Evaluation and utilization of the U.S. Germplasm Collection of Sunflower in Argentina.

Jose Bruniard *

* A.C.A. Sunflower Breeder. Merced 1425. c.c. 78. (2700) Pergamino. Republica Argentina. FAX/Tel: 54-477-20798.

SUMMARY

The objective of this work was the introduction of new sources of Germplasm into an established sunflower breeding program.

In 1988 the U.S. Germplasm Collection of Sunflower (Helianthuus annuus L.) consisted of about 659 accessions. Seed samples of this collection were supplied by the North Central Regional Plant Introduction Station, Ames, Iowa. The collection was assayed since 1988 at Pergamino, Republica Argentina. During the first two years, 1988 and 1989, the evaluation was based on phenotypic behavior, plant height, lodging, oil content, disease resistance and local adaptation. At this point the collection was reduced to a smaller group of 354 accessions with a better adaptation to Argentina. In 1990 a Top Cross was carried out using two inbred lines as testers. In 1991 replicated yield tests were conducted in order to estimate Combining Ability. With the results of the yield tests, and based on a previous classification by origin four synthetics were formed by recombination in 1992.

The synthetics thus formed are now incorporated to the breeding program as a source of new inbred lines. This paper summarizes the results of seven years of work.

INTRODUCTION

Argentine has in 1995/96 growing season about 3.000.000 ha. of sunflower with and expected mean yield of 1700 kg.ha^{-1}, being one of the most important producer of sunflower in the world.

The country has a long tradition in sunflower breeding with several private companies doing research to develop hybrids adapted to Argentine agriculture and climate, along with governmental effort in breeding and crop management, which results in a very competitive market.

The introductory stage of open pollinated varieties, in Argentine occurred in 1940-50 . Since 1972 the use of hybrids has been increasing, today almost 98 % of sunflower acreage is grown with hybrids. At present two or three generations of new hybrids has been released by companies with local research facilities and regional objectives.

The magnitude of the range of genes that constitute the germplasm of a given population of plants is described by the term genetic diversity. When crops were developed from the wild species individual plants were selected over many years by early agriculturalists on the basis of reproductive potential under cultivation, adaptation, and the preferences of those involved with seed production. Each primitive variety of a crop, thus, produced a smaller number of gene combinations or less genetic diversity than the species as a whole. (Seiler, 1988). This original constrain in the foundation of breeding programs is then deepened by modern breeding strategies that limit the scope to a few number of key traits, narrowing the genetics base and in some cases conducting to a plateau in yield increase. The use of new germplasm in breeding programs has the potential for markedly improving commercial hybrids hybrid sunflower production. With many world collections and free exchange of germplasm the problem for the breeder is not the amount of variability available, but its adequate assessment, classification, and carefully introduction into the breeding program. A massive introduction may increase dramatically the amount of work, without any beneficial effect, moreover, some detrimental traits might be introduced.

The objective of this work was the introduction of new sources of germplasm into an established sunflower breeding program.

The traits under evaluation were:

Oil Percentage. Oil percentage of sunflower depends on both the percentage of hull and the percentage of oil in the kernel. In early breeding efforts, oil percentage was increased by reducing hull percentage. Recent increases are attributed to an increases in kernel oil percentage. (Miller, 1987). Oil percentage is considered to be quantitatively inherited (Fick, 1978). In one study carried out in Spain using the Sunflower world collection, it was found a range of variation for percentage of oil content from 23 % to 56. (Fernandez-Dominguez, 1985).

Achene size. The achene or fruit of the sunflower consists of a kernel or seed and an adhering pericarp or hull. Achenes vary from 7 to 25 mm long and 4 to 13 mm wide. Achene size is most important to nonoilseed industry, which prefers a large achene. (Miller, 1987).

Height. Height is generally considered to be a quantitative character, although several reports indicates that reduced height or semidwarf characteristics may be controlled by a single recessive genes. In some crosses, considerable reduction in height occurs, while in other crosses, little reduction in height occurs. These observations suggest the complex genetic control of plant height. (Miller, 1978).

