STABILITY ANALYSIS OF SEED AND OIL YIELDS IN SAFFLOWER GENOTYPES UNDER DIVERGENT ENVIRONMENTS IN EGYPT

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ABSTRACT

The limitation of genetic materials and the genetic background information are two main problems hindering safflower (*Carthamus tinctorius* L.) planting in Egypt. The objectives of the present research were to identify the stability of local and exotic safflower genotypes and to assess the association among stability measures. Six safflower genotypes were cultivated under twelve environments (two locations × three plant densities × two winter seasons). A split-plot arrangement, in randomized complete blocks design with three replications was used. The main plots were devoted to the plant densities and sub-plots to the six genotypes. The used stability parameters were mean squares due to deviations from regression (S^2_d), regression coefficients (b_i) and the three non-parametric measures S^1, S^2 and S^3. On the basis of five different stability measures, the exotic cultivar Demo-137 was the most stable genotype for seed and oil yields ha^{-1} followed by the Line-1697. Highly significant and positive correlations were detected between each pair of (S^1 and S^2) for seed and oil yields ha^{-1} and between (S^2_d and S^3) for oil yield ha^{-1}. Significant and positive association were observed between each pair of (S^2_d and S^1), (S^2_d and S^2) and (S^2 and S^3) for oil yield ha^{-1}. Based on the safflower seed and oil yield performance and adopted stability measurements, the study tends to recommend the genotypes Demo-137 and Line-1697 as stable genotypes can be grown under the current agro-climatic conditions.

Key words: Safflower, Oil crops, Egyptian conditions, and Stability measurements.

INTRODUCTION

Safflower, basically, originated in the Middle East (Knowles, 1976) is considered as one of the promising oil seed crops in Egypt (Abu-Hagaza *et al.* 2009). Genotypes of safflower are growing in more than 60 countries, however half of its production comes from India (Omidi, 2002). The ability of the Egyptian agricultural production sector to sustain the oil production to feed the mountain population is mainly depending upon the sustainability of the triple of genotypes productivity, available space, and agro-economic variables. Currently, Giza-1 is the only safflower cultivar grown in Egypt. This motivated the Egyptian oil production sector to evaluate new safflower genotypes under different Egyptian environments in order to optimize yield simultaneously with the improvement of genotypic stability.

Introductions of the cultivated species can serve to expand the genetic diversity of such crop in developing countries. The selection of a new cultivar involves the evaluation of local and exotic germplasm is key step for cracking the lake of production and genotypes of oil crops in Egypt.

Hamza (2010) found that newly introduced safflower cultivars have contributed to increase productivity by permitting higher yields per unit area compared with the local cultivar and landraces.

On the other hand, justifying the genotype × environment interaction (GEI) is an important determinant when safflower grown under different environmental conditions. The importance of GEI in selecting the widely stable genotypes had studied by many researchers (Abdulahi *et al.*, 2009; Jamshidmoghaddam and Pourdad, 2013 and Shivani and Sreelakshami, 2013). Moreover, various techniques of stability had been extensively studied by many researchers. Finlay and Wilkinson (1963) and Eberhart and Russell (1966) described the regression technique. Moreover, Eberhart and Russell (1966) added the deviation mean squares S^2_d which describe the contribution of genotype to the interaction of G × E. With regard to repeatability of statistical measures, it is worthwhile to consider non-parametric methods such as S^1, S^2 and S^3 (Nassar and Huehn, 1987) which theoretically, are less susceptible to outliers. Correlation coefficients between the different stability parameters were studied by many investigators. Close association between stability parameters (S^2_d and b_i) was detected by Pourdad (2011). Highly significant and positive correlation coefficients were detected between each of S^1, S^2 and S^3 measures (Huehn 1990 and Abdulahi *et al.* 2007).

On the other hand, Weiss (2000) cleared that determination of the optimum plant density is essential to optimize safflower yield especially in the newly reclaimed soils. Many researchers reported that increasing plant density leaded to increase safflower seed and oil yields ha^{-1} (Sharifomghaddasi and Omidi, 2009; Emami *et al*., 2011; Amoughin *et al*., 2012; and Vaghar *et al*., 2014). However, Sharifi *et al.* (2012) showed that increasing plant density of safflower decreased seed and oil yields ha^{-1}. Safflower seed and oil yields were significantly affected by the genotypes (Abu-Hagaza, 1990; Camas *et al.*, 2007; Hamza, 2010 and Vaghar *et al*., 2014). Sharifi *et al.* (2012) reported significant interaction between genotypes and plant densities.

