A study on 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 initiated in the 1987/1988 season. The production of the crop dropped from 8 thousand tons in 1999/2000 to 4 thousand 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 condition, mal distribution and fluctuation of rains, a high percentage of empty seeds particularly in non-hybrid varieties, 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 stability, but there are fewer consensuses on the most appropriate 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 x environment (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 (bi) of the yield (Yij) 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 bi = 1 has average stability but genotypes which have slope greater than one and less than one are below and above average stability respectively. In addition to the bi, the deviation mean square (2d) which describes 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 genotypes to the varying environments. The 2d is strongly related to the remaining unpredictable part of variability of
Table 1. Pedigree of tested sunflower hybrids.

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

*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 ecoalvalence (W) and/or deviation from regression line ($d^2$) 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. 450 m 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
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:

\[
\text{Seed yield/ha (t)} = \text{seed weight (kg / plot)} \times 10000 \text{ m}^2 / \text{Plot area} (\text{m}^2) \times 1000
\]

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:

\[
W_i = (Y_{ij} - \bar{Y}_i - \bar{Y}_j + \bar{Y})
\]

Where:

\[
W_i = \text{Wricke ecovalance}
\]

\[
Y_{ij} = \text{mean yield of the } i^{th} \text{ genotype in the } j^{th} \text{ environment}
\]

\[
\bar{Y}_i = \text{mean of the } i^{th} \text{ genotype}
\]

\[
\bar{Y}_j = \text{mean of the } j^{th} \text{ environment}
\]

\[
\bar{Y} = \text{overall mean}
\]

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

\[
\hat{Y}_{ij} = X_i + b_i \cdot l_j
\]

Where:

\[
\hat{Y}_{ij} = \text{expected yield of } i^{th} \text{ genotype in } j^{th} \text{ environment}
\]

\[
X_i = \text{the mean yield of a genotype over environments}
\]

\[
b_i = \text{coefficient of regression line and was calculated as:}
\]

\[
b_i = \frac{1}{\bar{l}_j} Y_{ij} \cdot l_j / j \cdot l_j^2
\]

Where:

\[
\bar{l}_j = \text{sum of the products}
\]

\[
l_j = \text{sum of squares}
\]

\[
\bar{l}_i = \text{environmental index}
\]

The environmental index \(l_i\) 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:

\[
l_i = \left[ \sum Y_{ij} / g - \sum \frac{i \cdot \bar{Y}_{ij}}{gn} \right] \text{ with } l_i = \text{zero}
\]

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>df</th>
<th>Mean of squares</th>
</tr>
</thead>
<tbody>
<tr>
<td>Genotypes (G)</td>
<td>19</td>
<td>2.382**</td>
</tr>
<tr>
<td>Environments (E)</td>
<td>3</td>
<td>129.320***</td>
</tr>
<tr>
<td>GxE</td>
<td>57</td>
<td>0.835**</td>
</tr>
<tr>
<td>Pooled error</td>
<td>228</td>
<td>0.517</td>
</tr>
</tbody>
</table>

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

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 (\(\mu\)), and the ordinate with regression coefficients (bi). Observed yield of a given hybrid was then plotted against its bi value. The two vertical lines on the graph present the values \(\mu \pm \sigma\) and the horizontal ones denote the values \(b \pm \).

**RESULTS AND DISCUSSION**

Seed yield (t/ha) showed highly significant relationship (P ≤ 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 in conformity with those reported by Singh and Yadava (1986) and Bange et al. (1997).

Table 3 shows the means (\(\mu\)), regression coefficients (bi), deviation from regression line (\(\bar{d}\)) and Wricke ecovalance (Wi) 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 x 7, Ka99 x 13, Ka99 x 15, Ka99 x 17, Ka99 x 18, Ka99 x 25-2, Ka99 x 29, 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, Ka99 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 \(\bar{d}\) significantly different (P 0.05) from zero. More or less a pattern of ranking similar to the observed one based on the bi and \(\bar{d}\) 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 \(\bar{d}\) 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 \(\bar{d}\) not significantly different from zero. Hence, it...
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...
Hysun33 did not follow a particular pattern. They either had a mean yield below the average or a $d^2$ 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 $d^2$ 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 (li) 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 Hysun 33), evaluated at the four environments are depicted in Table 4. As for li, E1 had the highest positive index of 1.221 and hence, it was the most favorable, followed by E3, then E 2. On the other hand, E4, 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 E1, whereas the lowest one was determined at E4. 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 yields 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 for $Y \pm$ and $b^{-}\pm$ 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.

REFERENCES