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Genetic yield stability in some sunflower (*Helianthus annuus* L) hybrids under different environmental conditions of Sudan

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Nineteen locally developed sunflower (*Helianthus annuus* L.) hybrids and an introduced one (Hysun 33) were evaluated at two irrigated locations, New Halfa and Rahad for two consecutive seasons (2003/04 and 2004/05) in order to estimate stability of performance for seed yield per ha (t). A randomized complete block design with four replicates was applied at each location. Data on seed yield was collected. The variance of genotype x environment interaction (GxE) was highly significant, suggesting that the yield of the hybrids was inconsistent in different environments. The average ranking of the 20 hybrids, according to stability parameters showed that Salih was the first ranked hybrid followed by Ka99x7, Ka99x29, Ka99x13 and Shambat 6, whereas Hysun33 was the last ranking one. The two released hybrids (Salih and Shambat 6) were adapted favorable environments, whereas Ka99x25-2 adapted unfavourable conditions. However, the graph for scatter points for yield of the locally developed hybrids revealed that Salih and Shambat 6 were stable, whereas that of Hysun 33 was unstable under these environments and its yield was only increased with improving the conditions.

Key words: Sunflower, hybrids, yield, GxE interaction, stability.

INTRODUCTION

In Sudan, commercial production of sunflower was initia-ted in the 1987/1988 season. The production of the crop dropped from 8 thousand tons in 1999/2000 to 4 thou-sand tons in 2000/2001 season with an average yield of 0.39 t/ha and 0.73 t/ha, respectively. In the following two seasons (2001/2002 and 2002/2003) the production increased to 18 thousand tons with an average yield of 1.5 t/ha. Khidir (1997) summarized the major problems facing sunflower production in the Sudan to be, lack of adequate information about the crop under Sudan condi-tion, mal distribution and fluctuation of rains, a high per-centage of empty seeds particularly in non-hybrid varie-ties, the difficulty in finding good seeds and high yielding cultivar, importing of hybrid seeds from over-seas lead to high cost of production and the damages caused by birds and termites. Plant breeders

Generally agree on the importance of high yield stabi-

lity, but there are fewer consensuses on the most appro-priate definition of stability and on methods to measure and to improve yield stability. Stability in performance is one of the most desirable properties of a genotype to be released as a cultivar for wide range of application. The significance of genotype xenvironment (GxE) interaction in variety evaluation programme is well recognized (Miller et al., 1958). Finlay and Wilkinson (1963) pointed out that the slope of the linear regression (b_i) of the yield (Y_{ij}) of jth genotype and jth environment, on the mean yield (y.j) of all the genotypes in jth environment is helpful in testing the genotypic stability. They pointed that a genotype which has a $b_i = 1$ has average stability but genotypes which have slope greater than one and less than one are below and above average stability respectively. In addi-tion to the bi, the deviation mean square (^2d) which des-cribes the contribution of genotype to the GxE interaction is used (Eberhardt and Russell, 1966). Both statistics are used in different ways to assess the reaction of geno-types to the varying environments. The ^2d is strongly related to the remaining unpredictable part of variability of

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Table 1. Pedigree of tested sunflower hybrids.

Entry No.	Parents	Hybrids
1	R 1 (Male)	Ka99x 1
2	R5 (Male)	Ka 99 x 5 (Salih)*
3	R 6 (Male)	Ka 99x 6 (Shambat 6)*
4	R 7 (Male)	Ka 99 x 7
5	R 11 (Male)	Ka 99 x 11
6	R 13 (Male)	Ka 99 x 13
7	R 15 (Male)	Ka 99 x 15
8	R 17 (Male)	Ka 99x 17
9	R 18 (Male)	Ka 99x 18
10	R 22 (Male)	Ka 99 x 22
11	R 25-1 (Male)	Ka 99 x 25-1
12	R 25-2 (Male)	Ka 99 x 25-2
13	R 29 (Male)	Ka 99 x 29
14	R 30 (Male)	Ka 99 x 30
15	R 32 (Male)	Ka 99 x 32
16	R 35 (Male)	Ka 99 x 35
17	R 37 (Male)	Ka 99 x 37
18	R 41 (Male)	Ka 99 x 41
19	R 42M (Male)	Ka 99 x 42 M
20	Ka99 (Female)	
21	Hysun 33	Commercial hybrid

