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HETEROSIS FOR SEED YIELD AND RELATED TRAITS IN SUNFLOWER

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ABSTRACT

Twenty-six genotypes of sunflower (16 F_1-hybrids, four female lines, four restorer lines and two check varieties; Sakha 53 and Giza 102) were evaluated under two contrasting environments, i.e., loamy sand soil at A.R.C., Arab El-Awamer Res. Stn., and clay soil at Assiut Univ. Exper. Farm in season 2016. Genotypes mean squares of the studied traits was significant ($P \leq 0.01$) either in the separate or in the combined analysis. The differences between the two environments were significant for all traits except head diameter (HD). The genotype x environment interaction was significant for all traits, indicating differential responses of genotypes to the two environments. The sixteen hybrids showed negative significant heterosis ($P \leq 0.01$) for 50% flowering from the earlier check Giza 102 (standard heterosis; SH %), which ranged from -8.39 to -18.44% under loamy sand soil, and from -2.80 to -12.92% under clay soil. The heterotic effects were higher under loamy sand than under clay soil. The combined data showed that 4, 5 and 12 hybrids were significantly earlier than the mid-parent, better parent and the earlier check; respectively. The combined data over the two environments of plant height indicated that 15 hybrids showead negative significant standard heterosis ranged from -8.42 to -25.16%. This gives a good opportunity to select short sunflower hybrids. All the hybrids showed negative SH% for head diameter, and none of them exceeded the check variety in 100-SW. Otherwise, all the hybrids showed negative significant ($P \leq 0.01$) heterosis in husk% from the better check Sakha 53 either at the two environments or at the combined data. Over environments the SH% in oil% was positive and significant (p≤ 0.01) for four hybrids (ranged from 4.47 to 9.83%), for three hybrids in kernel weight and for one hybrid in number of seeds/head. Mid-parent heterosis in seed yield/head was positive and significant (P≤0.01) for 14 and 13 hybrids under loamy sand and clay soil; respectively, eight and three hybrids showed positive and significant BPH heterosis in seed yield/head under the respective environments. The positive and significant (P≤0.01) BPH in seed yield/head ranged from 16.54 to 685.33% under loamy sand soil, and from 13.42 to 70.38% under clay soil. Otherwise, only one hybrid No. 1 (A7 x Rf1) gave positive significant (P≤0.01) heterosis from the check hybrids Sakha 53 under clay soil and combined data. Mid-parent heterosis in oil yield/head was positive and significant (P≤0.01) for 14 hybrids under both environments and ranged from 3.35 to 823.12% under loamy sand, and from 3.01 to 151.88% under clay soil. Eight and three hybrids gave positive significant (P≤0.01) BPH under loamy sand and clay soil; respectively. The BPH in oil yield/head ranged from 9.48 to 708.95% and from 3.91 to 66.06% under the two respective environments. Standard heterosis in oil yield/head from the better check cultivar was positive and significant for five hybrids under loamy sand, one hybrid under clay soil and two hybrids in the combined data.

Key words: ***Heterosis, Helianthus annuus L., Standard heterosis***

INTRODUCTION

Sunflower (*Helianthus annuus* L.) is a wide spread edible oil crop all over the world. It ranked the second after soybean (Peniego *et al*., 2002). Sunflower seed contain high oil content ranging from 35-48%, with some types yielding up to 50% (Marinkovic, 1992), 20-27% protein (Nazir *et al*. 1994) and high percentage of poly unsaturated fatty acids (60%) including oleic acid (16.0%) and linoleic acid (72.5%) (Ghafoor and Ahmad, 2005). It is a short duration crop and can be grown at any time of the year in tropical and sub-tropical area, tolerant to drought, high oil content and yield potential. Heterosis of this crop has been exploited only over the past few decades. Hybrid sunflower became a reality with the discovery of cytoplasmic male sterility and effective male fertility restoration system during 1970 (Miller and Fick, 1997). Egypt faces severe shortage of oil and spends a heavy burden of foreign exchange on its import annually. Self-sufficiency of edible oil was12.4% as an average of 1995 to 1999. Imports of edible oils reached 2.0 million tons in 2015/2016. The cultivated area of sunflower in Egypt in 2016 was 8000 ha gave 22000 tons (FAO,2016). Kaya (2005) noted that the highest heterosis (288.3%)

and heterobeltiosis (98%) were found for oil yield. The highest standard heterosis (21.2%) was computed for seed yield. The lowest heterosis (–19.3%) and heterobeltiosis (-22.4%) were observed for hull rate. The lowest standard heterosis (-22.0%) was measured for oil yield. Habib *et al*. (2006) showed highest positive heterosis and heterobeltiosis for 100-achene weight, oil content, head diameter, plant height, number of seeds/head and oil yield. Reif *et al*. (2012) noted that for less complex traits, mid-parent performance serves as a good predictor for hybrid performance. Encheva *et al*. (2015) found positive heterotic effect of 212.7% for seed yield/ plant relative to parental average, followed by diameter of head (132.98%) in comparison to better parent. Negative heterotic effect was established for 1000 seed-weight, seed length, seed width and seed thickness. The aim of the present article was to identify crosses better than the check varieties in seed and oil yields.

MATERIALS AND METHODS

A. Genetic materials

Four cytoplasmic male sterile (CMS) lines (A-Lines; A7 and A19 from Argentine, and A15 and A21 from Russia), and four fertility restorer lines (RF-lines from Egypt), along with two check varieties of sunflower (*Helianthus annuus* L.) were planted at Assiut Agric. Res. St. Agric. Res. Center in summer season 2015, to develop 16 crosses. The sixteen single crosses, four CMS lines, four restorer lines and the two check varieties; Giza 102 and Sakha 53 were evaluated at two contrasting environments; loamy sand and clay soils at 2016 season. Planting dates were September 10th at Assiut Agric. Res. Stn. ARC. (loamy sand soil), and on September 20th, 2016 at Fac. Agric. Assiut Univ. Exper. Farm (clay soil). Randomized complete block designs with three replications were used in the two locations. The plot size was 2.4 m^2 (one row, 4-meter-long and 60 cm apart). Planting was done by hand in hills spaced 25 cm apart. Seedlings were thinned to one plant per hill two weeks later in both locations. The recommended cultural practices for oil seed sunflower production were adopted throughout the growing season. Five guarded plants were tagged. At flowering, days to 50 % flowering from sowing date until 50% of the plants showed their anthesis was recorded. The recorded characters on the tagged plants were; Plant height; cm (PH), head diameter, cm (HD), 100 seed weight; g (100-SW), husk percentage (Husk%) (a sample of seeds were peeled to husk and kernel; Husk% = (husk weight in the sample)/sample weight * 100, and Kernel% = (kernel weight in the sample)/sample weight * 100), oil percentage: was determined by Soxcelt apparatus using petroleum ether (BP60-80 c) as a solvent, according to the official method (A. O. A. C. 1980), kernels in 100 seeds (kernel; g): was estimated as kernel% * 100- SW, number of seed per head (NS/H), seed yield / head (SY/H; g) and oil yield per head (OY/H; g): was estimated as oil % * average seed yield/head.

