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# EVALUATION AND GENETICS STUDIES OF F1 SUNFLOWER HYBRIDS BETWEEN SETS OF LINES SELECTED IN USA AND SPAIN

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## SUMMARY

Genetic variability is essential for continued genetic improvement of any crop species. One potential source of genetic variability is the use of exotic or unadapted germplasm. Although considerable genetic variability may be available in germplasm repositories, indiscriminate introduction of exotic germplasm may not be as valuable as those introductions with previous known performance. The objective of our study was to determine the relative yield as well as other parameters (oil percentage, days to flowering, days to maturity, capitulum diameter, test weight and seed weight) of several F1 sunflower hybrids between sets of inbreds lines selected in the United States of America and Spain. Trials were conducted in each country to determine the response of the hybrids to each environment. The USA environment was better for all the hybrids in general; however USA X USA hybrids performed better than Spain X Spain hybrids in the USA and reciprocally in Spain, which is a proof of a better adaptation to the environment in which lines were selected. USA X Spain and Spain X USA hybrids in Spain and USA X Spain hybrids in USA outyielded other types of combinations, showing good combining ability. Thus it appeared that both USA and Spain inbred lines could be sources of useful alleles for yield in both breeding programs. Oil percentage did not appear to show any increase in the hybrids between lines selected in different environments.

## INTRODUCTION

Broadening the genetic base and increasing the yield potential and stability of the economic production of the major food crops are high research priorities in the world. Interest in the use of foreign or exotic sources of germplasm to increase the genetic variability of sunflower (Helianthus annuus L.) has increased in the breeding programs of many countries. The potential risk in extensive planting of a few genetically related cultivars and the potential benefits for the identification of superior new heterotic combinations and new alleles for pest resistance or superior quality standards have contributed to the increased intertest in foreign germplasm sources.

Additional genetic variability is available for breeding programs in germplasm repositories, but indiscriminate introduction of exotic germplasm collections may lower the breeding value of adapted elite breeding materials because undesirable genes may be introduced from unknown sources.

The objective of this study was to determine if sunflower inbred lines selected in the USA and Spain could contribute useful characteristics for breeding programs in both countries. The relative yield as well as other parameters of several F1 sunflower hybrids between sets of inbred lines selected in the United States of America and Spain was determined in trials conducted in both countries. in areas where most of the inbred lines had been selected.

Genetic and environmental variances were calculated for the measured traits in order to obtain information about their heritabilities as well as combining ability estimates of the lines.

## MATERIALS AND METHODS

The plant material included 5 cytoplasmic male sterile lines: CMS HA-300, CMS HA-301, CMS HA-302, CMS HA-207, CMS HA-822 and 5 restorer lines: RHA-271, RHA-273, RHA-274, RHA-275, RHA-278 selected in the USA as well as 5 cytoplasmic male sterile lines: A-1, A-21, A-2, A23, A-INIA and 3 restorer lines: R-1, R-22, R-23, selected in Spain. All lines were randomly selected from a pool of more than 50 lines. Two restorer lines (R-7 and R-17) from the spanish set had to be discarded since they produced low quantities of pollen under greenhouse conditions.

Seed of the 80 possible crosses (CMS X Restorer) were produced during the winters of 1984 in Cordoba

(Spain) and 1985 in Fargo (USA).

All F1 hybrids were evaluated in the USA at the experimental farm of the North Dakota State University at Casselton N.D. in 1985 and in Spain at the farm of the Agricultural Research Center (C.I.D.A) at Cordoba in 1986. Two hybrid checks were used: 991 (CMS HA-99 X RHA-271) and 894 (CMS HA-89 X RHA-274).

The experimental design was a 10 x 10 square lattice with 3 replications at each location. Plot size was two rows of 26 plants. Plot length was 6 meters with spacing between rows of 70 cm.

Data were collected at each location for seed yield (kg/ha), days from seeding to 50 % flowering, days from seeding to 50 % physiological maturity, plant height (cm.), capitulum diameter (cm.), seed test weight (kg/hl), 200 seed weight (gr.) and seed oil content (%) measured by nuclear magnetic resonance (NMR).

