A-1331 (EB-25 Revised)

Sunflower Production

NDSU

NDSU Extension Service
N.D. Agricultural Experiment Station
North Dakota State University

SEPTEMBER 2007

Foreword

The first edition of "Sunflower Production and Marketing Extension Bulletin 25" was published in 1975. This publication provided general information for growers, seedsmen, processors, marketing agencies and Extension personnel. Revised editions followed in 1978, 1985 and 1994. Interest and knowledge about sunflower production and marketing in the U.S. has increased greatly in the past 30 years. Marketing and processing channels have stabilized and have become fairly familiar to growers since 1985, but pest problems have shifted and new research information has become available to assist in production decisions.

This publication is a revision of the "Sunflower Production and Marketing Bulletin" published in 1994. The purpose is to update information and provide a production and pest management guide for sunflower growers. This revised publication is directed primarily to the commercial production of sunflower, not to marketing and processing. It will attempt to give specific guidelines and recommendations on production practices, pest identification and pest management, based on current information.

This publication also is directed primarily toward sunflower production in the northern Great Plains of the U.S. However, much of the information is relevant to other production areas. **All pesticides recommended have a U.S. Environmental Protection Agency label unless otherwise specified. This publication contains certain recommendations for pesticides that are labeled ONLY for North Dakota. The users of any pesticide designated for a state label must have a copy of the state label in their possession at the time of application. State labels can be obtained from agricultural chemical dealers or distributors. USE PESTICIDES ONLY AS LABELED.**

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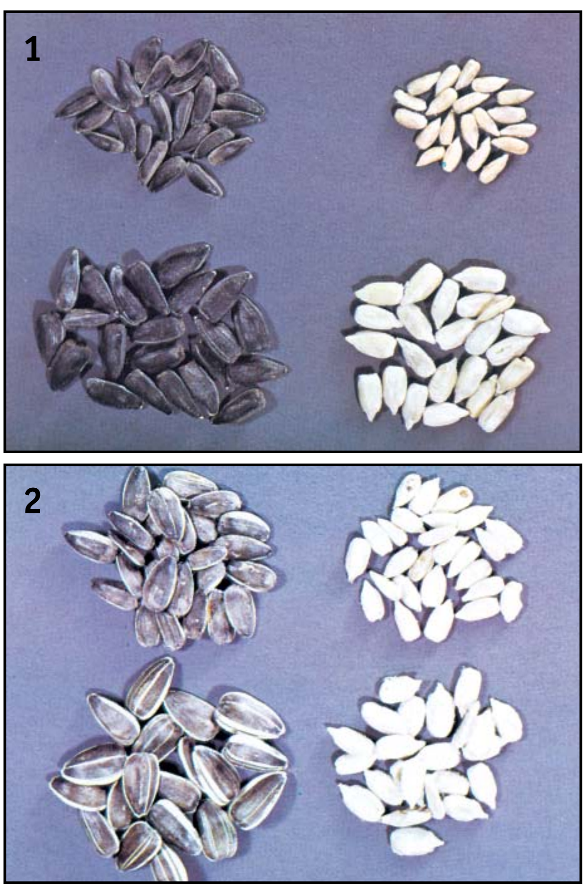
Contents

Introduction

(Duane R. Berglund)

Two primary types of sunflower are grown: (1) oilseed for vegetable oil production and (2) nonoilseed for human food and bird-food markets (Figure 1). The oilseed hybrids may be of three fatty acid types: linoleic, mid-oleic (NuSun) or high oleic. They are usually black-seeded and have a thin hull that adheres to the kernel. Seed of the oilseed varieties contains from 38 percent to 50 percent oil and about 20 percent protein. Some black-seeded oil types go into the hulling market for birdseed. Nonoilseed sunflower also has been referred to as confectionery sunflower, and is usually white striped and/or comes in large-seeded varieties.



Nonoilseed sunflower generally has a relatively thick hull that remains loosely attached to the kernel, permitting more complete dehulling. Seed of the nonoilseed hybrids generally is larger than that of the oilseed types and has a lower oil percentage and test weight.

Sunflower is a major source of vegetable oil in the world. Worldwide production of sunflower has increased since the last revision of this publication and peaked during the 1998-1999 period. The former Soviet Union remains the highest producer, followed by Argentina and then the U.S., which is third in production worldwide. Domestic use and exportation of nonoilseed sunflower also have increased. The majority of U.S. production of sunflower oil is exported, although domestic use is increasing.

The following chapters provide a historical perspective and background of the sunflower as a viable economic crop and provide the current information on worldwide and U.S. production, U.S. production practices, current pest identification and pest management practices, hail injury, herbicide use and damage, harvesting, drying, storing, and U.S. grades and standards for market.

Historical Perspective

Sunflower, native to North America, is the state flower of Kansas and grows wild in many areas of the U.S. Sunflower has a long and varied history as an economic plant, but the time and place of its first cultivation is uncertain. Sunflower was used by North

Figure 1. The two classes of sunflower based on seed characteristics: (1) oilseed hybrids grown as a source for oil and meal, and (2) nonoilseed hybrids-grown for human and bird food. Wholeseed and kernel types for both are shown. (Gerhardt Fick)

American Indians before colonization of the New World. Spanish explorers collected sunflower in North America and by 1580, it was a common garden flower in Spain (Figure 2). Early English and French explorers, finding sunflower in common use by the American Indians, introduced it to their respective lands. It spread along the trade routes to Italy, Egypt, Afghanistan, India, China and Russia. Sunflower developed as a premier oilseed crop in Russia and has found wide acceptance throughout Europe. Oilseed sunflower has been an economically important crop in the U.S. since 1966. Before 1966, sunflower acreage in the U.S. was devoted primarily to nonoilseed varieties.

The center of sunflower origin has been identified as limited to the western Plains of North America, but whether the domesticated type originated in the Southwest or in the Mississippi or Missouri River valleys has not been determined. The wild form of the cultivated sunflower is well-known, which is not true with most of our cultivated crop species today.

Figure 2. A 1586 drawing of sunflower.
(Mattiolus from Heiser)

The American Indians used sunflower as a foodstuff before the cultivation of corn. Sunflower also was used as a medicinal crop, source of dye, oil for ceremonial body painting and pottery, and as a hunting calendar. When sunflower was tall and in bloom, the bison fed on it, and according to stories told, the fat and the meat were good.

Cultivation of sunflower was undertaken by New World settlers as a supplementary food. Later, sunflower was grown primarily as a garden ornament. It also was grown as an ensilage crop in the late 1800s and early 1900s.

Expanded world production of sunflower resulted primarily from development of high-oil varieties by plant scientists and more recently by the development of hybrids. Sunflower is widely grown in the world where the climates are favorable and a high quality oil is desired.

Taxonomy

The cultivated sunflower *(Helianthus annuus L.)* is one of the 67 species in the genus *Helianthus*. All are native to the Americas and most are found in the U.S. It is a member of the Compositae family and has a typical composite flower (Figure 3). Jerusalem artichoke *(H. tuberosus L.),* another species, is grown on a limited basis for food and livestock feed in the U.S. A few species are grown as ornamentals and the rest are weeds, usually found in pastures or disturbed areas.

The basic chromosome number for the *Helianthus* genus is 17. Diploid, tetraploid and hexaploid species are known. The majority of the species are perennial, with only about a dozen annual species. Plant breeders have made interspecific crosses within the genus and have transferred such useful characteristics as higher oil percentage, cytoplasmic male sterility for use in production of hybrids, and disease and insect resistance to commercial sunflower.

Growth Stages

The division of growth into vegetative and reproductive stages as developed by Schneiter and Miller is shown in Figure 4. This scheme is important as it gives producers, scientists and the industry a common basis to discuss plant development.

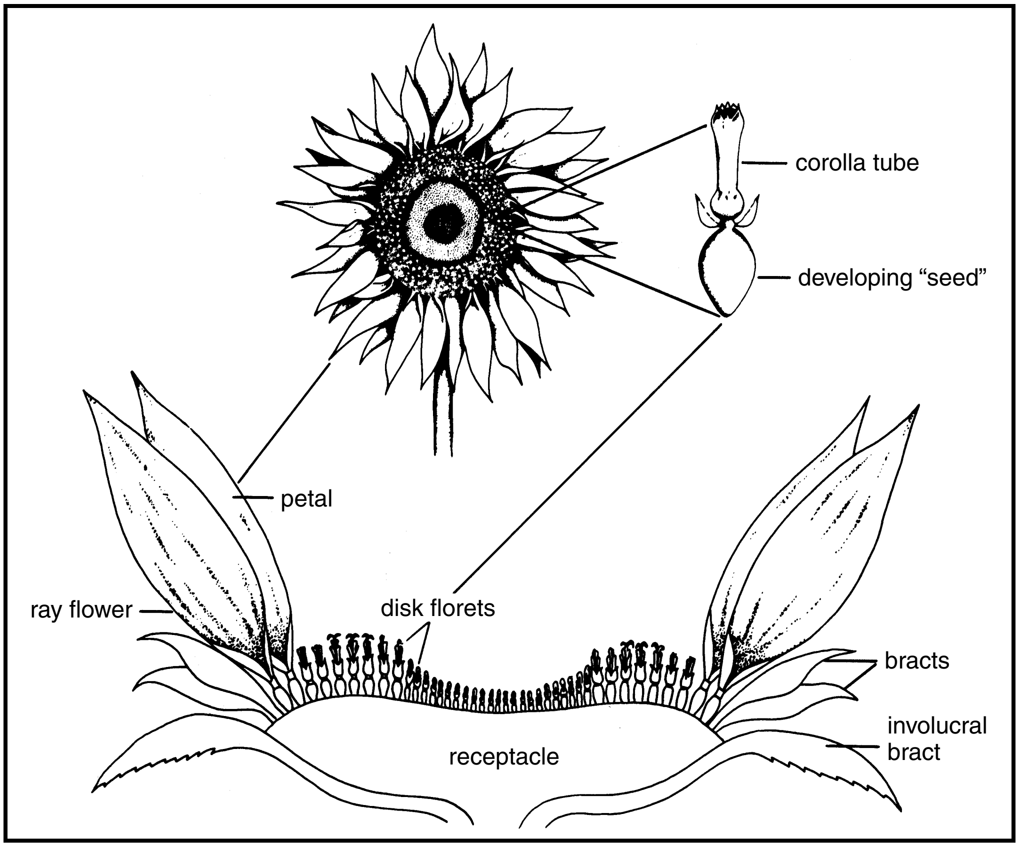


Figure 3. Details of the head of a sunflower and selected parts. (J. Miller and Christian Y. Oseto)

Table 1. Growing Degree Days: Sunflower Growth and Development

		Ave. days and GDD** units accum. from planting	
Sunflower Stage	**Plant Description**	**GDD units**	**Days**
VE	Emergence	167	10
V4	4 True Leaves	349	20
V8	8 True Leaves	545	28
V12	12 True Leaves	690	34
V16	16 True Leaves	772	38
V20	20 True Leaves	871	44
R1	Miniature Terminal Bud	919	46
R2	Bud <1" From Leaf	1,252	61
R3	Bud >1" From Leaf	1,394	67
R4	Bud Open Ray Flowers Visible	1,492	71
R5.1	Early Flower	1,546	73
R5.5	50% Flowered	1,623	77
R6	Flowering Complete	1,780	84
R7	Back of Head - pale yellow	2,052	86
R8	Bracts Green - head back yellow	2,211	104
R9	Bracts Yellow - head back brown	2,470	119

*Source: NDSU Carrington Research Extension Center - 2 years of data averaged from five sunflower hybrids.

**Sunflower growth and development responds to heat units similar to corn and several other crops. In sunflower, the base temperature of 44 F is used to determine Growing Degree Days (GDD). The daily GDD formula is: GDD=[(daily maximum temperature + daily minimum temperature) ÷ 2] – 44 degrees F.

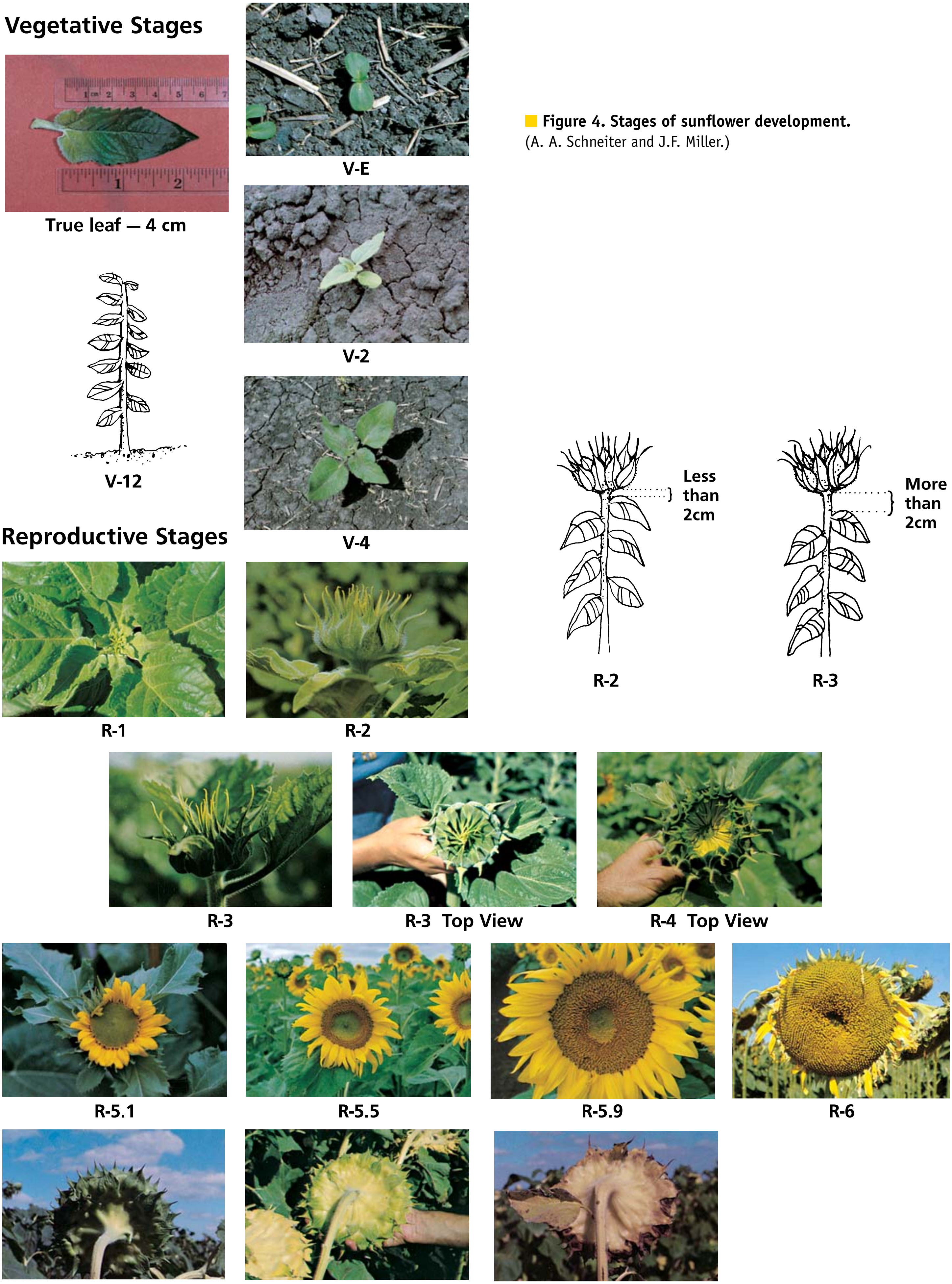


Figure 4. Stages of sunflower development.
(A. A. Schneiter and J.F. Miller.)

Description of sunflower growth stage

The total time required for development of a sunflower plant and the time between the various stages of development depends on the genetic background of the plant and growing season environment. When determining the growth stage of a sunflower field, the average development of a large number of plants should be considered. This staging method also can be used for individual plants. The same system can be used for classifying either a single head or branched sunflower. In the case of branched sunflower, make determinations using only the main branch or head. In stages R-7 through R-9, use healthy, disease-free heads to determine plant development if possible because some diseases can cause head discoloration. Also, in a number of recently released and grown hybrids, the stay-green characteristic is present, which means the yellowing or browning of the bracts may not be a good indicator of plant maturity.

Stage	Description
V (number) Vegetative Stages (e.g., V-1, V-2, V-3, etc.)	These are determined by counting the number of true leaves at least 4 cm in length beginning as V-1, V-2, V-3, V-4, etc. If senescence of of the lower leaves has occurred, count leaf scars (excluding those where the cotyledons were attached) to determine the proper stage.
R-1 Reproductive Stages	The terminal bud forms a miniature floral head rather than a cluster of leaves. When viewed from directly above, the immature bracts have a many-pointed starlike appearance.
R-2	The immature bud elongates 0.5 to 2.0 cm above the nearest leaf attached to the stem. Disregard leaves attached directly to the back of the bud.
R-3	The immature bud elongates more than 2 cm above the nearest leaf.
R-4	The inflorescence begins to open. When viewed from directly above, immature ray flowers are visible.
R-5 (decimal) (e.g., R-5.1, R-5.2, R-5.3, etc.)	This stage is the beginning of flowering. The stage can be divided into substages dependent upon the percent of the head area (disk flowers) that has completed or is in flowering. Ex. R-5.3 (30%), R-5.8 (80%), etc.
R-6	Flowering is complete and the ray flowers are wilting.
R-7	The back of the head has started to turn a pale yellow.
R-8	The back of the head is yellow but the bracts remain green.
R-9	The bracts become yellow and brown. This stage is regarded as physiological maturity.

From Schneiter, A.A., and J.F. Miller. 1981. Description of Sunflower Growth Stages. Crop Sci. 21:901-903.

Production

World Production

(John Sandbakken and Larry Kleingartner)

The sunflower is native to North America but commercialization of the plant took place in Russia. Sunflower oil is the preferred oil in most of Europe, Mexico and several South American countries. Major producing countries or areas are the former Soviet Union, Argentina, Eastern Europe, U.S., China, France and Spain (Table 2). These seven countries/areas of the world produce about 80 percent of the world's oilseed and nonoilseed sunflower. Historically, the former Soviet Union has been the No. 1 producer of sunflower, producing about 35 percent of the world's production annually. During much of the 1970s, the U.S. was the world's second largest producer, but in the 1980s, Argentina became firmly entrenched in second place.

U.S. Production

Acreage

The first sustained commercial production of oilseed sunflower in the U.S. occurred in 1966, when about 6,000 acres were grown. Total combined acreage of oilseed and nonoilseed sunflower increased gradually in the late 1960s and expanded rapidly in the 1970s, reaching a peak in 1979 at 5.5 million acres. The U.S. share of world production has declined in recent years as production in Argentina and other countries has increased. During the peak period of U.S. production, the U.S. produced about 15 percent of the world's sunflower production. In 2005, the U.S. market share was only 6 percent.

The rapid acreage increase in the late 1970s was stimulated by a variety of factors. Favorable yields in 1977 and 1978 brought about by improved hybrids and favorable weather conditions were key factors, along with excellent prices when compared with competitive crops.

Table 2. World Production of All Sunflower

	1996-1997	1997-1998	1998-1999	1999-2000	2000-2001	2001-2002	2002-2003	2003-2004	2004-2005	2005-2006	2006-2007 Forecast
Argentina	5.45	5.68	7.13	5.80	2.94	3.73	3.34	2.98	3.75	3.82	4.20
Eastern Europe	2.92	2.18	2.59	2.75	1.67	1.86	2.02	2.67	2.27	2.11	2.17
European Union	3.87	4.08	3.44	3.10	3.27	3.03	3.72	4.07	4.07	3.72	4.06
China, Peoples Republic of	1.42	1.17	1.46	1.77	1.95	1.75	1.95	1.82	1.70	1.83	1.85
former USSR	5.37	5.41	5.74	6.89	7.27	4.94	7.19	9.35	8.00	11.32	11.20
United States	1.60	1.67	2.39	1.97	1.61	1.55	1.11	1.21	.93	1.82	.92
India	1.30	1.16	1.17	.87	.81	.73	1.06	1.16	1.45	1.50	1.43
Turkey	.67	.67	.85	.82	.63	.53	.83	.56	.64	.80	.90
Other	1.99	1.87	2.83	2.98	3.01	3.55	2.74	3.07	3.58	3.25	3.77
World Sunflower Production (million metric tons)	**24.63**	**23.89**	**27.60**	**26.95**	**23.16**	**21.80**	**23.95**	**26.88**	**26.39**	**30.16**	**30.49**

Changes in the 1990 government farm program, which allowed planting flexibility while providing price support, led to an increase in sunflower acreage in 1991 relative to 1990. The government program established a marketing loan and a loan deficiency payment for sunflower and other oilseed crops.

The bulk of U.S. sunflower production occurs in North Dakota, South Dakota, Minnesota, Kansas, Colorado, Nebraska and Texas. Small acreages are grown in several other states (Table 3). The majority of the acreage harvested is for oil production versus nonoil uses. In 2005, the USDA reported that 2,032,000 acres of oil sunflower and 578,000 of nonoil sunflower were harvested (Table 4).

Seed Yield/Acre

Annual average sunflower yields from 1996 to 2005 ranged from 1,140 to 1,564 pounds per acre for oilseed and from 997 to 1,455 pounds per acre for nonoilseed sunflower. Average yields per acre during the 1996-2005 period were 1,349 pounds for oilseeds and 1,220 pounds for nonoilseed sunflower (Figure 5).

Pounds of Production

U.S. production of oilseed sunflower ranged from 1,763 million pounds (799,700 metric tons) in 2004 to 4,486 million pounds (2,035,000 metric tons) in 1998 (Table 5). Nonoilseed production ranged from 286 million pounds (130,000 metric tons) in 2004 to 844 million pounds (383,000 metric tons) in 1999.

Processing Plants

Four oil extraction plants in North Dakota, Minnesota and Kansas process oilseed sunflower. These four plants have a combined crushing capacity of 1,900,000 metric tons per year, according to industry estimates. Several smaller plants are located throughout the main sunflower production region.

