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SUMMARY

Seven cytoplasmic male sterile (CMS) lines (A-lines) and four fertility restorer lines (RF-lines) of sunflower (*Helianthus annuus* L.) were planted at Assiut Agric. Res. Stn., Agric. Res. Center in summer season 2015, to develop twenty-eight crosses. At harvest, three CMS lines did not give hybrid seeds enough to evaluate at two locations in season 2016. Therefore, sixteen single crosses, four testers, four fertile female lines (B-lines) and two check cultivars; Sakha 53 and Giza 102 were evaluated at two contrasting environments; loamy sand and clay soils. Planting dates were September 10^{th} at Assiut Agric. Res. Stn. (loamy sand soil), and on September 20^{th} 2016 at Fac. Agric. Assiut Univ. Exper. Farm (clay soil). A randomized complete block design with three replications were used. The recommended cultural practices for oil seed sunflower production were adopted throughout the growing season.

Results could be summarized as follows:

1- Evaluation of genotypes

Genotype mean squares of the studied traits were significant ($P \leq 0.01$) either in the separate or in the combined analysis. 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 for all traits.

1.1- Mean days to 50% flowering indicated that the F_1-hybrids, female and male lines were earlier than the two check cultivars, and earlier under loamy sand than under clay soil. Eight hybrids were significantly ($P \leq 0.01$) earlier than the earlier check cultivar Giza 102. The phenotypic and genotypic coefficients of variability were very low, and heritability in broad sense (43.17%) was intermediate.

1.2- Mean plant height of all genotypes was shorter than the two check cultivars, and shorter at loamy sand than at clay soil. The PCV, GCV and broad sense heritability were 13.85, 11.81 and 75.58%; respectively.

1.3- The combined means of HD showed that none of the F_1-hybrids exceeded the better check Giza 102. The GCV was 15.95, 14.41 and 11.84% at loamy sand, clay soil and from the combined analysis. The heritability estimates were high.

1.4- Stalk diameter of all genotypes was thicker under clay than under loamy sand soil, and the check variety Giza 102 was thicker than all the F_1-hybrids except one (A21 x Af5). Heritability estimates of stalk diameter was 74.19, 77.05 and 66.67% under loamy sand soil, clay soil and from combined analysis.

1.5- The combined means of 100-seed weight showed that none of the hybrids was heavier than the checks. The GCV was 27.58, 22.28 and 18.79% under loamy sand, clay soil and from the combined data. Very high estimates of broad sense heritability were recorded.

1.6- Husk % of the hybrids were significantly ($P \leq 0.01$) lower than the better check Sakha 53. Broad sense heritability estimates were 93.45, 96.84 and 47.21% at loamy sand, clay soil and from the combined analysis. Mean of husk weight in 100 seeds were in the same trend of husk %.

1.7- Oil % of all the F_1-hybrids were higher under loamy sand than clay soil, and five hybrids were significantly higher than the better check Giza 102. The GCV of oil % was high (10.11%) at loamy sand soil, medium (6.79%) at clay soil, and very low (1.52%) from the combined analysis. In consequence, the respective heritability estimates were 97.86, 86.25 and 5.69%.

1.8- The combined mean of oil weight in 100-seeds of the F_1-hybrids indicated that one hybrid exceeded significantly ($P \leq 0.01$) the better check Giza 102, and 12 hybrids showed insignificant differences with it. The GCV estimates were high; 28.84, 22.56 and 16.13% accompanied with heritability of 96.07, 93.67 and 44.44% at loamy sand, clay soil and from the combined analysis, respectively.

1.9- The combined means of kernel weight in 100-seeds indicated that three hybrids significant ($P \leq 0.01$) exceeded the better check Sakha 53 (A7 x RF2, A15 x RF2 and A21 x RF5). The GCV's of kernel weight were 30.67, 26.72 and 23.68% accompanied with heritability of 95.51, 96.54 and 77.78% at loamy sand, clay soil and combined analysis, respectively.

1.10- The combined results of NS/H showed that two F_1-hybrids; A7 x RF1 and A7 x RF5 exceeded significantly the better check Giza 102, and eight hybrids showed insignificant differences with it. The GCV was 31.3, 30.31, and 24.01% with heritability estimates of 96.05, 94.3 and 73.21% at loamy sand, clay soil and their combined, respectively.

1.11- Mean seed yield/head was higher at loamy sand than at clay soil. The combined means of the F_1-hybrids indicated that one hybrid (A7 x RF1) significantly exceeded the better check Giza 102, and three F_1-hybrids; A7 x RF5, A15 x RF2 and A21 x RF5 showed insignificant differences with Giza 102 in seed yield/head. The GCV was high and recorded 43.48, 39.33 and 33.57% with heritability of 98.85, 96.67 and 75.22% at loamy sand, clay soil and their combined.