The objectives of the present study were to identify the stability of exotic and local safflower genotypes and to assess the association among stability measures.

MATERIALS AND METHODS

Experimental sites and treatments

Six safflower genotypes presented in Table (1) were sown in yield trials under twelve environments (Table 2); three plant densities (80000, 160000 and 240000 plant ha^{-1}), two winter seasons (2011/2012 and 2012/2013) and two locations belonging to Agricultural Experiments Station, Faculty of Agriculture, Cairo University. These locations were Wadi El-Natroon, El-Beheira Governorate and Giza Governorate.

Table 1. Code, name, characteristics, origin and source of studied safflower genotypes.

Entry code	Name of genotype	Flower color		Spine	Oil content (%)	Origin	Source
		Before fertilization	After fertilization				
1	Giza-1 cv. (middle Egypt)	Yellow	Orange	Very spiny	29.6	Egypt	Agricultural Research Center (ARC), Ministry of Agriculture, Egypt.
2	Bani-Suef (middle Egypt)	Yellow	Red	Very spiny	30.6	Egypt	Somosta center (farmer's seed lots)
3	Aswan (upper Egypt)	Yellow	Orange	Very spiny	28.5	Egypt	Daraw center (farmer's seed lots)
4	Demo-137 cv.	Yellow	Orange	Spiny	33.6	USA	The exotic seeds
5	Line -1697	Orange	Red	Spiny	34.3	Cyprus	were kindly
6	Line -168	Yellow	Red	Spiny	32.1	Turkey	offered by ARC

Table 2. Code, locations characteristics, years and plant densities of tested environments.

Environment code	Location	Altitude	Longitude	Latitude	Planting date	Year	Plant density (1000 plant ha^{-1})
E1	Wadi El-Natroon	45.0 m	30º32' N	29º57' E	15 October	2011-2012	80
E2						2011-2012	160
E3						2011-2012	240
E4						2012-2013	80
E5						2012-2013	160
E6						2012-2013	240
E7	Giza	22.5 m	30°02' N	31°13' E	15 November	2011-2012	80
E8						2011-2012	160
E9						2011-2012	240
E10						2012-2013	80
E11						2012-2013	160
E12						2012-2013	240

Soil and water properties of the two experimental locations are presented in Table (3) and were carried out by the Reclamation and Development Center for Desert Soils, Fac. of Agric., Cairo Univ. Soil of Wadi El-Natroon site was sandy, saline and poor in nutrients (NPK), as well as, organic matter. Irrigation water was saline and poor in nutrients. Soil of Giza site was clay loam, rich nutrients (NPK) and organic matter. Irrigation water was low salt concentration for both seasons.

Under Wadi El-Natroon conditions, single super-phosphate fertilizer (15.5% P_2O_5) at the rate of 72 kg P_2O_5 ha^{-1} was applied uniformly before planting. Nitrogen was added in five doses of rate of 144 kg N ha^{-1}, in the form of ammonium nitrate (33.5% N). The first dose was added 21 days after planting and the rest of doses were applied at a 7-day intervals. Potassium sulphate (50% K_2O) at the rate of 120 kg K_2O ha^{-1} was added in five equal doses at a 7-day intervals. Fertigation system was used in drip irrigation. A mixture of micronutrients was also sprayed four times as a foliar application after thinning at 21-day intervals.

Table 3. Physical and chemical properties of soil and water at experimental locations in 2011-12 and 2012-13 seasons.

Properties	Experimental locations			
	Wadi El-Natroon		Giza	
Soil analysis	**2011-12**	**2012-13**	**2011-12**	**2012-13**
		Physical properties		
Sand %	95.16	94.85	36.5	33.2
Silt %	3.14	4.00	30.2	31.5
Clay %	1.00	1.15	33.3	35.3
Texture	Sandy	Sandy	Clay loam	Clay loam
		Chemical properties		
Soil (pH)	8.23	7.89	7.5	7.7
Ec (ds/m)	7.08	7.23	1.85	1.93
Organic Matter (%)	0.20	0.30	2.33	2.15
Total Ca Co_3 (%)	3.50	2.55	3.40	3.49
Available N (mg kg^{-1})	0.55	0.63	35.4	40.9
Available P (mg kg^{-1})	1.33	1.45	9.00	9.88
Available K (mg kg^{-1})	10	15	210	230
Irrigation water analysis				
Ec of irrigation water (ds/m)	4.0	4.2	0.78	0.86
pH of irrigation water	7.60	7.66	7.02	7.50
Irrigation system	Drip		Flooding	

On the other hand, flooding irrigation system was used under Giza location. Single super-phosphate fertilizer (15.5% P_2O_5) at the rate of 36 kg P_2O_5 ha^{-1} was applied uniformly before planting. Nitrogen was added in three doses of rate of 72 kg N ha^{-1}, in the form of ammonium nitrate (33.5% N). The first dose was added 21 days after planting and the rest of doses were applied at a 21-day intervals. Potassium sulphate (50% K_2O) at the rate of 60 kg K_2O ha^{-1} was added in two equal doses; before planting and flowering. A mixture of micronutrients was also sprayed twice as a foliar application after thinning at 21-day intervals and at the flowering stage.