Flowering. Recent reports have indicated separate genetic control over the number of days from planting to bud stage, from the bud stage to flowering, and from flowering to maturity. Several genes may be involved in each phase of the growing cycle. (Miller, 1978). In the study done in Spain and mentioned earlier, the range of variation found was: from 71 to 100 days.

Stalk strength. Stalk strength, or resistance to lodging, is an important breeding objective for breeders developing hybrids in climates with strong wind, high rainfall, or a combination of both. Several individual characters influence resistance to lodging, including stem diameter, stem outer wall thickness, plant height, and type of root system. Genetic control of stalk strength is quantitative. (Miller, 1978).

Head shape and inclination. Head shape and inclination is important in environments having considerable rain in the season . Moisture will concentrate on the back of the head, if the head is quite convex and the inclination parallel to the soil surface. Breeders have sought genotypes with a flat , thin receptacle. Breeder preference for degree of head inclination varies. Inclination parallel to the soil surface may be desired to prevent sun scald in production areas of high temperature and intense sunlight. Head shape and inclination are important for discouraging bird depredation. (Miller, 1978).

MATERIALS AND METHODS

Seed samples of the Sunflower World Collection as it was formed in 1988 were obtained from North Central Regional Plant Introduction Station, Ames, Iowa, U.S.A. In 1988 the U.S. Germplasm Collection of Sunflower (Helianthuus annuus L.) consisted of about 659 accessions. Seed samples of this collection were supplied by the North Central Regional Plant Introduction Station, Ames, Iowa, USA. The collection was assayed since 1988 at Pergamino, Republica Argentina. During the first two years, 1988 and 1989, the evaluation was based on phenotypic behavior, plant height, lodging, oil content, disease resistance and local adaptation. At this point the collection was reduced to a smaller group of 354 accessions with a better adaptation to Argentina. In 1990 a Top Cross was carried out using two inbred lines as testers. In 1991 replicated yield tests were conducted in order to estimate Combining Ability. With the results of the yield tests, and based on a previous classification by origin four synthetics were formed by recombination in 1992.

The synthetics thus formed are now incorporated to the breeding program as a source of new inbred lines.

1-) Evaluation "per se" of the sunflower world collection in 1988 and 1989.

Four row plots 5 m long .70 m apart were used for records in 1988 and

1989. Sowing dates, accessions planted and harvested are shown in Table 1.

The traits recorded for the "per se" evaluation were as follow:

Flowering date: was taken in days from planting to 50 % of plants at flowering in the plot. Early planting date (September) tend to increase the number of days to flowering in Argentina and late planting date (December) hasten flowering time, being October and November considered the normal planting date for Pergamino.

Plant height: plant height (H1) was taken in centimeters from the soil level to the top part of the plant at flowering time. A second plant height (H2) was recorded at maturity for the purpose of bending calculations.

Disease resistance: was recorded in 0-4 scale being 0= immune, 1-2-3 were considered different degrees of resistance and 4 very susceptible, all evaluations were done under natural infection at the field. The diseases present were: White Blister Rust (Albugo tragopogi (Pers.) Schroet.) and Rust (Puccinia helianthii. Schw.)

Oil content: was measured with a RMN (Bruker Minispec).

Bending of the capitulum: it is expressed as percentage of upright. % Upright = H1 / H2 * 100. The values near 100 % are almost completely upright and values around 50 % are for complete bending with horizontal capitulum.

2-) Combining Ability assessment in 1990.

After two year of "per se" evaluation, with those accessions selected, it was done a Combining Ability study. For this purpose in 1989 crosses were made between each one of the accessions and two inbred lines (sterile version). The two tester used were HA-89 inbred line and a private inbred line A 106 which is a full season line, stripped seed derived from PGRK population. The experimental design used were rectangular lattices 10x10, with an experimental unit of two rows plots, 5 meter long and 0.70 meter apart and 0.25 among plant within rows. The checks used in 1990 and 1994 yield tests were: Contiflor 3, ACA 884, Contiflor 15 and Dekalb G 103.