Statistical analysis

Combined analysis of variance was performed as outlined by Gomez and Gomez (1984) after carrying out the homogeneity of variances using Bartlett test. Heterosis was calculated from the mid-parent (MPH%= (F_1-MP)/MP*100), better parent (BPH% = (F_1-BP)/BP*100 and heterosis from the better check; standard heterosis SH% = (F_1-better check)/better check*100. The significance of heterosis was estimated using least significant difference test (LSD).

RESULTS AND DISCUSSION

It is obvious that the loamy sand soil has a light texture (Table 1), resulting in a proper porosity that causes a good balance between soil moisture and air contents compared to those of clay soil that display a heavy texture. Thus, plant roots can penetrate and spread in a greater area of the loamy sand soil relative to that of the clay one. Moreover, the loamy sand soil has a good physical properties and conditions that encourage plant roots to extend in more rhizosphere area to absorb water and nutrients. Also, the irrigation water goes through the clay soil very slowly causing the root zone to be saturated with water on the charge of soil air that is necessary for root respiration and spread. For the chemical and nutritional point of view, the loamy sand soil has a lower salt content (0.68 ds/m), and higher available phosphorus "P" (29.9 mg/kg) than the clay soil (1.07 ds/m and 11.17 mg/kg; respectively), even though, both are not saline. The available P content of the loamy sand soil is extremely sufficient for plant needs. However, the available P of the clay soil is considered marginal. In conclusion, the physical properties (soil texture, porosity and water distribution) and some chemical and nutritional properties (salinity and available P) of loamy sand soil are preferable. However, organic matter, extractable K, total nitrogen, soluble Ca, Mg, Na, K were higher in clay than in loamy sand soil.

Means and variances

The separate and combined analyses of variances for different traits are shown in Table 2.

Genotypes mean squares of the 10 studied traits was significant ($P \leq 0.01$) either in the separate or in the combined analysis, which reflects wide differences among genotypes (parents and crosses).

The differences between the two environments were significant ($P \leq 0.01$) for all traits except head diameter (HD). The genotypes by environment interaction was significant ($P \leq 0.05$) for days to 50% flowering and significant ($P \leq 0.01$) for the other traits, indicating differential responses of genotypes to the two environments. Javed and Aslam (1995), Jan *et al*. (2005), Kumar *et al*. (2014) and Khan *et al*. (2017) found significant mean squares for genotypes, environments (drought, locations and salinity) and their interaction for SY/P, HD, oil %, days to maturity and 100-seed weight.

Heterosis in seed yield and correlated traits

Heterosis was calculated at each environment and for the combined data. Mid-parent (MPH), better parent heterosis (BPH) and heterosis from the better check cultivar; standard heterosis (SH%) for the studied traits are presented in Table 3. Under loamy sand soil eight hybrids showed significant favorable heterosis from the better parent in days to 50% flowering ranged from -3.09 to -9.32%. However, under clay soil, only two hybrids; No. 14 and No. 15 showed negative significant heterosis from the earlier parent. Likewise, the sixteen hybrids showed negative significant heterosis ($P \leq 0.01$) from the earlier check Giza 102, which ranged from -8.39 to -18.44% under loamy sand soil, and from -2.80 to -12.92% under clay soil. The heterotic effects were higher under loamy sand than under clay soil. The combined data showed that 4, 5 and 12 hybrids were significantly earlier than the mid-parent, better parent and the earlier check; respectively.

Heterosis in plant height was more pronounced under clay than loamy sand soil. Eight hybrids showed significant ($P \leq 0.01$) BPH under clay soil, ranged from 19.79 to 45.65%. However, all the hybrids were significantly ($P \leq 0.01$) shorter than the shorter check Sakha 53 under loamy sand soil, and 14 hybrids under clay soil. The combined data over the two environments indicated that 16 and 7 hybrids showed positive significant heterosis from the mid-parent and better parent; respectively, while 15 hybrids showed negative significant standard heterosis ranged from -8.42 to -25.16%. This gives a good opportunity to select short sunflower hybrids.

Table 1. Some physical and chemical properties of representative soil samples in the *experimental sites before sowing (0-30 cm depth)*

Soil property	Assiut Res. Stn	Fac. Agric. Res. Farr
Particle - size distribution		
Sand (%)	78.24	27.4
Silt (%)	9.76	24.3
Clay (%)	12.00	48.3
Texture grade	Loamy sand	Clay
EC (1:1 extract) dSm^{-1}	0.68	1.07
pH (1:1 suspension)	8.19	8.01
Total $CaCO_3$ (%)	25.0	3.4
Organic matter (%)	0.06	0.24
$NaHCO_3$-extractable P (mg kg^{-1}	29.9	11.17
NH_4OAC-extractable K (mg kg	130	300
Total nitrogen (%)	0.04	0.08
Soluble Ca (mg kg^{-1})	100	190
Soluble Mg (mg kg^{-1})	12	72
Soluble Na (mg kg^{-1})	4.6	140
Soluble K (mg kg^{-1})	11.7	39
Soluble Cl (mg kg^{-1})	177.5	142
Soluble HCO_3 (mg kg^{-1})	610	427

* Each value represents the mean of three replications

Table 2. Mean squares of the studied traits under loamy sand, clay soil and their combined

