DEVELOPMENT AND IMPROVEMENT OF BREEDING POPULATIONS IN SUNFLOWER

By

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Summary

The USDA sunflower (*Helianthus annuus* L.) breeding program at Fargo, N.D. has used traditional inbreeding and hybridization procedures to develop superior inbred lines for production of commercial F_1 hybrids in the USA. In addition, research has been initiated to develop source populations to improve the effectiveness and efficiency of sunflower breeding. The two methods being used are intrapopulation and interpopulation improvement, depending on the specific breeding objective. Intrapopulation improvement will maximize improvement of the population itself and that of inbred lines derived from it. Interpopulation improvement maximizes simultaneous improvement in two populations and the hybrid performance between inbred lines extracted from the two different populations. The rate of improvement of hybrids is proportional to the simultaneous improvements of the two populations; therefore, the efficient development of new hybrids after each cycle of population improvement will be an important phase of the breeding program.

Breeding populations have been developed in both maintainer (B-line) and male (R-line) types. These populations will serve as sources for high seed yield, high seed oil percentage, disease resistance to downy mildew, Verticillium wilt, and Sclerotinia stalk and head rot, non-oilseed large achene, and non-oilseed large kernel. A reciprocal full-sib selection scheme has been initiated using male sterility induced by givverellic acid treatment of the buds at a specific time.

Introduction

Commercial sunflower (*Helianthus annuus* L.) growers in the United States have used modern cultural methods to maximize seed yield/hectare. Sunflower breeders have recognized the potential for greater seed yield and are developing inbreds from which still higher yielding hybrids may be produced. F_1 hybrids now are grown on nearly all the production units in the USA because of their higher yield potential, increased disease resistance, uniformity, and better self-fertility. Rapid release of new hybrids to farmers requires efficient and effective procedures to develop sunflower inbreds. The demand for hybrids with higher-yielding ability in variable environments also is great, and will increase as production costs per unit approach gross returns to the farmer. Several cultural practices, such as insecticide application for the sunflower moth, *Homoeosoma electellum* (Hulst), chemical desiccation for early fall harvest, and herbicide application for weed control are new costs to the producer; however, these practices have increased reliability of yields and crop stability and have made sunflower a consistent crop for the producer. Also, genetic potential may be expressed and measured more accurately if the above hazards to sunflower seed production are controlled.

Cytoplasmic male sterility and genetic fertility restoration have been used in production of F_1 sunflower hybrids since 1972. Inbred lines, both (B-line) and (R-line), were isolated directly from heterogeneous sources in the early breeding procedures to develop inbreds from which hybrids could be created. A backcrossing procedure was used to introduce the B-line germplasm into sterile cytoplasm. More recently, the sunflower breeding program at Fargo has shifted emphasis to the isolation of inbreds from improved breeding populations. Research objectives are to improve breeding populations from which more productive hybrids can be constructed. The purpose of this paper is to describe 1) the methodology of creating the breeding populations, 2) the utilization of specific selection procedures, and 3) the goals for several populations.

Objectives

The primary objectives relative to the development of improved superior breeding populations are in three major areas: 1) increase seed yield, 2) improve seed and oil quality characteristics, and 3) increase disease resistance.

Increasing seed yield

The trait of primary importance to the producer is seed yield. The combining ability of specific inbreds must be improved to increase yield of their hybrids. Therefore, efforts must be made on both the female and male line side, with different breeding populations formulated for each. Also, different techniques are necessary to utilize male and female populations. The male fertility restorers considered for inclusion in the restorer populations were selected for improvement from germplasm unrelated to the B-lines now used in hybrids. In addition, most restorer lines used in commercial hybrids in the USA contribute disease resistance to rust, *Puccinia helianthi* Schwog, and downy mildew, *Plasmopara halstedii* (Farl.) Berl. et de T., and lines processing this resistance were included. Also, most restorer lines now used are multiple-headed, a trait genetically controlled by a single recessive gene; lines with this trait were selected.

The B-line populations are composed of heterogeneous sources, possessing resistance to Verticillium wilt, *Verticillium albo-atrum* Reinke and Berth., having the single-headed trait, and having known general combining ability. Maximization of genetic variance within the population is a goal. Lines with sterile cytoplasm are not used in this population, as superior selections extracted will be introduced into sterile cytoplasm by a backcrossing procedure after identification.

Improvement of Quality

Greater oil content and percentage of linoleic acid composition of oilseed sunflower are desired. Larger achene size and larger kernel size with improved achene color (contrasting, uniform white and dark stripes) are goals for nonoilseed sunflower. Presently, this effort is being directed to incorporate these improved characters into the B-line side.

Improvement of Disease Resistance

New sources of disease resistance are sought to incorporate into sunflower inbreds. The disease causing most concern to scientists in the upper midwest and Canada is Sclerotinia stalk and head rot incited by Sclerotinia sclerotiorium (Lib.) D By. Sources of resistance have not been readily discernible, although several lines have been tentatively considered to be more "tolerant" of Sclerotinia than other lines. If resistance is additive, breeders will attempt to combine resistant genes (resistance) via "screening" a breeding population planted in infested soil. The breeding population method will be the best approach to identify future sources of tolerant or completely resistant germplasm to provide future hybrids protection.

