superior in all parameters as TSL, TDW and SVW, which were 54cm, 0.36 g and 5400 mg, respectively. The most highly heritabilities in broad sense (H) were found in A, FFD, GP, MTG, SL, and RFW. Which were 85, 81, 80.82, 76.96, 88.59 and 83.39, respectively. These results indicating the studied parameters very important in sorghum breeding program.

Keywords: germination; seedling; grain morphology; sorghum genotypes.

INTRODUCTION

Sorghum (*Sorghum bicolor* L.) Moench stands as the world's fifth major crop, following wheat, rice, maize, and barley [1]. Its significance is particularly evident in regions such as Asia, Africa, and various semi-arid zones [2, 3]. The versatility of sorghum is notable, finding its place in diverse applications. Typically, whole grain sorghum can be boiled akin to rice, roasted or popped like corn, and its derived flour is employed in creating dishes like porridge, pancakes, bread, dumplings, as well as brewed beverages. In Africa, for instance, sorghum grains are milled and fermented to craft beer. In Indian culinary traditions, sorghum flour serves as a primary ingredient for bread-making. Meanwhile, Korean recipes integrate sorghum with rice, and its flour finds use in cakes. In Egypt, sorghum is used as feed in form of forage, while the grains can be processed for poultry feeding. Sorghum is concentrated in the middle and upper parts of Egypt. During the time period 2000-2019, the mean of sorghum production is 821.92 thousand ton and the mean of sorghum area is 151.30 thousand hectares. In 2019, the highest production was recorded [4-7]. Different applications necessitate distinct sorghum varieties. The culinary realm often employs white grain sorghum, whereas the red and brown grain varieties, enriched with bioactive components like tannins, are favored for brewing beer [8]. Recognized for their potential health perks, these bioactive substances are increasingly utilized in processed foods for their functional properties [9]. One of the factors determining crop productivity is the optimal plant density per unit area, which depends on the rate, speed, and regularity of the germination process [10]. The important requirements for seed germination beside seed quality are sufficient moisture, ventilation and optimal temperature. The current investigation aimed to determine the germination and seedling parameters of some sorghum genotypes as well as the morphological grain.

MATERIALS AND METHODS

Plant materials

Plant materials (Table 1) comprised the kernels of sixteen sorghum ecotypes. These ecotypes are four accessions (PI574555, PI574560, PI574580 and PI574598) were introduced from the U.S. National plant germplasm system (NPGS), In addition, twelve Egyptian grain sorghum genotypes. These plant materials were grown in summer season of 2023 at the research farm of Faculty of Agriculture, Sohag University, Egypt in randomized complete block design (RCBD) with three replicates included in the sorghum-breeding program.

Table (1) Construction and Pedigree of the studied wheat Genotypes.

No	Genotype	Pedigree/origin
1	PI574555	USA
2	PI574560	USA
3	PI574580	USA
4	PI574598	USA
5	Giza-15	Egypt
6	Giza-113	Egypt
7	Giza-114	Egypt
8	H-	Egypt
9	H-	Egypt
10	H-	Egypt
11	Dorado	Egypt
12	Hours	Egypt
13	Amous	Egypt
14	Ramsees	Egypt
15	Atoon	Egypt
16	Toot	Egypt

Grain morphology parameters:

At harvesting and threshing, the panicles of the studied genotypes in summer season of 2023. Sorghum kernels were stored at room temperature for one months in a closed container to stabilize their moisture content (11%). The morphometric characters were performed on 50 kernels/entry in each replicate chosen randomly using digital image analysis (DIA) technique via mobile device running Android OS at maximal camera resolution, the smartphones Samsung

Galaxy A30s, with Seed Counter application for grain phenotyping. Morphometric parameters of grains were estimated in several steps as described by Komyshev et al [11]. Images were getting in a color image of grains placed arbitrarily on a white paper sheet A4 without any contact between grains to reduce the error at image capture. The paper sheet was placed on a dark background and the paper size was fixed to calculate the image scale and evaluate the grain sizes in metric units. The Seed Counter application receives images directly from the camera on the mobile device. Data of the counted grains and grain shape parameters in each seed are stored in XML format and exported in "tsv" format. The measured morphometric parameters are length (L), width (W), area (A), convex area (CA), perimeter (P), circularity index (CS), solidity (SO), aspect ratio (AR), in addition to the 1000-kernel weight (TKW). All parameters were measured according to (Table 2).

Table (2). The characteristics of the 1000-kernal weight and morphometric parameters

Parameter	Unit	Equation	Literature
1000-kernel weight (TKW)	Gm		
Length (L)	Mm		
Width (W)	Mm		
Area (A)	mm^2		[12]
Circularity index (Cs)		$4\pi*A/P^2$	[13]
Aspect Ratio		L/W	[16]
Perimeter (P)	M		[12]
Form factor density (FFD)	mg/mm^2	GW/L*W	[13]

Germination Parameters

Seeds surface of sorghum genotypes were sterilized by soaking in 1% sodium hypochlorite for 2 minutes, followed by three successive washings with distilled water. Fifteen seeds each sorghum genotypes were planted in folia dishes (17 x 13 x 2.5 cm), after filled with 350 gm sterilized sandy soil each. The seeds distributed in 3 rows with 5 seeds each (2.5 cm spaced between seeds). A Randomized complete block design (RCBD) in three replications used. The used blocks were Perpendicular to the direction of natural lighting. The dishes were irrigated with 75 ml of the solution two times at sowing and with 25 ml of the solution after 48 hours. After that 25 ml of distilled water applied per dish every 48 hours for all dishes until the end of experiment. The germinated seeds counted daily started at 3rd day and the final count has been don at 14th day after planting to calculate germination as the following.