Table 1. Planting dates, number of accessions under evaluation, number of accessions harvested and percentage of discarded, for each year.

Year	Sowing Date	Planted	Harvested	% Discarded
1988	December 12	659	394	40.2
1989	September 21	394	354	10.1
1990	Yield test (CA)	354	50 *	85.9
1992	December 10	69	48	30.4

* Selection based on Combining Ability.

Table 2. Evaluation of the world collection at Pergamino (Argentina) between 1988 and 1994.

Year	Breeding Procedure
1988	First year of "per se"" evaluation of 650 accessions.
1989	Second year of "per se" evaluation of 350 selected accessions. Crosses with two testers for Combining ability study.
1990	Combining Ability Study. Four lattices 10 x 10 at Pergamino.
1991	establishment of a core collection with the best 45 Combining Ability accessions, and synthesis of new populations based on Combining ability and origin.
1992	First cycle of recombination.
1993	Second cycle of recombination.
1994	Beginning of inbreeding.(S-1).

RESULTS

1-) Evaluation"per se" of the Iowa collection at Pergamino (Argentina) under two different planting date conditions (December 1988/89 (late) and September 1989/90 (early)).

Country of origin for the entire collection:

The world collection of sunflower in 1988 comprised accessions from 31 different countries, which represented more than the actual countries where sunflower is an important commercial crop. The contribution of each country is variable . For example Turkey had 89 accession more than the Soviet Union and USA, two with a long history of breeding. Table 3 lists all the contributor countries.

Table 3 - Contribution of different countries: origin of 367 accession, there was a number of unknown origin.

COUNTRY	ACC.#	COUNTRY	ACC.#	COUNTRY	ACC.#
Turkey	89	France	10	Syria	2
CIS	59	Poland	9	Italy	2
USA	36	Sth. Africa	9	Canada	2
Iran	35	Romania	7	Austria	2
Hungary	15	Australia	5	Germany	2
Yugoslavia	14	Ethiopia	5	Rhodesia	1
Kenya	12	Iraq	5	Brazil	1
Argentina	12	Uruguay	4	Bulgaria	1
Zambia	11	Egypt	3	England	1
Jordan	10	Spain	2	PRC	1

CIS = Community of Independent States, former Soviet Union.
PRC = Popular Republic of China.

Flowering date:

In 1988/89 evaluation was made on a late planting date (December 12), so the crop faces high temperature at the beginning of the growth stage, and needed less days to collect the growing degree days or temperature sum necessary for flowering. This is the reason for some of the accessions with less than 55 days from planting to mid-flowering. The range from planting to mid-flowering was between 51 and 68 (Table 4).

In 1989/90 accessions were planted early (September 21) , so the crop faces low temperature at the beginning of the growth stage, and needed more days to collect the growing degree days or temperature sums necessary for flowering. This is the reason why some of the accessions had more than 100 days from planting to mid-flowering. The range of days from sowing to flowering was between 61 to more than 110 which represents a considerable amount of variation. The most suitable materials for Argentina might be at mid-flowering between 75 and 90 days for an early planting date as September (Table 5).

Table 4. Days to flowering (1988/89). (late planting date: Dec. 12)

RANGE	ACC.#
51-54	3
55-60	106
61-65	244
+65	15

Table 5 - Days to flowering (1989/90) (early planting date: September 21)

RANGE	ACC.#
61-65	7
66-70	22
71-75	68
76-80	121
81-85	57
86-90	43
91-95	26
96-100	37
101-105	7
106-110	2
+110	2

Plant height:

Plant height was evaluated in 1989/90 planting. It is a trait also heavily affected by planting date. Early planting date tend to produce a crop with a shorter stature than that of normal (October) or late planting date (December). The range obtained was between 41 cm and more than 240 cm with a mean value of 123.35 cm (Table 6). The variability in plant height was tremendous and the shorter types were introduced immediately in planned crosses.