Source of variance	d.f.	Days to 50 % Flowering			PH		
		Loamy sand	Clay soil	Combined	Loamy sand	Clay soil	Combined
Reps	2	0.258	0.047		24.25	1023.37	
Env. (E.)	1			118.56**			31365**
Reps/Env.	4			0.16			523.881
Genotypes (G.)	25	17.748**	8.226**	19.96**	647.57**	2066.76**	2323.16**
G. X E.	25			6.03*			391.17**
Error	50	2.923	1.999		29.57	67.275	
Error com.	100			2.46			48.43
Source of Variance		HD			100-seed weight		
		Loamy sand	Clay soil	Combined	Loamy sand	Clay soil	Combined
Reps	2	0.275	1.246		0.308	1.156	
Env. (E.)	1			0.18			157.46**
Reps/Env.	4			0.76			0.73
Genotypes (G.)	25	24.842**	23.226**	38.43**	7.029**	2.284**	6.8**
G. X E.	25			9.64**			2.51**
Error	50	1.055	1.05		0.294	0.156	
Error com.	100			1.05			0.22

*, **; significant at 0.05 and 0.01% level of probability; respectively.

Table 2. Cont.

Source of Variance		Husk %			Kernel in 100 seeds; g		
		Loamy sand sand	Clay soil	Combined	Loamy sand	Clay soil	Combined
Reps	2	0.006	0.551		0.006	0.086	
Env. (E.)	1			23.45**			5.47**
Reps/Env.	4			0.28			0.05
Genotypes (G.)	25	27.424**	28.694**	40.57**	0.863**	0.408**	1.01**
G. X E.	25			15.55**			0.26**
Error	50	1.686	0.85		0.039	0.019	
Error com.	100			1.27			0.03
Source of Variance		Oil %			NS/H		
		Loamy sand	Clay soil	Combined	Loamy sand	Clay soil	Combined
Reps	2	3.168	6.0		127.0	34870	
Env. (E.)	1			1362.33**			200928**
Reps/Env.	4			4.58			17499
Genotypes (G.)	25	49.252**	18.8**	31.55**	113732.2**	128343.2**	186144.2**
G. X E.	25			36.58**			55931.2**
Error	50	1.206	2.36		4303.44	9094.16	
Error com.	100			0.02			6698.56
Source of Variance	d.f.	SY/H			OY/H		
		Loamy sand	Clay soil	Combined	Loamy sand	Clay soil	Combined
Reps	2	4.129	62.398		2.201	8.788	
Env. (E.)	1			4491.14**			1378.81**
Reps/Env.	4			33.26			5.49
Genotypes (G.)	25	724.77**	305.202**	814.01**	125.176**	36.143**	120.17**
G. X E.	25			215.97**			41.15**
Error	50	8.615	9.65		1.121	1.246	
Error com.	1000			9.13			1.18

Table 3. Mid-parent (MPH%), better parent (BPH%) and standard heterosis (SH%) at each environment and their combined data

Days to 50% flowering									
Hybrid	Loamy sand			Clay soil			Combined		
	MPH	BPH	SH	MPH	BPH	SH	MPH	BPH	SH
1-A7xRF1	-4.56**	-6.55**	-12.30**	-0.31	-1.21	-8.42*	-2.17	-3.91*	-5.06**
2-A7xRF2	-7.30**	-9.32**	-18.44**	-1.85	-1.85	-10.67**	-4.27**	-5.57**	-9.51**
3-A7xRF3	-8.98**	-9.26**	-17.88**	7.79**	6.79**	-2.80*	-0.35	-0.93	-5.06**
4-A7xRF5	2.18	1.86	-8.39**	2.17*	1.85	-7.30**	2.46	1.86	-2.39
5-A15xRF1	-3.07*	-5.95**	-11.74**	1.84	0.61	-6.74**	-0.62	-2.79	-3.86
6-A15xRF2	-1.28	-2.53	-13.97**	-0.93	-1.23	-10.11**	-1.11	-1.58	-6.84**
7-A15xRF3	-1.88	-3.09*	-12.30**	0.00	-0.62	-10.11**	-0.95	-1.25	-5.95**
8-A15xRF5	3.14*	2.50	-8.39**	5.59**	5.59**	-4.49**	4.38	4.06	-0.89
9-A19xRF1	-0.91	-2.38	-8.39**	0.61	0.00	-7.30**	-0.15	-1.21	-2.39
10-A19xRF2	0.95	-1.84	-10.62**	2.15*	1.84	-6.74**	1.55	0.00	-3.28*
11-A19xRF3	-1.54	-1.84	-10.62**	3.11**	1.84	-6.74**	0.77	0.00	-3.28*
12-A19xRF5	0.31	-0.61	-9.50**	1.23	0.61	-7.86**	0.77	0.00	-3.28*
13-A21xRF1	-6.46**	-9.52**	-15.09**	0.00	-1.21	-8.42**	-3.23**	-5.41**	-6.53**
14-A21xRF2	-4.82**	-5.73**	-17.32**	-2.17*	-2.47*	-11.23**	-3.47*	-3.77*	-9.20**
15-A21xRF3	-7.21**	-8.64**	-17.32**	-3.13**	-3.73**	-12.92**	-5.16**	-5.61**	-10.09**
16-A21xRF5	-0.95	-1.88	-12.30**	4.35**	4.35**	-5.61*	1.73	1.25	-3.56*

Table 3.Cont.