*Newly released hybrids

any genotype and is, therefore, considered a response of genotypes to environmental effects and may be regarded as a response parameter. According to Wricke (1962), a genotype with small values of ecovalance (Wi) and/or deviation from regression line (^{2}d) was a stable one and hence it contributed least to GxE interaction. Bange et al. (1997) pointed out that the potential yield of sunflower is highly dependent on environmental conditions throughout the life of the crop.

Becker and Leon (1988) stated that successful new hybrids must show good performance for yield and other essential agronomic traits, their superiority should be reliable over a wide range of environmental conditions. Therefore, the objective of this study was to evaluate 19 locally developed sunflower hybrids and an introduced one (Hysun33) under different irrigated environments with aim of estimating GxE interaction and identifying stable hybrids for yield.

MATERIALS AND METHODS

Locations

This trial was carried out at two locations, Faculty of Agriculture and Natural Resources at New Halfa (Lat.15°19´ N, Long. 35°36´ E and Alt. 450m above the sea level), Eastern Sudan. The soil is calcareous, alkaline in reaction (pH 8.3), nonsaline, nonsodic and moderately fertile. The climate is semi arid with mean annual rainfall of about 200 mm and maximum temperature of about 42°C in summer and 21°C in winter, and at Rahad Agricultural Research Station

Farm (Lat. 13° 31´N, Long. 34°32´ E and Alt. 411 m above the sea level). The Farm lies in the central clay plains of the Sudan. The soil is Vertisol with about 70% clay of low water permeability, high water holding capacity and with very low nitrogen and organic matter content. The climate is poor Savanna with mean annual rainfall of about 300 mm and maximum temperature of about 40° C in summer and 20°C in winter. At both locations, irrigation water was provided at ten days interval. At each location, the trial was carried out in summer and winter seasons, that is, four environments.

The plant material

The plant materials used in the study (Table 1) consisted of 19 single cross (F1) hybrids of sunflower (*Helianthus annuus* L.) derived from crossing nineteen locally generated restorer lines with one exotic male-sterile line (Ka99). Crossing was made by hand pollination at the University Farm, Faculty of Agriculture, University of Khartoum, at Shambat (Lat. 15° 46 N, Long. 32° 32 E and Alt. 380 m above the sea level) during winter season of 2003. Two of the resulting hybrids, recently released under the commercial names "Salih" and "Shambat 6" as well as the standard commercial hybrid "Hysun 33" were evaluated at the four mentioned environments.

Experimental procedures and data analysis

A randomized complete block design with four replicates was used for laying out the field experiment. Each block was divided into 20 plots, to which the hybrids were assigned randomly. The plot dimensions were six meters length and three meters width. Each accession was presented by four ridges, each six meters long and 0.70 m apart. Three seeds were sown in holes of 0.20 m distance along the ridge, and then thinned to one plant per hole, three

Table 2. Mean of squares from the combined analysis of Gx E interaction of seed yield (t/ha) for the 20 hybrids evaluated at the four environments.

Source of variation	df	Mean of squares
Genotypes (G)	19	2.382**
Environments (E)	3	129.320***
GxE	57	0.835**
Pooled error	228	0.517

** significant at P 0.01. *** significant at P 0.001

weeks after sowing. At New Halfa, sowing date was on 9th July 2003 for summer season and 27th October 2004 for winter. At Rahad, the sowing was on 20th July 2003 for the summer season and 2nd December 2004 for the winter season. Data was collected on seed yield per area unit (t/ha) according to the following equation:

$$\text{Seed yield /ha (t)} = \frac{\text{seed weight (kg / plot) x 10000 m}_2}{\text{Plot area (m}^2\text{) x 1000}}$$