Table 3. Total Planted Sunflower Acreage by States 1994-2006

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
North Dakota	1,590	1,450	1,180	1,470	1,990	1,700	1,330	1,070	1,370	1,210	880	1,140	900
South Dakota	940	960	700	825	940	920	720	715	640	505	435	550	535
Kansas	260	300	265	200	180	280	250	335	193	215	171	300	152
Minnesota	500	440	150	105	130	130	95	60	70	90	60	135	90
Colorado	100	115	110	85	160	270	220	195	130	130	135	215	100
Texas	34	44	31	88	47	75	60	108	35	59	41	145	54
Nebraska	75	90	47	55	70	101	90	82	60	66	56	99	53
Other States	68	79	53	60	51	77	75	68	60	91	95	125	100
Total U.S. Thousand Acres	**3,567**	**3,478**	**2,536**	**2,888**	**3,568**	**3,553**	**2,840**	**2,633**	**2,580**	**2,344**	**1,873**	**2,709**	**1,984**

Table 4. Harvested USA Sunflower Acreage 1994-2006

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Oilseed	2,943	2,829	1,934	2,212	2,897	2,695	2,116	2,060	1,815	1,874	1,424	2,032	1,587
Nonoilseed	487	539	545	580	595	746	531	495	365	323	287	578	277
Total Thousand Acres	**3,430**	**3,368**	**2,479**	**2,792**	**3,492**	**3,441**	**2,647**	**2,555**	**2,180**	**2,197**	**1,711**	**2,610**	**1,864**

Table 5. U.S. Sunflower Production 1994-2006

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
	Million Pounds												
Oilseed	4,223	3,398	2,844	2,986	4,486	3,498	2,910	2,804	2,070	2,260	1,763	3,178	1818
Nonoilseed	612	611	716	691	787	844	635	615	420	406	286	841	295
Total	**4,835**	**4,009**	**3,560**	**3,677**	**5,273**	**4,342**	**3,545**	**3,419**	**2,490**	**2,666**	**2,049**	**4,018**	**2113**

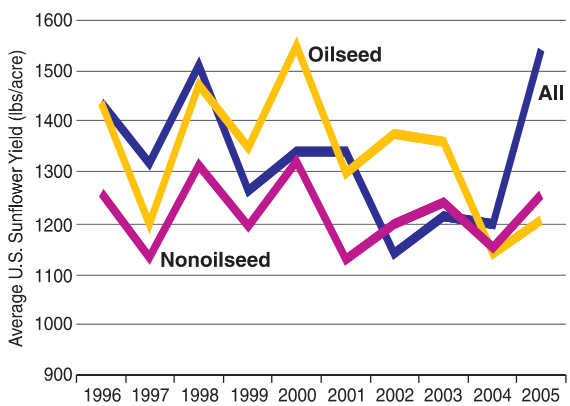


Figure 5. Average U.S. Sunflower Yield 1996-2005 in Pounds Per Acre.

Prices

Historically, sunflower depended heavily on the export market for either seed or oil. With the advent of NuSun and high oleic sunflower, the market has switched almost exclusively to a U.S. and Canadian market. Both of these oils are very stable and do not require hydrogenation as do competitive oils, such as traditional soybean and canola oils, when used in a frying application. Sunflower prices now are more determined by their relationship to corn oil prices. Large domestic users tend to buy in advance, thus prices are not directly affected by the Chicago soybean oil contract and are not as likely to be as volatile.

More opportunities are available to presell a portion of the crop well before planting begins. This ensures a domestic user of a supply and allows a producer to "lock in" a price for a portion of his production. Storage of sunflower is necessary. The domestic market needs a 12-month supply of oil and crushers will need a steady supply of seed. Crushers likely will have to provide producers with storage premiums for delivery in the out-of-harvest months. Oilseed sunflower producers have the advantage of multiple market options: the hulling market, the crush market or the bird food market. Supply and demand drive prices in all three markets. These markets are very specific and unique, with different values associated with them. Farmers should have samples of their crop graded to determine quality and talk directly to buyers to find out what they want in terms of seed specifications.

Nonoilseed (confection) sunflower production is geared to the "in-shell" markets. Today's confection hybrids produce a significant level of large seeds. Growers often are paid on a percentage of large seed. Quality standards for confection sunflower are high and allow little tolerance for off-color and insect damage. Most confection sunflower is produced on a contract basis. The seasonal average price during the 1994/95 to 2002/03 period ranged from \$5.89 to \$12.30 per hundredweight for oilseed sunflower and from \$11.90 to \$15.20 per hundredweight for nonoilseed sunflower. During that period, the nonoilseed price exceeded the oilseed price by \$3.85 per hundredweight on average.

Sunflower Marketing Strategy

(George Flaskerud)

Sunflower marketing strategies usually use the cash forward contract for locking in a price prior to harvest. Use of this contract may be appropriate on a portion of the sunflower crop, but so may the use of other marketing tools, such as hedging with futures or use of options (puts or calls). The best marketing alternative depends in part on the basis, which is the relationship between a cash and futures price.

Since a sunflower futures market does not exist, relationships between the sunflower cash price and other closely related futures markets need to be considered. Using the futures market of a different commodity for hedging is cross-hedging, while the cash and futures price relationship is the cross-basis. Two futures contracts are examined: soybean oil futures, which are traded on the Chicago Board of Trade, and canola futures, which are traded on the Winnipeg Commodity Exchange.

Historic prices were analyzed during 1997 through April 2004 to identify patterns and relationships useful for developing marketing strategies. Prices were standardized in U.S. dollars per hundredweight (US$/cwt).

Correlations indicate that changes in NuSun prices (40 percent oil) at Enderlin, N. D., are the most closely correlated with canola futures (correlation = .91). Soybean oil futures were a distant, second-best correlation (.75). These correlations suggest that canola futures should provide the most risk reduction for cross-hedging cash sunflower prices. However, with the current situation for sunflowers, soybean oil and canola need to be evaluated to determine which futures contract likely is to be the most profitable.

Price quotations for canola futures are in Canadian dollars (C$) per metric ton. The price quotation for November canola was C$352 on August 25, 2003, and the exchange rate was 1.41 C$/US$. In U.S. dollars per hundredweight, this quotation would be US$11.32 (C$352 divided by 1.41 divided by 22.046 = US$11.32).

Seasonal patterns for Enderlin NuSun prices (Figure 6) revealed a broad range of price behavior during individual marketing years (October-September). Highs occurred during August in 2000-01 and 2001-02, April in 1999-00, October in 1998-99 and November in 2002-03. The distribution of prices reveals that the pattern, on average, is to decline to lows in October and then increase to a peak in June before declining into the next marketing year.

The range in the monthly average, excluding the low and the high, was only $.53 per cwt. The within-year variations were considerably greater. The average within-year range was $3.07. During 2000-01 and 2001-02, when prices trended up, the average within-year range was $3.98. During the other years, the average within-year range was $2.47.

The tendency for the Enderlin NuSun cross-basis relative to canola futures (Figure 7) was to decline to a low in September and to remain nearly as low during October and November, and then to increase to a high in February-April before generally declining into the end of the marketing year. During three of the five years, the cross-basis was near its low in October. The range of the cross-basis was the narrowest during September and the widest during May. During October, the average cross-basis per cwt ranged from -$1.64 to -$.16 and averaged -$.99.

Relative to soybean oil futures, the Enderlin average cross-basis showed a pattern of marketing year lows per cwt in November (-$9.15), April (-$9.25) and September (-$9.16) and highs in February (-$8.08) and July (-$8.30). During October, the average cross-basis ranged from -$14.47 to -$6.59 and averaged -$8.95.

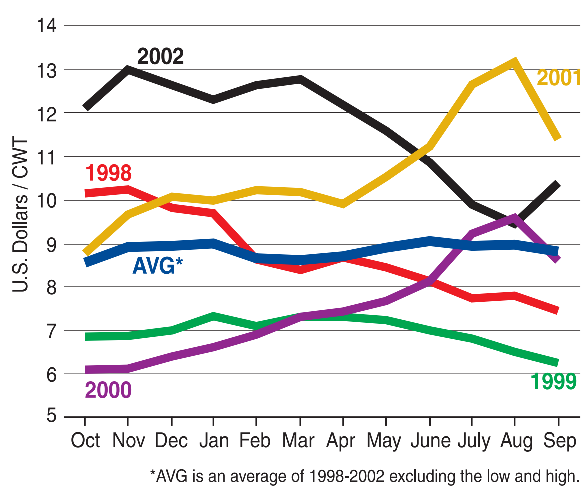


Figure 6. Seasonal Behavior of NuSun Prices at Enderlin, ND.

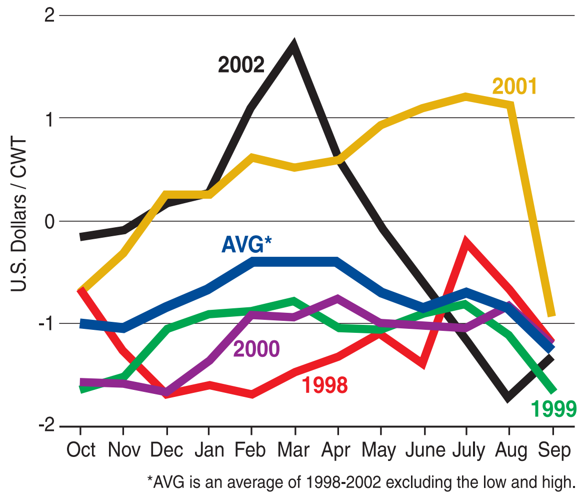


Figure 7. NuSun Cross-Basis at Enderlin, ND Relative to Nearby WCE Canola Futures.

Variability, as measured by the standard deviation, was greater for the cross-basis relative to soybean oil futures than for the cross-basis relative to canola futures. This suggests lower basis risk when cross-hedging with canola futures than with soybean oil futures.

From this information, marketing strategies can be developed. The seasonal pattern for Enderlin NuSun prices suggests that preharvest sales should be considered when prices are above the five-year average price. Prices declined into harvest during two of three years that prices were above the average early in the marketing year.

Use of the cash forward contract or cross-hedge would be appropriate on that portion of the sunflower crop that can be safely produced, i.e., on 20 percent to 40 percent of the crop. The cash forward contract would be preferred if it reflects an average or better cross-basis relative to sunflower oil futures or canola futures. A greater portion of the crop could be sold on a cash forward contract if it includes an act-of-God clause.

In addition to the cash forward contract or cross-hedge, a call option could be purchased to preserve upside potential. In the case of the cross-hedge, the call option would be purchased in the same futures contract. In the case of the cash forward contract, the call option could be purchased in either the soybean oil futures or canola futures. The put option is an alternative to using a cash forward contract or cross-hedge in combination with a call option.

For sunflowers that are not cash forward contracted, storage is an alternative. On average, storage was profitable during the 1998-99 to 2002-03 marketing years. However, the most profitable period of storage varied considerably. The most profitable sell or store strategy was to sell the 1998 crop at harvest, store the 1999 crop until January, store the 2000 and 2001 crops until August and store the 2002 crop for one month. Sell or store decisions are difficult and require frequent evaluation of fundamentals, cash prices, futures prices, basis and storage costs.

Additional marketing alternatives are available but beyond the scope of this article. Further information can be found in NDSU Extension publication EC-1270, "Managing Sunflower Price Risk."

Hybrid Selection and Production Practices

Hybrid Selection

(Jerry Miller)

Selection of sunflower hybrids to plant is one of the most important decisions a producer must make each season (Figure 8). First, three classes of hybrids - NuSun oilseed, traditional oilseed and confection hybrids are available,. Second, variables such as yield, quality factors, maturity, dry down, standability, and pest and disease tolerance, should be considered.

NuSun Sunflower

NuSun oilseed sunflower hybrids will produce an oil quality with more than 55 percent oleic fatty acid. This oil is in wide demand by the frying food industry and potentially could be a bottled oil. Some hybrid seed companies are providing a grower guarantee that their hybrids will make the minimum oleic grade. Some processors of NuSun sunflower also are providing contracts for producing seed of this quality. A premium may be paid to producers for planting NuSun hybrids.

Traditional Sunflower

Traditional oilseed sunflower hybrids have a high linoleic and lower oleic fatty acid quality in contrast with the NuSun hybrids. Traditional hybrids have been grown for their multipurpose marketability, with large export demand and hulling for the kernel market being most important.

Confection Sunflower

Confection sunflower hybrids are used primarily for in-shell and hulled kernel markets. They are characterized by having large seed, with a distinctive color striping on the hull. New hybrids with very long, large seed are in demand for the export market. Producers must be careful to set their combine concave widths properly to avoid hull damage on these hybrids. Producers generally plant confection hybrids at a lower plant population and increase insect scouting and control to maintain high kernel quality. Contracts are available to producers interested in planting confection hybrids.

Criteria for Hybrid Selection

Growers should use several criteria in hybrid selection. First, they should take an inventory of available hybrids being marketed in their area. Seed yield potential is an important trait to consider when looking at an available hybrid list. Yield trial results from university experiment stations, National Sunflower Association-sponsored trials and commercial companies should identify a dozen or so consistently high yielding hybrids for a particular area. Results from strip tests or demonstration plots on or near growers' farms should

Figure 8. A hybrid seed production field of sunflower. Female and male parents are planted in alternate strips across the field. (Marcia P. McMullen)

be evaluated. Yield results from previous years on an individual's farm and information from neighbors also are valuable. The best producing hybrids in a region may produce approximately 2,300 pounds per acre with good soil fertility and favorable soil moisture, or more than 3,000 pounds per acre in the most favorable growing conditions.

Oil percentage should be another trait to consider in oilseed hybrid selection. Several environmental factors influence oil percentage, but the hybrid's genetic potential for oil percentage also is important. Current hybrids have oil percentages ranging from 38 percent to more than 50 percent. Domestic oil processors have been paying a premium based on market price for more than 40 percent oil (at 10 percent moisture) and discounts for oil less than 40 percent. Current recommendations are to select a high-oil hybrid instead of a low-oil hybrid with the same yield potential, but don't sacrifice yield in favor of oil content.

Maturity and dry down are important characteristics to consider when deciding what hybrid to plant. Maturity is especially important if planting is delayed, being mindful of the average killing frost in your area. Yield, oil content and test weight often are reduced when a hybrid is damaged by frost before it is fully mature. An earlier hybrid likely will be drier at harvest than a later hybrid, thus reducing drying costs. Also, consider planting hybrids with different maturity dates as a production hedge to spread risk and workload at harvest.

The most economical and effective means to control sunflower diseases and other pests is planting resistant or tolerant hybrids and considering a minimum of three to four years' rotation between successive sunflower crops. Hybrids are available with resistance to rust, Verticillium wilt and certain races of downy mildew. New hybrids may be available with tolerance to Sclerotinia head and stalk disease. Growers should check with their local seed dealer or sunflower seed company representative to obtain this information. Stalk quality, another trait to consider, provides resistance to lodging, various diseases and other pests. Hybrids with good stalk quality are easier to harvest and yield losses generally are reduced, withstanding damages from pests and high winds. Uniform stalk height at maturity is another important trait to consider.

Hybrid selection may include selecting a hybrid with resistance to certain herbicides not previously available. This nontransgenic resistance either was derived from the wild species of sunflower or from mutagenesis. Sunflower hybrids can be sprayed with herbicides that control various broadleaf and grassy weeds either by one chemical or by a tank-mix of two chemicals. This technology will allow broad-spectrum weed control in minimum-till or no-till sunflower production, as well as with traditional production. Growers should check with their local seed dealer or sunflower seed company representative to obtain information regarding availability of these hybrids.

The last item to consider is to purchase hybrid seed from a reputable seed company and dealer with a good technical service record. This is particularly important if producers have any questions regarding production practices. Companies and seed dealers provide different services, policies and purchase incentives, including credit, delivery service and returns.

Semidwarf Sunflower

(Duane Berglund)

Semidwarf sunflower is 25 percent to 35 percent shorter than normal height hybrid sunflower. Research results show seed yield and oil content of semidwarf and normal height sunflower are similar in some years but not always. In drought stress years, seed yield of semidwarf sunflower was significantly less than normal-height hybrids. Most semidwarf sunflower have early maturity ratings, thus the potential for high yields is limited, compared with conventional-height sunflower. The semidwarf plant types appear to be less susceptible to lodging, which could be very important during years of optimum plant growth or where sunflower is grown under irrigation, in high-plant populations. Generally, the semidwarf sunflower can be planted in narrowly spaced rows or solid seeded. University research indicates root penetration and water use to a depth of 6 feet is similar for normal height and semidwarf sunflower. Beyond 6 feet, root penetration of the semidwarf may not be as great as that of taller plant types. Some sunflower breeders have observed that short-stature plants have demonstrated limitations in head size and ability of the plant to fill the center of the head. Also, slower seedling emergence has been reported for semidwarfs.

Sunflower Branching

(Duane Berglund)

Sunflower branching is an undesirable trait in commercial sunflower production. It can be caused by the genetics of a hybrid, environmental influences and herbicide injury.

Branching of various degrees can occur in sunflower, ranging from a single stem with a large single inflorescence in cultivated types to multiple branching from axils of most leaves on the main stem in the wild species. Branch length varies from a few centimeters to a distance longer than the main stem. Branching may be concentrated at the base or top of the stem or spread throughout the entire plant. Generally, heads on branches are smaller than heads on the main stem. Occasionally, some first-order branches have a terminal head almost as large as the main head. In most wild species, the head on the main stem blooms first, but generally is no larger than those on the branches. Studies on the genetics of top branching have shown that it is dominant over nonbranching and is controlled by a single gene. Sunflower literature reports that top branching in cultivated sunflower is controlled by a single dominant gene, but branching in wild species is controlled by duplicate dominant genes.

Source: Sunflower Technology and Production, ASA monograph number 35.

Figure 9. Soil Tests are the most reliable means for growers to determine fertilizer needs to obtain projected yield goals. (Dave Franzen)

Production Practices

Seed Quality

(Duane Berglund)

High quality, uniform seed with high germination, known hybrid varietal purity and freedom from weed seeds and disease should be selected to reduce production risks. The standard germination test provides an indication of performance under ideal conditions but is limited in its ability to estimate what will happen under stress. Accelerated aging is another method used to evaluate seed vigor. Any old or carry-over seed should have both types of tests conducted. Seed is sold on a bag weight basis or by seed count. Seed size designations are fairly uniform across companies. Most seed is treated with a fungicide and insecticide to protect the germinating seedling. Seed should be uniformly sized to allow precision in the planting operation.

Soils

(David Franzen)

Sunflower is adapted to a variety of soil conditions, but grows best on well-drained, high water-holding capacity soils with a nearly neutral pH (pH 6.5-7.5). Production performance on high-stress soils, such as those affected by drought potential, salinity or wetness, is not exceptional but compares favorably with other commercial crops commonly grown.

Soil Fertility

(David Franzen)

Sunflower, like other green plants, requires at least 16 elements for growth. Some of these, such as oxygen, hydrogen and carbon, are obtained from water and the air. The other nutrients are obtained from the soil. Nitrogen, phosphorus and sulfur are frequently deficient in soils in any climatic zone. Potassium, calcium and magnesium are frequently deficient in high-rainfall areas. Deficiencies of iron, manganese, zinc, copper, molybdenum, boron and chlorine are uncommon but can appear in many climatic zones.

A sunflower yield of 2,000 pounds per acre requires approximately the same amount of nitrogen, phosphorus and potassium as 40 bushels per acre of wheat.

The nutrient content of the soil, as determined by a soil test, is the only practical way to predict probability of a response to applied nutrients (Figure 9). A soil test will evaluate the available nutrients in the soil and classify the soil as very low (VL), low (L), medium (M), high (H) or very high (VH) in certain nutrients. A field classified as very low in a nutrient will give a yield response to applied fertilizer 80 percent to 100 percent of the time. A yield response is not always obtained because soil moisture or some other environmental factor may become limiting. A field classified as low will respond to applied fertilizer 40 percent to 60 percent of the time, a medium testing field will respond to added fertilizer 10 percent to 20 percent of the time and a high-testing field will respond to applied fertilizer only occasionally. Fields testing very high will not respond because the reserve of nutrients in the soil is adequate for optimum plant growth and performance.

Fertilizer Recommendations

(David Franzen)

Soil tests have been developed to estimate sunflower's potential response to fertilizer amendments. The most important factors in the fertilizer recommendations are the yield goal and the level of plant-available soil nutrients. In most climatic zones, predicting yield is impossible. Past yield records are a reasonable estimate of potential yield for the coming year. A yield goal for sunflower should be more optimistic than the average yield, and should approach the past maximum yield obtained by the grower on the same or a similar soil type. Nutrients not used by a crop in a dry growing season usually are not lost and can be used by the following crop.

From an economic standpoint, having a yield goal that is somewhat high is much more beneficial for a grower than having a goal that is too low. A low yield goal in a good growing season easily can mean lost income of \$30 to \$40 per acre. In contrast, a high yield goal in a dry growing season will result in a loss of only \$1to \$2 in additional interest on the cost of unused nutrients since most of the nutrients will be available to the subsequent crop.

The amounts of nitrogen, phosphorus and potassium recommended for various sunflower yield goals and soil test levels are shown in Table 6. For yield goals not shown in the table, use the formulas at the base of the table. The data in this table are based on the amount of nitrate-nitrogen (NO_3-N) in pounds per acre found in the top 2 feet of soil, the parts per million (ppm) of phosphorus (P) extracted from the top 6 inches of soil by the 0.5N sodium bicarbonate, and the ppm of potassium (K) extracted by neutral normal ammonium acetate in the top 6 inches of soil

Other nutrients are not usually deficient for sunflower. On sandy slopes and hilltops, sulfur may be a problem; however, sulfur would not be expected to be deficient in higher organic matter, depressional soils. The sulfur soil test is a poor indicator of the probability of response to sulfur fertilizers. Sunflower has not been shown to be responsive to the application of other nutrients, including micronutrients in the state.

Table 6. Nitrogen (N), phosphate (P_2O_5) and potash (K_2O) recommendations for sunflower in North Dakota.