Hybrid	Pant height								
	Loamy sand			Clay soil			Combined		
	MPH	BPH	SH	MPH	BPH	SH	MPH	BPH	SH
1-A7xRF1	27.31**	19.33**	-20.36**	32.48**	28.97**	-29.11**	30.03**	24.35**	-18.33**
2-A7xRF2	18.80**	7.12*	-28.51**	40.79**	27.41**	-29.97**	30.25**	17.69**	-22.71**
3-A7xRF3	6.60*	1.36	-32.35**	36.89**	27.73**	-29.80**	22.22**	15.10**	-24.41**
4-A7xRF5	17.71**	17.11**	-21.04**	13.03*	0.98	-29.45**	15.11**	7.78	-18.87**
5-A15xRF1	19.55**	1.91	-15.61**	61.64**	45.65**	-5.48	41.52**	24.16**	-1.38
6-A15xRF2	16.42**	-4.10	-20.59**	55.24**	30.87**	-15.07*	36.38**	13.69**	-9.70**
7-A15xRF3	9.49**	-5.46	-21.72**	38.21**	19.79**	-22.26**	24.10*	7.38	-14.71**
8-A15xRF5	8.73**	-1.37	-18.32**	25.03**	20.59**	-15.75*	17.56**	14.50**	-9.06**
9-A19xRF1	7.49*	-5.83	-26.92**	9.70	-2.07	-35.10**	8.65**	-3.84	-25.16**
10-A19xRF2	9.66**	-7.29*	-28.05**	30.76**	9.30	-27.57**	20.76**	1.50	-21.00**
11-A19xRF3	3.12	-8.45*	-28.96**	18.50**	1.81	-32.54**	11.13**	-3.02	-24.52**
12-A19xRF5	-3.90	-10.20**	-30.32**	8.93	6.13	-25.86**	3.19**	1.50	-21.00**
13-A21xRF1	3.32	-9.60**	-29.64**	22.46**	12.37	-29.97**	13.38**	1.69	-23.24**
14-A21xRF2	12.91**	-4.65	-25.79**	28.53**	10.17	-31.34**	21.00**	2.97	-22.28**
15-A21xRF3	10.16**	-2.33	-23.98**	23.99**	9.34	-31.85**	17.25**	3.67	-21.75**
16-A21xRF5	6.23*	-0.87	-22.85**	34.20**	26.96**	-11.30	21.50**	21.33**	-8.42**

*, **; significant at 0.05 and 0.01 level of probability; respectively.

Table 3.Cont.

Hybrid	Head diameter								
	Loamy sand			Clay soil			Combined		
	MPH	BPH	SH	MPH	BPH	SH	MPH	BPH	SH
1-A7xRF1	30.07**	26.35**	-20.36**	23.28**	7.12**	-16.48**	26.41**	15.50**	-15.45**
2-A7xRF2	41.42**	25.87**	-20.66**	25.58**	1.12	-21.16**	32.91**	11.97**	-18.04**
3-A7xRF3	42.57**	28.26**	-19.16**	16.28**	3.00**	-19.70**	27.92**	14.05**	-16.51**
4-A7xRF5	32.90**	24.07**	-9.80**	-8.68**	-9.36**	-29.33**	10.38**	7.32*	-16.84**
5-A15xRF1	3.74**	-17.82**	-16.44**	43.29**	42.93**	-17.36**	20.61**	4.71	-13.88**
6-A15xRF2	19.59**	-11.29**	-9.80**	66.20**	51.52**	-12.40**	39.16**	12.00**	-7.89**
7-A15xRF3	11.89**	-16.33**	-14.93**	37.62**	34.95**	-18.82**	23.40**	4.71	-13.88**
8-A15xRF5	7.26**	-8.03**	-6.49**	23.43**	8.17**	-16.92**	14.47**	11.16**	-8.58**
9-A19xRF1	10.05**	-6.39**	-20.66**	22.26**	6.41**	-17.36**	16.07**	-0.16	-16.05**
10-A19xRF2	24.79**	-1.41	-16.44**	29.15**	4.15**	-19.11**	26.94**	1.32	-14.81**
11-A19xRF3	3.58**	-17.42**	-30.02**	-5.92**	-16.53**	-35.17**	-1.30	-17.00	-30.21**
12-A19xRF5	5.76**	-1.76*	-16.74**	13.05**	12.43**	-12.69**	9.45**	5.16	-11.58**
13-A21xRF1	14.36**	3.74**	-24.28**	14.03**	1.59	-25.24**	14.19**	2.61	-22.05**
14-A21xRF2	34.83**	12.83**	-17.65**	29.16**	6.35**	-21.74**	31.89**	9.47**	-16.84**
15-A21xRF3	27.64**	7.87**	-21.27**	6.11**	-3.57**	-29.04**	16.26**	2.00	-22.51**
16-A21xRF5	25.06**	24.82**	-8.90**	28.16**	25.48**	-3.64**	26.66**	25.42**	-2.81

Table 3.Cont.

Hybrid	100- Seed weight								
	Loamy sand			Clay soil			Combined		
	MPH	BPH	SH	MPH	BPH	SH	MPH	BPH	SH
1-A7xRF1	131.44**	95.47**	3.75**	32.57**	-3.42**	-12.45**	76.41**	56.64**	-3.63
2-A7xRF2	156.06**	123.18**	9.84**	32.03**	-11.48**	-19.76**	87.94**	56.34**	-3.81
3-A7xRF3	215.90**	200.83**	21.64**	27.81**	-11.99**	-20.22**	106.59**	66.37**	2.36
4-A7xRF5	73.26**	27.24**	-0.73	-10.60**	-24.27**	-31.36**	28.59**	19.90	-14.70**
5-A15xRF1	20.54**	-13.21**	4.70**	47.56**	19.68**	-20.29**	29.96**	-2.65	-6.72
6-A15xRF2	54.43**	8.72**	31.15**	64.86**	20.67**	-19.63**	57.77**	12.50*	7.80
7-A15xRF3	30.28**	-13.03**	4.92**	54.64**	17.01**	-22.07**	38.78**	-3.41	-7.44
8-A15xRF5	0.79	-17.01**	0.11	18.11**	14.84**	-23.52**	6.96	-6.82	-10.71*
9-A19xRF1	8.70**	-20.52**	-8.78**	26.92**	2.03**	-30.43**	15.32**	-12.84	-18.69
10-A19xRF2	17.74**	-15.89**	-3.47**	43.22**	4.06**	-29.05**	26.39**	-9.14	-15.25**
11-A19xRF3	26.56**	-14.42**	-1.79**	-0.90**	-25.60**	-49.28**	16.78**	-18.09	-23.59
12-A19xRF5	9.20**	-8.28***	5.26**	22.41**	17.68**	-19.76**	14.13**	0.58	-6.17
13-A21xRF1	57.08**	37.27**	-2.57**	43.76**	14.81**	-20.36**	51.38**	27.13**	-10.71*
14-A21xRF2	94.79**	64.93**	17.06**	70.83**	23.46**	-14.36**	84.97**	46.25**	2.72
15-A21xRF3	100.20**	57.13**	11.52**	45.67**	8.74**	-24.57**	76.09**	35.14**	-5.08
16-A21xRF5	66.89**	59.35**	24.33**	22.81**	17.09**	-18.77**	47.88**	46.94**	4.54

Table 3. Cont.