1. **Germination percentage** (GP) = (n/N) × 100
   Where *n* is the number of germinated seed and *N* is the number of Sown seeds in each experimental unit.
2. **Germination Initial Time** (GIT): The number of days at first germinated seed.
3. **Maximum germination time** (MGT): Number of days until the highest count of germinated seeds.
4. **Germination Duration time** (GDT): The interval from GIT to MGT.
5. **Mean daily Germination** (MDG) = GP/MGT.
6. **Mean Germination time** (MGT): the count days until reached to 50% of germinated seeds. MGT = $(\sum n_i \times d_i)/\sum n_i$, Where n is the number of grains that germinated on the day (i); d_i is the number of days counted from the beginning of germination.
7. **Speed of Germination rate (SP):** The average of seed numbers germinated in one day. SP = $\sum(n_i/d_i)$
8. **Germination Coefficient** (GC) = **(**N/($\sum n_i \times d_i$)) × 100
9. **Germination value (GV)**: This combines both SP and GP. GV= PV × MDG, where PV is the Peak value, (PV = highest seed germinated/ Number of days). Gairola *et al.*, 2011
10. **Germination Vigor Index** (GVI) = N × SDW (mg), where *N* is total germinated seeds and SDW is shoot dry weight of seedling (mg).

Phenotypic and genotypic parameters:

The phenotypic and genotypic parameters were calculated for both the germination and seed morphological traits as follow:

Genotypic variance (V_g) = (MS_g – MS_e)/r

Phenotypic variance (V_P) = V_g + MS_e

Heritability in broad sense (H) = $\frac{V_g}{V_p}$ x 100

Phenotypic coefficient of variation (PCV) = $\frac{\sqrt{V_p}}{\bar{X}} x100$

Genotypic coefficient of variation (PCV) = $\frac{\sqrt{V_g}}{\bar{X}} x100$

Whereas; MS_g and MS_e are the mean squares of the genotypes and experimental error, respectively.

r: the number of replicates, $\bar{X}$ is the arithmetic mean of all studied genotypes

Statistical analysis:

The measured data were subjected to analysis of variance in completely randomized design using SAS software (SAS ver. 9.2, SAS Institute 2008). The least significant differences (LSD) between means for studied parameters analysis were estimated [14]. The parameters means of sorghum genotypes were compared using least significance difference (LSD) test at 0.05 probability level according to Gomez and Gomez 1984 [15].