The efficiency of the lattice analysis relative to a randomized complete block design was minimal. Therefore analyses of variance were computed with the unadjusted entry means from each experiment.

Mean squares for the entries were partitioned according to the factorial analysis of variance (Comstock and Robinson, 1952) for the male, female and interaction effects. Estimates of additive and dominance variances as well as narrow sense heritability were calculated for each combination of line sets in each particular environment.

## RESULTS AND DISCUSSION

Ranges and means for all measured characters are shown in Table I. Average values of all measured characters in the USA were greater than in Spain, except plant height. Days to flowering and days to maturity were clearly shortened in Spain in all hybrid combinations. This could have been due to the higher temperatures in Spain during the growing cycle. This marked difference, particularly during the period flowering-maturity, also influenced the seed oil content in all combinations, with oil % substantially higher in USA.

Average yield as well as yield components values (capitulum diameter, seed test weight and 200 seed weight) of all hybrid combinations were higher in the USA trial.

Hybrids between CMS-USA and R-USA lines outyielded CMS-Spain X R-Spain in USA and reciprocally in Spain. This fact suggest a better adaptation of hybrids in the environments where their parental lines were selected. However, hybrid combinations including parents (either CMS or R lines) from different origins yielded the highest in both country trials with the exception of CMS-Spain X R-USA in USA. This yield increase did not necessarily entail a homogeneous positive response of yield components measured in this study; for example, 200 seed weight values of CMS-USA X R-Spain were the highest in both USA and Spain trials whereas the seed test weight values of this combination were the lowest. Moreover the CMS-Spain X R-USA combinations which were the highest yielding in Spain, had the lowest value for 200 seed weight and the highest for seed test weight. Conversely CMS-USA X R-Spain combinations which yielded the highest in the USA trial, had the lowest 200 seed weight and the highest seed test weight values.

Parental lines of the CMS-Spain X R-Spain hybrids were selected for, among other characteristics, producing hybrids relatively earlier than the standard hybrids grown in Spain (894 types). These combinations flowered and matured the earliest in Spain whereas were the latest in days to maturity in the USA; conversely CMS-USA X R-USA combinations were the earliest in flowering and maturity in the USA and the latest in flowering and maturity in Spain. Genotype X environment interaction seems to have a great importance for these traits in the tested materials.

Estimates of genetic variances and heritabilities for the traits studied are given in Table II. These estimates have been figured based on the analysis of variance of the factorial design proposed by Comstock and Robinson (1952). This design estimates two values of additive variance and one estimate of dominance variance calculated directly from the mean square anestimates the general and specific combining ability variances (GCA and SCA)(Hallauer and Miranda, 1983).

Values of of GCA variances were greater than SCA variances for almost all the traits except yield, which has variance values comparatively higher. Narrow sense heritability estimates were fairly homogeneous in almost all combinations for each trait in the USA, except yield. This was not the tendency in Spain where the estimates were more heterogeneous and ranges of values were wider. Heritability values figured through male variance were in most traits very low or even negative, suggesting the low variablity for most of the characteristics in the restorer lines used in this study.

Seed yield heritability estimates were substantially low in both countries in most of the combinations. The importance of non-additive factors was quite obvious, and confirms the conclusions in other studies (Pathak, 1974; Dua and Yadura, 1985).

The major importance that specific combining ability has in seed yield is evident by observing the estimates of its variance in comparison with other traits; this fact has already been reported by other researchers (Unrau, 1947; Putt, 1966).

In relation to the estimates of heritability of other traits, it is interesting to note the low values for head diameter (= 20 %) and the higher and homogeneous values obtained in the USA for seed oil content in comparison with the ones obtained in Spain. The estimates of 200 seed weight (30-90 %) are higher than previously reported (Pathak, 1974; Shabana, 1974). Variance of GCA for this trait is quite larger than SCA variance. These values contrast with the ones reported by Putt (1966) who found that the components for general and specific combining ability for seed weight were about equal.

The narrow sense heritability estimates for days to flowering and maturity ranged between values quite normal and very similar to the ones reported by Unrau (1947) and Putt (1966).