At harvest, seed yield (kg ha^{-1}) was weighed from the whole area of each sub-plot and adjusted to kg per hectare. Oil yield (kg ha^{-1}) was calculated by multiplying seed-oil percentage by seed yield ha^{-1}. Seed oil percentage was determined according to AOAC (2000).

Experimental design

Experimental design was a split-plot arrangement in randomized complete blocks design, with three replications. The main plots were devoted to the three plant densities. The sub-plots were allotted to the six safflower genotypes. Each sub-plot consisted of 5 rows of 4 m length and 0.60 m width with an area of 12 m^2. Seeds were sown in hills 20, 10 and 7 cm apart, thereafter were thinned to one plant $hill^{-1}$ to give three plant densities (80000, 160000 and 240000 plant ha^{-1}). The analysis of variance for obtained data were analyzed according to procedures outlined by Steel *et al.* (1997) using MSTAT-C computer package (Freed *et al.*, 1989). Test for homogeneity of variance was used to compare between error variances over two years before deciding the validity of combined analysis. Regression techniques were used for the analysis of Genotypes × Environments interaction to estimate S^2_d and b_i by the method of Eberhart and Russell (1966). Huehn (1990) suggested non-parametric measures of phenotypic stability (S^1, S^2 and S^3), which were computed by using the ranks based on corrected values (x_{ij}^*) as follows:

$$x_{ij}^* = x_{ij} - (\bar{x}_{i.} - \bar{x}_{..})$$

$$S^1 = 2\sum |r_{ij} - r'_{ij}| / N\,(N-1)$$

S^1= mean of the absolute rank differences of genotype over the environments.

$$S^2 = \sum \left| r_{ij} - \bar{r}_{i.} \right| / N - 1$$

S^2 = is the common variance of the ranks.

$$S^3 = \sum \left| r_{ij} - \bar{r}_{i.} \right| / \bar{r}_{i.}$$

S^3= sum of absolute deviations of the r_{ij}`s from maximum stability expressed in $\bar{r}_{i.}$. Stability measurements for seed and oil yields were calculated using Gene-Biometrics Computer Package (Cruz, 2006). Simple correlation coefficients were calculated between all possible pairs of stability measures.

RESULTS AND DISCUSSION

Analysis of variance:

Combined analysis of variance based on Eberhart and Russell model presented in Table (4) shows highly significant differences among environment, genotypes, genotypes × environment, environment linear and genotypes × environment linear for seed and oil yields ha^{-1}. Similar trends were obtained by Abdulahi *et al.* (2007), Jamshidmoghaddam and Pourdad (2013) and Shivani and Sreelakshami (2013).

Table 4. Analysis of variance and Stability of seed and oil yields for six safflower genotypes grown in two locations and three plant densities in two years.

S.V	d.f	Mean squares	
		Seed yield	Oil yield
Environments (E)	11	2456654**	245377**
Genotypes (G)	5	1468400**	316982**
Genotype x Environment (GE)	55	184973**	22054**
Environment + (GE)	66	563587**	59275**
Environment Linear	1	27023196**	2699143**
Genotype x Environments Linear	5	438807**	54398**
Pooled deviation	60	132992	15683
Pooled Error	120	78827	8020

**** indicate significance at 1% probability level**

The percent contribution of G, E, GEI in the total sum of squares has been used as an indicator of the total variation attributed to each component, after eliminating the non relevant parts of variation due to replications and experimental error. The percent contribution of seed yield in the total variation was 61, 16 and 22% for E, G and GEI, respectively. Meanwhile, the percents of 49, 29 and 22% were recorded by oil yield for E, G and GEI, respectively. This indicates that the locations had the great impact on seed and oil yields. Moreover, such variation due to either G or GE interactions is a weight of how genotypes respond across environments or the differential response to different environments. GEI for both traits accounted for a relatively equal amount sum of squares. Significant GEI variation for each of both traits allowed for the subsequent analysis of GE interaction. Moreover, the safflower producer can exploit such variation and maximizing the genotype performance for each environment or a collection of similar environments. Similar trends were obtained by Abdulahi *et al.* (2007), Jamshidmoghaddam and Pourdad (2013) and Shivani and Sreelakshami (2013).