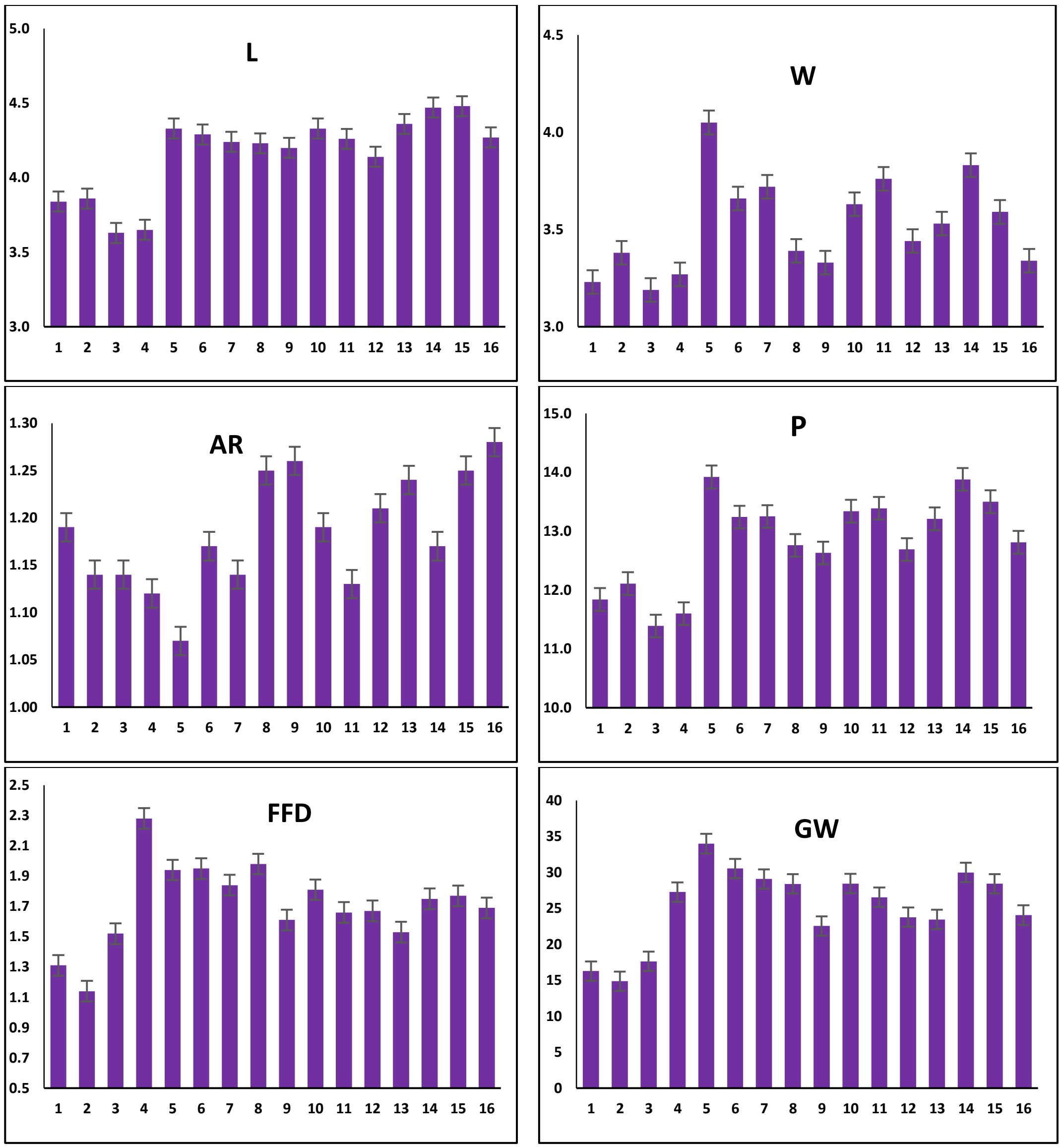
RESULTS AND DISCUSSION

Grain morphology and 1000-kernel weight

Significant differences were found among the studied genotypes in TKW and all grain morphology parameters (Table 3 and figure 1). The lowest values were 3.63 mm, 3.19 mm, 8.99 mm^2, 1.07,11.39, 1.14 mg/mm^2 and 14.86 mg, while the highest values were 4.48 mm, 4.05 mm, 13.69 mm^2, 1.26,13.92, 2.28 mg/mm^2 and 34.0 mg, for Length (L), width (W), area (A), aspect ratio (AR), perimeter (P), form factor density (FFD) and grain weight (GW), respectively. In general, the introduced accessions of grain sorghum (PI574555, PI574560, PI574580 and PI574598) were lower than the Egyptian sorghum ecotypes in all studied grain parameters. On the other hand, the highest values of L exhibited in the ecotype number 15, W, A, P and GW in ecotype number 5. the ecotypes No, 4, 9 and 15 exhibited the highest values of FFD, AR and L, which were 2.26 mg/mm^2, 1.26 and 4.48 mm, respectively. The data in table (4) represents the various components among studied grain sorghum ecotypes. Whereas, the genotypic variances were the highest for seed surface area (A) and grain weight (GW), which were 22.67 and 2.4, respectively. The heritability in broad sense were ranged from 0.59 in aspect ratio (AR) up to 0.85 in seed surface area (A), these results indicate to the studied sorghum genotypes widely diverged.

Table (3) Means of grain parameters of some grain sorghum ecotypes.

Ecotype	L	W	A	AR	P	FFD	GW
1	3.84	3.23	9.55	1.19	11.84	1.31	16.27
2	3.86	3.38	10.05	1.14	12.11	1.14	14.86
3	3.63	3.19	8.99	1.14	11.39	1.52	17.62
4	3.65	3.27	9.22	1.12	11.60	2.28	27.27
5	4.33	4.05	13.69	1.07	13.92	1.94	34.00
6	4.29	3.66	12.18	1.17	13.24	1.95	30.54
7	4.24	3.72	12.23	1.14	13.25	1.84	29.08
8	4.23	3.39	11.15	1.25	12.76	1.98	28.41
9	4.20	3.33	10.82	1.26	12.63	1.61	22.54
10	4.33	3.63	12.16	1.19	13.34	1.81	28.44
11	4.26	3.76	12.45	1.13	13.39	1.66	26.54
12	4.14	3.44	10.99	1.21	12.69S	1.67	23.77
13	4.36	3.53	11.89	1.24	13.21	1.53	23.46
14	4.47	3.83	13.28	1.17	13.88	1.75	30.00
15	4.48	3.59	12.46	1.25	13.50	1.77	28.42
16	4.27	3.34	10.96	1.28	12.81	1.69	24.06
RLSD 5%	**0.10**	**0.08**	**0.00**	**0.03**	**0.27**	**0.06**	**1.23**



(i) (j)

Figure 1: L: grain length; W: grain width; AR: aspect ratio; P: perimeter; FFD: form factor density; GW: grain weight. of sixteen sorghum genotypes

Table (4) Variance components of grain parameters of some grain sorghum ecotypes.