Yield Goal	Soil N plus fertilizer N	Soil Test Phosphorus, ppm					
			VL	L	M	H	VH
		Bray-1	0-5	6-10	11-15	16-20	21+
lb/acre	lb/acre-2 ft.	Olsen	0-3	4-7	8-11	12-15	16+
			- - - - - - lb P_2O_5/acre - - - - - -				
1,000	50		20	15	9	4	0
1,500	75		31	22	14	5	0
2,000	100		41	30	18	7	0
2,500	125		51	37	23	9	0

Nitrogen recommendation = 0.05 YG - STN - PCC
(Bray-1) Phosphate recommendation = (0.0225-0.0011 STP)YG
(Olsen) Phosphate recommendation = (0.0225-0.0014 STP)YG

Yield Goal	Soil Test Potassium, ppm				
	0-40	41-80	81-120	121-160	161+
lb/acre	VL	L	M	H	VH
1,000	36	25	14	3	0
1,500	53	37	21	5	0
2,000	71	50	28	6	0
2,500	89	62	35	8	0

(K, ammonium acetate extractant) Potash recommendation = (0.04100-0.00027 STK)YG
YG = Yield Goal
PCC = Previous Crop Credit
STN is the amount of NO_3-N in the top 2 feet of soil
STP, STK = Soil Test P or K, respectively
VL,L,M, H,VH = very low, low, medium, high and very high, respectively

Fertilizer Application

(Dave Franzen)

Germinating sunflower seed is similar to corn in its reaction to seed-placed fertilizer. Application of more than 10 pounds per acre of nitrogen (N) plus potash (K_2O) in a 30-inch row will result in reduced stands or injured seedlings. Dry soil conditions can increase the severity of injury. In row widths narrower than 30 inches, rates of N plus K_2O can be proportionally higher. For improved fertilizer rate flexibility, starter fertilizer should be placed in bands at least 2 to 3 inches from the seed row.

Producers have several good reasons to apply nitrogen in the fall, such as availability of labor, soil conditions, etc. However, the general principle with respect to nitrogen application is: The longer the time period between application and plant use, the greater the possibility for N loss. In other words, use judgment in making a decision on time of N application. In the case of sandy soils, fall application of N is not recommended. In many instances, a side-dress application of N when the sunflower plants are about 12 inches high may be preferable.

Phosphate and potash may be fall or spring applied before a tillage operation. These nutrients are not readily leached from soil because they form only slightly soluble compounds or attach to the soil. The phosphate and potash recommendations in Table 6. are broadcast amounts. The recommendations for soil that tests very low and low in P and K can be reduced by one-third the amount in the table when applied in a band at seeding. In minimum or no-till systems, phosphate and potash may be applied in a deeper band to reduce the buildup of nutrients at the soil surface that occurs with these systems. However, most comparisons among deep, shallow and surface applications have shown little difference in crop response.

Water Requirements for Sunflower

(Duane Berglund)

Sunflower has deep roots and extracts water from depths not reached by most other crops; thus it is perceived to be a drought-tolerant crop. Sunflower has an effective root depth around 4 feet, but can remove water from below this depth. Research on side-by-side plots has shown that sunflower is capable of extracting more water than corn from an equal root zone volume. With its deep root system, it also can use nitrogen and other nutrients that leach below shallow-root crops; thus it is a good crop to have in a rotation.

Seasonal water use by sunflower averages about 19 inches under irrigated conditions. Under dryland conditions, sunflower will use whatever stored soil moisture and rain that it receives during the growing season. When access to water is not limited, small grains use 2 to 3 inches less total water than sunflower during the growing season, whereas soybean water use is slightly greater. Corn uses 1 to 4 inches, and sugar beets use 2 to 6 inches more than sunflower, respectively, during the growing season.

These total water use values are typical for nondrought conditions in southeastern North Dakota. Small grains use the least total water since they have the fewest number of days from emergence to maturity. Sunflower and soybean have an intermediate number of days of active growth and corresponding relative water use. Corn ranks above sunflower in growth days and water use, while sugar beets rank highest in both categories.

However, water use efficiency does vary among these crops. Comparative water use efficiency measured as grain (pounds per acre or lb/A) per inch of water used on three dryland sites and two years in eastern North Dakota was 119, 222, 307, 41, 218, 138, and 127 for sunflower, barley, grain corn, flax, pinto bean, soybean and wheat, respectively. These results indicated that corn had the highest water use efficiency, sunflower and wheat were intermediate and flax the lowest. (Source: M. Ennen. 1979. Sunflower water use in eastern North Dakota, M.S. thesis, North Dakota State University).

Fertility has little influence on total water use, but as fertility increases, water use efficiency increases because yield increases. Yield performance has been shown to be a good indicator of water use efficiency of sunflower hybrids; higher yielding hybrids exhibit the highest water use efficiency.

Soil Water Management for Dryland Sunflower

(Duane Berglund)

Management practices that promote infiltration of water in the soil and limit evaporation from the soil generally will be beneficial for sunflower production in terms of available soil moisture. Leaving stubble during the winter to catch snow and minimum tillage are examples. Good weed control also conserves moisture for the crop. The use of post-applied and pre-emergence herbicides with no soil incorporation also conserves moisture when growing sunflower.

Sunflower has the ability to exploit a large rooting volume for soil water. Fields for sunflower production should be selected from those with the greater water-holding capacity and soils without layers that may restrict roots. Water-holding capacity depends mainly on soil texture and soil depth. The loam, silt loam, clay loam and silty clay loam textures have the highest water-holding capacities. Water-holding capacity of the soils in any field can be obtained from county soil survey information available from local Natural Resources Conservation Service (NRCS) USDA offices.

Sampling or probing for available soil moisture before planting also can help select fields for sunflower production. With other factors being equal, fields with the most stored soil moisture will have potential for higher yields. Where surface runoff can be reduced or snow entrapment increased by tillage or residue management, increases in stored soil moisture should occur and be beneficial to a deep-rooted crop such as sunflower.

Irrigation Management

(Tom Scherer)

Irrigation of sunflower by commercial growers is not common, but sunflower will respond to irrigation. Data collected by the USDA Farm Service Agency (FSA) for irrigated crops in North Dakota shows that an annual average of about 1,500 acres of sunflower are irrigated each year. Data for irrigated and dryland oil-type variety trials between 1975 and 1994 from the Carrington Research Extension Center show an average yield differential of about 500 pounds per acre. However, some years the irrigated trials yielded more than 1,500 pounds per acre more than the dryland plots, and some years the dryland plots actually had greater yield than the irrigated plots.

Irrigated sunflower seasonal water use averages about 19 inches. With good water management, average water use will increase from about 0.03 inch per day soon after emergence to more than 0.27 inch per day from head emergence to full seed head development. However, during July and August, water use on a hot, windy day can exceed 0.32 inch.

Research by Stegman and Lemert of NDSU has demonstrated the yield potential of sunflower grown under optimum moisture conditions and the effect of water stress at different growth stages. Sunflower yield is most sensitive to moisture stress during the flowering period (R-2 to R-5.9 reproductive stages) and least sensitive during the vegetative period (emergence to early bud). A 20 percent reduction of irrigation water application from plant emergence to the R-2 stage resulted in only a 5 percent reduction in yield, but a 20 percent reduction in irrigation water application during the R-2 to R-5.9 period resulted in a 50 percent yield reduction.

If soil water content is near field capacity at planting, research indicates that the first irrigation could be delayed until the root zone soil moisture is about 70 percent depleted. However, if pumping capacity is low (less than 800 gallons per minute, or gpm, for a 128-acre center pivot), a lesser depletion is advisable due to inadequate "catch-up capacity." Irrigations during the critical bud to ray-petal appearance (R-2 to R-5.0) period should be scheduled to maintain a low soil moisture stress condition (35 percent to 40 percent depletion). Irrigation should be avoided from R-5.1 to R-5.9 because of the susceptibility of the sunflower plant to head rot from Sclerotinia (white mold). Irrigate just before flowering in the bud stages R-3 to R-4. Soil moisture depletion again can approach 70 percent during late seed fill and beyond with little or no depression in yield.

Yield increases due to irrigation depend on several factors. Soil water-holding capacity and precipitation are two of the most important. Research indicates that the seed yield versus crop water use (ET) exhibits a linear relationship with a slope averaging 190 pounds per acre-inch. This means every additional inch of water applied by irrigation will increase seed yield by about 190 pounds per acre. Remember that the research was performed on the loam and sandy-loam soils of Carrington and Oakes, N.D. A yield increase of 50 percent or more with irrigation may be expected almost every year on coarse-textured soils. However, a seed yield increase from irrigation may not always occur on soils with higher water-holding capacities and with adequate precipitation. Adequate soil fertility is very important in achieving the higher yield potential under irrigation.

Management of applied irrigation water requires the combination of periodic soil moisture measurement with a method of irrigation scheduling. Soil moisture can be measured or estimated in a variety of ways. The simplest is the traditional "feel" method that is an art developed through time with extensive use and experience. For most irrigation water management applications, either the resistance block type of soil moisture measurement or tensiometers should be used. These are relatively inexpensive and require little labor to use effectively.

The soil water balance method of irrigation scheduling, otherwise known as the checkbook method, is popular and well-documented. With this method, a continuous account is kept of the water stored in the soil. Soil water losses due to crop use and soil surface evaporation are estimated each day based on the maximum temperature and the days since crop emergence. Precipitation and irrigation are measured and added to the soil water account each day. Errors in estimating water use will accumulate through time, so periodically measuring the moisture in the soil profile is necessary. Detailed instructions for using the checkbook method are published (North Dakota Extension publication AE-792). A computer program using this method also is available from the NDSU Agricultural and Biosystems Engineering Department.

Another form of irrigation scheduling is to use estimated daily water use values for sunflower (Table 7). This method, sometimes called the "water use replacement method," is based on obtaining daily estimates of sunflower water use and accurately measuring the amount of rain received on the field. Irrigations are scheduled to replace the amount of soil moisture used by the sunflower minus the amount of rain received since the last irrigation. Estimates of daily sunflower water use can be obtained several ways. AE-792 has a table for sunflower water use throughout the season based on weeks' past emergence and maximum daily air temperature. More accurate sunflower water use values, based on measured weather variables from the North Dakota Agricultural Weather Network (NDAWN), are available at the NDAWN Web site: http://ndawn.ndsu.nodak.edu/. Click on "Applications" on the left side of the home screen. Sunflower crop water use estimates can be obtained for the current growing season (between emergence and harvest) or for past growing seasons if you want to do some comparisons.

Table 7. Average daily water use for sunflower in inches per day based on maximum daily air temperature and weeks past emergence. For example, during the eighth week after emergence, if the daily air temperature were 85 degrees on a particular day, sunflower water use for that day would be 0.25 inch.

Maximum Daily Air Temperature	Week After Emergence														
°F	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
50 to 59	0.01	0.03	0.05	0.06	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.07	0.06	0.04	0.03
60 to 69	0.02	0.05	0.08	0.10	0.12	0.14	0.14	0.14	0.13	0.13	0.13	0.12	0.10	0.07	0.04
70 to 79	0.03	0.07	0.11	0.15	0.17	0.19	0.19	0.19	0.19	0.18	0.17	0.16	0.13	0.10	0.06
80 to 89	0.03	0.09	0.14	0.19	0.22	0.25	0.25	0.25	0.24	0.23	0.22	0.21	0.17	0.13	0.07
Above 90	0.04	0.11	0.17	0.23	0.27	0.30	0.30	0.30	0.29	0.29	0.27	0.26	0.21	0.15	0.09
				Bud		Ray Flower				100% Anther		Ray Petal Drop			

Tillage, Seedbed Preparation and Planting

(Roger Ashley and Don Tanaka)

Sunflower, like other crops, requires proper seedbed conditions for optimum plant establishment. Errors made at planting time may be compounded throughout the growing season. Seedbed preparation, soil tilth, planting date, planting depth, row width, seed distribution and plant population should be nearly correct as conditions permit.

Tillage and Seedbed Preparation

Tillage traditionally has been used to control weeds and incorporate herbicides in preparation for planting. When tillage is used in low rainfall areas, producers must take care to control weeds while leaving as much of the previous crop's residue intact as possible. Tillage never should occur when soils are too wet. Soils that are tilled when too wet and then dry will crust, turn lumpy and generally provide for poor seedbed conditions for germination and establishment.

Maintaining a moist seedbed is important if producers expect to have uniform germination and emergence across the field (Figure 10). Poor germination and emergence will influence the need for and the effectiveness of future management practices. Excessive tillage should be avoided where tillage is used to prepare the seedbed or to incorporate preplant herbicides. Excessive tillage will break down soil structure, cause compaction and crusting problems, reduce aeration, restrict water movement and provide conditions favorable for infection by downy mildew or other soil-borne diseases. Breakdown of soil structure also causes reduced nutrient and water uptake and reduces yield.

Figure 10. No-till one pass seeding systems preserve soil moisture and ground cover when water is limited. (Roger Ashley)

Tillage and planting equipment is available to provide systems with varying levels of surface residue for sunflower production. Production systems can range from conventional-till, where the quantity of surface residue covers less than 30 percent of the soil surface, to no-till, where the quantity of surface residue covers more than 60 percent of the soil surface.

Conventional-till Production Systems

Conventional-till production systems usually involve two or more tillage operations for weed control, incorporation of pre-emergence herbicides and incorporation of the previous crops residues. Pre-emergence herbicides may be incorporated with a tandem disk, chisel or sweep plows, disk harrow, long-tine harrow, rolling harrow or air seeders with sweeps in different sequences or combinations. Tillage sequences are determined by herbicide label requirements by the quantity of crop residue present at the beginning of the tillage operation, and by the seedbed requirements needed to match planting equipment capabilities.

Conventional tillage systems, with or without pre-emergence or post-emergence herbicide, may include the option of row cultivation once or twice during the early growing season before the sunflower reaches a height too tall for cultivation. A rotary hoe or harrow can be used just before sunflower emergence and/or at the V-4 to V-6 development stage. Harrowing or rotary hoeing between emergence and the V-4 stage can result in injury or death of the sunflower plant. Depending on planting depth and stage of crop development, stand losses are generally less than 5 percent if the sunflower crop has at least two fully expanded leaves. Proper adjustment of the harrow or rotary hoe will maximize damage to the weeds and minimize injury to the sunflower crop.

Minimum-till Production Systems

Minimum-till production systems use subsurface implements with wide sweeps, such as an undercutter (Figure 11), or harrow systems for application and incorporation of herbicides. These production systems leave between 30 percent and 60 percent of the soil surface covered by crop residue after planting. Minimum-tillage sunflower production systems rely on a good long-term crop rotation to help control difficult weeds. These systems rely on two incorporations of granular herbicides, such as Trifluralin 10G and Sonalan 10G. Herbicides can be applied in late fall (late October) or early spring (mid to late April) and incorporated with either an undercutter (at a soil depth of 2 inches) or a harrow system. A second incorporation just before or at sunflower planting is performed with an undercutter, harrow or air seeder with sweeps (Figure 12). The time between the application/first incorporation and the second incorporation should be at least three weeks to increase the opportunity for precipitation to occur and rewet the treated soil layer. Rewetting the treated soil layer dissolves and activates the herbicide granules before the second incorporation.

Figure 11. Undercutter sweep machine used to prepare seedbed, control small weeds and conserves soil moisture. (Al Black)

Figure 12. Air-seeder with sweeps used for minimum till sunflower planting. (Roger Ashley)

Air Drill Use

Solid-seeded sunflower has become popular with producers in some regions. Air drills commonly are used to plant solid-seeded stands. Advantages listed by producers include 1) improved utilization of equipment already owned and 2) ease of changing between crops.

Suggested adjustments to the air drill when planting sunflower include: 1) Use the proper metering roller; 2) Slow the metering roller speed; 3) Calibrate the drill. Run through the calibration cycle10 times and then three additional times to check for consistently metered weights; 4) Recalibrate the drill every time variety or seed lot changes; 5) Reduce airflow. Provide the minimum amount of air to move seed and fertilizer to the opener so the seed is not damaged; 6) Don't place all of your seed in the bin after the drill is calibrated. Place a couple of bags in the bin and run until the low seed light appears. Then place another bag in the hopper and run until the low seed light appears. Calculate the number of acres seeded. If you appear to be planting the correct seeding rate, place one more bag of seed in the hopper and run until the low seed light appears. If this seeding rate is correct, fill the seed bin and plant the rest of the field.

No-till Production Systems

No-till is a production system without primary or secondary tillage prior to, during or after crop establishment. No-till systems rely heavily on diverse crop rotations and pre- and postemergence herbicides, and minimize soil disturbance to control weeds. Crop rotations should include cool-season grass and broadleaf crops, as well as warm-season grass and broadleaf crops. These production systems maintain at least 60 percent surface covered by crop residue after planting. Crop residues protect soils from erosion, control weeds, suppress evaporation and improve soil water infiltration. Pre- and postemergence herbicide choices provide producers options that were not available just a few years ago. Residual herbicides can be applied in a timely manner to get adequate precipitation for activation. Burn-down applications of glyphosate or paraquat are needed before or shortly after planting but before emergence of the crop to control emerged weeds and volunteer crop. Spartan (sulfentrazone), a residual broadleaf weed herbicide, may be tank-mixed with glyphosate to control broadleaf weeds for six to eight weeks. At the present time, postemergence herbicides such as Poast (sethoxydim) and Clethodim provide excellent grassy weed control and Assert (imazamethabenz) will control wild mustard. Clearfield sunflower varieties were selected for tolerance of the herbicide Beyond (imazamox) and will allow postemergence control of both broadleaf and grassy weeds. However, ALS (acetolactate synthase)-resistant kochia is not controlled with this herbicide. For current information on registered sunflower herbicides, contact your county agent or weed control specialist.

Planting sunflower in a no-till production system may require the addition of residue managers to move a minimum of crop residue from the seed row so double-disc openers can place seed properly for seed to soil contact. Poor placement will delay or prevent germination, emergence and establishment of the crop. This, in turn, may lead to weed, insect and harvest management problems. Single-disc openers and narrow-point hoe openers have been used successfully to seed sunflower. Minimizing soil disturbance is important. Soil disturbance can bury weed seed, placing them in a favorable position to survive, germinate and establish. Weed seed left on the soil surface is exposed to weather, insects, birds and fungi and rapidly will lose viability. Low-disturbance no-till production systems provide the best opportunity for adequate seed zone soil water at planting.

No-till and One-pass Seeding

When low-disturbance openers, such as the single-disc style, are used, seed should be placed at least 2 inches deep. In undisturbed silt loam soils, the dry/wet interface usually will be found about 1 inch below the soil surface. In coarse-textured soils, this interface will be deeper. Planting at or just below this dry/wet interface will result in poor and/or uneven germination, resulting in either germinating seed running out of water and dying before the plant has a chance to establish or seed lying in dry soil until adequate rainfall is received.

One-pass seeding operations utilizing high-disturbance openers (sweeps, hoes and narrow points) can produce uneven stands under dry conditions. Seeding depth is more variable with these types of openers, compared with the single-disc style, and moisture conditions will be more variable. Long, dry periods at planting do occur in western North Dakota. Soils will dry below acceptable levels for germination to the depth of the disturbed soil in the seedbed. Uneven germination, emergence, plant stands and plants at different stages of maturity will occur unless adequate moisture is received shortly after planting to rewet the seedbed.

Anhydrous ammonia (Figure 13) sometimes is applied in one-pass seeding operations with openers specifically designed for ammonia application at the time of seeding. If moisture is sufficient and application rates do not exceed 50 pounds, little damage to germinating seed will occur. However, if the seedbed is abnormally dry and/or the soil does not seal properly between the anhydrous ammonia band and the seed, damage to germinating seed will occur.

More recently, no-till row planters with row cleaners ahead of double-disc openers are equipped with either

Figure 13. This one-pass seeding operation is seeding directly into wheat stubble. Anhydrous ammonia and seed are banded through special openers. Glyphosate and sulfentrazone were applied three days prior to seeding. (Roger Ashley)

a liquid or dry fertilizer attachment. These attachments band nitrogen fertilizers separately from the seed band, eliminating injury to the germinating seed.

Planting Dates

Sunflower may be planted during a wide range of dates. In the northern Great Plains, planting may extend from May 1 until late June. Early maturing hybrids should be selected for late planting or replanting in northern areas. Planting may be as early as two weeks before the last killing frost and as late as 100 days before the first killing frost in the fall.

Growing conditions during the season will affect yield, oil content and fatty acid composition. High temperatures during seed formation have been identified as the main environmental factor affecting the ratio of linoleic and oleic acid content. Therefore, the optimum planting date will be dependent upon the variety and location, as well as weather conditions during the growing season. Variety genetics also affect oleic content, so select adapted varieties for your area. High yields may be obtained from very early planting dates, but yields may be reduced by increased pest problems.

If sunflower is seeded early in narrow rows and weeds are controlled early with preplant and post-plant herbicide products, early canopy closure should control late-germinating weeds, eliminating the need for herbicides or cultivation later in the season. Also, early planting provides producers the opportunity to harvest high quality seed earlier with less cost required for postharvest handling. Late-June plantings often result in lower yields and oil content. In addition, when harvest is delayed by weather, mechanical drying of seed is required, thus adding to production expenses. The fatty acid profile also is affected by planting date. In a three-year planting date study in southwestern North Dakota, oleic fatty acid content was greatest when the planting date occurred around May 23 and lowest when the planting date was later than June 10.

Soil temperature at the 4-inch depth should be at a minimum of 45 F for planting. A temperature near 50 F is required for germination. Periods of soil temperature below 50 F delay germination and extend the period of susceptibility to seedling diseases, such as downy mildew, and to herbicide injury.

Figure 14. Solid seeded sunflower stand established using an air drill. (Roger Ashley)

Row Spacing and Plant Population

Sunflower will perform well in a wide range of plant populations and plant spacing. When adequate weed control exists, no yield differences have been detected between sunflower seeded in rows and solid seeded. Fields with a row spacing of less than 20 inches are considered to be solid seeded (Figure 14). In 2003, the National Sunflower Association field survey found 70 percent of the sunflower fields surveyed in southwestern North Dakota to have been solid seeded. Equidistant spacing of seeds should produce a uniform sunflower stand, which makes maximum use of resources, such as water, nutrients and sunlight. Seed spacing to achieve the desired plant population is listed in Table 8. Table 8 assumes seed germination is 90 percent and a 10 percent stand reduction will occur between emergence and harvest. The seed spacing must be adjusted with lower or higher germination rates, and thus spacing between seed.