Exploring the nature of GE interaction

Averages of seed and oil yields and ranks for the six safflower genotypes across the tested environments are presented in table (5). The difference between the highest and lowest genotypic values overall environments was 1661.9 and 648.6 kg ha^{-1} for seed and oil yields, respectively, that is quite large and reflect the location and seasonal effects in the genotypes used. The changes in genotypes ranks from one environment to another indicating the presence of high crossing over GE interaction. Genotypes (Line-168 and Line-1697) were among the highest order for at least five environments for seed yield and Line-168 at seven environments for oil yield. Line-168 recorded a good performance in E12 and E10 (2833.3 and 952.6 kg ha^{-1}) for seed and oil yields, respectively. However it was the lowest performance in E7 and E3 (2050.0 and 595.8 kg ha^{-1}) for seed and oil yields, respectively. When genotypes actually change, ranking from environment to environment this is often called “crossing over” or dynamic type of stability effect (Baker, 1990).

Table (5) also, shows which environments have the most variable yields. Environments of E9, E11 and E12 have relatively high average yields for seed and oil. Such difference in environments signals to the breeder something very important and needs to be discovered. These differences will pose serious problem to production and breeding programs and limits choice of location which is most suitable to selected genotypes. This argument reflects the importance of understanding the type and magnitude of GE interaction in safflower production and breeding programs carried out under Egyptian conditions in order to select a highly performance and genotypically stable genotype.

Table 5. Genotype × Environment interaction and ranks of seed and oil yields (kg ha^{-1}) of six safflower genotypes grown in twelve environments.

Env. / G.	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	Mean
						Seed yield (kg ha-1)							
Giza-1	1257.1(5)	1452.4(6)	2452.4(2)	1190.5(5)	1795.2(6)	1961.9(5)	1921.4(3)	2252.4(4)	2471.4(6)	1795.2(2)	2666.7(2)	2388.1(5)	**1967.1**
Bani-Suef	1738.1(2)	1961.9(3)	2333.4(4)	1785.7(3)	2142.9(4)	2338.3(4)	1302.4(6)	1571.4(6)	2495.2(5)	1529.5(5)	2595.2(4)	2397.6(4)	**2016**
Aswan	1404.8(4)	1880.9(5)	2390.5(3)	1171.4(6)	1842.9(5)	1952.4(6)	1326.2(5)	2128.6(5)	2547.6(4)	1426.2(6)	2066.7(6)	2373.8(6)	**1805.2**
Demo-137	1547.6(3)	1902.4(4)	2476.2(1)	1964.3(2)	2157.1(3)	2366.7(3)	2135.7(1)	2423.8(2)	2695.2(3)	1702.4(3)	2609.5(3)	2750.0(3)	**2227.6**
Line -168	2071.4(1)	2309.5(1)	2185.7(6)	2064.8(1)	2209.5(2)	2504.8(1)	2050.0(2)	2261.9(3)	2759.5(2)	2642.9(1)	2509.6(5)	2833.3(2)	**2366.9**
Line -1697	1223.8(6)	2019.0(2)	2333.3(5)	1666.7(4)	2263.3(1)	2481.0(2)	1540.5(4)	2452.4(1)	2933.3(1)	1619.1(4)	2678.6(1)	2847.6(1)	**2171.5**
Mean	**1540.5(12)**	**1921.0(8)**	**2361.9(4)**	**1640.6(11)**	**2068.5(7)**	**2267.5(5)**	**1712.7(9)**	**2181.7(6)**	**2650.4(1)**	**1785.9(10)**	**2521.0(3)**	**2598.4(2)**	**2104.2**
Env. Index	-551.9	-171.3	269.6	-451.8	-23.9	175.2	-379.7	89.4	416.5	-306.5	428.6	506.0	
						Oil yield (kg ha-1)							
Giza-1	368.7(5)	387.6(6)	648.2(2)	318.9(5)	456.2(6)	489.9(5)	611.2(3)	691.7(4)	733.0(4)	563.7(3)	824.2(4)	703.3(4)	**566.4**
Bani-Suef	501.5(2)	563.8(3)	624.0(3)	514.2(3)	559.3(4)	606.9(4)	412.3(5)	469.3(5)	695.5(6)	476.0(4)	758.2(5)	665.5(5)	**570.5**
Aswan	418.2(4)	492.5(5)	622.0(4)	304.0(6)	479.6(5)	485.1(6)	394.4(6)	613.3(6)	710.9(5)	418.2(5)	583.0(6)	641.9(6)	**493.7**
Demo-137	464.7(3)	541.3(4)	718.6(1)	567.8(2)	601.6(3)	642.1(2)	739.3(1)	819.9(1)	877.5(3)	582.6(2)	885.0(1)	887.0(3)	**693.9**
Line -168	645.5(1)	678.1(1)	595.8(6)	603.6(1)	626.8(2)	663.4(1)	728.0(2)	769.9(3)	915.9(1)	952.6(1)	853.5(3)	938.5(1)	**747.6**
Line -1697	356.1(6)	585.8(2)	621.5(5)	488.8(4)	641.2(1)	637.2(3)	507.3(4)	787.1(2)	911.1(2)	532.9(6)	860.8(2)	889.5(2)	**651.6**
Mean	**459.1(12)**	**541.5(10)**	**638.4(5)**	**466.2(11)**	**560.8(9)**	**587.4(7)**	**565.4(8)**	**691.9(4)**	**807.3(1)**	**587.7(6)**	**794.1(2)**	**787.6(3)**	**624**
Env. Index	-161.5	-79.1	17.7	-154.4	-59.8	-33.2	-55.2	71.2	146.9	-33.0	173.5	167.0	