Hybrid	Husk %								
	Loamy sand			Clay soil			Combined		
	MPH	BPH	SH	MPH	BPH	SH	MPH	BPH	SH
1-A7xRF1	30.04**	28.46**	-25.69**	14.65**	10.07**	-9.42**	-5.29**	-10.62**	-13.70**
2-A7xRF2	21.30**	21.14**	-22.65**	14.55**	8.68**	-14.15**	-7.44**	-13.75**	-14.44**
3-A7xRF3	21.96**	19.12**	-10.48**	7.42**	5.56**	-11.64**	10.42	9.04	-6.57**
4-A7xRF5	21.64**	9.83**	-17.62**	-15.34**	-26.41**	-12.04**	1.16	-1.77	-10.66**
5-A15xRF1	-2.55**	-21.13**	-23.93**	17.29**	16.85**	-17.49**	-5.02*	-13.90	-16.86**
6-A15xRF2	-5.05**	-22.51**	-21.14**	25.59**	23.60**	-34.65**	-13.88**	-23.43**	-24.05**
7-A15xRF3	-2.58**	-18.90**	-29.32**	22.94**	20.50**	-23.26**	-8.30**	-7.94	-22.71**
8-A15xRF5	0.19	-10.48**	-22.97**	-5.33**	-20.26**	-15.68**	-1.78	-6.98	-15.40**
9-A19xRF1	21.64**	10.14**	-24.42**	16.73**	10.44**	-14.46**	-7.54**	-12.58**	-15.59**
10-A19xRF2	10.59**	1.13**	-23.21**	3.15**	-3.54**	-19.83**	-11.06**	-16.96	-17.63**
11-A19xRF3	18.41**	10.81**	-26.90**	7.83**	4.38**	-14.80**	-2.19	-3.60	-17.07**
12-A19xRF5	1.33**	-0.22	-19.09**	1.31**	-10.77**	-28.43**	-9.37**	-11.82**	-19.80**
13-A21xRF1	12.37**	8.85**	-15.24**	22.15**	22.03**	-11.18**	-10.76**	-15.33**	-8.92**
14-A21xRF2	23.67**	21.09**	-20.65**	29.39**	27.68**	-17.54**	-17.87**	-21.06**	-15.09**
15-A21xRF3	13.62**	13.18**	-22.75**	0.09	-2.16**	-18.38**	-12.79**	-22.53**	-16.67**
16-A21xRF5	21.62**	11.79**	-24.30**	23.26**	3.59**	-21.23**	-18.33**	-24.63**	-18.93**

Table 3. Cont.

Hybrid	Kernel; g								
	Loamy sand			Clay soil			Combined		
	MPH	BPH	SH	MPH	BPH	SH	MPH	BPH	SH
1-A7xRF1	90.63**	90.04**	11.18**	29.73**	-12.27*	-15.23**	57.60**	25.74**	-2.29
2-A7xRF2	163.16**	135.36**	36.84**	44.87**	-7.57**	-10.69**	97.99**	44.85**	12.57*
3-A7xRF3	161.17**	123.05**	29.68**	22.30**	-13.83**	-16.73**	79.71**	36.76**	6.29
4-A7xRF5	51.37**	33.52**	1.59**	-10.57**	-23.68**	-26.25**	16.79*	12.50	-12.57
5-A15xRF1	30.20**	-3.25**	16.43**	50.97**	7.71**	-14.07**	38.28**	1.14	1.14
6-A15xRF2	113.67**	47.54**	77.56**	96.62**	31.18**	4.65**	106.72**	40.57**	40.57**
7-A15xRF3	37.97**	-7.42**	11.42**	55.43**	16.23**	-7.28**	44.72**	1.71	1.71
8-A15xRF5	13.28**	-7.55**	11.26**	-0.37**	-7.53**	-26.23**	6.98	-8.00	-8.00
9-A19xRF1	3.78**	-23.93**	-4.48**	39.94**	0.27**	-21.14**	17.37*	-14.61	-13.14
10-A19xRF2	31.46**	-10.27**	12.68**	59.83**	7.02**	-15.83**	42.74**	-3.37	-1.71
11-A19xRF3	33.07**	-11.65**	10.95**	-22.70**	-41.92**	-54.32**	9.24	-23.60	-22.29
12-A19xRF5	1.51**	-18.50*	2.35**	42.14**	32.80**	4.45 **	19.08**	1.69	3.43
13-A21xRF1	63.44**	60.78**	-2.78**	40.19**	0.89**	-21.78**	51.49**	26.45**	-12.57
14-A21xRF2	125.46**	98.21**	19.85**	89.41**	27.29**	-1.31**	107.61**	57.85**	9.14
15-A21xRF3	151.19**	111.11**	27.65**	52.02**	14.77**	-11.02**	96.88**	56.20**	8.00
16-A21xRF5	94.80**	74.80**	33.00**	26.00**	18.51**	-8.12**	58.70**	55.56**	12.00**

Table 3.Cont.

Hybrid	Oil %								
	Loamy sand			Clay soil			Combined		
	MPH	BPH	SH	MPH	BPH	SH	MPH	BPH	SH
1-A7xRF1	31.63**	6.61**	15.19**	-0.45	-0.91	-4.39 **	14.70**	3.04	6.27**
2-A7xRF2	8.29**	-14.62**	-0.88	-8.83**	-10.08**	-14.04 **	-0.49	-11.44	-6.70
3-A7xRF3	14.57**	-8.06**	1.79	-2.83**	-5.50**	-9.65 **	5.61	-4.39	-3.11
4-A7xRF5	23.76**	-1.57	11.62**	-3.38**	-8.25**	-12.28 **	10.02**	0.00	0.46
5-A15xRF1	1.23	0.01	10.72**	0.00	-4.55**	-7.89 **	0.67	-0.86	2.25
6-A15xRF2	-21.26**	-23.08**	-10.71**	-4.85**	-7.55**	-14.04 **	-13.91	-16.09	-11.60
7-A15xRF3	8.07**	8.06**	19.65**	-2.46**	-3.88**	-13.16 **	3.33	2.64	4.02
8-A15xRF5	-1.99*	-3.15**	9.83**	16.17**	15.01**	0.88	6.03**	5.79**	6.27**
9-A19xRF1	7.44**	7.44**	16.08**	-6.80**	-12.73**	-15.79 **	0.90	-2.16	0.91
10-A19xRF2	-5.97**	-9.23**	5.37**	-4.95**	-9.43**	-15.79**	-5.51	-9.31	-4.45
11-A19xRF3	2.86**	1.61	12.51**	20.60**	16.50**	5.26**	10.81	8.38**	9.83**
12-A19xRF5	5.65**	3.15**	16.97**	-5.15**	-6.12**	-19.30**	0.91	-0.88	-0.43
13-A21xRF1	7.30**	3.31**	11.62**	10.11**	-0.91	-4.39**	8.59**	1.30	4.47**
14-A21xRF2	5.79**	-1.54	14.30**	0.01	-8.49**	-14.91**	3.22	-4.65	0.46
15-A21xRF3	1.70*	-3.23**	7.15**	-0.52	-7.77**	-16.67**	0.70	-5.29	-4.02
16-A21xRF5	7.12**	0.79	14.30**	10.76**	5.10**	-9.65**	8.71**	2.67	3.13