	L	W	A	AR	P	FFD	GW
GV	0.07	0.06	22.67	0.21	0.59	0.27	21.41
PV	0.12	0.08	26.67	0.36	0.90	0.34	29.24
GCV	6.38	6.81	41.84	38.80	5.96	30.48	18.27
PCV	8.17	8.16	45.38	50.34	7.37	33.95	21.35
H	0.61	0.70	0.85	0.59	0.66	0.81	0.73

The data in table (5) represent the association between sorghum grain parameters as well as the grain weight. These finding indicated that, the geometric parameters associated positively or negatively with the grain weight are very beneficial for phytochemical breeding to improve these characteristics.

Table (5) Pearson correlation coefficients of grain parameters of some grain sorghum ecotypes.

	L	W	A	AR	P	FFD	GW
L		<.0001	<.0001	0.0114	<.0001	0.2564	<.0001
W	0.695		<.0001	0.0033	<.0001	0.049	<.0001
A	0.899	0.939		0.589	<.0001	0.0742	<.0001
AR	0.362	-0.416	-0.080		0.8288	0.2732	0.2686
P	0.941	0.893	0.990	0.032		0.1069	<.0001
FFD	0.167	0.286	0.260	-0.161	0.236		<.0001
GW	0.644	0.754	0.771	-0.163	0.747	0.813	

Germination Parameters:

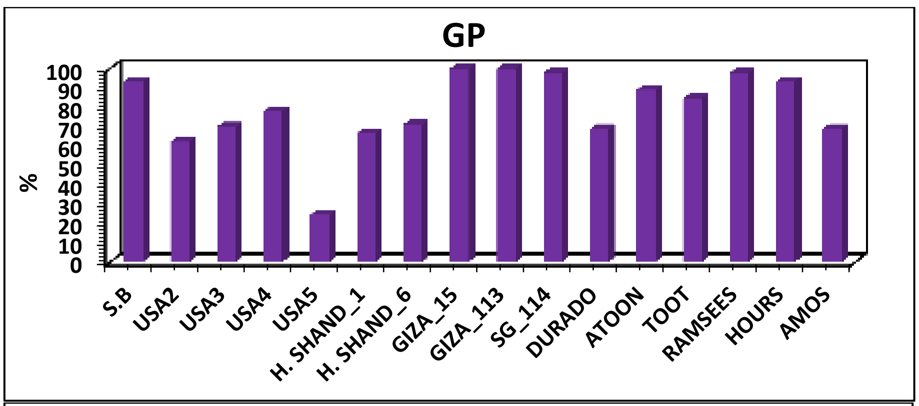
The results in table (6) and figure 2 showed that the significant differences among studied genotypes for all germination parameters. The highest germination percentage detected in Giza-13, Giza-113, which were 100% each, and SG-114 and Ramses, which were 97.8% each. The starting time of germination was 3 days for all studied genotypes, except the USA-5 genotype started to germinate after 4 days. Regarding to the maximum time germination, the genotype USA-5 completed its germinated in short time (4 days) that is due to its lower germination percentage (24%). On the other hand, the full germination was retarded in the genotypes SB, Giza-15, Giza-113, Ramses and Hours, whereas the MTG were 14, 15, 15, 14.67 and 14 days respectively. Therefore the GDT ranged from 3 (USA2 AND USA3) up to 5.33 day for USA5. The studied genotypes were ranged in MDG parameter from 4.07 for USA5 to 16.67 %/day for Giza-15, these indicated that Giza-15 characterized by faster germination than the others. The USA5 differed significantly in MGT comparing the other genotypes which its average time to complete the germination is 5.3 days. Otherwise the faster germination genotypes Giza-15 and Ramses which were 4.17 and 4.03 seed/day as well as their germination coefficients (GC) were the higher than the other (23.11 and 22.58) respectively.

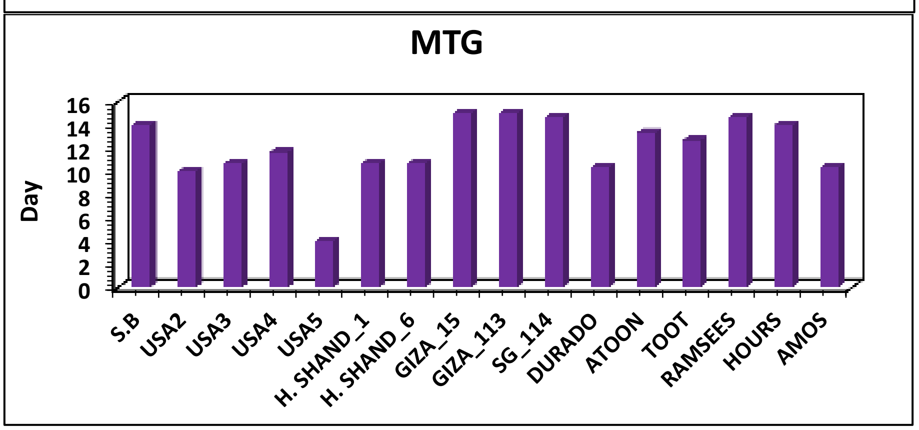
Variance component of germination parameters:

The lower part of table (5) represent the variance component of sorghum genotypes, whereas the phenotypic coefficient of variation (PCV) ranged from 6.3 in the GC to 37.96% in the GDT parameters. These finding of germination parameters considered as valuable tools for classification of sorghum genotypes. On the other hand, the GCV ranged from 6.03 in GDT up 28.36 % in SP. These results due to the genetic makeup of the sorghum genotypes. The high heritability in broad sense were 80.82, 7.33 and 76.96% for GP, SP and MTG, indicated that these parameters are highly affected by the genetic factors and lower affected with the environmental factors. On the other hand the GIT and GDT parameters are lower heritability percentage due to the controlling by environmental factors like temperature, water and nutrients than their controlling with genetic factors.