Eberhart and Russell (1966) explained that the ideal genotype is one which has the highest mean performance, a regression coefficient (b_i) value does not differ significantly from one and S^2_d does not differ significantly from zero. Mean performance, mean squares due to deviations from regression (S^2_d), regression coefficient (b_i) and non-parametric measures of S^1, S^2 and S^3 are calculated and presented in Table (6).

Table 6. Mean of seed and oil yields (kg ha^{-1}), S^2_d, b_i, S^1, S^2 and S^3 for six safflower genotypes.

Genotypes	Mean	S^2_d	b_i	S^1	S^2	S^3
		Seed yield (kg ha^{-1})				
Giza-1	1967.0	29011.70*	1.19	1.50	1.72	2.84
Bani-Suef	2016.0	38929.13**	0.95	1.53	1.84	3.41
Aswan	1805.2	32086.55*	0.91	2.02	2.93	5.38
Demo-137	2227.6	-3641.12	0.99	1.52	1.97	6.77
Line -168	2366.9	17475.30	0.52	2.18	3.52	5.60
Line -1697	2171.6	-5531.79	1.45	2.11	3.17	5.22
		Oil yield (kg ha^{-1})				
Giza-1	566.4	1131.75	1.29	2.09	3.33	4.73
Bani-Suef	570.5	3295.15*	0.61	2.09	3.42	4.80
Aswan	493.7	2717.72*	0.66	2.03	2.97	5.40
Demo-137	693.9	158.02	1.19	1.59	1.90	4.57
Line -168	747.6	7290.44**	0.82	2.26	4.02	6.62
Line -1697	651.6	734.14	1.43	1.82	2.42	4.36

*** and ** significant and highly significant different from 0.0 for the deviation mean squares at 0.05 and 0.01 levels of probability, respectively. S^2_d = Mean squares due to deviations from regression, b_i = Regression coefficient. S^1, S^2 and S^3 = Non-parametric measures.**

Results in Table (6) reveals that averages seed yield (kg ha^{-1}) for safflower genotypes ranged from 1805.2 kg for the land race Aswan to 2366.9 kg for the exotic Line-168. Values of S^2_d ranged between -5531.79 for the exotic Line-1697 to 38929.13 for the land race Bani-Suef. Only one genotype (Bani-Suef) exhibited highly significant S^2_d value. The two genotypes (Giza-1 and Aswan) were significant. Regression coefficient (b_i) ranged between 0.52 for Line-168 to 1.45 for Line-1697. None of the coefficients was significant. Figure (1A) reveals that line-1697 that enclosed by the upper portion circle exhibited seed yield greater than the grand mean and regression coefficient greater than one, therefore, it would be more adapted to grow under environments of favorable conditions (positive environmental index) or that of high input environments.