In conclusion, the importance of the non-additive effects for seed yield present in sunflower should be stressed. The value of using foreign germplasm in breeding sunflower for seed yield should also be noted. This value is not as evident for other plant and seed characteristics, where additive effects seem to bear a greater importance. For these traits, selection schemes based on increasing favourable alleles should be used.An effective hybrid testing program, including foreign material, is necessary if higher seed yields are the programs primary objectives.

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Table I. Ranges and means for eighty hybrids produced by crossing sets of sunflower lines selected in the USA and Spain and evaluated in both countries for eight traits.

| | | DAYS-FLOWERING | | DAYS MATURITY | | PLANT-HEIGHT | | HEAD DIAMETER | | TEST WEIGHT | | 200 SEED WEIGHT | | OIL SEED CONTENT | | YIELD | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Location | Entries | Range | Mean | Range | Mean | Range | Mean (cm) | Range | Mean (cm) | Range | Mean (Kg/Hl) | Range | Mean (gr) | Range | Mean (%) | Range | Mean (Kg/Ha) |
| U S A | CMS-SPAIN x R-SPAIN | 71.5-78.5 | 74.4 | 125.7-129.5 | 127.6 | 147.5-182.5 | 168 | 20.3-22.8 | 21.3 | 40.2-46.2 | 43.9 | 9.9-13.5 | 12.3 | 41.7-46.8 | 44.9 | 2747-3582 | 3132 |
| | CMS-SPAIN x R-USA | 69.0-76.7 | 72.8 | 119.7-129.7 | 126.3 | 142.5-185.0 | 160.2 | 19.4-23.7 | 21.9 | 41.9-47.1 | 44.9 | 8.9-14.7 | 12.7 | 38.5-47.4 | 43.3 | 2475-3797 | 3065 |
| | CMS-USA x R-SPAIN | 71.7-76.2 | 74.8 | 124.2-128.5 | 126.8 | 157.5-190.0 | 172.8 | 21.7-23.4 | 22.5 | 39.3-43.4 | 41.2 | 11.2-16.7 | 13.3 | 38.5-48.3 | 44.8 | 2919-4020 | 3389 |
| | CMS-USA x R-USA | 69.7-78.2 | 75.5 | 117.1-129.5 | 125.7 | 157.5-187.5 | 168.2 | 20.6-24.7 | 22.2 | 39.3-43.8 | 41.2 | 9.7-14.5 | 12.5 | 40.2-48.5 | 44.5 | 1937-3798 | 3263 |
| | ALL | 69.0-78.5 | 74.1 | 117.1-130 | 126.4 | 142.5-190.0 | 166.5 | 19.4-24.7 | 22.3 | 39.3-47.1 | 42.9 | 8.9-16.7 | 12.4 | 38.5-48.6 | 44.3 | 1937-4020 | 3202 |
| | HYBRID CHECKS | | | | | | | | | | | | | | | | |
| | 894 | | 77 | | 123 | | 170 | | 24.1 | | 41.2 | | 10.0 | | 43.6 | | 3396 |
| | 991 | | 79 | | 128 | | 180 | | 24.5 | | 40.7 | | 10.9 | | 44.8 | | 3523 |
| SPAIN | CMS-SPAIN x R-SPAIN | 66.2-71.7 | 68.6 | 85.7-93.2 | 89.6 | 152.5-188.7 | 169.1 | 13.5-16.0 | 14.6 | 33.1-39.2 | 36.6 | 8.7-12.5 | 10.4 | 38.8-42.6 | 41.1 | 2397-3314 | 2800 |
| | CMS-SPAIN x R-USA | 66.2-70.0 | 68.2 | 87.7-96.2 | 91.7 | 152.5-200.0 | 169 | 14.2-17.3 | 15.3 | 35.8-43.1 | 38.5 | 7.1-13.3 | 10.3 | 37.9-42.5 | 40.9 | 2596-4048 | 3181 |
| | CMS-USA x R-SPAIN | 66.2-70.7 | 68.9 | 86.0-93.2 | 90.3 | 157.5-192.5 | 174.9 | 14.7-18.6 | 16.2 | 30.3-35.4 | 32.4 | 10.4-12.5 | 11.3 | 35.6-44.2 | 39.7 | 2513-3534 | 3041 |
| | CMS-USA x R-USA | 68.7-76.7 | 71.6 | 92.0-99.5 | 94.6 | 152.5-203.7 | 176.8 | 14.4-17.5 | 15.6 | 32.5-39.9 | 35.7 | 8.6-13.9 | 10.3 | 39.5-44.7 | 41.5 | 1971-3970 | 2714 |
| | ALL | 66.2-76.7 | 69.5 | 85.7-99.5 | 91.8 | 152.5-203.7 | 172.8 | 13.5-18.6 | 15.4 | 30.3-43.1 | 36.1 | 7.1-13.9 | 10.5 | 35.6-44.7 | 40.9 | 1971-4048 | 2934 |
| | HYBRID CHECKS | | | | | | | | | | | | | | | | |
| | 894 | | 76 | | 98 | | 175 | | 15.0 | | 35.7 | | 7.5 | | 42.3 | | 2704 |
| | 991 | | 79 | | 100 | | 185 | | 17.8 | | 39.2 | | 8.6 | | 44.1 | | 3048 |