Table 3.Cont.

	NS/H								
Hybrid	Loamy sand			Clay soil			Combined		
	MPH	BPH	SH	MPH	BPH	SH	MPH	BPH	SH
1-A7xRF1	139.00**	114.31*	-14.48	112.64	75.37	38.89	122.81**	105.14**	18.79**
2-A7xRF2	144.92**	127.80*	-27.88	56.73	26.58	0.25	87.19**	58.39**	-8.28
3-A7xRF3	153.89**	138.55*	-24.48	59.30	13.02	-10.49	95.02**	52.46**	-11.71
4-A7xRF5	52.31	-0.31	2.13	29.94	29.05	2.20	41.00**	12.13	9.94
5-A15xRF1	17.11	-18.86	-16.07	3.03	-29.16	-2.87	9.58	-24.39	-3.06
6-A15xRF2	7.93	-31.83	-29.48	14.18	-22.62	6.11	11.39	-26.89	-6.27
7-A15xRF3	24.83	-20.79	-18.07	16.72	-27.52	-0.61	20.53**	-24.40	-3.07
8-A15xRF5	-14.10	-14.51	-11.57	-13.85	-32.39	-7.29	-13.98	-24.10	-2.69
9-A19xRF1	42.59	19.45	-29.44	-10.28	-40.08	-8.16	26.37**	-21.84	-13.39
10-A19xRF2	90.66	39.28	-17.73	-12.36	-42.25	-11.48	42.76**	-17.27	-8.33
11-A19xRF3	23.33	-9.28	-46.41	-24.86	-54.30	-29.95	8.99	-40.51	-34.08
12-A19xRF5	-16.30	-34.02	-32.41	-14.51	-35.48	-1.09	-5.10	-20.19	-11.56
13-A21xRF1	-14.12	-32.22	-53.25	-7.49	-29.24	-31.29	-10.52	-30.58	-38.68
14-A21xRF2	50.01	4.61	-27.84	3.42	-22.34	-24.59	23.48**	-10.25	-20.71
15-A21xRF3	55.84	9.36	-24.56	-7.66	-38.05	-39.85	21.55*	-16.78	-26.48
16-A21xRF5	-10.21	-24.88	-23.04	8.93	-1.72	-4.57	-1.19	-6.08	-7.92

Table 3. Cont.

Hybrid	SY/H								
	Loamy sand			Clay soil			Combined		
	MPH	BPH	SH	MPH	BPH	SH	MPH	BPH	SH
1-A7xRF1	434.16**	313.31**	-9.86**	163.00**	70.38**	23.35**	251.36**	176.32**	12.72**
2-A7xRF2	520.85**	472.50**	-19.03**	88.19**	13.42**	-17.88**	212.00**	115.76**	-11.99
3-A7xRF3	713.61**	685.33**	-6.22*	73.21**	0.46	-27.27**	245.54**	124.57**	-8.40
4-A7xRF5	124.82**	29.05**	4.08	16.92**	-1.19	-28.46**	71.29**	33.52**	-2.57
5-A15xRF1	20.21**	-29.63**	-10.17**	37.00**	-15.73**	-21.64**	26.31**	-24.74	-8.25
6-A15xRF2	33.83**	-25.67**	-5.12*	60.30**	-7.03*	-13.56**	43.40**	-19.11	-1.38
7-A15xRF3	26.86**	-31.05**	-11.99**	50.59**	-15.32**	-21.27**	35.38**	-25.52	-9.20
8-A15xRF5	-13.50**	-29.42**	-9.91**	-0.27	-23.33**	-28.72**	-9.03	-27.29	-11.36
9-A19xRF1	44.91**	-4.80	-33.86**	3.96	-37.44**	-34.24**	24.08**	-22.12	-28.73
10-A19xRF2	93.65**	16.54**	-19.04**	7.18*	-38.83**	-35.71**	48.90**	-12.83	-20.24
11-A19xRF3	33.91**	-22.34**	-46.05**	-37.59**	-65.36**	-63.59**	-3.25	-45.16	-49.82
12-A19xRF5	-2.68	-9.42**	-26.95**	4.42	-22.96**	-19.03**	0.41	-9.76	-17.42
13-A21xRF1	29.58**	-7.05**	-53.36**	23.74**	-18.88**	-44.19**	26.78**	-13.02	-45.38
14-A21xRF2	169.85**	72.96**	-13.22**	57.21**	-4.41	-34.24**	114.36**	33.85**	-15.94
15-A21xRF3	181.31**	71.80**	-13.80**	14.58**	-33.07**	-53.95**	98.84**	18.78**	-25.41
16-A21xRF5	49.95**	21.62**	-1.91	33.67**	15.39**	-20.62**	43.38**	33.39**	-2.67

Table 3. Cont.