Table (6) Germination parameters of some sorghum genotypes

	GP	GIT	MTG	GDT	MDG	*MGT*	*SP*	GC
S.B	93.3	3	14.00	4.33	15.56	4.62	3.22	21.65
USA2	62.2	3	10.00	3.00	9.84	4.45	2.04	22.50
USA3	70.0	4	10.67	3.00	11.67	4.67	2.33	21.42
USA4	77.8	3	11.67	5.33	11.76	5.30	2.02	18.92
USA5	24.4	3	4.00	2.00	4.07	4.25	1.01	23.58
H. SHAND_1	66.7	3	10.67	4.33	9.05	4.73	2.20	21.18
H. SHAND_6	71.1	3	10.67	3.67	11.02	4.66	2.69	21.48
GIZA_15	100	3	15.00	3.00	16.67	4.33	4.17	23.11
GIZA_113	100	3	15.00	3.33	15.87	4.49	3.98	22.33
SG_114	97.8	3	14.67	3.00	16.30	4.50	3.67	22.22
DURADO	68.9	3	10.33	3.67	10.56	4.56	2.64	22.02
ATOON	88.9	3	13.33	4.33	10.76	4.63	3.25	21.59
TOOT	84.4	3	12.67	4.33	12.65	4.60	3.19	21.88
RAMSEES	97.8	3	14.67	4.00	14.57	4.44	4.03	22.58
HOURS	93.3	3	14.00	3.33	14.76	4.43	3.71	22.56
AMOS	68.9	3	10.33	3.00	11.48	4.46	2.61	22.44
LSD 5%	**15.486**	**0.7221**	**2.4757**	**2.2518**	**4.5574**	**0.3958**	**0.8762**	**1.8787**
Variance Components								
VG	363.55	0.00	7.36	0.05	8.34	0.04	0.69	0.64
VP	449.80	0.19	9.57	1.87	15.81	0.09	0.96	1.91
PCV	26.81	14.14	25.82	37.96	32.36	6.62	33.58	6.30
GCV	24.11	0.00	22.65	6.03	23.50	4.10	28.36	3.65
H	80.82	0.00	76.96	2.52	52.75	38.43	71.33	33.68