Table II. Estimates of genetic variances and narrow sense heritabilities from the factorial design for each hybrid combination in each country.

| | DAYS FLOWERING | | | | | DAYS MATURITY | | | | | PLANT HEIGHT | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | CMS SP. X R SP. | CMS SP. X R USA | CMS USA R SP. | CMS USA X R USA | ALL | CMS SP. X R SP. | CMS SP. X R USA | CMS USA X R SP. | CMS USA X R USA | ALL | CMS SP. X R SP. | CMS SP. X R USA | CMS USA X R SP. | CMS USA X R USA | ALL |
| USA | | | | | | | | | | | | | | | |
| $\sigma^2_{GCA}$* | 68.3 | 29.6 | 14.9 | 81.2 | 90.3 | 23.6 | 25.5 | 15.9 | 78.2 | 62.1 | 302.6 | 1729 | 1427 | 2053 | 3026 |
| $\sigma^2_{SCA}$ | 1.7 | 3.3 | 1.5 | 8.1 | 7.2 | 3.8 | 4.5 | 1.6 | 10.5 | 7.6 | 146.2 | 121.6 | 20.2 | 114 | 114 |
| $\sigma^2_D$ | - | - | - | 1.5 | 0.3 | - | - | - | 0.9 | 0.8 | 11.1 | 14.9 | 17.2 | 11.3 | 11.9 |
| $\sigma^2_{A(F)}$ | 5.5 | 1.3 | 1.4 | 3.6 | 2.6 | 0.9 | 1.1 | 1.1 | 3.4 | 1.7 | 63.0 | 80.3 | 110.3 | 96.9 | 90.9 |
| $\sigma^2_{A(M)}$ | 0.8 | 0.6 | 0.2 | 0.2 | 0.3 | - | 6.4 | 0.4 | 2.9 | 2.7 | - | 15.6 | 25.8 | 27.0 | 22.9 |
| $h^2$(F) | 0.8 | 0.3 | 0.6 | 0.7 | 0.4 | 0.3 | 0.3 | 0.5 | 0.4 | 0.3 | 0.6 | 0.6 | 0.8 | 0.6 | 0.6 |
| $h^2$(M) | 0.1 | 0.1 | - | - | - | - | 0.9 | 0.1 | 0.3 | 0.4 | - | 0.1 | 0.1 | 0.1 | 0.1 |
| SPAIN | | | | | | | | | | | | | | | |
| $\sigma^2_{GCA}$ | 68.3 | 13.2 | 22.2 | 53.8 | 94.5 | 115.5 | 30.6 | 22.3 | 46.9 | 116.2 | 1269 | 1674 | 2271 | 2201 | 3428 |
| $\sigma^2_{SCA}$ | 1.7 | 2.1 | 1.0 | 9.9 | 7.5 | 7.0 | 13.4 | 8.3 | 9.6 | 16.8 | 169 | 220 | 90 | 330 | 227.7 |
| $\sigma^2_D$ | - | 0.4 | 0.1 | 2.2 | 1.7 | 1.5 | 3.1 | 4.4 | 1.6 | 3.8 | 12.2 | 25.5 | - | 42.1 | 24.2 |
| $\sigma^2_{A(F)}$ | 5.5 | 0.5 | 1.7 | 2.1 | 2.7 | 9.0 | 0.9 | 0.3 | 1.9 | 3.1 | 91.6 | 72.7 | 181.7 | 93.5 | 100.3 |
| $\sigma^2_{A(M)}$ | 0.7 | 0.1 | 0.1 | 0.2 | 0.3 | - | - | - | - | 1.9 | 12.8 | - | 11.5 | 0.8 | 2.5 |
| $h^2$(F) | 0.8 | 0.6 | 0.8 | 0.7 | 0.7 | 0.9 | 0.5 | 0.1 | 0.5 | 0.6 | 0.6 | 0.5 | 0.8 | 0.5 | 0.5 |
| $h^2$(M) | - | 0.1 | - | - | - | - | - | - | - | - | - | - | - | - | - |

