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POLLEN PRODUCTION IN
DIFFERENT LINES OF SUNFLOWERS AND
ITS RELATION TO PRODUCTION OF
CROSSED SEEDS

By George Obolensky

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POLLEN PRODUCTION IN
DIFFERENT LINES OF SUNFLOWERS AND
ITS RELATION TO PRODUCTION OF
CROSSED SEED

A DISSERTATION
SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES
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FACULTY OF AGRICULTURE
DEPARTMENT OF PLANT SCIENCE

by

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INTRODUCTION

Oil seeds constitute an important crop in many areas wherever agriculture is practiced. The varied industrial requirements for products derived from fats and oils have provided a continuous stimulus for agricultural research in these crops.

Oleaginous materials derived from oil seeds form the basis of a wide variety of finished products such as shortening, salad oil, soaps, paints, varnishes, printing ink, oil cloth, linoleum and lubricants.

Broadly speaking, it may be stated that the predominancy of old sources of fats and oils, namely, dairy cows, meat cattle and hogs, are on the economic defensive, and that the new sources derived from plants are on the increase. In Canada the main oil crop plants are sunflowers, soya beans, rape and flax. While progress has been made in developing varieties of sunflowers suited to oil seed production under Canadian conditions, there is a pressing need for an intensified breeding program in which particular emphasis is placed on such features as greater seed yield, higher oil content, better oil quality, earliness in maturity and suitability for machine harvesting.

Since vegetable oils are as yet produced on a relatively small scale from a few crops, it would appear that expansion in their production and use will depend in considerable measure on research in plant breeding technology and chemistry. By virtue of its long photoperiod the sunflower is the most suitable oil seed crop in northern regions.

One of the most important aspects in sunflower breeding is the

production and utilization of single cross hybrids as a means of obtaining better yields.

Although basically similar to the utilization of heterosis in hybrid corn, the technique of inbreeding and crossing in sunflowers is quite different, because of differences in their floral structure and mode of pollination. The task of hybridization is made more difficult because both male and female elements occur in the same flower. Under natural conditions pollination is affected by insects, mainly bees.

In artificial crossing, to produce hybrid seed, hand pollination is most common. Providing the flowering of lines used in a natural cross occurs simultaneously, the percentage of crossed seeds is undoubtedly affected by the degree of self-fertility of the female parent, and the amount of viable pollen produced by the male parent.

The purpose of the present project was to study pollen production in sunflower lines as a criterion for choosing parental material for the production of hybrid seed.

REVIEW OF LITERATURE

Despite the extensive research on the various phases of sunflower breeding, critical data relative to the production of pollen in different sunflower lines, in relation to a hybridization program, are rather meager.

Several investigators have reported that pollen production and pollen fertility are of importance in sunflower hybridization. Heiser (7) reported on testing pollen fertility by smearing anthers in lectaphenol and cotton blue. The grains which took a dark blue stain were counted as good. Unrau (20) stressed that the percentage of crossed sunflower seed produced by any line, when flowering occurs simultaneously, is undoubtedly affected primarily by the degree of self-fertility of the female parent and/or the amount of good pollen produced by the other line.

Platchek (14) showed that there is a range of self-fertility which extends from completely sterile to highly fertile plants. This author stressed also the point that the amount of pollen produced by the different varieties should not be overlooked in the determination and choice of the parents. He also stated that plants with white (colorless) pollen gave extremely well-developed heads.

Rudorf (16) in his breeding program succeeded in producing sunflower strains which showed sufficiently early ripening to be successfully grown in the rainy northwestern part of Germany. The heads can be used as a source of pretein and protein fodder, while the stems yield α - cellulose which is used for making paper and textiles.

Sharoyko (17) showed that the ash in the stalks and heads contained 4% Phosphorus and 35.3% Potassium. This high potassium content suggests that the sunflower plants can be utilized as fertilizer.

Marchenko (12) sees a new future for a cheap source of fructose production, from hybrids between *Helianthus annuus* x *Helianthus tuberosus*. One hectar (2.5 acres) produced 76 tons of green stalks which contain 15% fructose under the conditions of this test.