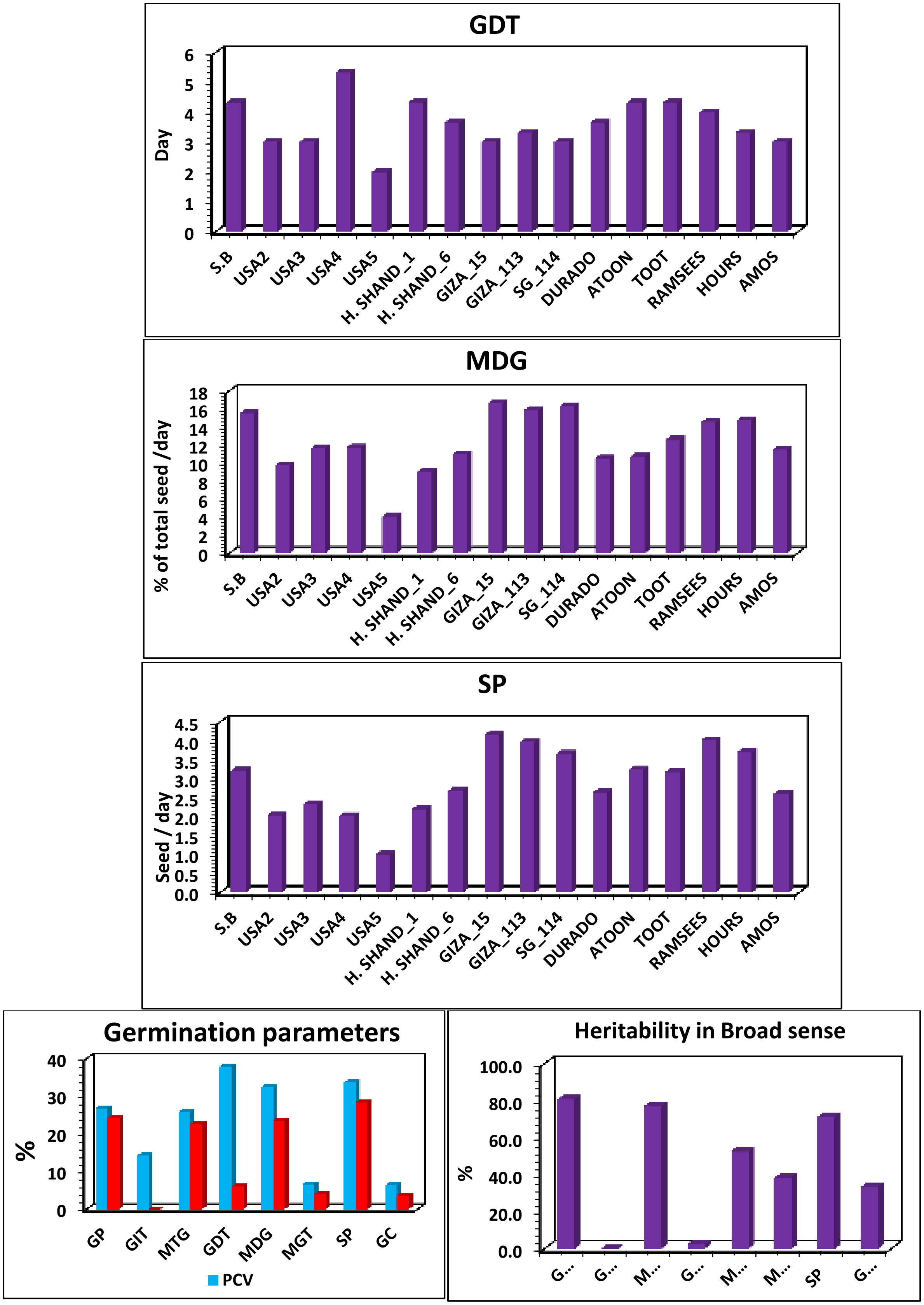


Figure 2: Germination parameters of some sorghum genotypes

Germination Parameters:

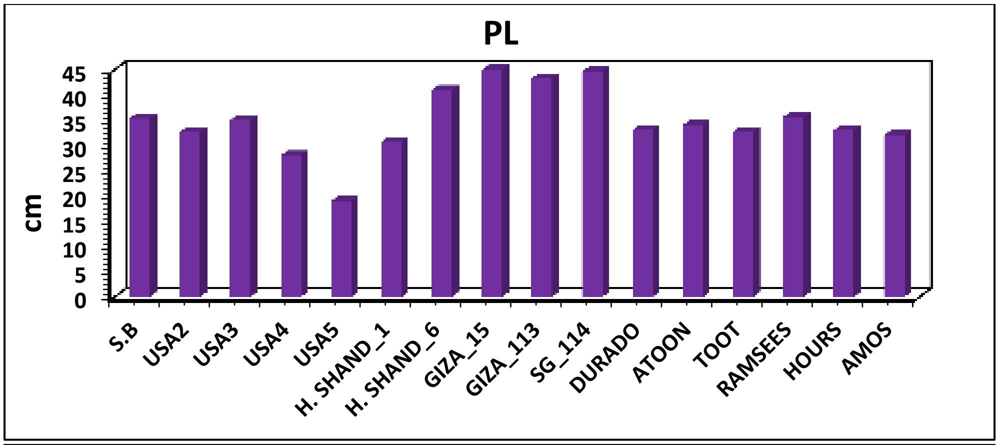
The results in table (7) and figure 3 represented that the significant differences among studied genotypes for all seedling parameters. The total, shoot and root length of seedling were ranged from 19.0, 7.5 and 11.5 cm up to 45, 22 and 23 cm in the genotypes USA-5 and Giza-15, respectively. The highest TFW, SFW and RFW were 4.08, 2.33 and 1.75 gm, respectively were found in the genotype Giza-15. Meanwhile the lowest weight of TFW, SFW and RFW were exhibited in the genotype USA-5, which were 0.26, 0.10 and 0.6 g, respectively. On the other hand the total dry weight (TDW) ranged from 0.15 to 0.36 g for USA-3 and Giza-15, respectively. As well as the seedling vigor index based on the total, dry weight (SVW), the highest seedling vigor value (5400 mg) and the lowest value (562 mg) were recorded in the USA-5 and Giza-15, respectively. These results may be due to the strength of germination processes rather than the seedling surrounding conditions.

Variance component of seedling parameters:

The variance component of sorghum seedling parameters represented in table 7. The phenotypic coefficient of variation (PCV) ranged from 20.91 in the RL to 52.07% in SL. These finding of seedling parameters considered as curcial tools for classification of sorghum genotypes. As well as the GCV ranged from 18.50 in RL up 49.01 % in SL. These results due to the genetic makeup of the sorghum genotypes. The PCV was closed to the GCV , meaning that these seedling parameters are lower affected by the environmental condition and it highly hertabilities. The high heritability in broad sense were 78.29, 88.59 and 83.39% for RL, SL and RFW, indicated that these parameters are highly affected by the genetic factors and lower affected with the environmental factors. Moreover, the other seedling parameters characterized by moderate heritability in broad sense due to the controlling by both environmental and genetic factors and/or the affecting by the interaction between the genetic and environmental factors.