Table 6 - Plant height (1989/90)

RANGE	ACC.#
41-60	4
61-80	29
81-100	94
101-120	102
121-140	58
141-160	56
161-180	28
181-200	8
201-220	9
221-240	2

Bending of the capitulum:

This trait is influenced by environment and yield for a particular year, nevertheless there were found considerable variation in types. Those with long neck, 41 to 60 % of up right, are used to produce types more tolerant to bird damage and also more tolerant to lodging. The more up right types, 91 to 110 % of up right, are more prone to bird attack but are preferred in areas were fast dry down is needed. Both types are available in considerable amount of accessions (Table 7).

Table 7 - Bending of the capitulum.

%UP-RIGHT	ACC.#
41-50	7
51-60	5
61-70	9
71-80	50
81-90	79
91-100	119
101-110	124

Rust Resistance:

Rust resistance was assessed using a scale from 0 to 4, the attack was only moderate but there was enough inoculum to produce reaction 3 and 4 (susceptible) and also to identify some genotypes presumably resistant and immune (Table 8). No further determination was done regarding rust reaction.

Table 8 . Rust resistance.

1988/89	
RESISTANT	2
SUSCEPTIBLE	237
NOT DETERMINED	153

1989/90	
RESISTANT	209
SUSCEPTIBLE	69
NOT DETERMINED	116

White Blister Rust Resistance

During 1988/89 there was a white blister rust attack that allowed to determine a full range of responses, with a considerably amount of sources for resistance: 296 accessions were resistant (Table 9).

Table 9 - White blister rust resistance, recorded in 1988/89.

Reaction	# Acces.
RESISTANT	296
SUSCEPTIBLE	69
NOT DETERMINED	29

Flower Color:

Normal yellow type was predominant (280 accessions), types with variable degree of purple color were found in 48 accessions , 36 accession were yellow/purple segregating (Table 10). Two yellow-lemon types were also detected.

Table 10 -Flower color.

COLOR	ACC.#
NORMAL YELLOW	280
YELLOW-PURPLE	36
PURPLE	48

Plant type:

The predominant type was the normal monocephalus type with 296 accessions. There were 33 branched types with 36 accessions segregating for the character (Table 11). Even though different types of branching were observed, no further evaluation was done.

Table 11 -Plant type.

COLOR	ACC.#
NORMAL	296
NORMAL-BRANCHED	36
BRANCHED	33

Seed size:

Due to the importance for commercial production of sunflower for oil type or confectionery, detailed classification according to seed size was done. There was a vast array or combinations in sizes and length of seed which are shown in Table 10. Every conceivable type was found and some of the accessions were immediately used to incorporate the character "long seed" into elite breeding lines. Also for future uses there were two populations synthesized for different purposes: "Bigseed", for confectionery purposes and "Smallseed". Table 12 shows the number of accessions for type of seed.

Table 12 -Seed size.

SIZE	ACC.#
SMALL-SHORT	16
SMALL	31
SMALL-LONG	22
SMALL/MEDIUM	5
MEDIUM-SHORT	158
MEDIUM-LONG	41
MEDIUM	1
MEDIUM/LARGE	19
LARGE-SHORT	9
LARGE	40
LARGE-LONG	28

Seed color:

As with size, seed there was a vast amount of variation for seed color. Black seed was the most common type, followed by stripped, being white and purple the less frequent. All the possible combinations of pure types were found in the Iowa collection (Table 13).

Table 13 - Seed color.