Lutikov (11) studied pollen production from the standpoint of insect pollination. He recommends a ratio of 1 - 1.5 bee hives per hectar of seeded sunflowers. Additional pollination by hand greatly increased the setting of seed.

Morozov (13) demonstrated that sunflower pollen loses its viability in the sunlight. It has its highest viability at a relative humidity of 100%.

Many other valuable papers dealing with the production and breeding of sunflowers have been published. In Canada a great amount of work was done by Putt (15), Putt and Unrau, Unrau and White (20) and others. Space does not permit detailed discussion of these papers; however, because of the increasing economical importance of this oil crop, a number of additional references are given in the Appendix.

These achievements at home and abroad indicate the important part that plant breeding experiments play toward making sunflowers a major oil crop of the future.

MATERIAL AND METHODS

This report deals with two separate experiments. The first experiment utilized selfed progenies from lines introduced at the University of Alberta in 1947; (see frequency tables of lines used in 1951 and 1952). In the second experiment, the two standard lines which are used in the production of the hybrid "Advance" were subjected to a new hybridization trial.

A - Experiment 1.

1. Analysis of Pollen Production; Sunflower Lines used in the Project 1951 - 1952.

In 1951, due to poor germination as a result of a very wet fall and early frost, most of the breeding material was lost. Therefore, the pollen production studies in 1952 were continued on material substituted as being similar to material used in 1951, and on German and Yugoslav introductions not previously used. In both years the study of pollen production in the different lines was based on random samples of 5 florets collected from each of 5 random heads selected from each line and subline.

2. Method of Sampling, and Developing a Microscopic Technique for Pollen Analysis.

An attempt was made to use the same number of plants in each line in order to ensure adequate sampling. Whenever some variation in stand occurred, the material was collected from the greatest number of

available plants. To avoid pollen loss, florets were collected just prior to protrusion of stigmas from the fully extended anthers.

The florets were grasped with forceps, gently separated from the ovary, collected in vials and stored at a temperature of 35°F. Those lines which had not begun to bloom by the first frost were disregarded.

Since sunflower pollen has the tendency to stick together in clumps, it was necessary to find a reagent in which the pollen grains could be uniformly dispersed. The following reagents were tested:

1. Water + Dreft 0.1 - 0.5% by wt.
2. Carbowax 0.1 - 1% solution, prepared by melting Carbowax and adding water.
3. Petroleum oil fractions.
4. Water + Vatsol K 0.1 - 0.5% by wt.
5. Normal Calberla's Solution.
6. Medi-Calgon (Sodium Hexametaphosphate).

The most favorable reagent was Medi-Calgon. The normal procedure for preparing the pollen material for microscopic examination was to crush and wash the five florets in a 1/4 ml. of saturated solution of Medi-Calgon. A microscopic slide bearing three drops of this liquid, containing the dispersed pollen, was prepared and examined under low power magnification. Five horizontal and five vertical readings were made on each slide. A total of ten readings was thus made for each plant. The counts of the ten readings for each individual plant were summated and divided by ten, giving the average pollen grain production per plant. Thus the total of all readings in one line or subline gave an average for

that specific line or subline.

In order to present this great amount of material in a summarized form, it was necessary to make frequency tables for the 1951 and 1952 analyses and the standard error of the mean ($\bar{S}_x$) calculated, (see page 10).

B - Experiment 2.

In the first part of this experiment, varying proportions of the two inbred lines, S - 37 - 388 (female parent) and Sunrise (male parent) were grown in separate rows in 1951, in the following continuations:

- (a) 2 rows of each - alternating.
- (b) 4 rows of S - 37 - 388, 2 rows of Sunrise.
- (c) 6 rows of S - 37 - 388, 2 rows of Sunrise.

The seed was harvested separately from the two inbred lines, and a yield trial from the 1951 material conducted in 1952. Each plot was 20 feet long and consisted of 24 - 27 rows.

Method of Obtaining Hybrid Sunflower Seed from Different Concentrations of the Two Parental Lines in the Crossing Block.