Table (7) the seedling parameters of some sorghum genotypes

	TSL	**RL**	**SL**	**SFW**	**RFW**	**TFW**	**TDW**	**SVW**
S.B	35.33	17.67	17.67	1.09	1.32	2.40	0.19	2660
USA2	32.67	13.67	19.00	0.62	0.95	1.58	0.19	1867
USA3	35.00	15.50	19.50	0.84	0.89	1.73	0.15	1535
USA4	28.00	11.00	17.00	0.82	0.91	1.73	0.20	2400
USA5	19.00	7.50	11.50	0.10	0.16	0.26	0.24	862
H. SHAND_1	30.67	12.67	18.00	0.73	0.89	1.62	0.15	1530
H. SHAND_6	41.00	15.67	25.33	1.28	1.21	2.49	0.20	2203
GIZA_15	45.00	22.00	23.00	2.33	1.75	4.08	0.36	5400
GIZA_113	43.33	17.00	26.33	2.13	1.57	3.70	0.30	4550
SG_114	44.67	18.33	26.33	1.83	1.68	3.51	0.29	4207
DURADO	33.00	13.00	20.00	0.79	1.08	1.88	0.22	2287
ATOON	34.00	13.33	20.67	1.18	1.56	2.74	0.28	3713
TOOT	32.67	14.00	18.67	0.95	1.15	2.10	0.20	2560
RAMSEES	35.67	16.33	19.33	1.38	1.85	3.24	0.28	4163
HOURS	33.00	15.33	17.67	1.14	1.35	2.49	0.23	3197
AMOS	32.00	14.00	18.00	0.96	1.04	2.00	0.21	2253
LSD	**5.4464**	**4.5449**	**3.2281**	**0.333**	**0.4302**	**0.6919**	**0.085**	**1318**
VG	8.29	13.52	0.31	0.16	0.86	0.00	8.29	1366887
VP	15.72	17.26	0.35	0.23	1.04	0.01	15.72	1991594
PCV	26.77	20.91	52.07	39.32	43.38	31.04	26.77	49.75
GCV	19.44	18.50	49.01	33.04	39.62	21.79	19.44	41.21
H	52.74	78.29	88.59	70.59	83.39	49.26	52.74	68.63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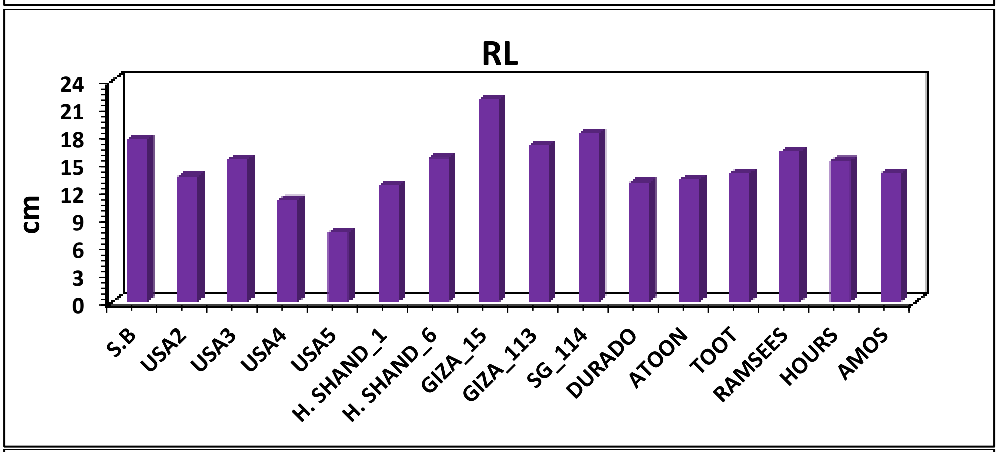
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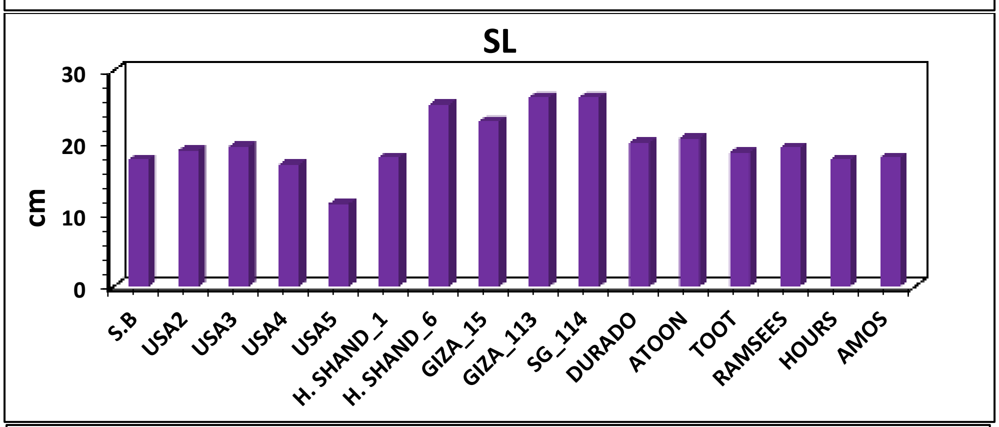
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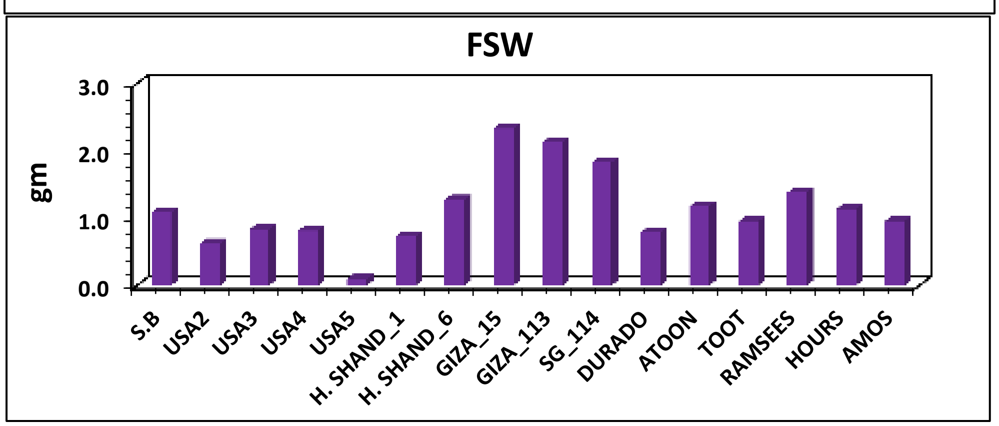
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GIZA_113
SG_114
DURADO
ATOON
TOOT
RAMSEES
HOURS
AMOS