Color	ACC.#
BLACK	137
STRIPPED	114
BLACK-STRIPPED	48
STRIPPED-BLACK	25
STRIPPED-WHITE	11
WHITE	9
WHITE-STRIPPED	8
BLACK-STRIPPED-WHITE	7
BROWN	4
STRIPPED-BLACK-WHITE	4
WHITE-STRIPPED-BLACK	3
BLACK-WHITE	2
BLACK-STRIPPED-BROWN	2
BLACK-PURPLE	2
WHITE-BLACK	2
STRIPPED-GRAY	2
WHITE-STRIPPED-BLACK-PURPLE	2
BLACK-GRAY-WHITE	1
BLACK-STRIPPED-GRAY-WHITE	1
BLACK-STRIPPED-WHITE-PURPLE	1
BLACK-STRIPPED-PURPLE	1
BLACK-WHITE-STRIPPED	1
STRIPPED-BLACK-PURPLE	1
STRIPPED-BROWN-BLACK	1
STRIPPED-WHITE-PURPLE-BLACK	1
STRIPPED-WHITE-PURPLE	1
STRIPPED-WHITE-BLACK	1
PURPLE	1

2-) Assessment of the Combining Ability.

The estimation of the combining ability of the world collection after two years of "per se" evaluation was done with 354 accessions, each one of the collections were crossed with two testers. The resulting combinations were evaluated in replicated yield test. Those accession that were over the yield of best checks at 10 % level of probability in combination with both tester, were considered to have EXCELLENT Combining Ability, those accessions that were better than the best check, in hybrids with only one of the tester, were classified as having VERY GOOD Combining Ability, and those that had no significant differences with the best checks were classified as having GOOD Combining Ability. Table 14. It must be remembered that the checks were chosen among the best single cross hybrids in the Argentinean market.

Table 14. Grouping of the accessions according to its combining ability.

Yield test results	Combining Ability	Number of accessions
Better with two testers than the best check	Excellent	5
Better with one tester than the best check	Very good	15
No significant differences with one or two tester against the best check	Good	24

Total number of accessions in replicated yield test with 354

Total number of accessions selected for Combining Ability.....44

Table 15. Country of origin for the accessions with good Combining Ability and relative contribution of each country.

Country	Accessions	%	Country rate (1)
CIS	13	29.5	22 %
Argentina	8	18.2	66.6 %
USA	4	9.1	11.1 %
Unknown NN	3	6.8	13.6 %
Iran	3	6.8	8.5 %
Iraq	2	4.5	
Turkic	2	4.5	1.7 %
Kenya	2	4.5	
Zambia	1	2.2	
Uruguay	1	2.2	
Australia	1	2.2	
Poland	1	2.2	
Rumania	1	2.2	
Italy	1	2.2	
Spain	1	2.2	

(1) The country rate was calculated because the original number of accessions was different for each country. It try to reflect the proportional contribution of each country.

Synthesis of new populations:

With the results of the yield test and taking into account the country of origin of the fortyfour accessions selected for Combining Ability, and the reaction for restorer genes, four populations were formed: one with all the accessions coming from the former Soviet Union, with 13 accessions, it was named IOWA-URSS-B, other with 8 accessions from Argentina, IOWA-ARG-B, one combining twelve of all the other countries: IOWA-VARIOUS-B, and finally there were eleven collections with a fertile reaction in the hybrids: IOWA-RF.

DISCUSSION

The data collected after two years of "per se " evaluation were useful to reduce by 50.3 % the sunflower collection, to those best adapted to Argentina, by flowering time, plant height, lodging resistance and tolerance to some fungal diseases.

Also this preliminary evaluation allow us to detect some sources of reduced plant height, big seed, white color in the seed, that were incorporated rapidly to the breeding program.

Then the Combining Ability study was more important because it allow us to discard 85 % of the accession and separate those having restorer genes for the cytoplasmic male sterile system.

Among those accessions with good combining ability, the analysis of the contribution by country revealed that Argentina had 66 %, which proves the so often mentioned local adaptation of germplasm.

The combination of "per se" evaluation, Combining Ability and synthesis of new populations is a useful method to integrate alien germplasm into a breeding program.

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