Desired seed spacing may be calculated using the following formula:

SS = (6,272,640/RS)/(PP/(GR x SR)

Where:

- SS = in row seed spacing in inches
- RS = between row spacing in inches
- PP = desired plant population at harvest
- GR = germination rate as a decimal. For example, if germination is 95 percent, then germination rate = .95.
- SR = stand reduction as a decimal. This reduction is a result of other factors between germination and final harvest population. For example, if a 10 percent reduction is expected, then 100 percent - 10 percent = 90 percent, or .9.

Sunflower plants will compensate for differences in plant population by adjusting seed and head size. As plant population decreases, seed and head size will increase. Oilseed hybrids generally are planted at higher populations than confection varieties, as the size of harvested seed is less important. Plant populations for oilseed sunflower should be between 15,000 and 25,000 plants per acre, with adjustments made for soil type, rainfall potential and yield goal. Lower populations are recommended for soils with lower water-holding capacity and if normal rainfall is inconsistent or inadequate. Confection sunflower should be planted at populations between 14,000 and 20,000 plants per acre. Preharvest dry down is more rapid in higher plant populations because of the smaller head size. However, higher plant populations may result in increased lodging and stalk breakage. Producers who solid seeded sunflower use seeding rates of 18,000 to 23,000 plants per acre.

Proper planting equipment adjustment and operation is one of the most important management tasks in sunflower production. Plateless and cyclo air planters have been used effectively to get good seed distribution. Double-seed drops should be avoided and planter adjustments should be made. Conventional plate planters will provide good seed distribution by using correct planter plates, properly sized seed and proper seed knockers. Commercial seed companies have plate recommendations for all seed sizes. Grain drills and air seeders may be used for seeding, although uniform depth of planting and seed spacing may be a problem unless proper adjustments and modifications are made.

Postharvest Tillage

After harvest, tillage of sunflower stalks is not recommended because snow-trapping potential is diminished, thereby reducing soil water conservation potential during the winter for the following crop. Also, because of the nature of sunflower residues, a late harvest followed by late fall tillage leaves the soil extremely susceptible to wind and water erosion.

Table 8. Seed spacing required for various populations, assuming 90 percent germination and 10 percent stand loss.

Plants per acre	Row Spacing 7.5	12	18	22	28	30	36
	- - - - - - - inches between seeds in the row - - - - - - -						
12,000	56.5	35.3	23.5	19.2	15.1	14.1	11.8
14,000	48.4	30.2	20.2	16.5	13.0	12.1	10.1
16,000	42.3	26.5	17.6	14.4	11.3	10.6	8.8
17,000	39.8	24.9	16.6	13.6	10.7	10.0	8.3
18,000	37.6	23.5	15.7	12.8	10.1	9.4	7.8
19,000	35.7	22.3	14.9	12.2	9.6	8.9	7.4
20,000	33.9	21.2	14.1	11.5	9.1	8.5	7.1
21,000	32.3	20.2	13.4	11.0	8.6	8.1	6.7
22,000	30.8	19.2	12.8	10.5	8.2	7.7	6.4
23,000	29.5	18.4	12.3	10.0	7.9	7.4	6.1
24,000	28.2	17.6	11.8	9.6	7.6	7.1	5.9
25,000	27.1	16.9	11.3	9.2	7.3	6.8	5.6
Feet per 1/1,000 acre	69.7	43.6	29	23.8	18.7	17.4	14.5

Highlighted seed spacings provide nearly equal-distant spacing between plants for a given row spacing and plant population.

Crop Rotation

(Greg Endres)

Having a proper rotation sequence with all crops, including sunflower, is important. Research shows that sunflower seed yield is greater following most other crops than sunflower (Tables 9 and 10).

Growers who do not rotate sunflower fields likely will be confronted with one or more of the following yield-reducing problems:

1. Disease and disease-infested fields
2. Increased insect risk
3. Increasing populations of certain types of weeds
4. Increased populations of volunteer sunflower
5. Soil moisture depletion.
6. Phytotoxicity or allelopathy of the sunflower residue to the sunflower crop

Therefore, producers have many valid reasons for rotating sunflower fields.

Table 9. Seed yield of sunflower based on previous crop, Crookston, Minn., 1972-78.

Previous crop	Seed yield/acre (pounds)				4-yr. ave.
	1973	1975	1977	1978	
Sunflower	852	1,338	1,852	1,781	1,456
Potato	908	1,279	2,348	1,605	1,535
Sugar beet	770	1,683	2,358	2,168	1,745
Pinto bean	946	1,410	2,282	1,674	1,578
Wheat	1,284	1,549	2,339	1,655	1,706
LSD .05	240	121	292	132	

Table 10. Seed yield of various crops following sunflower, Mandan, N.D., 1999-2000.

Previous crop	Seed yield
Sunflower	870 lbs/A
Canola	1,200 lbs/A
Flax	22.5 bu/A
Soybean	35.2 bu/A
Field pea	41.7 bu/A
HRS wheat	49.2 bu/A
Barley	70.0 bu/A

Risks of sunflower disease will be greatly magnified by short sequencing of sunflower in a crop rotation. Sclerotinia or white mold (wilt, stem rot and head rot) is the primary disease concern with a poor sunflower rotation. Other disease concerns with improper rotations include Verticillium wilt, Phoma and premature ripening. Rotations of at least three- or four-year spacings between sunflower or other Sclerotinia-susceptible crops (e.g., canola, dry bean, soybean) are recommended to help reduce disease risk. The sunflower disease section in this publication contains specifics on the characteristics and methods of control for each disease.

Crop rotation may help reduce but will not prevent insect problems in sunflower. Proper rotations help reduce populations of insects that overwinter in the soil or sunflower plant residue. Crop rotation will not reduce damage from insects that migrate into an area from other geographic regions or from fields planted to sunflower the previous year that are in proximity to current-season fields. Rotations recommended for reducing sunflower disease risks also will reduce insect risks.

Rotation of other crops with sunflower can reduce the buildup of many weed species. Also, proper crop rotation increases weed management options, including cultural, mechanical and chemical weed control. Consult records of previous field management to determine if long-residual herbicides that would adversely affect sunflower production were used. Volunteer sunflower also can become a serious weed problem in repeat sunflower and other crops. For additional details. refer to the weed management section of this publication, herbicide labels and NDSU Extension Service publication W-253, “North Dakota Weed Control Guide.”

Different patterns of soil moisture utilization are important considerations when planning sunflower rotations. Sunflower is a deep-rooted and full-season crop. Sunflower has intermediate water use requirements, compared with other crops (see water requirements section in this publication). Sunflower is relatively tolerant to effects of short water-stress periods, especially if the moisture stress occurs before the crop is in the reproductive stages. In limited-moisture growing seasons, sunflower following a shallower rooted and short-season crop (e.g., small grain, canola, flax) will allow the sunflower to extract residual water from a greater depth in the soil profile.

Continuous cropping of crops such as corn, wheat and soybeans results in yields that are depressed below the level obtained when a crop is rotated with other crops. The same effect is observed with sunflower, even when variable factors such as fertility, disease, insects and moisture are well-managed. This response with continuous cropping is known as allelopathy. Toxic materials in the sunflower residue, development of antibodies and the increase of soil-borne disease organisms all have been suggested as causes for allelopathy in sunflower. This effect has been demonstrated repeatedly and emphasizes a need to rotate sunflower.

Suggested sunflower rotations for North Dakota will vary somewhat by geographic region, primarily because of different precipitation zones. For practical purposes, the state can be divided into east and west regions. Suggested rotations for these regions are listed in Table 11. Rotations may be varied by substituting other crops in the rotation, but the time spacing of the sunflower crop should be observed strictly or increased. See NDSU Extension Service publication EB-48, "Crop Rotations for Increased Productivity," for additional details on crop rotation.

Pollination

(Gary Brewer)

Native sunflower and the early varieties of sunflower were self-incompatible and required insect pollination for economic seed set and yields. However, because numbers of pollinators were often too low to ensure adequate seed set, current hybrids have been selected for and possess high levels of self-compatibility. Although self-compatible sunflower hybrids usually outproduce self-incompatible cultivars, modern hybrids benefit from insect pollination.

The agronomic value of insect pollinating activities to current hybrids varies among hybrids, fields and years. Controlled studies indicate that in most sunflower hybrids, seed set, seed oil percentage, seed yields and oil yields increase when pollinators (primarily bees) are present. Literature reports indicate that yield could increase as much as 48.8 percent and oil percentage could increase 6.4 percent in bee-exposed hybrids. However, despite the increases in yield and oil concentration that occur, the benefit of insect pollination of sunflower often is overlooked (Figure 15).

Seed companies and growers who produce F1 hybrid seed for planting must use bees to transfer pollen from the male parent to the female parent. Although native wild bees are often better pollinators of sunflower than honey bees, the honey bee is the only managed pollinator of sunflower available. However, if pollen sources other than sunflower are nearby, the honey bee

Table 11. Sunflower rotation examples for North Dakota.

Year	West		East	
1	Sunflower	Sunflower	Sunflower	Sunflower
2	Small grain	Pulse crop*	Soybean*	Small grain
3	Pulse crop*	Small grain	Small grain	Soybean *
4		Flax or small grain		Corn

*medium susceptibility to Sclerotinia.

Figure 15. Bees and hives are occasionally placed in sunflower fields to boost the native population to assure a better seed set. (Reid Bevis)

will forage sunflower primarily for nectar and will not transfer sunflower pollen efficiently.

Honey bee colonies are placed in seed production fields at a rate of one hive per one to two acres. A bee density of more than 20 bees per 100 heads in bloom is needed to transfer sufficient pollen from the male line to the female sterile line. Placement of honey bee colonies will depend upon proximity and acreage of competing nectar and pollen sources. With no competition, all honey bee colonies are placed at one end of the target field. With competing nectar and pollen sources, placement of honey bee colonies at 800-foot intervals may be necessary.

Sunflower genotypes vary in their attractiveness to the honey bee. Honey bees prefer short corolla length, unpigmented stigmas, many stomata on the nectary and high sucrose content of the nectar. Glandular trichomes on the anthers and ultraviolet reflecting and adsorbing pigments also may be important in honey bee preference. Although some crops, such as oilseed rape, have been selected for honey bee preference, this has not been done with sunflower.

Maximum seed yields often require the use of insecticides to protect the crop from insect competitors. Unfortunately, many of the major insect pests of sunflower attack the crop when it is flowering. Thus, insecticides used to control the pest also harm pollinating bees. If pollinator activity is decreased, yield and oil percentage may decline. The hazards to honey bees can be minimized with adequate communication and cooperation among beekeepers, growers and pesticide applicators. Beekeepers must inform applicators of the location of apiaries and be prepared to move or protect colonies. When insecticide spraying is justified, applicators must make every attempt to notify beekeepers in advance.

Pest Management

(Janet Knodel and Larry Charlet)

Integrated Pest Management

Sunflower can be a high-risk crop because of potential losses from diseases, insects, birds and weeds. These potential risks require that growers follow integrated pest management (IPM) practices. IPM is a sustainable approach to managing pests by combining biological, cultural, physical and chemical tools in a way that minimizes economic, health and environmental risks to maintain pest populations below levels that cause unacceptable losses to crop quality or yield. The concept of pest management is based on the fact that many factors interact to influence the abundance of a pest. Control methods vary in effectiveness, but integration of these various population-regulating factors can minimize the number of pests in sunflower and reduce the cost of managing pest populations without unnecessary crop losses. IPM also recommends the judicious use of chemical pesticides when needed and suggests ways to maximize effectiveness and minimize impact on nontarget organisms and the environment.

Economic Injury Level and Economic Threshold Levels

One major component of a pest management program is determining when tactics should be implemented to prevent economic loss. Economic loss results when pest numbers increase to a point where they cause crop losses that are greater than or equal to the cost of controlling the pest. An economic injury level (EIL) is defined as the level of pests that will cause economic damage. An EIL recognizes that treatment is justified for some pest population levels while others are not of economic importance.

An economic threshold level (ETL) is the level or number of pests at which tactics must be applied to prevent an increasing pest population from causing economic losses. Usually the ETL is lower than the EIL. The ETL has been defined most extensively for insect pests; fewer ETLs have been established for other types of pests. The ETL varies significantly among different pests and also can vary during different developmental stages of the crop. Crop price, yield potential, crop density, cost of control and environmental conditions influence the ETL and EIL. Generally, the ETL increases as cost of control increases and decreases as the crop value increases.

Monitoring Pest Population Levels

In general, fields should be evaluated regularly to determine pest population levels. A weekly field check is usually sufficient, but field checks should be increased to two or three times a week if the number of pests is increasing rapidly or if the number is approaching an economic threshold level. Pests should be identified accurately because economic threshold levels and control measures vary for different organisms. In addition, when insects pests are monitored, many insects are beneficial and may help reduce numbers of injurious insects; recognizing which are pests and those that are beneficial is important.

Tools of Pest Management

Tools of pest management include many tactics, of which pesticides are only one. These tactics can be combined to create conditions that are the least conducive for pest survival. Chemical or biological pesticides are used when pests exceed economic threshold levels; sometimes they are necessary when control is needed quickly to prevent economic losses.

Some of the tools or components of pest management that can be used to reduce pest populations are:

Biological Controls

Beneficial insects
Beneficial pathogens
Host Resistance

Cultural Controls

Planting and harvest dates
Crop rotation
Tillage practices

Mechanical/Physical Controls

Temperature
Weather events
Trapping

Chemical Controls

Pesticides
Attractants
Repellents
Pheromones

Summary

Growers should examine their operations and minimize pest damage by adopting integrated pest management practices based on the use of economic threshold levels, when available, plus carefully monitoring and combining various control methods. Significant progress with sunflower pest management has been made and undoubtedly will continue to be made in the future to aid successful sunflower production. The following sections provide current information on management of insects, diseases, weeds, birds and other sunflower pests. A growing season calendar shows the major sunflower pest problems and time of occurrence in the northern Great Plains production area (Figure 16).

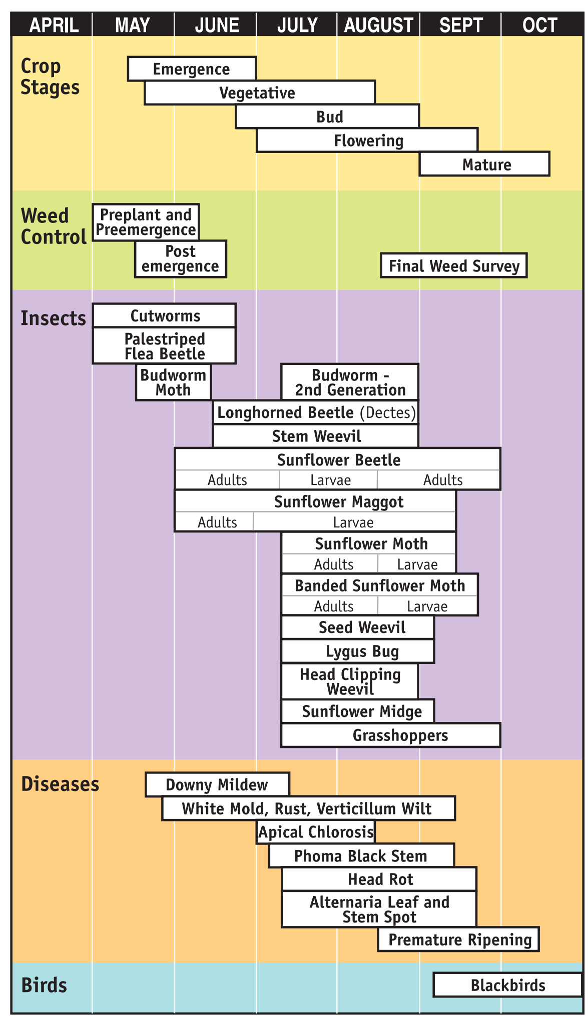


Figure 16. A growing season calendar indicating time of occurrence of major sunflower pests.
(J. Knodel)

Quick Reference Guide to Major Sunflower Insects

The information presented on this page is designed to be a quick reference for growers, crop consultants, field scouts and others. Since this information is very brief, the user should refer to the following pages for more detailed data on life cycles, damage, descriptions, etc.

Insects	Description	Occurrence, Injury and Economic Threshold (ET)
Cutworms (several species)	Dirty gray to gray brown. Grublike larva, 0.25 to 1.5 inches in length.	ET – 1 per square foot or 25 percent to 30 percent stand reduction. Appear in early spring when plants are in the seedling stage, chewing them at or slightly above ground.
Palestriped Flea Beetle	Adult: 1/8 inch long and shiny black, with two white stripes on the back. The hind legs are enlarged and modified for jumping.	ET – 20 percent of the seedling stand is injured and at risk to loss due to palestriped flea beetle feeding. Scout for flea beetles by visually estimating population on seedlings or using yellow sticky cards placed close to the ground.
Sunflower Beetle	Adult: reddish-brown head, cream back with three dark stripes on each wing cover. Body 0.25 to 0.5 inch long. Larva: yellowish green, humpbacked in appearance, 0.35 inch in length.	ET – 1 to 2/seedling (adults), or 10 to 15/seedling (larvae). Adults appear in early June, larvae shortly thereafter. Both adults and larvae chew large holes in leaves.
Sunflower Bud Moth	Adult: wingspread 0.63 to 0.75 inch, gray brown with two dark transverse bands on forewings. Larva: Cream-colored body (0.33 to 0.4 inch) with a brown head.	ET – none. First generation adults appear in late May to mid-June. Second generation adults appear in midsummer. Larvae from first generation damage terminals and stalks, whereas second generation larvae feed in receptacle area.
Longhorned Beetle *(Dectes)*	Adult: pale gray and 5/8 inch (6 to 11 mm) in length, with long gray and black banded antennae. Larvae: yellowish with fleshy protuberances on the first seven abdominal segments (1/3 to 1/2 inch)	No scouting method or ET has been developed. Adults are present from late June through August. Larvae tunnel and feed in the petioles and stem pith and girdle the base of plants. Stalks often break at the point of larval girdling.
Sunflower Stem Weevil	Adult: small (0.19 inch long) weevil with a gray-brown background and white dots on the back.	ET – 1 adult/3 plants in late June to early July. Adults appear in mid to late June, with larvae in stalks from early July to late summer.
Thistle Caterpillar (Painted Lady Butterfly)	Adult: wingspread of 2 inches, upper wing surface brown with red and orange mottling and white and black spots. Larva: brown to black, spiny, with a pale yellow stripe on each side, 1.25 to 1.5 inches in length.	ET – 25 percent defoliation, provided that most of the larvae still are less than 1.25 inches in length. Adults appear in early to mid-June, with larvae appearing shortly thereafter. Larvae chew holes in leaves.
Sunflower Midge	Adult: small (0.07 inch), tan, gnatlike insect. Larva: cream or yellowish, 0.09 inch long, tapered at front and rear.	ET – none. Adult emergence begins in early July. Larvae feed around head margin and at the base of the seeds, causing shrinkage and distortion of heads.
Sunflower Seed Weevils	Adults: the red sunflower seed weevil is about 0.12 inch long and rusty in color. The gray sunflower seed weevil is about 0.14 inch long and gray in color. Larvae: both species are cream-colored, legless and C-shaped.	ET – generally 8 to 14 adult red sunflower weevils per head (oil) and one per head (confectionery). Adults appear in late June to early July. Treat for red sunflower seed weevil at R5.1 to R5.4. Larvae feed in seeds from mid to late summer.
Sunflower Moth	Adult: body is 0.38 inch long, with 0.75 inch wingspread. Color is buff to gray. Larva: brown head capsule with alternate dark and light lines running longitudinally, 0.75 inch in length.	ET – 1 to 2 adults/5 plants at onset of bloom. Adults are migratory and usually appear in early to mid-July. Larvae tunnel in seeds from late July to late August.
Banded Sunflower Moth	Adult: small 0.25-inch straw-colored moth with brown triangular area on forewing. Larva: in early growth stage, off-white, changing to red and then green color at maturity, 0.44 inch in length.	ET – See banded sunflower moth section for egg or adult sampling methods for determining ET. Sampling should be conducted in the late bud stage (R-3), usually during mid-July. Adults appear about mid-July to mid-August. Larvae present in heads from mid-July to mid-September.
Lygus Bug	Adult: small (0.2 inch in length), cryptically colored insects with a distinctive yellow triangle or "V" on the wings and vary in color from pale green to dark brown. Nymph (immature stages): usually green and similar in appearance to the adults, but lack wings.	ET - for CONFECTION SUNFLOWERS ONLY – 1 Lygus bug per 9 heads. Two insecticide sprays are recommended: one application at the onset of pollen shed or 10 percent bloom, followed by a second treatment 7 days later.
Sunflower Headclipping Weevil	Adult: metallic, black, 0.25-inch long body with a long "snout." Larvae: 0.25 inch in length.	ET – none. Adults appear in mid to late July and create feeding punctures around stalk just below the heads. Heads drop off.

NOTE: The insects discussed above are listed in the order that they likely are to occur throughout the growing season; however, the various insects may or may not appear, depending upon overwintering survival and environmental conditions as the season progresses. The table is intended simply as a guide to when fields should be checked for possible presence of the various insects known to infest sunflowers.

Insects

(Janet Knodel and Larry Charlet)

Sunflower plays host to a number of insect pests. In the major sunflower producing areas of the Dakotas, Minnesota and Manitoba, approximately 16 species of sunflower insects can cause plant injury and economic loss, depending on the severity of infestation. However, during any one growing season, only a few species will be numerous enough to warrant control measures. The sunflower insects of major importance in the northern Great Plains have been sunflower midge, *Contarinia schulzi* Gagne'; sunflower beetle, *Zygogramma exclamationis* (Fabricius); sunflower stem weevil, *Cylindrocopturus adspersus* (LeConte); red sunflower seed weevil, *Smicronyx fulvus* LeConte; and the banded sunflower moth, *Cochylis hospes* Walsingham. Recently, Lygus bugs have been an economic problem for the confection and hulling sunflower seed market. Populations of the long-horned sunflower stem girdler, *Dectes texanus* LeConte, have been increasing in North and South Dakota.