In the second part of Experiment 2, seeds of the two inbred lines were grown together in the same row, but in varying proportions:

- (a) 50-50 proportion of seed of the two.
- (b) 60 seeds of S - 37 - 388 to 40 seeds of Sunrise.
- (c) 70 " " " " 30 " " "
- (d) 80 " " " " 20 " " "
- (e) 90 " " " " 10 " " "

These plots were sown in three 40-foot rows and isolated from each other by at least 1/4 of a mile.

In all tests, the seeds were sown about 2 inches deep in rows 3 feet apart with a V-belt hand-seeder.

The plants were considered to be mature when the backs of the heads were yellow and the involucre bracts were brown. Because of the wet weather, the plants were left in the fields until after frost. When thoroughly dry, the heads were threshed and the seed cleaned.

In the spring of 1952 a yield trial was set up, from seed obtained in the different mixtures of the parental lines. Due to heavy seed losses as the result of extremely unfavorable weather, the yield trial was limited to three randomized single row plots, with a 36-inch spacing.

Due to the above-mentioned unfavorable conditions, germination was extremely poor. Since the unfavorable climatic conditions prevented drying and threshing of this material, the amount of hybridization from the different combinations of the two parent lines had to be estimated by visual selection. Hybrids were distinguished from selfs mainly on the following visually observable characteristics:

- (a) Size and vigour of plant.
- (b) Head and plant type.
- (c) Seed coat color and shape.

EXPERIMENTAL RESULTS

A - Experiment 1.

1. Pollen Production of Inbred Lines of Sunflowers.

In order to illustrate the method of evaluating the pollen producing capacities of the lines, examples of the microscopic counts of pollen grains are given in Table I.

The data on comparative pollen production in the different lines are shown in the frequency distribution given in Tables II, III and IV. Results obtained in 1951 were divided into two sections: first, varieties with more than one mean reading (Table II - Each datum is the mean of several means, each of the latter being the mean of 10 slide readings each from 5 plants of a line), and second, varieties having only one mean, the data being on a single plant basis (Table III, 1951 data; Table IV, 1952 data; - Each datum is the mean of 10 readings from a single plant). Considered in the light of their standard errors, it is clear that certain lines can be considered as favorable, and certain others as unfavorable material for individual plant selection toward heavier pollen production.

2. Analysis of Data.

The analysis of variance for 1951 was made on three kinds of data:

1. With all means included.
2. With more than one mean.
3. With means on single plant basis.

TABLE I. SAMPLE OF RESULTS FROM MICROSCOPIC DETERMINATION OF POLLEN PRODUCTION OF TWO LINES OF SUNFLOWERS IN TWO YEARS

Line No.	Plant	Readings in 1951										Total	Aver.	$\bar{x}$	$s\bar{x}$
		1	2	3	4	5	6	7	8	9	10				
876 - 10	1	30	28	26	27	22	31	29	28	21	23	265	26.5		
	2	25	31	39	31	20	21	24	40	28	26	285	28.5		
	3	19	22	26	27	32	19	25	21	27	25	245	24.5		
	4	23	24	31	26	29	22	21	25	19	22	242	24.2		
	5	18	29	25	32	25	28	22	20	21	26	246	24.6	25.7	± 0.82
Readings in 1952															
876 - 10	1	37	20	27	38	36	34	23	32	26	31	314	31.4		
	2	33	29	31	25	32	33	27	28	25	27	290	29.0		
	3	23	22	28	30	31	25	33	20	24	26	262	26.2		
	4	20	24	29	33	28	31	26	37	24	29	281	28.1		
	5	27	23	38	27	30	27	37	25	21	28	283	28.3	28.6	± 0.84
Readings in 1951															
3268	2	13	15	13	12	11	25	13	12	10	16	140	14.0		
	3	18	27	51	17	11	15	38	24	12	21	234	23.4		
	1	18	32	10	11	15	12	26	15	7	9	155	15.5		
	4	15	17	20	11	14	13	14	15	10	16	145	14.5		
	5	13	85	19	4	14	14	13	18	13	16	209	20.9	17.7	± 1.89
Readings in 1952															
3268	2	25	24	24	21	19	27	20	21	21	22	224	22.4		
	3	28	29	24	32	23	26	26	26	20	23	257	25.7		
	1	28	27	32	27	29	28	26	24	24	29	274	27.4		
	4	21	16	15	18	20	18	17	19	16	22	182	18.2		
	5	24	18	17	19	21	18	19	22	23	21	202	20.2	22.8	± 1.69