Oil yield/H									
Hybrid	Loamy sand			Clay soil			Combined		
	MPH	BPH	SH	MPH	BPH	SH	MPH	BPH	SH
1-A7xRF1	509.89**	307.57**	4.59**	151.88**	66.06**	28.95**	270.64**	213.99**	17.82**
2-A7xRF2	498.65**	344.56**	-20.87**	69.87**	3.91**	-19.30**	158.51**	119.00**	-17.82
3-A7xRF3	823.12**	708.95**	-7.18**	52.71**	-11.95**	-31.63**	168.91**	127.81**	-14.52
4-A7xRF5	134.69**	28.10**	20.64**	13.54**	-8.46**	-28.91**	226.20**	33.44**	3.69
5-A15xRF1	15.01**	-32.18**	-2.96**	43.66**	-9.57**	-13.60**	27.67**	-25.18	-4.47
6-A15xRF2	3.35**	-41.90**	-16.87**	53.44**	-9.35**	-13.38**	22.91**	-31.78	-12.90
7-A15xRF3	40.09**	-24.34**	8.26**	40.43**	-21.05**	-24.56**	44.46**	-23.30	-2.07
8-A15xRF5	-16.79**	-31.01**	-1.30	25.77**	-5.81**	-10.01**	-1.42	27.69**	-0.78
9-A19xRF1	41.70**	-5.63**	-27.05**	-0.65	-38.12**	-37.69**	22.58**	-20.83	-29.29
10-A19xRF2	77.97**	9.48**	-15.37**	3.01**	-39.62**	-39.20**	43.91**	-13.43	-22.68
11-A19xRF3	38.57**	-20.43**	-38.49**	-24.83**	-57.98**	-57.68**	9.40	-37.95	-44.59
12-A19xRF5	-3.40**	-12.05**	-17.18**	4.00**	-23.44**	-22.90**	-0.66	-7.11	-17.04
13-A21xRF1	25.76**	-7.96**	-49.06**	41.26**	-1.10	-38.88**	32.28**	-4.99	-43.29
14-A21xRF2	183.67**	87.45**	3.74**	54.00**	-1.38	-39.05**	128.98**	49.29**	-10.89
15-A21xRF3	166.75**	61.03**	-10.88**	20.70**	-28.04**	-55.53**	104.52**	22.80	-26.70
16-A21xRF5	49.43**	18.63**	11.71**	54.35**	36.57**	-15.60**	51.04**	33.53**	3.76**

All hybrids showed positive significant (P≤0.01) MPH in head diameter under loamy sand soil, eight of them exceeded significantly the better parent, ranging from 3.74 to 28.26%. Under clay soil, positive significant MPH in head diameter was observed for 14 hybrids, 11 of them showed significant (P≤0.01) BPH ranged from 3.00 to 51.52%. It could be noticed that heterosis in head diameter was higher at loamy sand than at clay soil. On the other hand, all the hybrids showed negative significant (P≤0.01) heterosis from the better check Giza 102 in head diameter either under loamy sand or clay soil (Table 3). Combined data over environments showed that 15 and 8 hybrids significantly exceeded mid- and better parent; respectively, while all hybrids showed negative SH% in head diameter.

Mid-parent heterosis in seed index was positive and significant (P≤0.01) for 15 hybrids under loamy sand and 14 hybrids under clay soil. Likewise, BPH was positive and significant (P≤0.01) for nine hybrids under loamy sand and 11 hybrids under clay soil. Likewise, standard heterosis from Sakha 53 was significant (P≤0.01) and positive for ten hybrids and ranged from 3.75 to 24.23% under loamy sand soil. However, all the hybrids were significantly (P≤0.01) lower than the check hybrid Sakha 53 under clay soil in 100-SW reflecting the interaction of environments with genotypes. The combined data indicated that 15 hybrids gave positive significant MPH ranged from 14.13 to 106.59%, and eight hybrids showed positive significant BPH ranged from 27.13 to 66.37%. Otherwise, the combined data indicated none of the hybrids exceeded the better check in 100-SW. Khan *et al*. (2004) reported MPH of 104.6% for 1000-seed weight, otherwise, Encheva *et al*. (2015) noted negative heterotic effects for 1000-seed weight.

Mid-parent heterosis in husk % was positive and significant (P≤0.01) for 12 hybrids under loamy sand soil and ranged from 1.33 to 30.04%, and for 13 hybrids under clay soil, and ranged from 7.42 to 29.39%. Likewise, 11 hybrids showed positive significant BPH under loamy sand, and 11 hybrids under clay soil. Otherwise, all the hybrids showed negative significant (P≤0.01) heterosis from the better check Sakha 53 either at the two environments or at the combined data, indicating that all the hybrids were better in husk% than the two checks. Zhao-Cheng *et al*. (1988) observed high heterosis in hull content.

Mid-parent heterosis in oil percentage was positive and significant (P≤0.01) for 12 hybrids under loamy sand soil, and for four hybrids under clay soil. Likewise, five and three hybrids under the respective environments showed positive and significant BPH in oil percentage. Standard heterosis from the better check variety Giza 102 was positive and significant (P≤0.01) for 13 hybrids under loamy sand soil, and for only one hybrid under clay soil. The standard heterosis from the combined data in oil% was positive and significant (p≤ 0.01) for four hybrids ranged from 4.47 to 9.83%.

Mid-parent heterosis in kernels weight, 100-seeds was positive and significant (P≤0.01) for all hybrids under loamy sand soil, except three hybrids under clay soil. Likewise, nine and ten hybrids showed positive and significant (p≤ 0.01) BPH under loamy sand and clay soil; respectively. Standard heterosis in kernels weight from the better check Sakha 53 was positive and significant (P≤0.01) for 14, two and three hybrids under loamy sand, clay soil and combined data; respectively.

Respect number of seeds/head, mid- and BPH was significant for three hybrids under loamy sand soil. However, none of the hybrids showed significant standard heterosis from the better check at both environments. Mid-parent, BPH and SH as calculated from the combined date indicated that 9, 3 and one hybrid showed significant heterosis; respectively. Habib *et al*. (2006) and Encheva *et al*. (2015) noted high heterosis for this trait.