Intrapopulation Improvement

A recurrent selection scheme for improved yield was initiated to improve a B-line population utilizing two restorer lines as inbred line testers. Although this scheme would theoretically be considered recurrent selection for specific combining ability, utilizing two testers should provide information pertaining to general combining ability. Horner et al (1973) and Russell et al (1973), both working with maize, reported that using an inbred tester was effective in improving general, in addition to specific, combining ability. After results from testcrosses are evaluated, self-pollinated seed from plants producing high-yielding testcrosses are bulked. In the next generation, the population is random mated and the resulting intercross population serves as the cource for the next cycle of selection.

The recurrent selection scheme was selected based on the theory that genetic variability in the population would be maintained while allowing increased frequency of desirable genes and gene combinations. Since yield is not a highly heritable character, use of testcross yield results will provide the selection criteria. Also, the breeding program is actively involved in release of improved germplasm to commercial breeders to use in F_1 hybrids. Since the inbred testers are inbred lines suitable as parents, the testcross results may indicate potential combinations for commercial F_1 hybrids after generations of inbreeding and conversion to male sterility.

Improvement of quality characteristics has been relatively easy to manage by using a simple recurrent selection scheme. This involves selfing plants in the source populations, analyzing the selfed seed of each plant for quality and intercrossing the superior types to form new populations for the next cycle of selection.

Three types of populations are being evaluated. In the oilseed program, oil percentage has been improved by using this scheme. Lines derived from the third cycle of selection have oil percentages up to 12.4% higher than the original population. As increases in oil percentage may be associated with undesirable agronomic changes (Fick and Rehder 1977), agronomic characters are evaluated in recurring cycles of the selection scheme. In the nonoilseed program, selection is for larger achenes and kernels in recurring cycles. The simple recurrent selection scheme has produced good results for simply inherited characters with relatively high heritability.

Improvement of disease resistance to Sclerotinia stalk and head rot is in the initial phase, the development of the source populations. A mass selection scheme should most fully utilize the variability present. Plants possessing ability to survive and produce pollen will be allowed to random mate with similar plants. The population will be planted in soil infested with Sclerotinia to allow resistant genes and gene combinations to be identified over several years.

Interpopulation Improvement

Changes in genetic variances in a population will occur very slowly as the gene frequencies gradually change for complex traits such as seed yield. The efficiency and effectiveness of improving breeding populations for seed yield will be enhanced if a reciprocal recurrent selection scheme is developed that would simultaneously improve two populations with direct selection of lines from each to be used as parents in F_1 hybrid combinations. The reciprocal full-sib sleection method developed for maize (Hallauer, 1967, Lonnquist and Williams 1967, Hallauer and Eberhart 1970) and effectively used in the development of maize inbred lines and breeding populations (Hallauer 1973) has been adapted to sunflower breeding (Miller and Fick, 1978).

Since hybrid sunflower requires two separate and genetically distinct parents (female and male restorer lines), these two types have been desiganted as the two populations. Reciprocal full-sib sleection requires that at least one of two sunflower populations have plants with multiple heads. As a secondary requirement, selfed seeds must be obtained from each of the two plants selected for hybridization. The fertility restorer line population has the multiple-headed characteristic, and gibberellic acid (GA_3) applied at rates of 50-100 ppm will induce sterility in selected heads while allowing self-pollinated seeds to develop on secondary heads of the restorer line plants (Miller and Fick, 1978).

In the first year, 120 crosses were attempted between the two populations, designated 1) downy mildew resistant, restorer line synthetic and 2) Verticillium wilt resistant, B-line synthetic. A minimum of 160 seeds was established as the required number of crossed seeds to conduct an adequate yield test. The minimum number was obtained in 98 crosses, 100 seeds were obtained on 14 crosses, and 8 crosses failed to produce adequate seed.

The first yield trial was planted in 1978 at the Agronomy Seed Farm, Casselton, ND, in cooperation with the Agricultural Experiment Station, North Dakota State University.

The GA_3 technique to make interpopulation crosses among plants of different populations also is invaluable for use in recurrent selection programs that require testcrossing and to use in random mating populations. The reciprocal full-sib selection scheme has been initiated in the nonoilseed breeding program.

Inbreeding

After a superior line is identified from a population, the remnant seed from the self-pollinated plants is planted in the breeding nursery as a single row. Within row selection is made for desirable agronomic characteristics and bags are placed over the developing heads to exclude foreign pollen. Inbreeding usually is continued for a minimum of 3-4 generations with high self-compatibility an important criterion evaluated after each harvest. The primary effect of inbreeding is to fix genes governing characters with low heritability, which are the characters that usually are most important to breeding and alos most difficult to handle under other methods. An additional testcross with potential parental lines is made in the first selfing generations and advanced yield tests are grown to identify the final selections. Inbred lines, both restorer and male sterile with its maintainer, are released and registered under a numbered designation.

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