Infestation of sunflower insects must be monitored regularly, usually weekly, to determine the species present and if populations are at economic threshold levels. Furthermore, proper timing of insecticidal treatment is essential to maximize control.

The following sections provide information on the identification, life cycle, damage, scouting methods, economic threshold levels and management of some of the most common insect pests of sunflower in the northern Great Plains. A preliminary quick reference guide to sunflower insects is available.

Sunflower pests are not distributed evenly throughout a field, and fields should be checked in several locations. Some insect pests, such as banded sunflower moth, are concentrated in areas of a field or are more abundant near the edge of a field than in the middle. Determining the extent of a pest population on the basis of what is found in only one or two small areas of a field is impossible. At least five sites per 40-acre field should be monitored to collect good information on the nature and extent of a pest infestation.

Sampling sites should be at least 75 feet in from the field margin to determine whether an entire field or a portion of the field requires treatment. When infestations occur primarily along field margins, delineating those and treating as little of the field as needed to provide economic control may be possible. In most cases, 20 plants per sampling site should be examined in the Z or X pattern as shown (Figure 17).

Crop consultants who are trained in pest management scouting may be hired. Consultants should be able to identify pest and beneficial insects and provide information about pest management.

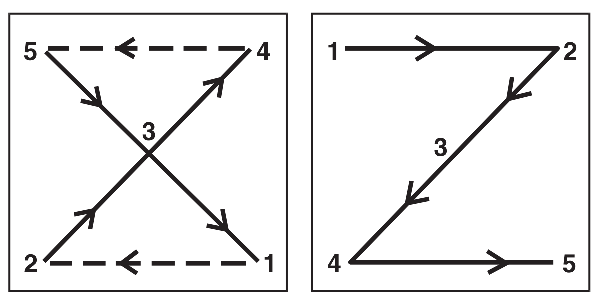


Figure 17. The X and Z scouting patterns.

Wireworms

Species: various

Description: Wireworm larvae (Figure 18) are hard, smooth, slender, wirelike worms varying from 1.5 to 2 inches (38 to 50 mm) in length when mature. They are a yellowish white to a coppery color with three pairs of small, thin legs behind the head. The last body segment is forked or notched.

Adult wireworms (Figure 19) are bullet-shaped, hard-shelled beetles that are brown to black and about ½ inch (13 mm) long. The common name "click beetle" is derived from the clicking sound that the insect makes when attempting to right itself after landing on its back.

Figure 18. Wireworm larvae. (Mark Boetel)

Figure 19. Click beetle or adult wireworm. (Roger Key, http://www.insectimages.org)

Life Cycles: Wireworms usually take three to four years to develop from the egg to an adult beetle. Most of this time is spent as a larva. Generations overlap, so larvae of all ages may be in the soil at the same time. Wireworm larvae and adults overwinter at least 9 to 24 inches (23 to 61 cm) deep in the soil. When soil temperatures reach 50 to 55 F (10 to 13 C) during the spring, larvae and adults move nearer the soil surface.

Adult females emerge from the soil, attract males to mate, then burrow back into the soil to lay eggs. Females can re-emerge and move to other sites, where they burrow in and lay more eggs. This behavior results in spotty infestations throughout a field. Some wireworms prefer loose, light and well-drained soils; others prefer low spots in fields where higher moisture and heavier clay soils are present.

Larvae move up and down in the soil profile in response to temperature and moisture. After soil temperatures warm to 50 F (10 C), larvae feed within 6 inches (15 cm) of the soil surface. When soil temperatures become too hot (>80 F, 27 C) or dry, larvae will move deeper into the soil to seek more favorable conditions. Wireworms inflict most of their damage in the early spring, when they are near the soil surface. During the summer months, the larvae move deeper into the soil. Later as soils cool, larvae may resume feeding nearer the surface, but the amount of injury varies with the crop.

Wireworms pupate and the adult stage is spent within cells in the soil during the summer or fall of their final year. The adults remain in the soil until the following spring.

Damage: Wireworm infestations are more likely to develop where grasses, including grain crops, are growing. Wireworms damage crops by feeding on the germinating seed or the young seedling. Damaged plants soon wilt and die, resulting in thin stands. In a heavy infestation, bare spots may appear in the field and reseeding is necessary.

Scouting Method: Decisions to use insecticides for wireworm management must be made prior to planting. No rescue treatments are available for controlling wireworms after planting. Producers have no easy way to determine the severity of infestation without sampling the soil. Infestations vary from year to year. Considerable variation may occur both within and between fields.

Sometimes the past history of a field is a good indicator, especially if wireworms have been a problem in previous seasons. Also, crop rotation may impact population levels.

Two sampling procedures are available. One procedure relies on the use of a corn-wheat seed mixture used as bait, placed in the soil, which attracts the wireworms to the site (Figure 20). The other involves digging and sifting a soil sample for the presence of wireworms.

Economic Threshold: If the average density is greater than one wireworm per bait station, the risk of crop injury is high and a soil insecticide should be used at planting to protect the sunflower. If no wireworms are found in the traps, risk of injury is low; however, wireworms still may be present but were not detected by the traps. When digging soil samples, 12 or more wireworms in 50 3-inch by 3-inch (8 cm by 8 cm) samples, is likely to result in damage to sunflower.

Management: Seeds should be treated with an approved insecticide for protection of germinating seeds and seedlings.

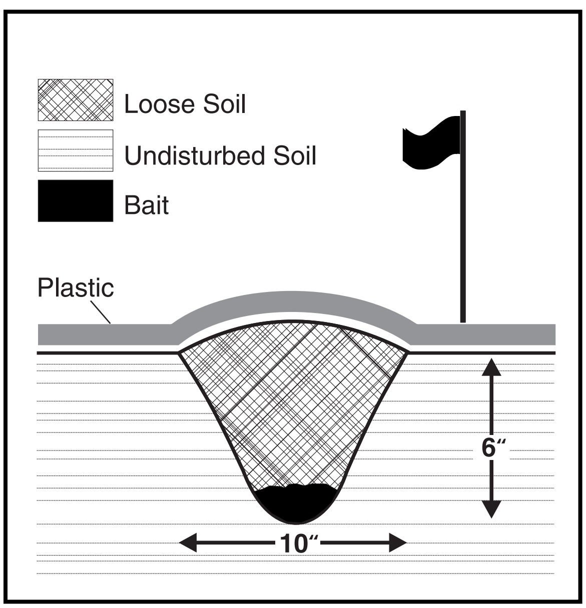


Figure 20. Wireworm bait station. (Extension Entomology)

Seedcorn Maggot

Species: *Delia platura* (Meigan)

Description: Seedcorn maggots are larvae of small flies resembling houseflies. The adult is a light gray fly about 0.2 inch (5 mm) long. Larvae are white, cylindrical, tapered anteriorly and also about 0.2 inch (5 mm) long (Figure 21). Larvae can be found inside damaged seeds or in the soil nearby.

Life Cycle: After soil temperatures reach 50 F (10 C) in the spring, the flies emerge, mate and then deposit eggs in soil, especially where high organic matter exists. Eggs hatch in a few days and the maggots burrow into seeds. Infected seeds often do not emerge, resulting in stand loss. Even when infested seeds do germinate, plants may be weakened. No effective preplant monitoring techniques are available for seedcorn maggots. Fields with extensive decaying organic matter, such as those that are heavily manured or where a cover crop has been turned under, are particularly attractive to egg-laying flies.

Damage: The first sign of seedcorn maggot damage is areas in the field where seedlings have not emerged. Seedcorn maggots hollow out seeds or eat portions of seedlings. Damage is most common in early plantings while the soil is cool, and if organic matter is high, such as when a green plant material is plowed into a field before planting. Females are strongly attracted to decaying organic matter for laying eggs.

Scouting Method: Scouting to determine the risk of seedcorn maggot infestation has not been developed.

Figure 21. Seed corn maggot larvae. (Ric Bessin, University of Kentucky)

Cutworms

Species:
Darksided cutworm *Euxoa messoria* (Harris)
Redbacked cutworm *Euxoa ochrogaster* (Guenee)
Dingy cutworm *Feltia jaculifera* (Walker)

Description: Darksided cutworm — Forewings of the adult darksided cutworm are usually light, powdery and grayish brown with indistinct markings (Figure 22). The larvae are pale brown dorsally and white on the ventral areas (Figure 23). Sides have numerous indistinct stripes. At maturity, they are about 1.25 to 1.5 inches (32 to 38 mm) long and 0.19 inch (5 mm) wide.

Redbacked cutworm — The forewings of the adult redbacked cutworm are reddish brown with characteristic bean-shaped markings (Figure 24). The larvae are dull gray to brown with soft, fleshy bodies and may be 1 to 1.25 inches (25 to 32 mm) long when fully grown (Figure 25). Larvae can be distinguished by two dull reddish stripes along the back.

Dingy cutworm — Forewings are dark brown with bean-shaped markings as in the redbacked cutworm adults (Figure 26). Hind wings in the male are whitish with a broad, dark border on the outer margin; in the female they are uniform dark gray. The larvae have a dull, dingy, brown body mottled with cream color. The dorsal area is pale with traces of oblique shading (Figure 27).

Life Cycles: The female darksided and redbacked cutworm moths deposit eggs in the soil in late July and early August. The eggs remain dormant until the onset of warm weather the following spring. The larvae of both species emerge from late May to early June. They continue to feed and grow until about the end of June, when fully grown larvae pupate in earthen cells near the soil surface. The pupal period lasts about three weeks. Both species have one generation per year.

The adult dingy cutworms emerge in August and are active until mid-October, with peak activity in September. Eggs are deposited in plants in the Compositae family in the fall. The larvae develop to the second or third instar in the fall and overwinter in the soil. Pupation occurs in the spring to early summer. One generation of this species is produced per year.

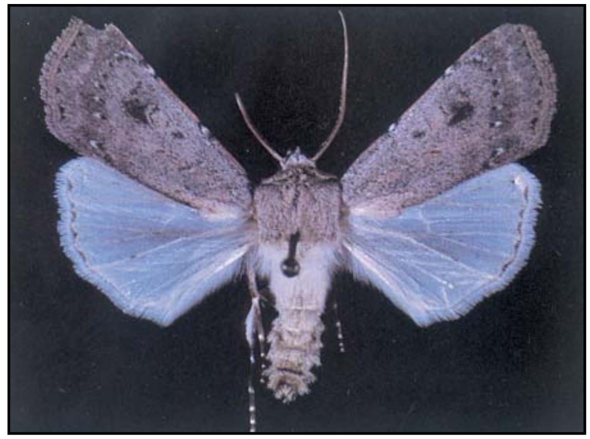


Figure 22. Adult - Darksided cutworm
Euxoa messoria. (Extension Entomology)

Figure 23. Larva - Darksided cutworm
Euxoa messoria. (Extension Entomology)

Figure 24. Adult - Redbacked cutworm
Euxoa ochrogaster. (Extension Entomology)

Figure 25. Larva - Redbacked cutworm
Euxoa ochrogaster. (Extension Entomology)

Damage: Cutworm damage normally consists of crop plants being cut off from 1 inch (25 mm) below the soil surface to as much as 1 to 2 inches (25 to 50 mm) above the soil surface. Young leaves also may be severely chewed as a result of cutworms (notably the darksided species) climbing up to feed on the plant foliage.

Most cutworm feeding occurs at night. During the daytime, the cutworms usually will be just under the soil surface near the base of recently damaged plants. Wilted or dead plants frequently indicate the presence of cutworms. Cut-off plants may dry and blow away, leaving bare patches in the field as evidence of cutworm infestations.

Scouting Method: Sampling should begin as soon as sunflower plants emerge, and fields should be checked at least twice per week until approximately mid-June. The Z pattern should be used in scouting fields for cutworms, with sampling points one and two near the margin as indicated in Figure 17.

Stand reduction is determined by examining 100 plants per five sampling sites for a total of 500 plants.

Figure 26. Adult - Dingy cutworm *Feltia jaculifera*. (Extension Entomology)

Figure 27. Larva - Dingy cutworm *Feltia jaculifera*. (Extension Entomology))

A trowel or similar tool should be used to dig around damaged plants to determine if cutworms are present, since missing plants in a row do not necessarily indicate cutworm damage (damage may be caused by a defective planter, rodents or birds).

The Z pattern should be used again to determine cutworm infestation level by examining five 1-square-foot (30 by 30 cm) soil samples per site (in the row) for a total of 25 samples.

Economic Threshold: One larva per square foot (30 by 30 cm) or 25 percent to 30 percent stand reduction.

Management: Several different insecticides are registered for cutworm control in sunflower. Postemergent treatment with an insecticide provides quick control of surface feeding cutworms.

Palestriped Flea Beetle

Species: *Systena blanda* (Melsheimer)

Description: The adult is about 1/8 inch (3.2 mm) long and shiny black, with two white stripes on the back. The hind legs are enlarged and modified for jumping (Figure 28).

Life Cycle: The life cycle of palestriped flea beetles on sunflower fields is poorly understood. However, the adult flea beetles seem to overwinter in the field under soil clods, field debris and crop residues. They become active again in the spring, perhaps feeding first on alfalfa and weeds before moving to and feeding on sunflower seedlings in June. They have been observed feeding on sunflower through July. Palestriped flea beetles have a wide host range, which includes various weeds, potato, tomato, carrot, peanut, corn, oat, cotton, pea, beans, strawberry, watermelon, grape and

Figure 28. Adult - Palestriped flea beetle. (Michael Catangui, SDSU)

pumpkin. Palestriped flea beetles are considered an important pest of commercially grown vegetables in some areas of the U.S. Recently, palestriped flea beetles have been observed delaying regrowth of alfalfa and also were observed feeding on soybean seedlings in eastern South Dakota.

Damage: Palestriped flea beetles chew on the cotyledons, leaves and hypocotyls of sunflower seedlings, causing them to wilt and die. Injured leaves become riddled with holes, giving them a "lacey" appearance (Figure 29). The sunflower plant is most sensitive to palestriped flea beetle injury from seedling emergence (V-E) through the four-leaf stage (V-4). Significant stand losses may result from heavy feeding injury by the palestriped flea beetles.

Figure 29. Damaged sunflower leaves by palestriped flea beetle. (Michael Catangui, SDSU)

Scouting Method: Surveys may be accomplished by using yellow sticky cards placed close to the ground (Figure 30). Sampling seedlings for beetles also can aid in estimating populations and feeding injury levels. Palestriped flea beetles move very fast and are hard to count directly on the seedlings or catch with an insect net.

Economic Threshold: Control is recommended when 20 percent of the seedling stand is injured and at risk to loss due to palestriped flea beetle feeding. This economic threshold is a guideline based on published hail injury data that predicts potential yield loss relative to seedling stand loss.

Management: Palestriped flea beetles are hard to control with chemical insecticides; research has shown that treatments may provide up to 75 percent control of adults.

Figure 30. Yellow sticky trap for monitoring palestriped flea beetles. (Michael Catangui, SDSU)

Sunflower Beetle

Species: *Zygogramma exclamationis* (Fabricius)

Description: The sunflower beetle is associated exclusively with sunflower. Adults (Figure 31) closely resemble adult Colorado potato beetles and may be confused with potato beetles. However, sunflower beetles are smaller and do not feed on potatoes, and Colorado potato beetles do not feed on sunflower. The head of the adult is reddish brown and the thorax (area between head and abdomen) is pale cream-colored with a reddish-brown patch at the base. Each front wing cover is cream-colored and has three dark stripes that extend its length. A shorter lateral stripe ends at the middle of the wing in a small dot that resembles an exclamation point. The beetle is ¼ to ½ inch (6 to 12 mm) long and 3/32 to 3/16 inch (2 to 4 mm) wide. Eggs are about 1/16 inch (1.5 to 2 mm) long, cigar-shaped and cream yellow. Sunflower beetle larvae are yellowish green with a brown head capsule and humpbacked in appearance. Newly hatched larvae are about 1/16 inch (1.5 to 1.75 mm long), and will reach a length of about an inch (8 to 10 mm) when fully developed (Figure 32).

Figure 31. Adult - Sunflower beetle *Zygogramma exclamationis.* (Extension Entomology)

Life Cycle: The sunflower beetle has one generation per year in North Dakota. The adults overwinter in the soil, emerging in late May or early June. Shortly after emergence, the beetles begin to feed, mate and lay eggs singly on stems and undersides of leaves. Adults live for about 8½ weeks and lay eggs for a six- to seven-week period. Each female lays approximately 850 eggs, with a range of 200 to 2,000 eggs. Eggs hatch into larvae in about one week (Figure 33). The larvae have four instars, which feed and are present in fields for about six weeks. When mature, the larvae enter the soil to pupate in earthen cells. The pupal stage lasts from 10 days to two weeks. Adults of the new generation emerge and feed for a short period on the bracts of the sunflower head or on the uppermost leaves of the plant before re-entering the soil to overwinter.

Damage: Adult sunflower beetles damage plants soon after they emerge from overwintering. Damage to cotyledons is generally slight, but the first true leaves may be severely damaged or completely consumed. Fields may be severely defoliated if beetles are numerous. Adults feed predominately on leaf margins while

Figure 32. Larva - Sunflower beetle *Zygogramma exclamationis.* (Larry Charlet)

Figure 33. Eggs - Sunflower beetle. (Larry Charlet)

larvae feed on the entire leaf surface. When larvae are numerous, damaged leaves take on a lacy appearance. Most larval feeding occurs at night, and adults will feed during the day. During the daytime, larvae typically rest in the terminal growth area, where they are easily found in leaf axils and flower buds. If larval feeding is severe, defoliation can reduce yield due to poor seed set or fill.

The late summer generation of emerging sunflower beetle adults and late-maturing larvae rarely causes economic damage to the sunflower crop. However, in some cases, they have been abundant enough to cause feeding injury on late-planted sunflower.

Scouting Method: Sampling sites should be at least 75 to 100 feet (23 to 31 m) from the field's margins when determining if an entire field should be treated. Adults and/or larvae should be counted on 20 plants at each of five sampling sites along an X pattern for a total of 100 plants. The average number of adults and/or larvae per plant then should be determined.

The average percent defoliation of plants is determined when damage is evident in the field by examining 20 plants per five sampling sites for a total of 100 plants (Figure 34).

Economic Threshold: As sunflower plants develop, they can tolerate more feeding damage. In the seedling stage, one to two adults per seedling is the recommended economic threshold. For larvae, the treatment threshold is when populations reach 10 to 15 larvae per plant, or when approximately 25 percent defoliation occurs on the upper eight to 12 leaves (active growing part). Management normally is advised if defoliation reaches the 25 percent to 30 percent level at the late vegetative and early bud stages and it appears (based on larval size of less than ¼ inch or 6 mm) that more defoliation will occur on the actively growing part of sunflower plant. However, if defoliation is 25 percent and the majority of larvae are about 1/3 inch (8 mm) long, they have reached maturity and soon will stop feeding. Then, management probably is not warranted.

Management: Insecticide seed treatments and foliar insecticides are effective in reducing spring populations of the adult sunflower beetle. Application of a foliar insecticide is recommended only when beetle populations have reached an economic threshold level in a field. Insecticides are effective in preventing economic loss when applied to actively feeding adults and/or larvae. Adult and larval populations of sunflower beetle decrease as planting date is delayed. Defoliation also is lower at the later planting dates. As a result, delayed planting is effective in preventing yield reductions caused by sunflower beetle feeding, but may make fields more attractive to later season insects, such as red sunflower seed weevil. Spring or fall cultivation does not reduce the overwintering populations of sunflower beetle adults or influence the pattern of emergence from the soil during the spring and summer. Sunflower hybrids with resistance to the sunflower beetle are not available. Natural enemies include parasites of the eggs, larvae and adults. General predators, such as ladybird beetles, carabid beetles, lacewings, stink bugs, nabids and anthocorids, destroy both eggs and larvae of the sunflower beetle.

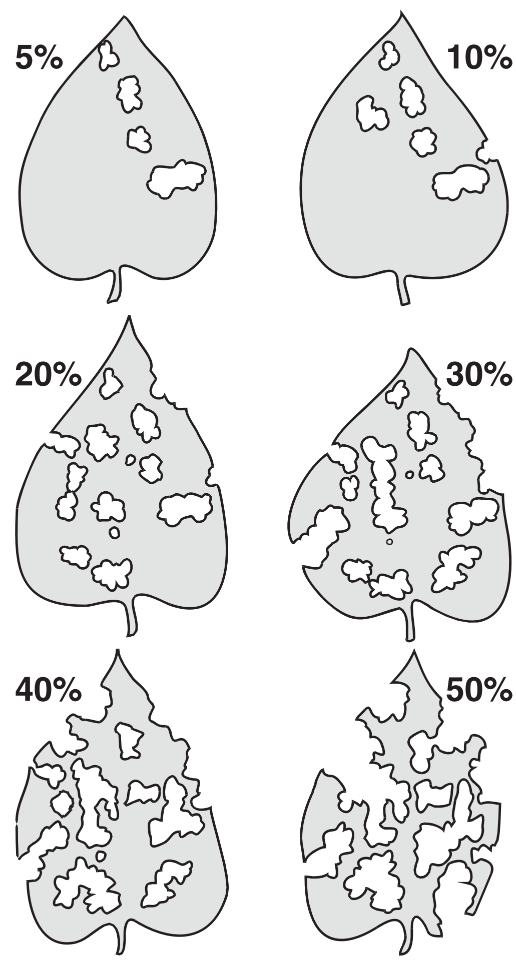


Figure 34. Percent defoliation of sunflower leaves. (Extension Entomology)

Sunflower Bud Moth

Species: *Suleima helianthana* (Riley)

Description: Sunflower bud moths have a wingspread of about 0.63 inch (16 to 18 mm). Each gray-brown forewing has two dark transverse bands (Figure 35). One band extends across the middle of the wing and the second band is near the wing tip. The larva has a dark head capsule with a smooth, cream-colored body and is 0.31 to 0.43 inch (8 to 11 mm) at maturity (Figure 36).

