Genetics and Breeding of Sunflower

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ABSTRACT

Considerable progress has been made to improve sunflower through breeding and genetics programs. Continued improvement appears feasible. Present information suggests that large numbers of new lines and hybrids are available that are superior in yield potential, disease and insect tolerance, agronomic traits, and/or oil quantity and quality characteristics.

Sunflower (*Helianthus annuus* L.) is a relatively new crop in the United States with very rapid expansion of acreage occurring within the last 15 years. Present production is centered primarily in the Dakotas and Minnesota with nearly five million acres grown annually.

Several significant developments have occurred in the area of plant breeding and varietal improvement to account for at least part of the increased production. One of these developments was the introduction into the USA of high oil varieties from the Soviet Union in the mid 1960s. These varieties had oil percentages in the range of 40-45% as compared to 30-35% for varieties grown previously.

Another significant development was the discovery of cytoplasmic male sterility and genes for fertility restoration, a discovery that allowed for the production of hybrid sunflower. The hybrids were introduced during the early 1970s. They showed about a 25% yield advantage over the open-pollinated varieties, improved disease resistance, greater uniformity in height and flowering, and a greater degree of self-compatibility. The latter is a trait that alleviates the dependency on high insect pollinator populations for good seed set.

Sunflower breeders are generally optimistic that further improvements in varietal development can be realized. Major objectives in current programs include higher yield potential, improved resistance to disease and insect pests, greater self-compatibility, resistance to stalk lodging, higher oil percentage, and alterations in fatty acid composition.

Yield Potential

Average sunflower yields in the USA are currently on the order of 1200 - 1400 kg/ha. Under favorable growing conditions and good management practices, seed yields of 2200 kg/ha are relatively common and yields as high as 3400 kg/ha have been reported. Seed yields of experimental hybrids approaching 5600 kg/ha have been obtained in test plots. Thus the potential exists for higher yields and it is likely that continued improvements of a more or less gradual nature can be expected through further breeding efforts and improved production practices.

Disease and Insect Resistance

Numerous disease and insect pests attack sunflower. Diseases and insects probably represent more of a problem than they do in competing crops such as wheat and corn. Fortunately, resistance to most of the major diseases of sunflower has been identified and incorporated into presently grown hybrids. The wild species of sunflower have proven very useful in breeding for disease resistance in the past and represent excellent sources of germplasm should resistance to new diseases or new races of pathogens be needed in the future.

At least partial resistance to several damaging insects appears possible through development of sunflower types with altered chemical and morphological characteristics. Some of these possibilities include pubescent leaf types for control of several leaf-feeding insects, and seeds possessing the so-called "armored" layer for reducing damage from certain seed infesting insects.

Self-Compatibility

Sunflower is generally considered a cross-pollinating crop, pollination occurring primarily by honey bees. Wide variation exists among sunflower lines and hybrids for the ability to self-pollinate without bees, and types that are nearly 100% self-pollinating or self-compatible have been identified. Seed yields of highly self-compatible hybrids are generally higher than those of low self-compatibility when honey bee populations are low, or when bees are not active due to adverse weather conditions. As a result of strong selection for high self-compatibility, breeders have recently developed hybrids that are much less dependent on bees than varieties previously available.

Lodging

Strong winds and storms during the growing season may cause sunflower plants to lodge and break over in the field, making harvesting extremely difficult. New semidwarf hybrids that grow only 3-4 ft tall and show much improved resistance to lodging are being developed. It is expected that these dwarf types will be grown on an increasing percentage of the acreage in the next few years.

Oil Percentage

Oil in sunflower seed grown in the USA average ca. 44% on a dry weight basis. Several new hybrids are available that produce nearly 50% oil, and experimental lines with as high as 63% oil have been reported. The latter types have extremely thin hulls and the seeds are easily damaged in harvest and handling. Thus, further improvements in oil percentage are possible but hybrids with extremely high oil percentages may not be realized soon in commercial production because of harvesting difficulties.

Fatty Acid Composition

Sunflower oil from seed grown in the northern production area of the USA consists of ca. 6% palmitic, 5% stearic, 18% oleic and 68% linoleic acids. The relative proportions of oleic and linoleic acids vary with temperatures during the seed maturation period, higher temperatures resulting in higher oleic acid percentages. Thus sunflower seed grown in

the southern USA with a generally warmer climate has a higher oleic acid percentage, but rarely do these percentages exceed 40.

Recently, sunflower lines have been identified that produce oleic acid percentages of ca. 80% and as high as 90% on an individual plant basis. The high oleic lines do not appear to be temperature-sensitive, as oleic acid percentages fluctuated only 3-4 percentage units when grown in widely varying climates.