| | HEAD DIAMETER | | | | | TEST WEIGHT | | | | | 200 SEED WEIGHT | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | CMS SP. X R SP. | CMS SP. X R USA | CMS USA X R USA | CMS USA X R USA | ALL | CMS SP. X R SP. | CMS SP. X R USA | CMS USA X R SP. | CMS USA X R USA | ALL | CMS SP. X R SP. | CMS SP. X R USA | CMS USA X R SP. | CMS USA X R USA | ALL |
| USA | | | | | | | | | | | | | | | |
| $\sigma^2_{GCA}$* | 5.7 | 15.2 | 1.5 | 12.5 | 15.6 | 38.8 | 40.1 | 22.9 | 14.6 | 139 | 11.4 | 21.5 | 31.3 | 8.7 | 29.6 |
| $\sigma^2_{SCA}$ | 2.6 | 4.4 | 1.1 | 3.7 | 3.4 | 1.2 | 2.7 | 0.4 | 2.9 | 3.1 | 1.2 | 1.0 | 1.0 | 1.7 | 2.4 |
| $\sigma^2_D$ | 0.2 | 0.3 | - | 0.3 | 0.2 | - | 0.3 | - | 0.3 | 0.5 | 0.2 | 0.1 | 0.1 | 0.2 | 0.4 |
| $\sigma^2_{A(F)}$ | 0.3 | 0.5 | 0.1 | 0.4 | 0.4 | 3.1 | 1.9 | 1.9 | 0.6 | 4.2 | 0.8 | 1.0 | 2.5 | 0.4 | 0.9 |
| $\sigma^2_{A(M)}$ | - | 0.1 | - | - | 0.1 | 0.5 | 0.4 | - | 0.3 | 0.3 | - | 1.0 | 0.1 | 1.1 | 0.7 |
| $h^2$(F) | 0.2 | 0.2 | - | 0.2 | 0.1 | 0.8 | 0.7 | 0.8 | 0.4 | 0.7 | 0.8 | 0.8 | 0.9 | 0.4 | 0.6 |
| $h^2$(M) | - | - | - | - | - | 0.1 | 0.1 | 0.1 | 0.1 | 0.5 | - | 0.8 | - | 0.9 | 0.4 |
| SPAIN | | | | | | | | | | | | | | | |
| $\sigma^2_{GCA}$ | 8.0 | 8.0 | 9.2 | 3.3 | 17.4 | 28.5 | 27.2 | 34.6 | 44.5 | 143 | 21.0 | 14.7 | 4.6 | 1.5 | 17.5 |
| $\sigma^2_{SCA}$ | 1.9 | 1.4 | 1.4 | 3.7 | 2.9 | 7.1 | 5.8 | 2.3 | 11.3 | 8.5 | 1.1 | 1.9 | 0.5 | 5.8 | 23.0 |
| $\sigma^2_D$ | 0.3 | - | - | 0.1 | 0.1 | 1.2 | 0.3 | - | 2.1 | 1.3 | 0.1 | 0.3 | - | 1.1 | 0.5 |
| $\sigma^2_{A(F)}$ | 0.5 | 0.4 | 0.4 | - | 0.5 | 1.8 | 1.6 | 2.6 | 1.6 | 4.4 | 1.6 | 0.6 | 0.4 | - | 0.5 |
| $\sigma^2_{A(M)}$ | 0.1 | 0.3 | 0.3 | - | - | - | 1.5 | - | 0.6 | 2.4 | - | 1.3 | 0.1 | 0.3 | 0.5 |
| $h^2$(F) | 0.6 | 0.3 | 0.3 | - | 0.2 | 0.6 | 0.4 | 0.7 | 0.4 | 0.6 | 0.8 | 0.6 | 0.4 | - | 0.3 |
| $h^2$(M) | - | 0.2 | 0.2 | - | - | - | 0.3 | - | 0.1 | 0.3 | - | 0.9 | - | 0.3 | 0.3 |