1.12- The combined means of oil yield/head, g showed that the best three hybrids were A7 x RF1 (18.18 g), A7 x RF5 (16.00 g) and A21 x RF5 (16.01 g), compared to 12.05 g for Sakha 53 and 15.43 g for Giza 102. The GCV in oil yield/head was 44.54, 39.34 and 32.33% with heritability estimates of 99, 96.0 and 68% at loam sand, clay soil and their combined, respectively.

2- Phenotypic and genotypic correlations

The phenotypic correlations of SY/H at loamy sand soil were negative and low (-0.245) with days to 50% flowering, and with husk % (-0.2301), while they were positive and high with PH (0.7905), HD (0.924), SD (0.86), NS/H (0.9159) and 100-seed weight (0.8786) and its components [husk weight in 100 seeds (0.8513), kernel weight (0.7875) and oil weight (0.8687)]. Seed yield/head showed low correlation with oil % (0.2631). The genotypic correlation of SY/H with the other traits were in the same direction, but slightly higher than phenotypic correlations. Under clay soil the correlations of SY/H with the other traits were lower than those at loamy sand soil.

The correlations of SY/H based on the combined analysis were high with morphological traits (PH, HD and SD) and very high with 100-seed weight and NS/H, and exceeded unity at genotypic level for four cases (PH, husk weight, oil weight and NS/H) because of the large mean squares of GxE.

The correlations of oil yield/head were low with days to 50% flowering intermediate or low with oil %, and mostly negative with husk % under loamy sand soil, clay soil and combined analysis either at phenotypic or genotypic level. However, they were high with SY/H, NS/H, kernel weight in 100 seeds, oil weight in 100 seeds, husk weight in 100 seeds, SD and HD.

3- Path-coefficient analysis

The direct and indirect effects of the contributing traits of SY/H, varied greatly from loamy sand to clay soil. Considering that the breeder always evaluates the breeding materials under a variety of environments to get reliable estimates of genetic parameters, therefore, the combined estimates of direct and indirect effects of SY/H component traits should be taken in consideration. The results indicated that the direct and indirect effects of the component traits at genotypic level could be ranked as husk weight followed by NS/H, kernel weight and oil weight.

4- Line tester analysis

Separate and combined analyses of variance indicated significant mean squares of genotypes for all traits. Lines and testers mean squares were also significant except four cases, indicating the presence of additive variance. Mean squares of parents vs crosses and lines x testers were significant for all traits except for oil %, indicating the presence of non-additive in the inheritance of these traits. The significant interaction of lines x environments and testers x environments denotes to the interaction of additive x environment for all traits except few cases. The interactions mean squares of LxTxE were significant for all traits except for oil weight in 100 seeds, indicating that non-additive (dominance and epistasis) varied from environment to another.

5- The role of additive and non-additive variances

Results of the combined analysis indicated that the ratio σ^2A/σ^2D was less than unity for all traits, and the role of dominance was more important than the additive effects.

6- General combining ability for males and female lines

The GCA effects for female and male lines varied greatly from trait to another, and none of them could be considered good combiner for most traits.

7- Specific combining ability effects

7.1- The performance of the F_1-hybrids in days to 50% flowering were mostly related to the GCA of the parents rather than the SCA of the hybrids.

7.2- The combined analysis of plant height showed that eight hybrids gave negative SCA effects. All the F_1-hybrids were significantly ($P \leq 0.01$) shorter than the two check cultivars.

7.3- The SCA effects of head diameter based on the combined analysis, indicating that eight hybrids had positive SCA, only two were significant. The best hybrids in head diameter were A15 x RF2 (19.97 cm), A15 x RF5 (19.82 cm), A19 x RF5 (19.17 cm) and A21 x RF5 (21.07 cm).

7.4- The hybrid A21 x RF5 showed positive significant SCA effects for stalk diameter. It gave the best SD (2.20 cm) with insignificant difference with the better check Giza 102 (2.31 cm).

7.5- The SCA effects of 100-seed weight were positive and significant for four combinations (A7 x RF2, A15 x RF2, A19 x RF5 and A21 x RF5). These combinations and another six showed insignificant differences in 100-seed weight with the better check Sakha 53.

7.6- All the F_1-hybrids either showed negative or positive SCA effects for husk % and husk weight in 100 seeds, were significantly lower than the better check Sakha 53.