Figure 35. Adult - Sunflower bud moth *Suleima heliathana.* (Extension Entomology)

Life Cycle: Two generations of sunflower bud moth are produced per year in North Dakota. Adults emerge from overwintering pupae during the last week of May to mid-June.

A few days after adult emergence, eggs are deposited on the terminals of immature sunflower or on the receptacle of mature sunflower. Eggs also are deposited in leaf axils. The hatched larvae begin tunneling into the sunflower plant. The initial infestation in mid-June is characterized by an entrance hole surrounded by black frass, or insect excrement.

Mature larvae pupate within the sunflower plant. Pupae move to the opening of the entrance holes formed in the stem or head tissue so that adults can emerge easily.

The second-generation adults appear in July and August. Infestation by the second-generation larvae is not economically important.

Figure 36. Larva - Sunflower bud moth *Suleima heliathana.* (Extension Entomology)

Damage: In early planted sunflower, 65 percent to 85 percent of the infestations occur in the stalks. In late-planted sunflower, most infestations occur in the pith areas of the head.

Up to 4,000 larvae per acre have been reported in North Dakota and 24,000 larvae per acre have been reported in Texas. Despite these high populations, economic loss due to this insect has been minimal. The only time yield loss is noticeable is when larvae burrow into unopened buds, preventing proper head development. The larvae normally do not feed on developing seeds but confine feeding activities to the fleshy part of the head. Yield loss has not been economically significant, although injury by the larva produces malformations in both the head and stalk.

Scouting Method: A field monitoring scheme for this insect has not been established since it is not of economic significance.

Economic Threshold: None established.

Management: Insecticide use has not been warranted for control of sunflower bud moth.

Long-horned Sunflower Stem Girdler or Longhorned Beetle

Species: *Dectes texanus* LeConte

Description: The adult is pale gray and 5/8 inch (6 to 11 mm) in length, with long gray and black banded antennae. (Figure 37) Eggs are about 0.1 inch (1.9 mm) long and elongate, and turn dark yellow prior to hatch. Mature larvae are yellowish and 1/3 to 1/2 inch (7 to 13 mm) in length. Larvae bear fleshy protuberances on the first seven abdominal segments. (Figure 38).

Life Cycle: Adults appear in mid-June to early July in the southern Plains. Emergence continues through August, with 50 percent emerged by mid-July in Texas. Eggs are laid four to eight days after mating and eggs are deposited singly in leaf petioles. Approximately 50 eggs are laid per female, with about one-third viable. Eggs hatch in six to 10 days. Larvae tunnel and feed in the petioles and stem pith and finally move to the base of the plant to overwinter. Larvae develop through six instars. In late summer, the mature larvae girdle the inside of the lower stalk or root crown, move below the girdle and pack frass into the tunnels. Stalks often break at the point of girdling, leaving the larva protected in its frass-packed tunnel during the winter. The larvae are cannibalistic and stalks usually harbor only a single larva, even though several may have hatched in a stalk. This insect has one generation per year. Host plants include sunflower, soybean, ragweed and cocklebur.

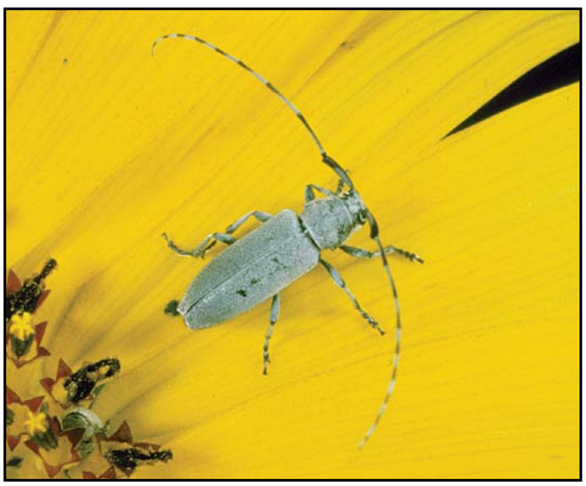


Figure 37. Adult - Longhorned beetle *Dectes texanus.* (Extension Entomology)

Figure 38. Larva - Longhorned beetle *Dectes texanus.* (Extension Entomology)

Damage: Plant damage due to adult feeding appears to be insignificant since the scars do not penetrate the cortex nor encircle the stalk. Larval feeding is apparent when stalks lodge at the point of the girdle, about 2.5 to 3.5 inches (7 to 9 cm) above the soil surface.

Scouting Method: None has been developed.

Economic Threshold: None established.

Management: In the southern Plains, later planting dates and fall or winter tillage have reduced sunflower infestations by this pest. Perennial sunflower species are resistant to stalk infestation, indicating the possibility of breeding cultivars resistant to the long-horned sunflower stem girdler. Chemical treatments on soybean and sunflower are ineffective against larvae and were determined to be impractical against adults because of the extended emergence period. When larvae are present in the stalks, plants do not always lodge. Utilizing lower plant populations that encourage thicker stalks may help reduce damage from lodging. If fields are suspected to be infested, prompt harvesting will limit losses from lodging.

Sunflower Maggots

Species:
Sunflower receptacle maggot, *Gymnocarena diffusa* (Snow)
Sunflower maggot, *Strauzia longipennis* (Wiedemann)
Sunflower seed maggot, *Neotephritis finalis* (Loew)

Description: The adult forms of all three sunflower maggots (flies) have wings with a distinct brown or yellowish-brown pattern. The name "picture-wing fly" has been given to flies of this type. While all three fly species are similar in appearance, they do have distinguishing differences.

Gymnocarena diffusa - This species is the largest of the three, with a body about 0.4 inch (10 mm) long and a wing span of approximately 0.75 inch (19 mm) (Figure 39). The eyes of this species are bright green and the wings have a yellowish-brown and somewhat mottled appearance. *G. diffusa* larvae attain a length of nearly 0.31 inch (8 mm) at maturity. The larvae taper from the front to rear and are yellowish white (Figure 40).

Strauzia longipennis - Adults of this species have a wing spread of about 0.5 inch (13 mm) and a body 0.25 inch (6 mm) long (Figure 41). The wings bear broad, dark bands that form a fairly distinct F-shaped mark near the tips. The larvae of *S. longipennis* are creamy white, headless and legless, as are the other two species (Figure 42). They taper slightly at both ends and attain a length of about 0.28 inch (7 mm) at maturity.

Neotephritis finalis - This sunflower maggot is the smallest of the three species, with the adult having a body length of about 0.25 inch (6 mm) and a wing span of approximately 0.28 inch (7 mm) (Figure 43). The wings have a brown lacelike appearance. *N. finalis* larvae attain a length of 0.19 inch (4.5 mm) at maturity. The small, brown pupa of *N. finalis* is found in the face of the sunflower bud, usually surrounded by a small number of damaged florets (Figure 44).

Life Cycles: Adults of *G. diffusa* emerge in late June to early July after sunflower buds reach 2 to 4 inches (5 to 10 cm) in diameter. Eggs are laid on the bracts

Figure 39. Adult - Sunflower receptacle maggot *Gymnocarena diffusa*. (Extension Entomology)

Figure 40. Larva - Sunflower receptacle maggot *Gymnocarena diffusa*. (Extension Entomology)

Figure 41. Adult - Sunflower maggot *Strauzia longipennis*. (Extension Entomology)

Figure 42. Larva - Sunflower maggot *Strauzia longipennis*. (Extension Entomology)

of the developing sunflower heads. Egg laying occurs from mid-July through August. The hatched larvae tunnel into the spongy tissue of the receptacle. Damage to the head is negligible. After 30 days, the mature larvae cut a small emergence hole on the underside of the receptacle and drop into the soil to pupate. Overwintering pupae are found about 7.5 inches (19 cm) deep in the soil by August or early September. Some larvae will pupate in the sunflower head. Only one generation per year occurs in North Dakota.

Strauzia longipennis has one generation per year. This insect overwinters as a larva in plant debris in the soil. Pupation and adult emergence is completed in early June. Females lay eggs in stem tissue of young sunflower, and larvae feed in the pith tissue for much of the growing season.

Figure 43. Adult - Sunflower seed maggot *Neotephritis finalis.* (Extension Entomology)

Figure 44. Pupae - Sunflower seed maggot *Neotephritis finalis.* (Extension Entomology)

Unlike the other two species of sunflower maggots, two complete generations per year of *N. finalis* occur in North Dakota. Adults of *N. finalis* emerge during the first week of July. Egg deposition occurs on the corolla of incompletely opened sunflower inflorescences. The total larval period is 14 days. The first generation of *N. finalis* pupates in the head; the second generation overwinters in the soil as pupae.

Damage: Damage by sunflower maggots has been negligible.

The maggots of *Gymnocarena diffusa* feed on the spongy receptacle tissue of the sunflower head and feeding may cause partially deformed heads. Larvae do not feed on developing seeds.

The magnitude of damage to sunflower seeds by *N. finalis* larvae depends largely on the stage of larval and seed development. Seed sterility occurs when newly hatched larvae tunnel into the corolla of young blooms. Observations indicate that a single larva feeding on young flowers will tunnel through 12 ovaries. Mature larvae feeding on older sunflower heads will destroy only one to three seeds.

While infestation levels of *S. longipennis* occasionally have reached nearly 100 percent, damage from larval feeding is usually light. Part of a commercial sunflower field next to a grassed waterway or other water source sometimes supports a higher than usual infestation. Under these conditions, high larval numbers of eight to 10 per stalk may be found and stalk breakage can occur. Stalk breakage of up to 30 percent of the plants has been recorded.

Scouting Method: A scouting method has not been developed for sunflower maggots because of the negligible injury caused by these insects.

Economic Threshold: None established.

Management: Insecticide use has not been warranted for control of sunflower maggots.

Sunflower Stem Weevil

Species: *Cylindrocopturus adspersus* (LeConte)

Description: Adult sunflower stem weevils are about 3/16 inch (4 to 5 mm) long and grayish brown, with varying-shaped white spots on the wing covers and thorax (Figure 45). The snout, eyes and antennae are black. The snout is narrow and protrudes down and backward from the head. Eggs are deposited inside the epidermis of sunflower stems and are very small (0.51 mm long by 0.33 mm wide), oval and yellow, making them difficult to see. The larvae are ¼ inch (5 to 6 mm) long at maturity, legless and creamy white with a small, brown head capsule (Figure 46). They are normally in a curled or C-shaped position within the sunflower stalk. Pupae are similar to the adult in size and creamy white

Life Cycle: Only one generation occurs per year. Larvae overwinter in sunflower stalks and crown roots and pupate in the spring, and adults emerge in mid to late June, feeding on the epidermal tissue of the sunflower foliage and stem. This feeding does not affect plant vigor. Mating occurs soon after emergence of adults. Just prior to egg laying, females descend to the lower portion of the plant to deposit eggs individually in the stem tissue. Approximately 50 percent of oviposition occurs by mid-July. Upon hatching in early July, the first instar (larval growth stage) larvae feed on subepidermal and vascular tissue. Feeding is concentrated in the pith tissue as the larvae develop to third and fourth instar stages. By the last week in August, the larvae descend while feeding to just above the soil surface. A chamber is constructed in the stem, and the weevil overwinters there as a fifth instar larva. Pupation of the overwintering larva occurs the following year in early June.

Damage: Adult sunflower stem weevil feeding causes minor damage to the stem and leaf tissue of the plant. More importantly, adult weevils have been implicated in the epidemiology of the sunflower pathogen Phoma black stem *(Phoma macdonaldii Boerma)* and charcoal stem rot *(Macrophomina phaseolina* (Tassi) Goid).

Larval injury can cause the stem to weaken from tunneling, pith destruction and especially by construction of overwintering chambers at the stalk base. At larval infestations of 20 to 25 or more per stalk, the plants run a risk of stalk breakage and loss of the entire capitual (head). Risk of breakage is greatest when plants are under drought stress and/or during periods of high winds. The breakage typically occurs at or slightly above the soil line, in contrast to breakage attributed to a stalk disease, which normally occurs farther up on the stalks.

Scouting Methods: Field monitoring for sunflower stem weevils to estimate population size is important. However, adults are difficult to see on the plants due to their small size, cryptic color and "play dead" behavior. They are inactive on the plant or fall to the ground when disturbed and remain motionless. Adults can be found on both surfaces of the leaves, the lower portions of the stem, in leaf axils, within the dried

Figure 45. Adult - Sunflower stem weevil *Cylindrocopturus adspersus.* (Extension Entomology)

Figure 46. Larva - Sunflower stem weevil *Cylindrocopturus adspersus.* (Extension Entomology)

cotyledons or in soil cracks at the base of the sunflower plant. Yellow sticky traps were unsuccessful in relating captured adult numbers to larval infestations.

Sampling for the larval stage is difficult since they develop totally within the sunflower plant. The only method for detecting the presence of larvae is to split the sunflower stem, a time-consuming process.

Field scouting for adults should begin when plants are in the eight- to 10-leaf stage, developmental stage V-8 to V-10, or late June to early July, and continue until mid-July. Select sampling sites 70 to 100 feet in from the field margin. Count the number of adults on five plants at five randomly selected sampling sites throughout the field for a total of 25 plants. Calculate the average number of weevils per plant. Use an X pattern (or W pattern) to space sample sites throughout the entire field. When scouting for stem weevils, approach plants carefully and slowly to avoid disturbing the adults.

Economic Threshold: Average field counts of one adult sunflower stem weevil per three plants can result in damaging larval densities of more than 40 larvae per stalk at the end of the season.

Management: Insecticidal treatment, if needed based on field counts, should be initiated in late June or early July before significant egg laying has occurred. Cultural control tactics, including delayed planting, altered plant population and tillage, are useful for managing the sunflower stem weevil. Delayed planting of sunflowers until late May or early June has been effective in reducing densities of larvae in the stem. Reducing plant population results in an increased stalk diameter and, as a result, decreases damage from lodging. Combinations of disking to break up stalks and moldboard plowing to bury them at a depth of 6 inches (15 cm) can increase larval/pupal mortality and severely impact the emergence of adult stem weevils. Otherwise, larvae/pupae are physically protected in the woody stalks. Survival is affected only by performing both operations. Greenhouse and field experiments have shown resistance to feeding, oviposition and larval development in many native species of sunflower. Field research for resistant sunflower germplasm is under way. Natural enemies of the sunflower stem weevil include parasitic wasps that attack both the egg and larval stages.

Black Sunflower Stem Weevil

Species: *Apion occidentale* (Fall)

Description: Adults are black and only 0.1 inch (2.5 mm) long from the tip of the snout to the tip of the abdomen (Figure 47). The snout is very narrow and protrudes forward from the head, which is small in relation to the rather large, almost globose body. Larvae of A. occidentale are very similar in appearance to *C. adspersus,* except they are only 0.1 to 0.12 inch (2.5 to 3 mm) long at maturity and yellowish (Figure 48).

Life Cycle: *Apion occidentale* overwinters as an adult in soil, plant residue, sod and weed clusters and begins to emerge and feed on volunteer sunflower as soon as the plants reach the early seedling stage. Females deposit eggs under the epidermis of the stem or leaf petioles. Larvae emerging from these eggs tunnel in the pith area of the stem, pupate and emerge as adults in early August. Little or no adult activity is observed

Figure 47. Adult - Black sunflower stem weevil *Apion occidentale.* (Extension Entomology)

Figure 48. Larva - Black sunflower stem weevil *Apion occidentale.* (Extension Entomology)

for about two weeks in late July and early August. Black sunflower stem weevil adults emerging in August also feed on the leaves and stems of the plant, but as the plant matures and the leaves begin to die, the adults move under the bracts of the sunflower head, where they can be observed feeding until the plants are harvested.

Damage: Adult feeding generally is considered as insignificant mechanical injury. Like the sunflower stem weevil, the black sunflower stem weevil is suspected of vectoring Phoma black stem disease in sunflower fields. In situations of extremely high populations feeding on seedling sunflowers, stand loss has occurred. However, in most cases, populations are too low to cause economic damage and stalk tunneling only results in minor injury to the plant.

Scouting Method: A scouting method has not been developed for the black sunflower stem weevil.

Economic Threshold: None established.

Management: Recommendations for insecticidal control of this insect have not been developed.

Figure 49. Adult - Sunflower root weevil *Baris strenua.* (Extension Entomology)

Figure 50. Larva - Sunflower root weevil *Baris strenua.* (Extension Entomology)

Sunflower Root Weevil

Species: *Baris strenua* (LeConte)

Description: Adults are rather robust-looking weevils, with a somewhat oval-shaped body (Figure 49). They are 0.25 inch (6 mm) long and have a short, almost blunt, downward projecting snout. Their coloration is dull black in contrast to the shiny, black appearance of *A. occidentale.* Baris strenua larvae are similar in appearance to *C. adspersus* larvae but much larger and are not located in the sunflower stalk (Figure 50).

Life Cycle: Adult root weevils emerge during the latter part of June. They feed on sunflower foliage in early morning and late afternoon. About two weeks after emergence, the adults begin to congregate around the root zone near the soil surface. Continued feeding and copulation occur during this period. Feeding activity during this period produces callus tissue, under which the bright yellow eggs are deposited two or three at a time. Hatching of the larvae normally occurs during the second week in July. *Baris strenua* larvae are not very mobile. Most of the feeding (consisting of circular tunnels) and development to fourth instar takes place in the same area where hatching occurs. At about the time that the fourth larval stage is reached in late August to early September, the plant becomes significantly dehydrated and encapsulation of the larvae within a "soil cocoon" begins. This "larval cocoon" overwinters among the remaining roots in the soil. Overwintering larvae have been recovered from a depth of 15 inches (38 cm) in North Dakota.

Damage: The sunflower root weevil adult, like the other two stem weevils, causes negligible mechanical injury to the foliage of the sunflower plant. The destruction of root tissue by the larvae of the sunflower root weevil causes the plants to wilt and lodge if the infestation is severe. The damage to fields attacked by the weevil tends to be localized.

Scouting Method: A scouting method has not been developed because damage caused by this pest has been minor.

Economic Threshold: None established.

Management: Insecticide use has not been warranted for the control of the sunflower root weevil.

Thistle Caterpillar (Painted Lady)

Species: *Vanessa cardui* (Linnaeus)

Description: The body of the adult is about 1 inch (25 mm) long with a wingspread of about 2 inches (50 mm) (Figure 51). The upper wing surfaces are brown with red and orange mottling and white and black spots. The undersides of the wings are marble gray, buff and white. Each hind wing possesses a row of four distinct and obscure eyespots. Eggs are small, spherical and white. The larvae are brown to black and spiny, with a pale yellow stripe on each side (Figure 52). When mature, the larvae are 1.25 to 1.5 inches (32 to 38 mm) long. The chrysalis, or pupa, is molten gold and about 1 inch (25 mm) long.

Figure 51. Adult - Painted lady butterfly *Vanessa cardui.* (Extension Entomology)

Figure 52. Larva - Painted lady butterfly *Vanessa cardui.* (Extension Entomology)

Life Cycle: The painted lady butterfly is indigenous to the southern U.S. and migrates annually to the northern U.S. and Canada. The painted lady breeds in the north-central states and Canada, migrates south for the winter and returns to the northern areas in early June. Eggs are laid on Canada thistle, wild and cultivated sunflower, and many other host plants. Hatching occurs in about one week. Larvae feed on sunflower until they reach maturity in late June or early July. Chrysalids are formed and hang from the leaves of the plant. Butterflies will emerge in about 10 days from the chrysalid and a second generation begins.

Damage: The caterpillars (larvae) feed on the leaves and, when numerous, may defoliate infested plants. The larvae produce a loose silk webbing that covers them during their feeding activity. Black fecal pellets produced by the larvae often are found in proximity to the webbing.

The effect of defoliation by the larvae on the yield of sunflower is similar to that described for defoliation by sunflower beetle larvae.

Scouting Method: Sampling sites should be at least 75 to 100 feet (23 to 31 m) from the field margins when collecting data to determine whether an entire field should be treated. Infestations frequently will be concentrated in areas of a field where Canada thistle plants are abundant. Plants should be examined carefully for the presence of eggs and/or larvae.

The field should be monitored by using the X pattern, counting 20 plants per sampling site for a total of 100 plants to determine percent defoliation (Figure 35).

Economic Threshold: The threshold is 25 percent defoliation, provided that most of the larvae are still less than 1.25 inch (32 mm) long. If the majority of the larvae are 1.25 to 1.5 inches (32 to 38 mm) long, most of the feeding damage already will have occurred and treatment is not advised.

Management: Insecticide use generally has not been warranted for control of larvae of the painted lady. However, instances of high localized infestations have occurred within certain fields where spot treating may be necessary. Disease outbreaks, indicated by dying larvae present on leaves, often occur when large populations are present.

Sunflower Midge

Species: *Contarinia schulzi* Gagne'

Description: The tan body of the adult sunflower midge is about 0.07 inch (1.69 mm) long, with a wingspan of about 0.19 inch (4 mm) (Figure 53). The wings are transparent with no markings except the veins. The larvae attain a length of nearly 0.09 inch (2.42 mm) at maturity and they are cream to yellowish orange when fully grown (Figure 54). They are tapered at the front and rear, with no legs or apparent head capsule.

Life Cycle: The sunflower midge overwinters in the soil as a cocooned larva and pupates during June and July in North Dakota and Minnesota. Typically, the initial peak of first-generation adult emergence occurs in early to mid-July. A second peak occurs about seven to 10 days later. They prefer to lay eggs on sunflower buds with a diameter greater than 1 inch (25 mm). Larvae initially feed on margins of the head between the bracts surrounding the heads. Larvae migrate to the base of the developing seeds and to the center of the head as it develops. Presence of the larvae frequently is determined by necrotic areas at the base of or between the bracts. As midge larvae mature, they move to the surface of the head and drop to the ground. A partial, second generation occurs in August. Second-generation adults oviposit among the seeds.

Damage: Damage to sunflower is a result of first-generation larval feeding in developing heads. When populations are low, damage is restricted to the base of the bracts of the head and causes slight localized necrosis but little if any economic loss. When many larvae are present, feeding prevents ray petal formation and distorts the growth of the developing sunflower head. If the abnormal growth is severe, the back of the head overgrows the front and little or no seed production occurs (Figure 55). If an infestation occurs in the early bud stage, the bud may be killed.