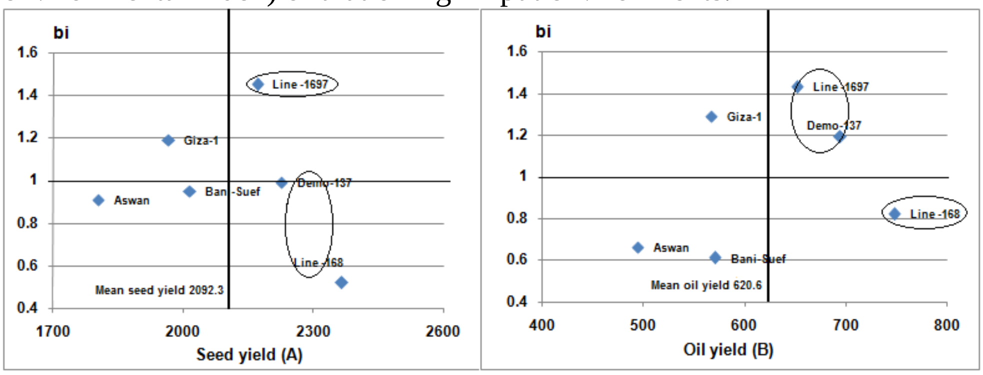

Figure 1. Safflower seed (A) and oil (B) yields ha^{-1} for six genotypes averaged over twelve environments

On the other hand, genotypes enclosed by lower portion circle exhibited regression coefficient smaller than one and mean performance greater than the grand mean. These genotypes would be more adapted to grow under unfavorable growth conditions (negative environmental index). Genotypes (Line-1697, Demo-137 and Line-168) were high mean seed yield and non-significantly different from a unit regression coefficient ($b_i = 1$) and had small non-significant deviation from regression (s^2_d). Thus, they possessed average (ideal) stability and highly predictive behavior and can be grown in the studied range of environmental conditions. The non-parametric stability measures (S^1, S^2 and S^3) showed that Giza-1 cv. exhibited the lowest values of S^1, S^2 and S^3 followed by Bani-Suef for S^2 and S^3, as well as, Demo-137 for S^1. Based on parametric and non-parametric stability measurements, it could be concluded that the exotic cultivar Demo-137 was the most stable genotypes for seed yield ha^{-1}.

Results in Table (6) shows that the oil yield (kg ha^{-1}) for safflower genotypes ranged from 493.7 kg for Aswan to 747.6 kg for Line-168. The Line-168 exhibited highly significant S^2_d value, the two genotypes (Bani-Suef and Aswan) exhibited significant S^2_d. Values of S^2_d ranged between 158.02 for Demo-137 (more stable) to 7290.44 for Line-168. Regression coefficient (b_i) ranged from 0.61 for Bani-Suef to 1.43 for Line-1697. All genotypes exhibited insignificant regression coefficient.

Figure (1B) reveals that genotypes enclosed by the upper portion circle exhibited safflower oil yields greater than the grand mean and regression coefficient greater than one. Thus, it would be more adapted to grow under environments of high input environments. On the other hand, Line-168 exhibited regression coefficient smaller than one and mean performance greater than the grand mean. This genotype would be more adapted to grow under unfavorable growth conditions. Genotypes (Line-168 and Demo-137) were high mean oil yield and non-significantly different from a unit regression coefficient ($b_i = 1$) and had small non-significant deviation from regression (S^2_d). Thus, they possessed average stability and highly predictive behavior and could be considered ideal, since they maintained good performance in environments with low oil yield inputs.

On the other hand, significance of S^2_d from zero associated with genotype Line-168 invalidates the linear prediction. This genotype had the top mean oil yield, S^2_d deviated significantly from zero and regression coefficients less than one, thus it was regarded as sensitive to environmental changes, and one may not be able to comment on its stability from Eberhart and Russell's model point of view. Regarding the non-parametric measures (S^1, S^2 and S^3), genotype Demo-137 exhibited the lowest values of S^1 and S^2 followed by Line-1697. Also, Line-1697 exhibited the lowest value of S^3. Based on the safflower oil performance, a parametric and non-parametric measurements of stability, genotype Demo-137 and Line-1697 were considered as wide stable for the studied growing conditions.

Simple correlation coefficients:

Rank correlations among the stability parameters ranged from low to high in magnitude (Table 7). Results indicate that highly significant and positive correlation coefficients were detected between the pair (S^1 and S^2) for seed yield ha^{-1}, and each pair of (S^2_d and S^3) and (S^1 and S^2) for oil yield ha^{-1}, which indicates that any of these parameters could be a satisfactory parameters for measuring stability. Therefore, significant and positive associations were observed between (S^2_d and S^1), (S^2_d and S^2), as well as, (S^2 and S^3) for oil yield ha^{-1}. Results in Table (7) clear that S^2_d and other stability parameters could be used in addition to mean oil yield by safflower breeders in the selection process when G × E interaction is present. Similar trends were obtained by Huehn, (1990), Abdulahi, *et al.* (2007) and Pourdad (2011).