TABLE II. FREQUENCY DISTRIBUTION OF POLLEN PRODUCTION OF DIFFERENT VARIETIES OF SUNFLOWERS IN 1951 (VALUES ARE MEANS FROM 5 DIFFERENT PLANTS)

Variety	Class Centers										N	Ground Mean	s-x
	12.5	17.5	22.5	27.5	32.8	37.5	42.5	47.5					
1. Early Short Stem (Intro. from Hungary)	3	3	4	1							11	19.53	± 1.79
2. Aerohead (Intro. from Pullman)		5	13	12	3	1					34	24.95	± 0.81
3. Mennonite (from Saskatoon)		1	3	6	5		1				16	28.79	± 1.74
4. S-791 (from Saskatoon)		3	2	4							9	22.83	± 1.49
5. S-37-49-2-3-3-2 (from Saskatoon)		3	1	2	1						7	22.57	± 2.01
6. S-37-25 (from Saskatoon)			2		2						4	27.43	± 2.17
7. S-37-402 (from Saskatoon)		1	5	4	2						12	25.93	± 1.36
8. S-37-388		1	1	2							4	23.95	± 2.08
9. Sunrise		2		1							3	20.43	± 3.49
10. 876-10 (Dr. Fryer's Selection)	1	5	19	9	1						35	22.93	± 0.66
11. Saratov (Intro. from Argentina)			1	1	1						3	28.40	± 3.13
12. 952-72-3 x S-791						2					2	36.90	± 0.15
13. S-791 (Early Planting)					3						3	33.57	± 0.14
14. 3268 (Intro from Iowa)	1	5									6	16.40	± 1.02

TABLE III. FREQUENCY DISTRIBUTION OF POLLEN PRODUCTION OF
DIFFERENT VARIETIES OF SUNFLOWERS IN 1951
(ON A SINGLE PLANT BASIS)

Variety	Class Center										N	Mean	s_x^2
	12.5	17.5	22.5	27.5	32.5	37.5	42.5	47.5					
1. Kruglik (Intro. from Argentina)											3	14.37	+ 0.79
2. Hybrid (17876 x Saratov)				5							5	27.98	+ 0.65
3. C.V.O. 35-2-5		2	2		1						5	22.92	+ 2.43
4. C.V.O. 31-2-1			1	3	1						5	28.02	+ 1.60
5. C.V.O. 9-2-5				2	2	1					5	32.42	+ 2.04
6. C.V.O. 77.23			3								3	22.57	+ 0.69
7. S - 37 - 402			2	2	1						5	26.52	+ 2.08
8. S - 37 - 49		5									5	17.18	+ 0.88
9. S - 37 - 25			3								3	22.10	0.92

1
12
1

TABLE IV. FREQUENCY DISTRIBUTION OF POLLEN PRODUCTION OF DIFFERENT VARIETIES OF SUNFLOWERS IN 1952 (ON A SINGLE PLANT BASIS)