Often midge damage is restricted to field margins or small portions of fields and economic losses are minimal. However, when populations are very heavy, damage will extend throughout the field and substantial economic losses occur. The extent of damage from second generation larvae is unknown.

Scouting Method: None established.

Economic Threshold: None established.

Management: Because effective chemical and other controls are not available, sunflower midge management relies on cultural practices done prior to planting. If a midge infestation is anticipated, new fields should be established away from fields damaged the previous season. To minimize the risk of all plantings being at their most susceptible stage at midge emergence, several planting dates should be used. If available, growers should consider using a tolerant hybrid.

Figure 53. Adult - Sunflower midge *Contarinia schulzi.* (Extension Entomology)

Figure 54. Larva - Sunflower midge *Contarinia schulzi.* (Extension Entomology)

Figure 55. Severe damage to receptacle and seed development occurs when midge infection is high. (Extension Entomology)

Red Sunflower Seed Weevil

Species: *Smicronyx fulvus* LeConte

Description: Red sunflower seed weevil adults are 0.1 to 0.12 inch (2.5 to 3.06 mm) long and reddish brown (Figure 56). The larvae are small, 0.10 inch (2.54 mm) long, cream-colored, legless and C-shaped (Figure 57).

Life Cycle: Red sunflower seed weevil emergence occurs in late June and early July. The newly emerged adults feed on sunflower buds or floral tissues. Once pollen is available, the adults include it in their diet. Females need to feed on sunflower pollen for several days prior to egg deposition. Eggs are deposited within young developing seeds. Normally a single egg is placed in each seed, although 8 percent to 12 percent of the seeds may contain several eggs.

Figure 56. Adult - Red sunflower seed weevil *Smicronyx fulvus.* (Extension Entomology)

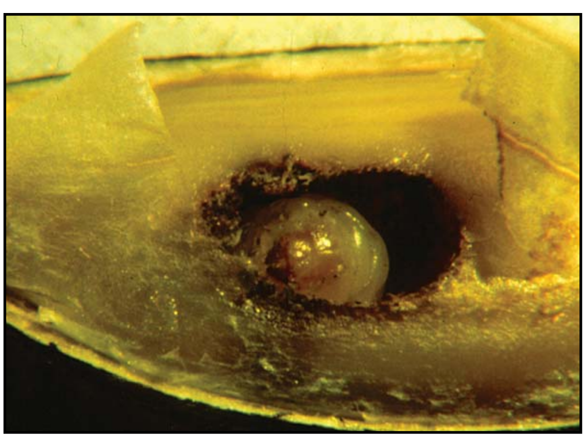


Figure 57. Larva - Red sunflower seed weevil *Smicronyx fulvus.* (Extension Entomology)

The small, white eggs hatch in approximately one week. The larvae consume a portion of the kernel, and this feeding causes economic damage. After completion of larval development, the majority of the larvae drop to the ground. Larval drop occurs from mid-August through September. The larvae overwinter in the soil at a depth of about 6 inches (15 cm). Larvae pupate in late June of the following year and the pupal period lasts about one week. A single generation per year is produced in North Dakota.

Damage: While the kernel of some seeds may be totally eaten, most seeds are only partially consumed. The separation of undamaged from weevil-damaged seed is difficult.

Most larvae drop from the head to the soil after completing their development, but a small percentage may remain in the seed and are present at harvest. Growers who encounter a seed weevil infestation may want to delay harvest to allow most of the weevil larvae to exit the seeds to avoid having larvae in the harvest bin.

Larvae that are still in the seed at bin filling time are done feeding and can cause heating and moisture problems. Larvae harvested with the seed cannot be controlled until they have completed development and have emerged from the infested seeds. Once emerged, they are susceptible to fumigation. But fumigation normally is not recommended. However, the most advantageous time to initiate control of seed weevil is in the field when the adult weevils are active, but prior to egg deposition.

Economic Thresholds: The economic threshold varies with differences in plant population, the cost of insecticide application and the market price of sunflower. The procedure for calculating the economic threshold is discussed in the NDSU Extension sunflower seed weevil publication (E-817). Currently, an infestation level of four to seven seed weevil adults per head in oil sunflower or one seed weevil per head in confectionery sunflower is the average economic threshold.

The optimal period for insecticide treatment is when at least three out of 10 plants in the field are at early bloom (R-5.1 to R-5.4, Figure 4) and the economic threshold has been reached. If spray application is delayed past when more than four out of 10 plants are at stage R-5.4, many eggs already will be laid in the developing seeds and those eggs and larvae cannot be controlled. If fields are sprayed too early, reinfestation may occur in areas with a high weevil population. After spraying, fields should be rechecked periodically to determine if reinfestation is reaching the economic threshold. Continue rechecking until most of the heads in the field have reached the R-5.7 stage. At that stage, most eggs already will have been laid and most seeds will be too mature to be suitable for further red seed weevil egg oviposition.

Scouting Method: Begin by taking samples from 12 plants, three plants from each of the four field sides. Sampling sites should be at least 75 feet (21 m) in from field borders, which often have an inordinately high number of weevils. The total number of weevils counted should be compared to the sequential sampling table in the most recent NDSU Extension sunflower seed weevil publication (E-817). According to the table, take one of three possible actions: Stop sampling, no action is needed; stop sampling and treat; or, take more samples because a decision cannot be reached. When populations are low or high, sequential sampling allows a quick decision with few samples. If populations are near the economic threshold, more precision is needed to making an accurate determination and more samples are required.

NOTE: To more precisely check individual sunflower heads for red sunflower seed weevils, the face of the heads should be sprayed with a commercial formulation of mosquito repellent containing diethyl toluamide (DEET). This will cause the weevils to move out from between the florets where they can be more accurately counted. Consult the most recent NDSU Extension sunflower seed weevil publication (E-817) for a table to convert the visual counts to the absolute number of weevils (both counted and uncounted).

Management: Several federally registered insecticides are available for control of sunflower seed weevils in the U.S. Early planting of sunflower reduces achene damage caused by the red sunflower seed weevil without causing a measurable reduction in oil content and achene weight.

Surrounding a sunflower field with a ring of early blooming sunflower effectively can trap immigrating red sunflower seed weevils into a small portion of the field, where they can be controlled efficiently. The trap cropping method given in publication E-817 is as effective and more cost efficient than standard insecticide treatment for control of red sunflower seed weevils.

Gray Sunflower Seed Weevil

Species: *Smicronyx sordidus* LeConte

Description: Adults of the gray sunflower seed weevil are slightly larger (0.14 inch long) than *S. fulvus* and gray (Figure 58). The larvae are small, 0.12 inch long (3.1 mm), cream-colored, legless and C-shaped (Figure 59).

Life Cycle: Gray sunflower seed weevil emergence occurs in late June and early July and reaches 50 percent emergence about 10 days before the red sunflower seed weevil. The newly emerged adults feed on floral buds. Oviposition occurs on flowers in the bud stage and before red sunflower seed weevil oviposition begins. Female gray sunflower seed weevils do not lay as many eggs as do females of the red sunflower seed weevil.

Figure 58. Adult - Gray sunflower seed weevil *Smicronyx sordidus.* (Extension Entomology)

Figure 59. Larva - Gray sunflower seed weevil *Smicronyx sordidus.* (Extension Entomology)

The larvae feed in a single achene, and infested achenes are enlarged and protrude above surrounding uninfested achenes. The majority of the larvae drops to the ground from mid-August through September and overwinters in the soil. Larvae pupate in late June and a single generation per year is produced in North Dakota.

Damage: Seeds infested by the gray seed weevil lack a kernel and, due to their light weight, the seeds may be lost during the harvesting process. Because of their low population levels and low fecundity, the gray sunflower seed weevil usually does not cause economic damage, especially in oil sunflower fields. In confection fields, however, populations of the gray sunflower seed weevil may be sufficiently high to warrant treatment at the late bud stage (R-3 to R-4).

As with the red sunflower seed weevil, larvae normally drop from the head to the soil after completing their development. Larvae that do not emerge will present the grower with the same problem as unemerged red sunflower seed weevil larvae.

Scouting Method: Normally, gray sunflower seed weevil populations are too low to cause economic damage. However, if an area has had a history of high populations, fields, especially confection fields, should be sampled beginning at bud stage R-2 (Figure 4). Sampling should be done as for the red sunflower seed weevil and continue until plants are blooming.

Economic Thresholds: None established.

Management: Several insecticides are federally registered for control of sunflower seed weevils in the U.S. If fields are to be treated with insecticides, they should be sprayed while the plants are still in early bud stage. By late bud stage, most oviposition already will have occurred.

Sunflower Moth

Species: *Homoeosoma electellum* (Hulst)

Description: The adult is a shiny gray to grayish tan moth about 0.38 inch (9 mm) long, with a wingspan of about 0.75 inch (19 mm) (Figure 60). The hind wings are devoid of markings; however, the forewings have a small, dark, discal dot near the center of each wing and two or three small, dark dots near the leading margin of each wing. When at rest, the wings are held tightly to the body, giving the moth a somewhat cigar-shaped appearance. The larva has alternate dark and light-colored longitudinal stripes on a light brown body (Figure 61). The larva is about 0.75 inch (19 mm) long at maturity.

Figure 60. Adult - Sunflower moth *Homoeosoma electellum.* (Extension Entomology)

Figure 61. Larva - Sunflower moth *Homoeosoma electellum.* (Extension Entomology)

Life Cycle: Sunflower moth migrations from the south-central U.S. normally appear in North Dakota in early to mid-July. The moths are highly attracted to sunflower that is beginning to bloom. Individual female moths will deposit up to 30 eggs per day on the surface of open sunflower heads. The eggs hatch within 48 to 72 hours and the newly emerged larvae feed on pollen and florets. The larvae begin tunneling into seeds upon reaching the third instar (larval growth stage). This tunneling continues throughout the remainder of larval development. Larval development from hatching to full maturity takes about 15 to 19 days.

Damage: The young larvae of the sunflower moth feed primarily on florets and pollen. Older larvae tunnel through immature seeds and other parts of the head. A single larva may feed on three to 12 seeds and forms tunnels in both the seeds and head tissue. Larvae spin silken threads, which bind with dying florets and frass to give the head a trashy appearance. Severe larval infestations can cause 30 percent to 60 percent loss, and in some cases, the entire head can be destroyed. Sunflower infested with sunflower moth has an increased incidence or risk of Rhizopus head rot.

Scouting Method: Sampling sites should be at least 75 to 100 feet (23 to 31 m) from field margins. The X pattern should be used in monitoring a field, counting moths on 20 heads per sampling site for a total of 100 heads. Scouting is most accurate in the early morning or late evening, when moths are active. Sex pheromone lures are available commercially for monitoring with traps to indicate their arrival and local populations. Insecticide applications should be considered when pheromone trap catches average four moths per trap per day from the R-3 through R-5 growth stages.

Economic Threshold: The economic threshold for sunflower moth is one to two adults per five plants at the onset of bloom or within seven days of the adult moth's first appearance. If using pheromone traps, consider the threshold mentioned in the Scouting Method section.

Management: A number of federally labeled insecticides are registered for control of the sunflower moth.

Banded Sunflower Moth

Species: *Cochylis hospes* Walsingham

Description: The adult has a dark band across the buff or yellowish-tan forewings (Figure 62). The wingspan is about 0.5 inch (13 mm). Early instar larvae are off-white; late instar larvae are pinkish to red with a brown head capsule (Figure 63). Larvae will be about 0.44 inch (11 mm) at maturity.

Life Cycle: The life cycle of the banded sunflower moth is similar to that of the sunflower moth, except that the adults emerge from local overwintering sites rather than migrating into North Dakota. Banded

Figure 62. Adult and eggs - Banded sunflower moth *Cochylis hospes.* (Extension Entomology)

Figure 63. Larva - Banded sunflower moth *Cochylis hospes.* (Extension Entomology)

sunflower moths begin to emerge from the soil about mid-July and are present in the field until mid-August. Adults tend to congregate in field margins on weeds or adjacent crops during the day and then move into the crop in the evening. Within a week after emergence, they begin to lay eggs on the outside of the bracts of the sunflower head. Eggs may be found through early August and hatch in five to eight days. Larvae develop through five instars and are present in sunflower heads from mid-July to mid-September. After feeding to maturity, larvae drop to the ground and spin cocoons in the soil to overwinter. Pupation takes place in late June or early July the following year. The pupal period lasts about 12 days.

Damage: The newly hatched larvae move from the bracts to the florets of the sunflower head, where they enter open florets to feed. When the eggs hatch, young larvae feed on bract tissue before moving into the head. A sunflower head is susceptible to infestation only during the flowering period. The larvae feed in the florets until the third instar. During later stages of larval development, the insect tunnels through the base of the floret into the seed. The larvae may consume part or all of the contents of the developing seed. The larvae usually enter near the top of the seed and leave by way of the same opening after the contents are eaten. Each larva may destroy several (five to seven) seeds. Small areas of silken webbing on mature sunflower heads indicate the presence of banded sunflower moth larvae within the head.

Adult Scouting Method and Economic Threshold: Sampling sites should be at least 75 to 100 feet from the field margins. In monitoring a field, use the X pattern (Figure 17), counting moths on 20 plants per sampling site to obtain the total number of moths per 100 plants. Sampling should be conducted in the late bud stage (R3), usually during mid-July. If treatment is warranted, it should be applied at the R5.1 sunflower plant growth stage (when 10% of head area has disk flowers that are flowering or completed flowering.)

During the day (late morning to early afternoon) the moths remain quiet, resting on upper or lower surfaces of the leaves of sunflower plants. When disturbed, they flutter from plant to plant. When sampling for moths during the day, the decision to treat or not is based on comparing the mean number of adult moths in the field to the EIL for moths. The EIL number is the number of moths per head that will, if not damaged, result in seed damage with a value equal to the cost of treatment. Use the following formula based on treatment costs, plant population and market price to determine the adult EIL for day sampling.

$$\frac{\textbf{EIL}}{\text{(moths per 100 plants)}} = \left[\left[\frac{\text{(Treatment Cost (\$)/Market Price)}}{\text{Plant Population}}\right] \text{x } 582.9\right] - 0.7$$

The constants in the formula simplify the calculation and include the amount of loss attributable to each banded sunflower moth larva produced per plant.

A sample calculation of the EIL based on moth sampling for the following conditions is given below.

Insecticide treatment cost = $8/acre
Market price = $0.09/lb.
Plant population = 20,000/acre

$$\textbf{EIL} = \left[\left[\frac{(\$8/\$0.09)}{20{,}000}\right] \text{x } 582.9\right] - 0.7$$

= 19 moths per 100 plants

For this set of variables, an infestation of about 1.9 moths per 100 plants will result in sufficient larvae to destroy seeds in the sunflower head equal to the $8 treatment cost per acre in a field of 20,000 plants per acre with a market value of 9 cents per pound. If the adult population has reached or exceeded this level, then the growner should consider the use of a chemical insecticide to prevent larval seed damage.

Egg Scouting Method and Economic Threshold: Banded sunflower moth eggs can be counted accurately using a low power magnifier. A head-mounted 3.5X magnifier is recommended. Egg counts should be made when most of the sunflower plants are at stage R-3. However, buds should be selected randomly to avoid bias. Sampling for banded sunflower moth egg populations in commercial fields should be conducted as follows:

1. Divide each side of the field to be surveyed into 1,312-foot (400 m) sections.
2. Sample the center of each 1,312-foot (400 m) section at 20 feet (6 m) into the field from the field margin.
3. Randomly select five buds at each sample site.
4. Randomly select six bracts from the outer whorl on each bud and count the banded moth eggs. Average the egg counts from the five buds.

Compare the average egg count to the EIL.

Economic Injury Level (EIL) is the number of eggs per six bracts.

$$\mathbf{EIL} = \frac{\mathbf{TC}}{\mathbf{V \times PP \times 0.00078}}$$

V = Market value per lb
PP = Plant population per acre
TC = Treatment cost

Example: TC = $8, V = $0.10, and PP = 16,000
The EIL is 6.4 eggs per six bracts.

Economic Distance (ED) is the distance into a field from a sample site on the field edge where an economically damaging population is expected to extend. ED gives you the capability to diagram the extent of the EIL within a field. Economic Distance:

$$ED = e^{\left[\frac{\frac{EIL}{(E)} - 1.29}{-.194}\right]}$$

E = Average six bract egg count at 20 feet (6 m)
*EIL based on eggs per six bracts

Economic Distance Example:

Field Size: 800 m by 800 m with average egg counts of 15 per six bracts per sample site.

The EIL is 6.4 eggs per six bracts.

The ED is 280 feet.

In this case, only 37 percent of the field would need treatment, resulting in a savings of 63 percent.

Management: Deep fall plowing of sunflower stubble in Manitoba has reduced moth emergence the following season by about 80 percent; however, this is not practical for areas practicing conservation tillage. Research in North Dakota has demonstrated that delaying planting of sunflower until late May or early June helps reduce infestation levels of the banded sunflower moth. Parasitic wasps attack both the eggs and larvae of the moth. Predators also consume eggs and larvae.

Since banded sunflower moths have a tendency to congregate around field margins, perimeter spraying has been used with some success. This will minimize insecticide treatment costs and impact on pollinators.

Lygus bugs

Species: Tarnished plant bug, *Lygus lineolaris* (Palisot de Beauvois) and other *Lygus* species

Description: The most common species occurring in sunflower fields is the tarnished plant bug. It attacks at least 385 different plant species and occurs in 39 U.S. states and five Canadian provinces. Adults (Figure 64) are small, cryptically colored insects with a distinctive yellow triangle or "V" on the wings and 0.2 inch (4 to 5 mm) in length. They vary in color from pale green to dark brown. The immature stages, or nymphs (Figure 65), are similar in appearance to the adults, but lack wings and are usually green in color. They often are confused with aphids, but lygus move much more rapidly.

Figure 64. Adult - Lygus bug (Tarnished plant bug) *Lygus lineolaris.* (Scott Bauer, http://www.ars.usda.gov/is/graphics/photos/insectsimages.new.htm)

Figure 65. Nymphs - Lygus bug *Lygus lineolaris.* (Scott Bauer, http://www.ars.usda.gov/is/graphics/photos/insectsimages.new.htm)

Life Cycle: Adults overwinter in plant debris along field margins and shelterbelts. Populations probably move to sunflower from alfalfa, canola or other crops when those plants either have senesced or been harvested. Sticky trap catches in North Dakota showed that lygus bugs were present throughout the reproductive growth stages of sunflower. These insects produce at least two generations per year in the northern Plains. The biology of other Lygus species is similar.

Damage: Oilseed sunflower are not believed to be at risk to damage from Lygus feeding at this time. The presence of scarring on confection or nonoilseed sunflower seeds, known as kernel brown spot (Figure 66), is caused by lygus bugs feeding on the developing seed. The quality issue is significant because processors discount the finished product with only 0.5 percent damage. The incidence of damage in 2006 ranged between 1 percent and 5 percent in some production areas of the northern Plains. Lygus feed preferentially on either the developing reproductive organs or on the apical meristematic and leaf primordial tissue, causing a necrosis around the feeding site due to the injection of enzymes. This tissue destruction causes the brown spot on the sunflower kernel, resulting in a bitter taste to the seeds. Greenhouse and field studies showed that 33 to 38 seeds were damaged per adult lygus bug, and that all reproductive growth stages (R-4 to R-5) were vulnerable to attack. Damage was reduced if heads were infested after flowering was completed (R-6 to R-7).

Figure 66. Kernel brown spot caused by Lygus bug. (Larry Charlet)

Scouting Method: A scouting method has not been developed for lygus bug in sunflower.

Economic Threshold: Approximately 36 seeds are damaged by each adult. Therefore, 0.5 percent damage on heads with 800 seeds would occur with feeding on only four seeds per head. Thus, populations of adult lygus at levels of one per nine heads could result in economic loss to the producer through the reduction of seed quality.

Management: Lygus can be treated at the same time confection sunflower is treated for other insects, such as the seed weevil and banded sunflower moth. Two treatments are recommended to sufficiently protect confection sunflower heads from insect feeding: one application at the onset of pollen shed, or approximately 10 percent bloom, followed by a second treatment seven days later. This program should control insects adequately on confection sunflower throughout flowering, minimizing the potential feeding damage.

Sunflower Headclipping Weevil

Species: *Haplorhynchites aeneus* (Boheman)

Description: The sunflower headclipping weevil adult is shiny black (Figure 67). The weevil is about 0.31 inch (8 mm) long from the tip of the snout to the rear of the abdomen. The area behind the head and thorax is large and "squared" in relation to the narrow and prolonged head and snout.

Headclipping weevil larvae are cream-colored, somewhat C-shaped and grublike and 0.16 to 0.24 inch (4 to 6 mm) long (Figure 68).

Life Cycle: Adults emerge in mid-July and are active for a two- to three-week period. The females feed on pollen and nectar of flowering heads. In preparation for egg laying, the female makes one nearly complete row of feeding punctures around the circumference of the stalk just below the head and then lays an egg in the head. The girdled head subsequently falls to the ground, where larval development and overwintering occur.

Damage: Head clipping by *H. aeneus* is the most apparent type of damage caused by this weevil and frequently occurs along field margins. The percent of "clipped heads" in a field is normally very low (1 percent to 3 percent). However, losses up to 25 percent have been reported in individual fields (Figure 69).

Scouting Method: The weevils' presence is determined using the X scouting pattern. If the adults are encountered only periodically throughout the sampling sites, controls should not be necessary.

Economic Threshold: None established.

Management: Insecticide use has not been warranted for control of the sunflower headclipping weevil.