Table 7. Spearman correlation coefficients between the stability parameters (Index I vs. Index II) for seed and oil yields of safflower.

Index I	Index II	Seed yield (kg ha^{-1})	Oil yield (kg ha^{-1})
$\bar{x}$	S^2_d	-0.63	0.32
$\bar{x}$	b_i	-0.29	0.31
$\bar{x}$	S^1	0.26	-0.14
$\bar{x}$	S^2	0.37	-0.01
$\bar{x}$	S^3	0.48	0.33
S^2_d	b_i	-0.35	-0.63
S^2_d	S^1	-0.24	0.80*
S^2_d	S^2	-0.29	0.84*
S^2_d	S^3	-0.69	0.94**
b_i	S^1	-0.21	-0.53
b_i	S^2	-0.28	-0.53
b_i	S^3	-0.25	-0.54
S^1	S^2	0.99**	0.99**
S^1	S^3	0.41	0.70
S^2	S^3	0.48	0.73*

*** and ** significant and highly significant at 0.05 and 0.01 levels of probability, respectively.**
$\bar{x}$ = Mean, S^2_d = Mean squares due to deviations from regression, b_i = Regression coefficient,
S^1, S^2 and S^3 = Non-parametric measures.

REFERENCES

Abdulahi, A., R. Mohammadi and S. S. Pourdad (2007). Evaluation of safflower (*Carthamus tinctorius* L.) genotypes in multi environment trails by nonparametric methods. Asian J. plant Sci. 6(5): 827-832.

Abdulahi, A., S. S. Pourdad and R. Mohammad (2009). Stability analysis of seed yield in safflower genotypes in Iran. Acta Agronomica Hungarica 57(2): 185–195.

Abu-Hagaza, N. M. (1990). Variability and inter-relationships between economic characters in safflower. Proc. 4th conf. Agron., Cairo Univ. Fac. Agric., II, pp. 1-12.

Abu-Hagaza, N. M., N. M. Mahrous, S. A. Mohamed and M. H. Abd El-Hameed (2009). Response of some promising safflower genotypes to nitrogen levels under drip irrigation in Wadi El-Natroon. Egypt. J. Plant breed. 13: 183-198.

Amoughin, R. S., A. Tobeh and S. J. Somarin (2012). Effect of plant density on phenology and oil yield of safflower herb under irrigated and rainfed planting systems. J. Medicinal Plants Res. 6(12): 2493-2503.

A.O.A.C. (2000). Official methods of analysis of A.O.A.C. International. 17th ed. by Horwitz, W. Suite (ed.) Vol. (2), chapter (41): 66-68.

Baker, R. J. (1990). Cross over genotype-environmental interaction in spring wheat. In: Genotype-by-Environment interaction and Plant breeding. Kang, M. S. (Eds.), Department of Agronomy, Louisiana, Agric. Exp. Sta., LSU, Agricultural Center, Baton Rouge, LA. Pp. 42-51.

Camas, N., C. Cuneyt and E. Enver (2007). Seed yield, oil content and fatty acids composition of safflower (*Carthamus tinctorius* L.) grown in northern Turkey conditions. J. Fac. Agric. OMU, 22 (1): 98-104.

Cruz, C. D. (2006). Programe Gene-Biometrics. 1st ed. Vicosa, MG (Eds.), v.1. 382 p.

Eberhart, S. A. and W. A. Russell (1966). Stability parameters for comparing varieties. Crop Sci. 6: 36-40.

Emami, T., R. Naseri, H. Falahi and E. Kazemi (2011). Response of yield, yield component and oil content of safflower (cv. Sina) to planting date and plant spacing on row in rainfed conditions of Western Iran. American-Eurasian J. Agric. Environ. Sci. 10(6): 947-953.

Finlay, K. W. and G. N. Wilkinson (1963). The analysis of adaptation in a plant breeding programme. Aust. J. Agric. Res. 14: 742-754.

Freed, R. S. P., S. Einensmith, S. Gutez, D. Reicosky, V. W. Smail, and P. Wolberg (1989). MSTAT-C analysis of agronomic research experiments. Michigan Univ. East Lansing, USA.

Hamza, M. (2010). Response of some promising safflower genotypes to different nitrogen levels under modern irrigation systems in newly reclaimed soils. Ph.D thesis, Cairo Univ. Fac. Agric. Egypt, 134 p.

Huehn, M. (1990). Nonparametric measures of phenotypic stability. Part 2: Applications. Euphytica 47: 195-201.

Jamshidmoghaddam, M. and S. S. Pourdad (2013). Genotype × environment interactions for seed yield in rainfed winter safflower (*Carthamus tinctorius* L.) multi-environment trials in Iran. Euphytica 190: 357-369.