Variety	Class Centers										N	Grand Mean	s- x
	17.5	22.5	27.5	32.5	37.5	42.5	47.5	52.5	57.5				
1. 2283/1			1	3		1				5	32.5	+ 2.36	
2. 2129/2					1		3	1		5	45.6	+ 2.02	
3. 2197/3				1	2	2				5	39.0	+ 1.61	
4. 2148/1								4	1	5	54.1	+ 0.91	
5. 2183/1							3	2		5	49.6	+ 0.84	
6. 2188/1					2	1	1	1		5	43.4	+ 2.58	
7. 2162/3						1	4			5	45.9	+ 1.39	
8. 2140/2						2	2	1		5	46.2	+ 1.50	
9. 2193/1						2	3			5	46.1	+ 1.19	
10. 2146/2					1	1	1	2		5	47.0	+ 2.87	
11. 2149/3							1	4		5	51.3	+ 0.90	
12. 2127/2					3	2				5	40.4	+ 1.02	
13. 2169/2				1	4					5	37.4	+ 0.76	
14. 2176/1					2	3				5	39.9	+ 2.09	
15. 2104/1				1	4					5	37.2	+ 0.87	
16. 2281/2			1	4						5	30.3	+ 0.73	
17. 2209/2					4	1				5	39.3	+ 0.93	
18. 2132/1					2	2		1		5	42.3	+ 2.43	

TABLE IV. (Continued)

Variety	Class Centers										Grand Mean	s $\bar{x}$
	17.5	22.5	27.5	32.5	37.5	42.5	47.5	52.5	57.5	N		
19. S - 37 - 402				5						5	32.0	± 0.59
20. Novi-Sad 4 (Intro. from Yugoslavia)					3	2				5	39.2	± 0.60
21. Pole Star					3	2				5	39.4	± 0.71
22. S - 37 - 388		3	1	1						5	26.6	± 1.79
23. S-791 x 952-72		2	2	1						5	26.8	± 1.89
24. Aerohead	1	3	1							5	23.1	± 1.07
25. (Intro. from Pullman)			1	2	1	1				5	35.1	± 2.41
26. S - 791				1	1	1	2			5	41.1	± 2.87
27. 876-10 (Dr. Fryer's Selec.)			5							5	28.1	± 0.13
28. 3268 (Intro. from Iowa)	1	2	2							5	22.8	± 1.69
29. S - 37 - 402				5						5	32.0	± 0.59

(1) The analysis of variance of data with all means included (Tables II and III combined) is given in Table V.

TABLE V. ANALYSIS OF VARIANCE (ALL MEANS INCLUDED) FOR 1951

Source	D.F.	M.S.	F.
Total	162	----	
Varieties	27	84.54	4.22**
Error	135	20.05	

The highly significant F value indicates a significant difference in pollen production between the different varieties. The Least Significant Difference (L.S.D.) was computed in order to compare the means of varieties generally to those of the two standard lines, S - 37 - 388 and Sunrise. The value obtained was

$$\text{L.S.D.} = 5.44$$

Compared to S - 37 - 388

$$(\bar{x} = 23.95 \pm 5.44 = 29.39 \text{ or } 18.51)$$

varieties 952 - 72 - 3 x S - 791

S - 791 (early planting)

C.V.O. 9 - 2 - 5

produced significantly more (29.39 and over) and varieties

3628 (Intro. from Iowa)

Kruglik

S - 57 - 49

significantly less (18.51 or less) pollen.

Compared to Sunrise

$$(\bar{x} = 20.43 \pm 5.44 = 25.87 \text{ or } 14.99)$$

varieties Hybrid (17876 x Saratov)

C.V.O. 31 - 2 - 1

C.V.O. 9 - 2 - 5

S - 37 - 402

S - 791 (early planting)

952 - 72 - 3 x S - 791

Saratov

S - 37 - 25

Mennonite

produced significantly more (25.87 and over)

and the variety

Kruglik

significantly less (14.99 or less) pollen.

In order to avoid any error due to the inclusion of some lines having only one mean in the analysis of Table V, the analysis was repeated on the data of Table II and Table III separately. The test of homogeneity was applied to the variances of the two analyses. The following results were obtained:

(2) Analysis of variance for data with more than one mean:-

Varietal effect, $F = 6.49^{**}$

L.S.D. = 3.998

Compared to S - 37 - 388

$$(\bar{x} = 23.95 \pm 3.996 = 27.95 \text{ or } 19.95)$$

varieties Mennonite

Saratov

952 - 72 - 3 x S - 791

S - 791 (early planting)

Hybrid (17876 x Saratov)

C.V.O. 35 - 2 - 5

C.V.O. 9 - 2 - 5

produced significantly more (27.95 and over)

and varieties

3623 (Intro. from Iowa)

Kruglik

Early Short Stem

S - 37 - 49

Significantly less (19.95 or less) pollen.