7.7- Five hybrids (A7 x RF1, A15 x RF3, A15 x RF5, A19 x RF3 and A21 x RF1) gave significant SCA effects for oil %, and significant surpassed the better check Giza 102.

7.8- Twelve hybrids gave oil weight in 100 seeds, did not differ significantly from the better check Giza 102, irrespective of their sign of

SCA, and one hybrid (A21 x RF5) gave oil weight significant exceeded the better check.

7.9- The combined SCA effects of kernel weight was positive and significant for four hybrids, three of them (A7 x RF2, A15 x RF2 and A21 x RF5) exceeded significantly the better check Sakha 53.

7.10- The combined SCA effects of NS/H were positive and significant for two hybrids (A7 x RF1 and A19 x RF2), the first one exceeded significantly ($P \leq 0.01$) the better check Giza 102, while the second did not. There was a weak relation between the SCA effects and the performance of the hybrids.

7.11- The combined SCA effects of SY/H were positive and significant for three hybrids (A7 x RF1, A15 x RF3 and A21 x RF5). The first one yielded 46.45 g/H and exceeded significantly the better check Giza 102 (41.21 g/H). The hybrids performances were not in accordance with the sign and significance of SCA effects.

7.12- The SCA effects of oil yield/head were positive and significant for five hybrids. Only one of them (A7 x RF1) (18.18 g/head) surpassed significantly the better check Giza 102 (15.43 g/H). The other four either lower than or equal to the check cultivars. The performance of the hybrids in oil yield/head was not in accordance to the sign and significance of SCA effects.

8- Heterosis in seed yield and related traits:

Heterosis was measured from the mid-parent (MPH), better parent (BPH) and the better check cultivar for each trait at the two locations and their combined.

8.1- The sixteen hybrids showed significant ($P \leq 0.01$) and negative heterosis in days to 50% flowering from the earlier check Giza 102, ranged from -8.39 to -18.44% under loamy sand, and from -4.49 to -12.29% under clay soil, and eleven hybrids from the combined data ranged from -3.28 to -10.09%.

8.2- All the hybrids were significantly ($P \leq 0.01$) shorter in plant height than the shorter check cultivar Sakha 53 under loamy sand soil, 14 hybrids under clay soil and 15 hybrids from the combined data.

8.3- Significant and positive heterosis in head diameter from the better parent ranged from 3.74 to 28.6% and from 3.00 to 51.52% at loamy sand and clay soil, respectively. However, all the hybrids showed negative heterosis from the better check cultivar Giza 102 in both environments, and 15 hybrids from the combined data.

8.4- Heterosis from the better check Sakha 53 in 100-seed weight was positive and significant for 10 hybrids, and ranged from 3.75 to 24.23% under loamy sand soil. None of the hybrids exceeded significantly the better check in the combined data.

8.5- All the hybrids gave negative and significant SH% in husk % ranged from -10.48 to -29.32%, from -9.42 to -28.43% and from-6.57 to -24.05% at loamy sand, clay soil and their combined, respectively.

8.6- Thirteen hybrids showed positive and significant heterosis from Giza 102 in oil %, and ranged from 5.37 to 16.97% at loamy sand soil, one hybrid (5.26%) at clay soil, and four hybrids ranged from 4.47 to 9.83% for the combined data.

8.7- Heterosis in kernel weight from the better check Sakha 53 was positive and significant for 14 hybrids, and ranged from 1.59 to 77.56% at loamy sand soil, and significant for only two hybrids at clay soil and combined data.

8.8- Mid and better parent heterosis in NS/H was significant for three hybrids at loamy sand soil. However, none of the hybrids showed significant heterosis from the better check under the two environments, but one hybrid (A7 x RF1) showed significant heterosis ($p \leq 0.01$) from the better check for the combined data.

8.9- The BPH in seed yield/head was positive and significant for eight hybrids at loamy sand soil; ranged from 16.54 to 685.33%, and only for three hybrids; A7 x RF1 (70.38%), A7 x RF2 (13.42%) and A21 x RF5 (15.39%). One hybrid; A7 x RF1 gave significant ($P \leq 0.01$) standard heterosis from the combined data.

8.10- The BPH in oil yield/head ranged from 9.48 to 708.95%, from 3.91 to 66.06%, and from27.69 to 213.99% at loamy sand, clay soil and their combined; respectively. Five hybrids showed positive and significant heterosis ($P \leq 0.01$) from the better check, ranged from 3.74 to 20.64% at loamy sand soil, one hybrid; A7 x RF1 (28.95%) at clay soil and two hybrids; A7 x RF1 (17.82%) and A21 x RF5 (3.76% from the combined data.