The high oleic oil from these hybrids should help create new markets for sunflower oil especially in the deep-fat frying industry, as a substitute oil in export channels, and for chemical and industrial purposes. Limited production of high oleic hybrids is expected as early as 1983.

Disease Problems of Sunflowers

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ABSTRACT

Sunflower, the second most important oilseed crop in the world, was developed as a crop in eastern Europe, but is a native of North America. The pathogens causing many of its major diseases are also native to North America. Although a profitable crop, sunflowers have fairly low value per hectare. Disease control must, therefore, be inexpensive, by resistant varieties or seed treatment or cultural practices, rather than repeated field application of chemicals. Rust, a limiting factor in many countries, has been successfully controlled everywhere by resistance from wild sunflowers discovered in Canada about 1950. New races are posing problems in Argentina and Australia, but new resistance may be available. Verticillium wilt has been destructive in some areas but resistance is available from wild sunflowers and Russian high-oil varieties. Downy mildew, highly destructive in many countries, has been effectively controlled by two genes from the original rust-resistant material. A new race attacking this resistance was discovered in 1980: resistance to it appears to be available. Sclerotinia stalk rot and head rot, caused by a pathogen with wide host range, is much harder to control by breeding. Leaf spot diseases have long been a limiting factor in some European countries and elsewhere, but were considered minor in North America until recently. Broom rape, a root parasite which almost destroyed the crop in the USSR and elsewhere in eastern Europe, does not attack it in North America. It is controlled by resistant varieties.

INTRODUCTION

Sunflowers (*Helianthus annuus*) are native to North America; many wild species occur from Canada to Northern Mexico. Taken back to Europe by the first explorers and conquerors, sunflowers were long considered merely ornamental until they were developed as a source of edible oil in Russia in the 19th century. The crop spread from there to eastern Europe, Argentina, and limited areas elsewhere (1). After the release of high-oil varieties by the USSR, sunflower growing began or increased in many countries. After the discovery of cytoplasmic male sterility (2) and restorers (3) which made production of hybrid sunflowers practical, the crop rapidly assumed major importance worldwide, second only to soybeans among the annual oilseeds (4, 5).

Sunflowers are highly adaptable and can yield well from beyond 50° north of the equator to 40° south of it. Any crop grown over such a range will encounter tremendous variability in soil, climate and weather. Even where environmental conditions are favorable, there may be hazards. These include market and other economic factors, bird and insect predation, weeds and diseases.

DISEASES: CAUSES AND CONTROLS

Disease of plants may be caused by such diverse agencies as environmental factors, fungi, bacteria, viruses, nematodes and parasitic higher plants. Fungi cause most of the diseases which have been destructive on sunflowers in various countries (6). Like sunflowers, many of their fungal pathogens appear to be native to North America. Unfortunately, some of the most destructive have spread with seed or by other means and now affect sunflowers almost everywhere that they are grown. Some diseases which are destructive in other parts of the world have not yet attacked sunflowers in North America, but at least one of them has appeared here recently (6, 7).

New or foreign diseases may sometimes be kept out of a country, or their introduction may be delayed, by well designed quarantines or embargoes. Control of diseases present in the country may be attempted by cultural practices, such as crop rotation; by the use of appropriate chemicals; and by breeding resistant varieties. The choice of control measure may be dictated not only by what is biologically possible, but also by what is agronomically desirable, or economically feasible.

Sunflowers have been a profitable crop for many growers in the last ten years, but their value per unit area is relatively low. Average production costs and average yields under good management were calculated for 1978 for North Dakota (8). Using those values and average prices received by US farmers from 1977/78 to 1981/82 (4), the net returns during those five years varied from ca. $15 to $75 per hectare. Because of such narrow profit margins, sunflower growers cannot consider the repeated applications of chemicals to control disease which are normal in growing crops such as potatoes or apples. They must depend on other means of disease control.

Agronomic practices may be very useful in reducing damage from some diseases. Appropriate date of seeding, depth of seeding, etc., may help reduce disease losses. Rotation with appropriate nonhost crops can give good control of some pathogens. Seed treatment with chemicals is much cheaper and easier than field applications of chemicals, and can be useful in some cases. A single well timed field application of fungicide may be economic in some instances. The most desirable control, and cheapest and easiest for the growers, is the use of resistant varieties where possible.

Close to 100 species of microorganisms and viruses have been reported on sunflowers throughout the world, and about 30 in North America (9). Ten to twelve diseases are described as major problems in various countries (10); half of them are important in North America. As the first commercial production of sunflowers for edible oil in North America started in Canada, in Southern Manitoba, and sunflower breeding and disease research programs were established there, I shall discuss diseases in the order in which they assumed priority in those programs, then add some of major interest elsewhere. All but the last disease to be discussed are caused by fungi.