The data from the four environments were subjected to the combined analysis of variance to estimate the variance of genotype x environment interaction (Gomez and Gomez, 1984). Stability of performance for the tested hybrids was carried out following Eberhardt and Russell (1966) procedure. Moreover, the stability of performance for yield was estimated for the twenty hybrids over the four environments using the formula suggested by Wricke (1962) as follows:

$$W_i = \quad (Y_{ij} - Y_{i.} - Y.j + Y.)$$

Where;

W_i = Wricke ecovalance
Y_{ij} = mean yield of the ith genotype in the jth environment $Y_{i.}$ = mean of the ith genotype
$Y.j$ = mean of the jth environment
$Y.$ = over all mean

Expected yield of the Ith genotype in j^{th} environment was calculated by the formula suggested by Eberhardt and Russell (1966) as:

$$\acute{Y}_{ij} = X_i + b_i I_j$$

Where:

$\acute{Y}_{ij}$ = expected yield of ith genotype in j^{th} environment. X_i = the mean yield of a genotype over environments
b_i = coefficient of regression line and was calculated as:

$$b_i = \quad _j Y_{ij} I_j / \quad _j I_j^2$$

Where:

$_j Y_{ij} I_j$ = the sum of the products
$_j I_j^2$ = the sum of squares.
I_j = environmental index.

The environmental index I_j for I^{th} environment is defined as the deviation of the mean of all the genotypes at a given location from the overall mean, and was calculated as:

$$I_j = [\{ \quad I Y_{ij} \} / g - \{ \quad _I \quad _j Y_{ij} \}_{/ gn]} \text{ with } \quad _i I_j = zero$$

Where:

g = number of genotypes and n = number of environments

Moreover, a scatter graph of the stability was also plotted to estimate the stability of performance for the yield. The abscissa was marked with yield levels (μ), and the ordinate with regression coefficients (b_i). Observed yield of a given hybrid was then plotted against its b_i value. The two vertical lines on the graph present the values $\mu \pm$ ^{and} the horizontal ones denote the values $b \pm$.

RESULTS AND DISCUSSION

Seed yield (t/ha) showed highly significant relationship (P $\leq$ 0.01) of genotype x environment interaction (Table 2), suggesting an inconsistency in the performance of the hybrids across the four environments. Therefore, there is a need for assessing stability of performance for each of the twenty hybrids in order to identify hybrids with superior yield. These results are inconformity with those reported by Singh and Yadava (1986) and Bange et al. (1997).

Table 3 shows the means (μ), regression coefficients (b_i), deviation from regression line (^2d) and Wricke ecovalance (W_i)) with ranking (R) for seed yield (t/ha). Ten hybrids had means exceeding the average (3.58 t/ha) by 0.6 - 31.8%. These were Ka99 x7, Ka99 x13, Ka99 x15, Ka99 x17, Ka99 x18, Ka99 x25-2, Ka99 x29, Salih, Shambat 6 and Hysun33. Eleven hybrids had bi around unity with probability level equal to one. These were Ka99 x 1, Ka99 x 7, Ka99x11, Ka99 x 15 , Ka 99 x 18, Ka99 x 25-1, Ka99 x 29, Ka99x30, Ka99 x 37, Salih and Shambat 6. However, none of the twenty hybrids had a bi significantly different from unity. Only two hybrids (Ka99 x 15 and Hysun33) had ^2d significantly different (P 0.05) from zero. More or less a pattern of ranking similar to the observed one based on the bi and ^2d for the hybrids was followed by Wricke ecovalance (Wi).