Compared to Sunrise

$$(\bar{x} = 20.43 \pm 3.996 = 24.43 \text{ or } 16.43)$$

varieties Aerohead

Mennonite

S - 37 - 25

Saratov

952 - 72 - 3 x S - 791

S - 791 (early planting)

S - 37 - 402

Hybrid (17876 x Saratov)

C.V.O. 31 - 2 - 1

C.V.O. 9 - 2 - 5

produced significantly more (24.43 and over)
and varieties

Kruglik

3628 (Intro. from Iowa)

significantly less (16.43 or less) pollen.

(3) Analysis of variance with means on single plant basis:-

Varietal effect $F = 16.36^{**}$

L.S.D. = 1.301

To test the validity of combining all data into a single analysis of variance, Bartlett's test of homogeneity was applied, giving

$F = 2.36^{**}$

The F value being highly significant shows that the analysis must be considered heterogeneous, and therefore the combined analysis was invalid.

Analysis of variance applied to the 1952 data (Table IV) gave for varietal effect:-

$F = 39.86^{**}$

L.S.D. = 3.73

8 - 37 - 388; $\bar{x} = 26.6 \pm 3.73 = 30.33$ or 22.87.

The above analysis shows that many lines differ significantly in pollen production. This indicates that the method developed for pollen evaluation can be successfully used in choosing the male and

female parent in a hybridization program for high or low pollen production.

3. Correlation of Pollen Production in 1951 and in 1952 by Genetically Similar Material.

As a further step, a correlation coefficient was computed for the bivariate data arising from pollen counts made in 1951 and 1952 on genetically similar lines, with the object of determining the degree of interdependence or co-variation in pollen production over the two years.

A value of $r = 0.729^{**}$ was obtained. To check this highly significant correlation coefficient, a t test for paired data for both years was applied, which confirmed the result obtained above -

$$t = 3.715^{**}$$

The high significance of the r and t tests shows that the constancy in pollen production is due to genetically pure material, the lines showing the same trend in both years. The higher readings of pollen in 1952 are very probably due to better climatic and environmental conditions.

The highly significant correlation indicates conclusively that relative pollen production of different lines is consistent from year to year.

The general trend of pollen production in two years is shown in Fig. 1.

4. Evaluation of Differences in Pollen Production between Early and Late Varieties.

To check whether a real difference occurs in pollen production of early and late lines, a t test for unpaired data was

POLLEN PRODUCTION OF GENETICALLY SIMILAR SUNFLOWER LINES IN 1951 AND 1952

Fig. 1.

applied:-

$$\bar{x}_1 = 27.45 \quad (\text{early})$$

$$\bar{x}_2 = 24.32 \quad (\text{late})$$

$$t = 1.40 \quad (\text{D.F. } 26)$$

The insignificant t value indicates that earliness or lateness does not affect pollen production. The relation to the genes for pollen production being obvious, the result obtained needs no explanation. This finding has importance, however, in the matter of practical selection. We may conclude that selections for high pollen production will not be differential with respect to earliness, and vice versa.

5. Relationship of Pollen Production to Self-Fertility.

An experiment to evaluate the correlation between pollen production and per cent selfed seed was conducted on several lines of a German introduction, which were selected for this purpose because of the uniformity within lines and a variability between lines. For this purpose, five heads in each line were selfed, and at maturity threshed by hand.

Since it was not possible to tell whether seeds were fertile or not, by visual observation, it was necessary to examine each kernel separately, to determine the percentage of selfed seed. The pollen and seed counts were always made from the same head, giving the bivariate data necessary for the computation of the correlation coefficient.

The correlation coefficient r obtained was

$$r = 0.178$$

The significance of the correlation coefficient r was tested

COMPARISON OF SEED SET AND POLLEN

PRODUCTION IN SELFED SUNFLOWER LINES

- 22 -

by the t test according to Johnson (4). The value obtained, $t = 1.187$, is insignificant, which means that $r = 0.178$ is not significant.