| | OIL SEED CONTENT % | | | | | YIELD | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | CMS SP. X R SP. | CMS SP. X R USA | CMS USA X R SP. | CMS USA X R USA | ALL | CMS-SP X R-SP | CMS-SP X R-USA | CMS-USA X R-SP | CMS-USA X R-USA | ALL |
| USA | | | | | | | | | | |
| $\sigma^2_{GCA}$* | 15.9 | 32.1 | 117 | 75.6 | 102 | 460496 | 930224 | 570000 | 117970 | 377190 |
| $\sigma^2_{SCA}$ | 4.3 | 2.7 | 4.1 | 5.7 | 5.3 | 100176 | 267764 | 195256 | 491676 | 315603 |
| $\sigma^2_D$ | 0.2 | 0.2 | - | 0.7 | 0.5 | - | 43363 | 18943 | 91752 | 52031 |
| $\sigma^2_{A(F)}$ | 0.9 | 1.4 | 9.4 | 3.5 | 3.0 | 30026 | 36123 | 31228 | - | 1924 |
| $\sigma^2_{A(M)}$ | 0.3 | 1.9 | - | 2.3 | 1.6 | - | - | - | 3262 | 14487 |
| $h^2$(F) | 0.4 | 0.5 | 0.7 | 0.6 | 0.5 | 0.4 | 0.3 | 0.3 | - | - |
| $h^2$(M) | - | 0.7 | - | 0.4 | 0.2 | - | - | - | - | - |
| SPAIN | | | | | | | | | | |
| $\sigma^2_{GCA}$ | 13.4 | 9.9 | 70.4 | 12.6 | 35.9 | 378144 | 718560 | 726832 | 624992 | 214690 |
| $\sigma^2_{SCA}$ | 2.5 | 2.1 | 2.9 | 7.1 | 6.1 | 291032 | 485328 | 178232 | 662096 | 541850 |
| $\sigma^2_D$ | - | - | - | 1.1 | 0.9 | 58806 | 108233 | 28505 | 157603 | 123818 |
| $\sigma^2_{A(F)}$ | 0.9 | 0.4 | 5.6 | 0.3 | 0.9 | 7259 | 11661 | 45216 | - | - |
| $\sigma^2_{A(M)}$ | 0.3 | 1.2 | 0.7 | 1.0 | 0.9 | 5928 | 4903 | - | 1728 | 9579 |
| $h^2$(F) | 0.5 | 0.2 | 0.8 | 0.2 | 0.2 | 0.1 | 0.1 | 0.5 | - | - |
| $h^2$(M) | 0.1 | 0.7 | 0.9 | 0.5 | 0.2 | 0.1 | - | - | - | - |

* $\sigma^2_{GCA}$= General combining ability variance; $\sigma^2_{SCA}$= Specific combining ability variance; $\sigma^2_D$= Dominance variance; $\sigma^2_A$= Additive variance; $h^2$= narrow sense heritability (F, M = female, male)