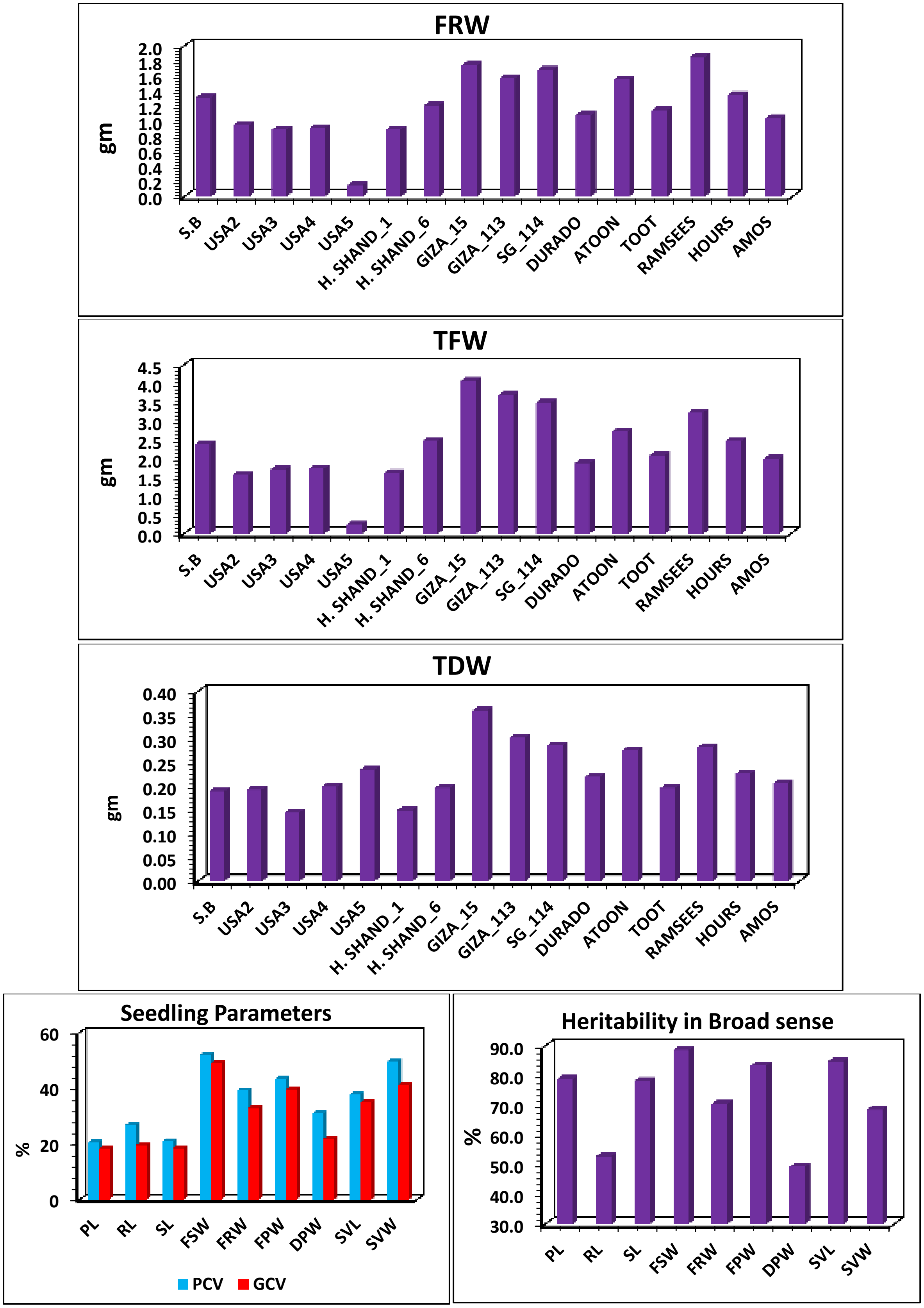

Figure 3: the seedling parameters of some sorghum genotypes

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