The r value being insignificant means that there is no correlation between the percentage of selfed seed and pollen production in the tested lines. Since the percentage of selfed seed depends also on genes for self-compatibility, more samples in given lines should be analyzed to check the variation of correlation in single lines, which might fluctuate with (+) and (-) values around zero.

Their relation is shown graphically in Fig. 2.

B - Experiment 2.

Hybrid Seed Production from Different Proportions of Parental Seed in the Sowing Mixture.

Poor germination, due to unfavorable weather conditions during the fall of 1951, caused very unequal stands. Therefore, an attempt was made to determine the percentage of hybrid to selfed plants by visual observation. These results are given in Tables VI and VII.

Since no yield data is presented, no test of significance has been calculated for the hybridization test.

These results as presented therefore cannot be cited as supporting or rejecting the effectiveness of visual selection of hybrid plants. On the basis of the observation of 1952, the percentage of hybrid plants indicates that fewer male plants may be used than has been the normal practice in the production of hybrid sunflowers.

TABLE VI. PERCENTAGE OF HYBRIDS IN DIFFERENT MIXTURES OF PARENT LINES

Proportion (F,M)	Rep. I		Rep. II		Rep. III	
	N	%	N	%	N	%
2 x 2	0	-	7	85.0	6	83.1
2 x 4	5	80.0	3	75.0	0	-
2 x 6	0	-	0	-	4	75.0
50 x 50	0	-	20	85.0	0	-
60 x 40	11	81.8	22	72.7	15	80.0
70 x 30	6	66.6	3	66.6	13	70.0
80 x 20	21	85.7	24	70.8	14	64.3
90 x 10	16	75.0	23	70.0	13	83.3

N = Number of plants in the row.

TABLE VII. PERCENTAGE OF HYBRIDIZATION IN PARENTAL SELECTIONS FROM DIFFERENT ROW AND SEED MIXTURE PROPORTIONS

Sunrise			S - 37 - 388		
Proportion (F,M)	N	%	Proportion (F,M)	N	%
2 x 2	0	-	2 x 2	0	-
2 x 4	0	-	2 x 4	0	-
2 x 6	0	-	2 x 6	0	-
50 : 50	21	86.0	50 : 50	4	75.0
60 : 40	9	78.0	60 : 40	15	80.0
70 : 30	0	-	70 : 30	13	69.0
80 : 20	10	70.0	80 : 20	15	73.0
90 : 10	15	80.0	90 : 10	17	82.0

N = Number of plants

DISCUSSION AND CONCLUSIONS

The results presented suggest that the various characters of interest are not all equally amenable to selection.

In this study, if we consider first the average pollen production over the two years, the data within each experiment are very similar. It could also be suggested that observed discrepancies were due to climatic and environmental conditions. The result obtained may be very useful as a guide in designing future experiments for evaluating parental lines.

The analysis of variance of the data recorded on pollen production indicates clearly that the method used is effective for isolation of superior pollen-producing lines and plants. In future this method could be extended in analyzing the percentage of viable pollen in the lines tested. The estimate of the variance component for specific pollen production is very regular and exhibits the same trend for two years. In both years, chance variation arising from sampling appears not to have had an important influence on the results obtained for any particular line. Some lines may exhibit improved performance; others remain constant, and still others may be inferior when compared to standard lines. If one extends the original analysis of simple correlation between pollen production and the setting of selfed seed to include, as a third variable, data from open pollinated lines, by using a multiple correlation test, more information might be obtained.

The appropriate test of significance in this case depends upon

the specific information the data are expected to provide. Since correlation of pollen production in two years is highly significant, we can assume that selection for high pollen production will be effective if the objective is to obtain parental lines with high pollen production.

From the results obtained, it would appear that a lower proportion of male plants are required for production of hybrid seed than is commonly used. There may be two approaches to the production of hybrid sunflower seed:-

1. The selection of male parents of very high pollen production permitting high set of hybrid seed in the female parent with a minimum number of male plants; (Ex.: 2 x 4; 2 x 6 or 2 x 8 row planting).