With respect to stability parameters assessed, hybrids; Ka99 x 1, Ka99 x 7, Ka99 x 13, Ka99 x 17, Ka99 x 29, Salih and Shambat 6 had higher than the average, bi above unity and ^2d not significantly different from zero. They were considered to be below average in stability, so they were sensitive to environmental changes and hence they could be recommended for favorable environment. Hybrid Ka99 x 25-2 was above average in stability, in that it had mean seed yield above the average, bi below unity and ^2d not significantly different from zero. Hence, it

Table 3. Mean yield (μ), regression coefficient (bi), deviation from regression (^2d) and ecovalance (Wi) with ranking (R) on seed yield (t/ha) for the 20 sunflower hybrids evaluated at four environments.

| Hybrid	Mean (μ)	R	bi	R	Probability	d^2	R	Wi	R	Average(R)
Ka99X1	3.46	12	0.891	8	1.000	0.122	17	0.018	7	11
Ka99X7	3.60	10	1.128	12	1.000	0.042	5	0.000	1	2
Ka99X11	3.04	20	0.969	1	1.000	-0.116	15	0.299	19	18
Ka99X13	3.88	4	1.143	14	0.409	-0.037	3	0.085	12	4
Ka99X15	3.66	8	1.050	3	1.000	0.366*	19	0.005	4	7
Ka99X17	3.95	3	1.166	16	1.000	0.093	14	0.134	16	16
Ka99X18	3.74	5	1.111	9	0.337	-0.091	13	0.023	8	8
Ka99X22	3.41	13	0.468	19	0.114	0.059	6	0.032	9	14
Ka99X251	3.13	19	0.872	11	1.000	0.021	1	0.209	17	15
Ka99X25-2	3.64	9	0.676	18	0.288	0.119	16	0.002	3	12
Ka99X29	3.71	7	1.132	13	1.000	0.061	7	0.015	6	3
Ka99X30	3.25	17	0.913	6	1.000	-0.081	11	0.114	13	13
Ka99X32	3.23	18	1.104	7	0.055	-0.126	18	0.127	15	19
Ka99X35	3.33	14	0.840	15	0.365	-0.038	4	0.069	10	10
Ka99X37	3.31	15	1.078	5	1.000	-0.070	9	0.075	11	9
Ka99X41	3.56	11	0.879	10	0.333	-0.085	12	0.001	2	6
Ka99X42M	3.25	16	0.778	17	0.268	-0.026	2	0.114	14	17
Salih	3.71	6	1.036	2	1.000	-0.070	8	0.014	5	1
Shambat 6	4.05	2	1.063	4	1.000	0.080	10	0.213	18	5
Hysunn 33	4.72	1	1.704	20	0.161	0.376*	20	1.275	20	20
Overall mean	3.58									

* significant at P ≤ 0.05

Table 4. Environmental indices (Ii) and expected means (Ý) for seed yield (t/ha) of 5 selected hybrids evaluated at four environments.

Hybrid	Envir. (E)	Index Expected (I) (Ý)	
Ka99 x 7	E₁	1.221	4.970
	E₂	-0.154	3.419
	E₃	0.644	4.319
	E₄	- 1.708	1.666
Ka99 X 18	E₁	1.221	5.098
	E₂	- 0.154	3.570
	E₃	0.644	4.465
	E₄	- 1.708	1.843
Salih	E₁	1.221	4.972
	E₂	-0.154	3.547
	E₃	0.644	4.374
	E₄	-1.708	1.937
Shambat.6	E₁	1.221	5.345
	E₂	-0.154	3.886
	E₃	0.644	4.733
	E₄	-1.708	2.250
Hysun33	E₁	1.221	6.800
	E₂	-0.154	4.456
	E₃	0.644	5.816
	E₄	-1.708	1.809