Knowles, P. F. (1976). Safflower germplasm: Domesticated and wild. Calif. Agric. 31(9): 12-13.

Nassar, R. and M. Huehn (1987). Studies on estimation of phenotypic stability: test of significance for nonparametric measures of phenotypic stability. Biometrics 43: 45-53.

Omidi, T. A. H. (2002). Floret removal effects on grain and oil yield and their components in spring safflower. Sesame Safflower Newsl. 17: 71-75.

Pourdad, S. S. (2011). Repeatability and relationships among parametric and non-parametric yield stability measures in safflower (*Carthamus tinctorius* L.) genotypes. Crop Breed. J. 1(2): 109-118.

Sharifi, S., M. Naderidarbaghshahi, A. Golparvar and A. H. Nayerain-Jazy (2012). Effect of plant density on the PAR extinction coefficient and yield of safflower cultivars.Technical J. Engineering and Applied Sci. 2(8): 223-227.

Sharifmoghaddasi, M. R. and A. H. Omidi (2009). Determination of optimum row-spacing and plant density in Goldasht safflower variety. Advan. Environ. Biology 3(3): 233-238.

Shivani, D. and C. Sreelakshmi (2013). Studies on genotype x environment interaction and stability parameters in safflower. Electronic J. of Biosciences 1(2): 50-53.

Steel, R. G. D., J .H. Torri and D. A. Dickey (1997). Principles and Procedures of Statistics: A Biometrical Approach, 3rd ed,. Mc Graw-Hill, New York. 666p.

Vaghar, M. S., K. Shamsi, S. Kobraee and R. Behrooz (2014). The effect of planting row interval and plant density on the phonological traits of safflower (*Carthamus tinctorius* L.) under dry land condition. Intl. J. Biosciences 4(12): 202-208.

Weiss, E. A. (2000). Oilseed Crops, 2nd ed., Blackwell Science, Oxford, Ch.: 4, pp. 93-129.

تحليل الثبات لمحصول البذرة والزيت لبعض التراكيب الوراثية من القرطم تحت بيئات متباعدة في مصر

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تواجه زراعة القرطم في مصر مشكلتان رئيسيتان قلة التراكيب الوراثية وكذلك المعلومات الأساسية عن التركيب الوراثي. يهدف هذا البحث إلى التعرف على ثبات ثلاثة تراكيب وراثية محلية وثلاث مستوردات من القرطم. زرعت التراكيب الوراثية الستة في 12 بيئة عبارة عن موقعين تابعين لكلية الزراعة، جامعة القاهرة وهما محطة البحوث الصحراوية بوادي النطرون ومحطة بحوث الجيزة وثلاث كثافات نباتية (80000، 160000، 240000 نبات هكتار $^{-1}$) وموسمين شتويين متتاليين (2011- 2012 و2012-2013). استخدم تصميم القطع المنشقة مرة واحدة في ثلاث مكررات، حيث وضعت الكثافات النباتية في القطع الرئيسية والتراكيب الوراثية في القطع المنشقة. اجري تحليل الثبات لمحصول البذرة والزيت (هكتار $^{-1}$) باستخدام مقاييس الثبات التالية: متوسط مربعات الانحرافات عن خط الانحدار (S^2_d)، معامل الانحدار (b_i)، وثلاثة مقاييس لا معلمية هي (S^1, S^2, S^3) وتم تقدير تقدير مدي قوة التلازم بين هذه المقاييس الخمسة. اظهرت النتائج تفاعلا معنويا بين التراكيب الوراثية والبيئات وان الصنف المستورد ديمو- 137 كان أكثر التراكيب الوراثية ثباتاً لمحصول البذور والزيت يليه السلالة- 1697. وأظهرت نتائج الارتباط بين مقاييس الثبات ارتباطا موجباً وعالي المعنوية بين المقاييس اللا معلمية (S^1 وS^2) لمحصولي البذرة والزيت، وكذلك بين متوسط مربعات الانحرافات عن خط الانحدار (S^2_d وS^3) لمحصول الزيت. ايضا لوحظ ارتباط معنوي موجب بين (S^2_d وS^1)، (S^2_d وS^2) وكذلك بين (S^2 وS^3) لمحصول الزيت. وبناءاً علي آداء وثبات التراكيب الوراثية من القرطم لمحصولي البذور والزيت توصي هذه الدراسة بزراعة التركيبين الوراثيين المستوردين ديمو- 137 والسلالة- 1697 تحت مدي البيئات موضع الدراسة.