2. Reduction of the male parent percentage in mixture combination as shown in Tables VI and VII. (Ex.: 60 : 40; 70 : 30; 80 : 20; 90 : 10).

Such a mixture would permit the harvesting of the entire crossing plot without separation of male and female plants. The data obtained in this test, while only from one year, are nevertheless so encouraging that this approach to hybrid seed production should be followed up on a larger scale.

An alternative method might be the selection for high pollen production in both parents, which might result in high reciprocal crossing. This also could be used on the row or seed mixture basis of the above methods.

Normally, selection is practiced for several attributes simultaneously. The larger the number of attributes under selection at any

one time, the smaller will be the selection differential for each characteristic. Now, considering the correlation more specifically, the determination of pollen production is not a common practice. If conclusions are to be confined to particular lines used, then the variation associated with generations (in the line and between lines) is correctly judged significant.

Data presented show that a selection between lines and in the line itself during the process of sunflower breeding, can be done.

Visual selection for determining yielding ability must be more detailed if it is to provide a good differential. When conditions are favorable, the percentage of hybrids are readily classifiable visually, whereas differences in yielding ability are much more difficult to evaluate. Yield being the most complex from a genetical standpoint and most affected by environmental variations, lends itself least to visual selection.

This experiment is now being repeated, in expectation that future yield tests will give us the answer concerning relative effectiveness of the hybridization rates.

SUMMARY

Two separate experiments were conducted in which sunflower lines were tested for their pollen production, and hybridization performance.

In the first experiment, lines derived from a common source were tested for their pollen production. In the second experiment, two standard varieties were tested for their combining ability.

The tested lines differed significantly in their pollen production. It was further shown by correlation analysis that these differences were maintained over two seasons. It is concluded that the technique developed in the investigation can be used advantageously in selecting male and female parents in a breeding program.

Experiments on mixed seed rates of two standard varieties failed to give yield data, and consequently, no definite conclusions may be drawn.

Agriculture and industry are just beginning to recognize the sunflower as an important source of oil and other substances. Since this crop has not been intensively studied, future investigators should be quite effective in advancing its relative importance, both as to production and utilization.

APPENDIX

Additional Literature

To stress the increasing economical importance of this oil crop, a number of additional references will be cited at this point.

Ezra Levin (10), a food chemist in Montebello, Illinois, set up a processing plant for sunflower oil production. He used ethylene dichloride as a solvent, which literally washes the oil from the crushed seed, conserves the food value and acts as a preservative. Since 1945 the sunflower is growing in importance as a cash crop in Piatt County, Illinois.

Voropajev and Shtifanova (22) discuss the growing importance of sunflower production in Siberia as an oil crop, and state that thirty per cent of the oil crop's acreage in the province of Omsk is actually under Sunflower. Gorobeow (5), head of the collective farm, "Molotov" reports the issuance of an over-all order to collective farms to seed 2 - 5 sunflower rows at 30 - 45 foot spacing on summer fallow, in order to catch snow and preserve moisture. Igonin (8) describes the increasing practice of winter seeding of sunflowers in the U.S.S.R as a means of providing earlier harvesting.

Bonvincini (2), discussing his results in breeding sunflowers, stresses the growing importance of this plant in its contribution to oil crops expansion in Italy. Volynzev (23), in a report of the State Commission for Testing Varieties of Grains, Oil Crops and Grasses, states that sunflowers have become the basic oil seed crop of the U.S.S.R.

New varieties have been developed with 60 - 66% oil in hull-less seed, and with a reduction of the husk percentage to 23 - 24 per cent.

There has been great interest in Stojkovich's (18) work in developing the new Yugoslav variety, "Novi-Sad 4," which was tested for the first time this year, and also in Tarchinski's (19) quick method for determining oil content during the selection of oil crops.

Sunflowers being the source of such valuable products as vegetable oil, α - cellulose, pectin and potassium, the potential value of research work done on this crop can be readily seen.

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