could be considered as adapted hybrids for unfavorable environmental conditions. However, hybrid Ka99x11, Ka99x15, Ka99x18, Ka99x22, Ka99x25-1, Ka99x30, Ka99x32, Ka99x35, Ka99x37, Ka99x41, Ka99x42M and
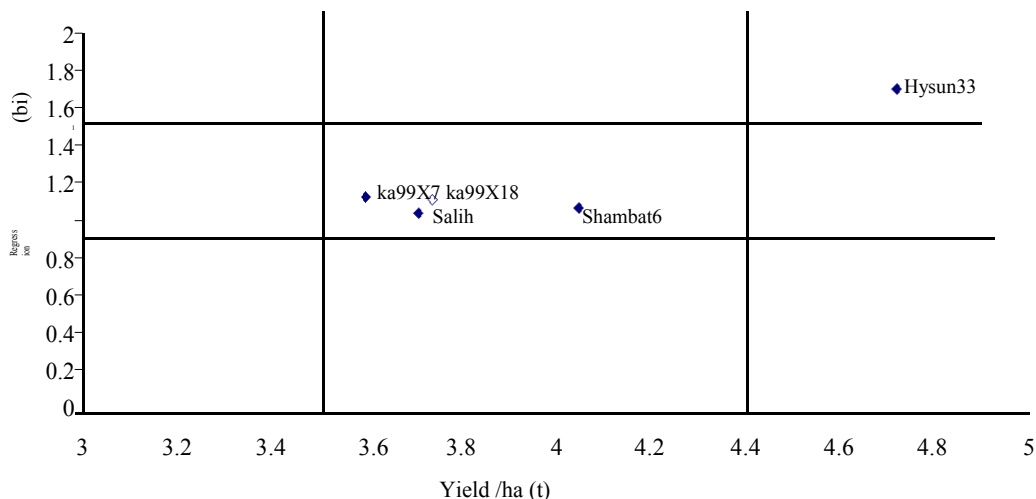
Figure 1. Stability of performance. Scatter graph for yeild (t/ha) on regression coeficients (bi), point for only five hybrids are shown

Hysun33 did not follow a particular pattern. They either had a mean yield below the average or a ^{2}d significantly different from zero and therefore, they were not adapted. From the average ranking of the hybrids, Salih was the first ranked followed by Ka99 x 7, Ka99 x 29, Ka99 x 13 and Shambat 6. These five hybrids had the least contribution to G x E interaction as indicated by their low values of ^{2}d and Wi. Therefore, they are considered as the most stable hybrids in terms of yield.For the sake of simplicity, the four environments, of summer season in New Halfain, winter season in New Halfa, summer season in Rahad and winter season in Rahad, are symbolized as E1, E2, E3 and E4 respectively. The environmental indices (Ii) and the expected means (Ý) for the seed yield (t /ha) of five arbitrary selected hybrids (Ka99 x 7, Ka99 x 18, Salih, Shambat 6 and Hysun33), evaluated at the four environments are depicted in Table 4. As for I_i, E_1, had the highest positive index of 1.221 and hence, it was the most favorable, followed by E_3, then E $_2$. On the other hand, E_4 , recorded the highest negative index of -1.71, and thus it was the poorest one. The highest expected mean yield (Ý) for each hybrid was determined at E_1, whereas the lowest one was determined at E_4. Shambat 6 gave the highest seed yield (t/ha), under unfavorable environmental conditions followed by Salih, Ka99 x 18, and Hysun 33. El-Hity (1994) reported that the indigenous hybrids and the open pollinated crops are higher yielder and more adapted to the local environments than the introduced hybrids. The scatter graph of the stability for the five selected hybrids is shown in Fig.1. It is apparent that while the point for Hysun33 deviated from the zone of interception of the two vertical and the horizontal lines, the points for the locally developed hybrids were within the zone. Moreover, all the points for the locally developed hybrids fall near the lines for Ý ± and that for b¯ ± . Therefore, they were more stable in yield.

Dabholkar (2001) reported that, a point of stable genotype should fall within the zone of interception of the two vertical and horizontal lines of Ý ± and b¯ ± in the scatter graph for estimating stability of performance of a genotype. Based on the results obtained in this study, the following conclusions could be drawn:-

1. The significant genotype x environment interactions for seed yield indicates the importance of evaluating the hybrids at different environments.
2. Salih and Ka99 x 17, are most likely adapted hybrids to favorable environmental conditions whereas, Ka99 x 25-2 is the most stable hybrid for yield under adverse conditions.
3. The yield of the locally developed hybrids is stable under different environmental conditions and less affected by the poor environments, whereas the yield of Hysun33 fluctuated and only increased with improving the environmental conditions.
4. Emphasis should be made on Ka99 x 25-2, since it is stable for yield under adverse environmental conditions and had a wide range of adaptation.

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