Mid-parent heterosis of seed yield/head was positive and significant (P≤0.01) for 14 and 13 hybrids under loamy sand and clay soil; respectively, eight and three hybrids showed positive and significant BPH heterosis in seed yield/head under the respective environments. The positive and significant (P≤0.01) MPH in seed yield/head ranged from 20.21 to 713.61%, and from 16.54 to 685.33% for BPH under loamy sand soil. Under clay soil, the significant and positive MPH ranged from 7.18 to 163.0%, and from 13.42 to 70.38% for the BPH. Otherwise, none of the hybrids showed positive significant standard heterosis in seed yield/plant from the better check variety under loamy sand soil, and only one hybrid No. 1 (A7 x Rf1) gave positive significant (P≤0.01) heterosis from the check hybrids Sakha 53 under clay soil and combined data. Singh *et al*. (1984) reported heterosis in seed yield ranged from 47 to 205%. Ahmad ***et al***. (2005) found heterosis for seed yield of 21.2%. Encheva *et al*. (2015) reported heterotic effect of 212.7% for seed yield/plant.

Mid-parent heterosis of oil yield/head was positive and significant (P≤0.01) for 14 hybrids under both environments and ranged from 3.35 to 823.12% under loamy sand, and from 3.01 to 151.88% under clay soil. Eight and three hybrids gave positive significant (P≤0.01) BPH under loamy sand and clay soil; respectively. The BPH in oil yield/head ranged from 9.48 to 708.95% and from 3.91 to 66.06% under the two respective environments. Standard heterosis in oil yield/head from the better check cultivar was positive and significant for five hybrids under loamy sand, one hybrid under clay soil and two hybrids in the combined data. Pathak *et al*. (1983) detected negative increases in oil content in sunflower hybrids. However, Kaya (2005) noted heterosis of 288.3% and heterobeltosis of 98% for oil yield.

Habib *et al*. (2006) found high positive heterosis in oil content.

- Breeding implication of heterosis results:

Results of heterosis varied greatly from loamy sand to clay soils environments. Therefore, heterotic effects should be surveyed over a variety of environments to identify the proper hybrids for one or more environments. The present results showed that all the 16 hybrids were significantly earlier, shorter in plant height and lower in husk % from the better check cultivar. It is a good opportunity to identify the proper hybrid for these traits. Standard heterosis from the better check variety in oil % from the combined data was positive and significant for four hybrids, and ranged from 4.47 to 19.83%. Furthermore, oil yield/head showed positive and significant SH for five hybrids, ranged from 3.74 to 20.64% under loamy sand soil, one hybrid under clay soil and two hybrids from the combined data. Respect to seed yield/head, MPH, BPH, and SH as calculated from the combined data indicated that 13,7 and one hybrids; respectively, showed significant heterosis.

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قوة الهجين في محصول البذرة والصفات المتعلقة فى دوار الشمس

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أجرى تقييم 26 تركيب وراثي (16 هجين + أربعه أمهات+ أربعه أباء تحمل جينات معيده للخصوبة +صنفين كونترول هما جيزة 102 وسخا 53) تحت ظروف الأرض الرملية السلتيه في محطه بحوث عرب العوامر– مركز البحوث الزراعية بأسيوط ، والأرض الطينية بكلية الزراعة جامعة أسيوط في موسم 2016 .كانت الفروق بين التراكيب الوراثية معنوية جدا سواء في التحليل المفرد أو المجمع. كذلك كانت الفروق بين البيئتين معنوية لكل الصفات عدا قطر القرص. وكان

التفاعل البيئي الوراثي معنويا لكل الصفات مشيرا إلى اختلاف استجابة التراكيب الوراثية للبيئات . أظهرت صفة التزهير في كل الهجن قوه هجين سالبه ومعنوية جدا من الكونترول جيزة 102 (قوه هجين قياسية) تراوحت من-8.39 الى-18.44%فى الأرض الرملية السلتيه، ومن-2.80 الى-12.92 فى الارض الطينيه. كان تأثير قوة الهجين اعلى في الارض الرمليه السلتيه منه فى الأرض الطينية. وتشير النتائج المجمعة للمنطقتين إلى أن 4،5،12 هجين كانت مبكره معنويا عن متوسط الابين ،والاب الاعلى والكنترول ، على الترتيب. كما ان 15 هجين كانت اقصر معنويا عن الكنترول بقوه هجين تراوحت من -8.42 الى -25.16% ، مما يعطى فرصه جيده لانتخاب هجن قصيره. كما اظهرت كل الهجن قوه هجين قياسيه سالبه بالنسبه لقطر القرص. كما لم يتفوق اى هجين عن الكنترول فى وزن 100 بذره. اضافه الى ان كل الهجن اظهرت قوه هجين قياسيه معنويه جدا لصفه نسبة القشر عن الكونترول سخا53 ، سواء على مستوى المنطقه او النتائج المجمعه. واظهرت اربعه هجن قوه هجين معنويه جدا تراوحت من 4.47 الى 9.83% للبيئتين معا فى نسبه الزيت ، وثلاثه هجن فى وزن اللب وهجين واحد فى عدد البذور فى الراس . كانت قوه الهجين عن متوسط الابين معنويه جدا فى 14 هجين فى الارض الرمليه السلتيه ،13 هجين فى الارض الطينيه، كذلك ثمانيه ، واربعه هجن اظهرت قوه هجين موجبه ومعنويه فى وزن البذره للراس عن الاب الاعلى لنفس البيئتين على الترتيب ، تراوحت من 16.54 الى 685.33% فى التربه الرمليه السلتيه ، ومن 13.42 الى70.38% في الأرض الطينية، في حين اظهر هجين واحد فقط قوة هجين قياسية عن الكونترول سخا 53 في الأرض الطينية وعلى مستوى البيئتين . وبالنسبة لصفة محصول الزيت للراس أظهر 14 هجين قوة هجين موجبة ومعنوية جدا عن متوسط الابين على مستوى البيئتين ، تراوحت من 3.35 الى823.12 % فى الأرض الرملية السلتيه، ومن 3.01 الى151.88% في التربة الطينية. كذلك ثمانية هجن ، وثلاثه هجن اعطت قوة هجين معنويه جدا عن الاب الاعلى فى الارض الرملية السلتيه والطينية ، على الترتيب ، تراوحت من 9.48 إلى 708.95% في الأرض الرملية السلتيه ، ومن 3.91 الى 66.06% فى الارض الطينيه .وبالنسبه لقوه الهجين القياسيه لمحصول الزيت للراس كانت موجبة ومعنوية لخمسة هجن في الأرض الرملية السلتيه، وهجين واحد في الارض الطينية ، وهجينين على مستوى البيئتين .