Figure 67. Adult - Sunflower headclipping weevil *Haplorhynchites aeneus.* (Extension Entomology)

Figure 68. Larva- Sunflower headclipping weevil *Haplorhynchites aeneus.* (Extension Entomology)

Figure 69. Sunflower headclipping weevil damage. (Extension Entomology)

Diseases of Sunflower

(Carl Bradley, Sam Markell and Tom Gulya)

Sunflower *(Helianthus annuus)* is unique in that it is one of the few crop plants that are native to North America. The genus *Helianthus* comprises more than 60 annual and perennial species, with one to several species found in every state. Since wild sunflower is a native plant, a native population of diseases and insects that can attack cultivated sunflower also is present in most areas of the U.S. Sunflower is also unusual in that it is both a field crop, with two distinct subtypes (oil and confection), and is grown as a garden flower and for the cut-flower industry. At least 30 diseases, caused by various fungi, bacteria and viruses, have been identified on wild or cultivated sunflower, but fortunately, only a few are of economic significance as far as causing yield losses. When considering sunflowers as an ornamental plant, even small spots on the foliage are enough to reduce marketability, and thus proper disease identification is necessary to decide upon appropriate disease management. See Appendix 1 for a listing of all known sunflower diseases that occur in the world.

The most important diseases in the northern Great Plains are Sclerotinia wilt, Sclerotinia head rot and downy mildew. Rust, especially on confection sunflowers, and Phomopsis stem canker are important in some years, but are of less overall concern. Phoma black stem is almost universally prevalent, but is not thought to cause yield losses. Leaf diseases caused by *Alternaria, Septoria* and powdery mildew, head rots caused by *Botrytis* and *Erwinia,* and Verticillium leaf mottle are diseases that either are observed infrequently in the northern Great Plains or have not occurred with sufficient intensity to be considered serious.

The most important sunflower disease in both the central Great Plains (Kansas, Nebraska, Colorado, Texas) and California is Rhizopus head rot. Sclerotinia head rot and wilt, downy mildew and Phoma black stem are of sporadic importance. In the central Great Plains, rust can be severe on sunflower grown under center pivot irrigation, and Phomopsis stem canker has been of concern in years of plentiful rainfall. Under drought conditions, charcoal rot is also of concern in the central Great Plains. In California, rust, followed by various stalk rots, are the most prevalent diseases after Rhizopus head rot. For complete details on the incidence and severity of sunflower diseases, visit the National Sunflower Association Web site (www.sunflowernsa.com), where the proceedings of the annual "Sunflower Research Workshop" are posted.

The production of ornamental sunflowers in the U.S. is scattered across at least 41 states, and includes both field and greenhouse production. Greenhouse-grown sunflower is prone to *Pythium* and *Phytophthora* root rot and *Botrytis* blight, as well as the range of sunflower-specific pathogens. Field-grown ornamental sunflower, especially in the Midwest, is prone to the same pathogens that attack oilseed sunflower. Sclerotinia wilt, rust, powdery mildew, Rhizopus head rot, southern blight and root knot nematodes are cited as the major diseases. Since cosmetic appearance is so important on ornamental crops, even diseases considered as minor on an oilseed sunflower crop are of consequence to ornamental sunflower. Thus, obscure diseases, such as leaf smut, cocklebur rust and petal blight, have been cited as causing losses to ornamental sunflower in the U.S. and abroad.

Effective control measures for most sunflower diseases are:

- Planting resistant hybrids
- A minimum rotation of four years between successive sunflower crops
- Seed treatment for control of downy mildew and damping-off
- Tillage to bury crop residue that may harbor pathogens
- Foliar fungicides for rust and other foliar diseases

Many sunflower diseases are controlled by single dominant genes for resistance (e.g., downy mildew, Verticillium leaf mottle). Most sunflower hybrids in the U.S. have resistance to Verticillium leaf mottle, several races of downy mildew and several races of rust. Unfortunately, the rust and downy mildew pathogens continue to evolve and new races are found periodically. This requires commercial seed companies to add new genes to their hybrids so their hybrids can remain resistant to the ever-changing pathogens. Some other disease organisms, such as *Sclerotinia,* require multiple genes for resistance, which makes development of resistant hybrids much more difficult. Great strides have been made in making sunflower hybrids more tolerant of both Sclerotinia wilt (root rot) and Sclerotinia head rot. No current hybrids can be considered immune to either type of *Sclerotinia* infection, but then again, breeders have so far been unable to develop immune varieties for other Sclerotinia-susceptible crops. Disease reaction varies widely among hybrids, and growers are encouraged to consult seed companies and Extension or public research personnel for recommended disease-resistant varieties. Producers also should remember that disease response is highly influenced by environment. Disease evaluations made in only one location may not accurately predict a hybrid's performance in all areas.

Crop rotation helps reduce populations of many important sunflower pathogens in the soil. Most sunflower diseases are caused by pathogens specific to sunflower. *Sclerotinia,* however, attacks many crops, and susceptible crops (such as mustard, canola, crambe, soybean and dry edible bean) should be interspersed in rotation with corn and cereals, which are nonhosts of *Sclerotinia.* Rotation time away from sunflower is influenced by the occurrence and severity of diseases noted in the current year. Regular monitoring of fields and maintaining accurate records are also important in determining rotation practices. Rotation will have a minimal effect on foliar diseases since the pathogen spores may be carried by wind from distant fields. Currently, only two fungicides are employed for foliar disease control, with several others in the registration process. Consult state Extension publications for more details.

The arrangement of the sunflower diseases in the following section is based on time of appearance during the growing season and the plant part affected. Early season diseases (e.g., downy mildew and apical chlorosis) are covered first, followed by foliar diseases (including virus diseases), stalk and root infecting diseases (including nematodes) and finally, head rots and other diseases of mature plants.

For additional information and photos of sunflower diseases, visit the National Sunflower Association Web site (www.sunflowernsa.com) and the Web site of the USDA Sunflower Research Unit in Fargo, N.D. (www.ars.usda.gov/main/site_main.htm?modecode=54420520), as well as the heavily referenced chapter on sunflower diseases in "Sunflower Technology and Production" edited by A.A. Schneiter and published by the Agronomy Society of America as Monograph No. 35. For current information on the disease resistance of commercial hybrids, please consult NDSU publication A652, "Hybrid Sunflower Performance Testing," available in hard copy or on the Web at www.ext.nodak.edu/extpubs/plantsci/rowcrops/a652.pdf.

I. Early Season Diseases

Downy Mildew

Description: Downy mildew has been observed on cultivated and wild sunflower throughout the U.S. and was quite common before the advent of resistant hybrids and the use of fungicides as seed treatments. It is most serious in areas with flat topography or heavy, clay soils that foster waterlogged conditions conducive for disease development.

Typical systemic symptoms in seedlings include dwarfing and yellowing (chlorosis) of the leaves (Figure 70) and the appearance of white, cottony masses (fungal mycelium and spores) on the lower and sometimes upper leaf surface during periods of high humidity or dew (Figure 71). Most infected seedlings are killed, but those that survive will produce stunted plants with erect, horizontal heads with little, if any, seed (Figure 72). When seedlings are infected several weeks after emergence, or a fungicide seed treatment inhibits rather than prevents infection, the plants usually start showing symptoms at the four-, six- or eight-leaf stage. This situation is referred to as "delayed systemic infection." These plants are characterized by some degree of stunting, with typical downy mildew leaf symptoms starting at some level in the plant (with lower leaves appearing normal). If susceptible plants are exposed to the mildew pathogen after the seedling stage, they also may develop a thickened, clublike root and become stunted, but may not show foliar symptoms. All infected plants serve to perpetuate the pathogen in the soil and are more prone to drought stress and lodging.

Sunflower plants also display localized foliar lesions due to airborne downy mildew spores. The infected spots are generally small, angular lesions (delimited by veinlets) with white sporulation on the underside of the lesion. These local lesions may coalesce into larger lesions, but they rarely result in a systemic infection, and thus have minimal impact upon yield.

Dwarfing and distortion of leaves also are symptoms typical of herbicide drift damage, especially from 2,4-D and related phenoxy compounds, and may be confused with downy mildew symptoms (Figure 73). Herbicide damage, however, never will exhibit the white appearance (fungal mycelium and spores) on the underside of the leaves nor the chlorosis typical of downy mildew.

Figure 70. Dwarfing and discoloration of sunflower resulting from infection by downy mildew. (D.E. Zimmer)

Figure 71. Lower surface leaves on downy mildew infected plants frequently exhibit a white cottony growth of fungus. (D.E. Zimmer)

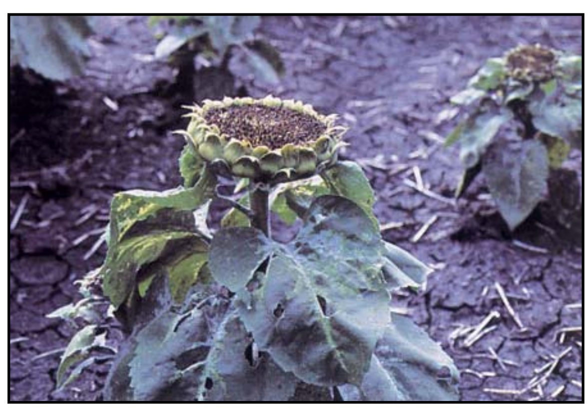


Figure 72. Plants infected with downy mildew seldom produce heads; when they do, the heads do not nod but remain erect and produce little or no seed. (T. Gulya)

Disease Cycle: Downy mildew is caused by the obligate fungus *Plasmopara halstedii,* which is soil-borne, wind-borne and seed-borne. Sunflower plants are susceptible to systemic infection before the seedling roots exceed 2 inches in length. This short period may range up to a maximum of two to three weeks, depending on soil temperature and moisture. Cool, water-saturated soil during this period greatly favors infection. The fungus may persist in the soil for five to 10 years as long-lived oospores. While this downy mildew fungus does not infect any crops other than sunflower and Jerusalem artichoke, weeds in the Compositae family, such as marsh elder, are susceptible, and thus may serve as reservoirs for the fungus.

Sunflower planted on land with no previous sunflower history occasionally has shown downy mildew infection. There are three principle ways downy mildew may occur in fields with no previous history of sunflower. Windblown and soil-borne spores account for the majority of such infections. Spores of the fungus occurring on volunteer sunflower or wild annual sunflower, even a few miles distant, may be blown to newly planted fields and result in substantial infection under favorable conditions of cool, water-logged soils. Spores also may adhere to soil particles and move to neighboring fields during dust storms. Water running through an infested field also may carry mildew spores into a previously disease-free field.

Modern seed production practices, coupled with stringent inspection of certified seed, virtually eliminate the possibility of introducing downy mildew into a "clean" field via infected seed. Seed from infected plants is generally either nonviable or so light in weight that it is separated during seed processing. A slight possibility remains that viable seed may be produced on infected plants. These seeds may produce healthy plants, systemically infected seedlings or plants with latent infection in which the fungus is localized in the roots and does not produce symptoms on the leaves. These latent infections, however, will help perpetuate the disease in the field.

Figure 73. Damage to sunflower from 2,4-D or growth regulator type herbicides may be mistaken for downy mildew symptom. (D.E. Zimmer)

Damage: Severely infected plants may die before or shortly after emergence or in the seedling stage. The few plants reaching maturity seldom produce viable seed. Heads on these plants typically face straight up, rendering them extremely vulnerable to bird feeding.

Yield losses from downy mildew can be substantial, depending on the percentage of infected plants and their distribution within the field. If infected plants are scattered randomly throughout a field, yield losses probably will not be observed unless infection exceeds 15 percent. Sunflower have excellent compensating ability when healthy plants are adjacent to infected plants. When the disease is in a localized area, such as a low spot in a field, and all plants are infected, the resultant yield loss is much greater.

Management: The continued discovery of new downy mildew races and the occurrence of mildew strains resistant to Apron XL (mefenoxam) and Allegiance (metalaxyl) seed treatment have altered management strategies. When these seed treatments were effective, seed companies had no need to develop resistant varieties. Now most seed companies are developing hybrids that use multirace immunity, which should be effective despite the development of new races. Not all hybrids in a company's lineup will have downy mildew resistance, however. At least two dozen races of the fungus have been identified in the U.S., but annually, usually two to three races make up the majority of races. Fortunately, lines released by the USDA are available that confer resistance to all known races.

With the appearance of downy mildew strains that are insensitive to metalaxyl and mefenoxam fungicide seed treatments (Apron XL, Allegiance), efforts are under way to find replacement seed treatments. The fungicide azoxystrobin (Dynasty) recently has been labeled for use on sunflower as a seed treatment for downy mildew suppression. As other effective chemicals are registered for use as sunflower seed treatments, the most effective management strategy would be to use two fungicides at the same time. A two-fungicide treatment will improve disease control and probably be less costly, in addition to delaying the development of fungicide resistance in downy mildew. Seed-applied fungicides will protect against root infection by all races, and thus will augment protection offered by resistant hybrids.

Seed applications, however, will not protect against foliar infection. Since the fungicides are water-soluble, they can be washed off shallow-planted seed with excessive rainfall, resulting in poor disease control. Selection of downy mildew-resistant hybrids is the most effective way of controlling downy mildew. Seed companies are actively incorporating genes that control all known races, and these hybrids will be immune, at least until a new race emerges. Additional management practices that minimize downy mildew problems include extended crop rotations, eradication of volunteer sunflower, avoiding poorly drained fields or those with excessive low areas and delaying planting until warm soil temperatures foster rapid seedling growth.

Apical Chlorosis

Description: Apical chlorosis is the one of two bacterial diseases of sunflower that is noticed with any regularity in the U.S. The causal organism is *Pseudomonas syringae* pv. *tagetis.* Apical chlorosis is striking and seldom goes unnoticed. The major symptom of the disease is the extreme bleaching or chlorosis of the upper leaves (Figure 74). Apical chlorosis may be distinguished from iron chlorosis or nitrogen deficiency by the complete lack of green pigment and the uniformity of the chlorosis. With mineral deficiencies, the veins characteristically remain green. In addition, the white leaves affected by apical chlorosis never will “regreen,” while those due to mineral deficiencies will.

Disease Cycle: Apical chlorosis occurs only during the vegetative growth stage when leaves are actively expanding. It is most severe in young seedlings during cold weather and in water-logged soils.

Damage: Plants affected by apical chlorosis usually will produce new green leaves in several weeks with little discernible effect other than striking white leaves in the middle of the plant. Thus, yield reductions due to apical chlorosis are minimal. However, if long periods of cold spring temperatures coincide with water-logged soils, seedlings affected by apical chlorosis may die. Yield losses still will be minimal as healthy neighboring plants should compensate for the dead seedlings.

Management: No hybrids are completely immune to apical chlorosis. The only control recommendation at present is to follow a four-year rotation to avoid increasing the population of the bacteria in the soil. Roguing (identifying and removing) infected plants in seed production fields will eliminate the disease and minimize the possibility of infected seed. This same bacterium will produce apical chlorosis on other Compositae weeds, such as thistles, ragweed, other *Helianthus* species (including cultivated Jerusalem artichoke), marigold and zinnia. Thus, controlling volunteer sunflowers and *Compositae* weeds, as potential disease reservoirs, will help minimize soil populations of this bacterium.

Figure 74. Apical chlorosis is characterized by an extreme bleaching or chlorosis of the upper leaves. (William K. Pfeifer)

II. Foliar Diseases

Rust

On most crops, rust refers to a single fungal species. On sunflower, the main fungus causing rust is *Puccinia helianthi,* which is worldwide in distribution and causes economic losses. In North America, four other *Puccinia* species are found on wild and cultivated sunflower: *P. canaliculata* (nutsedge rust), *P. enceliae, P. massalis* and *P. xanthii* (cocklebur rust), plus one rust from another genus, *Coleosporium helianthi.* The following discussion will deal mainly with *P. helianthi,* with minimal descriptions of the other rust fungi.

Description: Rust occurs in all sunflower production areas of the U.S. and Canada and also is widespread on wild sunflower. Most oilseed hybrids have had good resistance to the prevailing rust races, but changes in the rust population in the last decade have resulted in greater rust severity and occasionally in substantial losses in seed yield or seed quality. Confection hybrids are generally more susceptible to rust (and other diseases) than oilseed hybrids. At least 25 different rust races have been identified in the U.S., which makes breeding for rust resistance a challenge. Rust, incited by the fungus *Puccinia helianthi,* is characterized by cinnamon-colored spots or uredial pustules, which primarily occur on the leaves (Figure 75) but also on the stems, petioles, bracts and the back of the head under severe infestations. The initial appearance of rust is determined by adequate rainfall and warm temperatures, so the disease usually occurs in late summer in the northern Great Plains. The uredial pustules turn black with the advent of cool temperatures as the brown urediospores are replaced by black overwintering teliospores.

Disease Cycle: This rust completes its entire life cycle on sunflower and does not require an alternate host, as do some cereal rusts. *Puccinia helianthi* overwinters on plant debris as teliospores (thick walled, resting spores). These spores germinate in the spring to produce basidiospores that infect volunteer seedlings or wild sunflowers. This initial infection results in the formation of pycnia (generally on the underside of leaves), which, in turn, leads to aecial pustules, generally on the upper surfaces of leaves or cotyledons. The aecia are small (1/8 inch), orange cup-shaped pustules that may occur singly or in small clusters (Figure 76). The aeciospores are spread by wind to other sunflower plants, where they initiate the cinnamon-brown uredial pustules. The uredial stage is the repeating portion of the rust life cycle. Rust multiplies rapidly under favorable conditions of warm temperatures and either rain or dew. Thus, even in dry years, if night temperatures are low enough to promote dew formation on leaves, this minimal amount of leaf wetness will be sufficient to initiate rust infection. Excessive rates of nitrogen fertilization and abnormally high seeding rates result in excessive foliage, which increases humidity within the canopy and favors rust development.

Damage: Rust not only reduces yield, but also reduces oil, seed size, test weight and kernel-to-hull ratios. Late-planted fields of susceptible hybrids are generally more severely damaged by rust than earlier-planted fields. Irrigated fields also are apt to have more severe infection as the constantly wet leaves provide an ideal environment for the rust fungus to multiply.

Figure 75. Rust occurs most commonly on leaves and after flowering. The cinnamon-red pustules produce summer spores; the black pustules occur late fall and produce overwintering spores. (D.E. Zimmer)

Figure 76. Aecial cups of *Puccinia helianthi*. (T. Gulya)

Management: The most effective way to avoid loss from rust is by planting rust-resistant hybrids. With sunflowers grown under center pivot irrigation, night irrigation fosters more rust infection since the spores germinate best in the dark. Headline (pyraclostrobin) and Quadris (azoxystrobin) are registered for control of rust on sunflower, and additional fungicides may become registered. Refer to the most current edition of the "North Dakota Field Crop Fungicide Guide" (PP-622) available from the NDSU Extension Service to view fungicide products registered on sunflower. The injury threshold (i.e., disease severity above which fungicide spraying is warranted to minimize yield loss) developed for using tebuconazole is when the rust severity on the upper four leaves is **3 percent** or greater. High rust severity on lower leaves has less impact upon seed yields, as the upper leaves are the ones supplying most of the photosynthate for the developing seeds.

Sunflower rust, like cereal rusts, occurs as many different "physiological races," which constantly change. Thus, hybrids selected for rust resistance eventually become susceptible as rust races change. Seed companies continually are testing their hybrids in different locations to determine rust resistance against the various races from region to region. Rust evaluations made under conditions of natural infection or with artificial inoculation of specific races also are done by university research centers, and this information frequently is found in the NDSU publication "Hybrid Sunflower Performance Testing" (A652). A few other management practices, besides rust-resistant hybrids, that can minimize rust are available. Destruction of volunteer plants and wild annual sunflower occurring in the vicinity of commercial fields as early in the spring as possible will reduce sources of inoculum. High rates of nitrogen fertilizer and high plant populations both foster dense canopy development that in turn create ideal conditions for rust infection, and thus should be avoided if rust is of concern.

Other Rusts: As mentioned previously, four other *Puccinia* species and one *Coleosporium* species of rust can infect sunflower in parts of the U.S. None of them have yet to be reported to be of economic significance on cultivated sunflower, but they might be considered potential nuisance foliar pathogens on ornamental sunflowers. As sunflower production expands into new areas, especially in the south-central and southwestern U.S., the possibility of other *Puccinia* species attacking cultivated sunflower increases.

Puccinia xanthii, commonly known as cocklebur rust, is easy to distinguish from *P. helianthi* based on pustule size. This rust is microcyclic, with only telia and basidiospores, and does not exhibit the five spore stages of a full-cycle (macrocyclic) rust such as *P. helianthi.* On sunflower, the telial pustules are few in number, range from 1/4 to 3/8 inch in diameter, are distinctly puckered (convex) and bear a layer of dark brown spores only on the underside of leaves. As the teliospores germinate in place, the spore layer changes from brown to gray. As little as two to three hours of dew at temperatures of 68 to 77 F is sufficient for *P. xanthii* infection. Sunflower is minimally susceptible to this rust. The main host for this rust is cocklebur (*Xanthium* species), with some authors also listing ragweed *(Ambrosia)*. This rust has been seen only once on sunflower, and only in North Dakota.

Puccinia enceliae and *P. massalis* are two rusts that are recorded on wild *Helianthus* species in the southwestern U.S. and have been shown to infect cultivated sunflower in greenhouse tests. No reports of them being identified on or causing yield losses to cultivated sunflower are known. *Puccinia massalis* is reported only on Texas blueweed *(Helianthus ciliaris)* in the Rio Grande Valley of Texas and New Mexico. Uredial pustules are indistinguishable from those of *P. helianthi.* Positive identification of *P. massalis* requires microscopic examination of teliospores for the placement of germ pores. *Puccinia enceliae* occurs on wild *Helianthus* and dessert shrubs in the genera *Viguiera* (goldeneye and resin bush), *Encelia* (brittlebush) and *Tithonia* (Mexican sunflower) in the desert regions of western U.S. and northern Mexico. Uredial and telial pustules of *P. enceliae* on sunflower are similar in appearance to those of *P. helianthi.* Positive identification of *P. enceliae* requires microscopic examination of teliospores. Neither of these two *Puccinia* species has been observed on sunflower in the northern Great Plains.

Puccinia canaliculata is a full-cycle, heteroecious rust that has its aecial stage on sunflower and cocklebur *(Xanthium strumarium),* and its uredial and telial stage on sedges of the genus *Cyperus.* This rust had been considered as a possible mycoherbicide for control of the noxious weed yellow nutsedge. On sunflower, the aecial pustules look very similar to the telial pustules of *P. xanthii* in shape, with the main difference that the *P. canaliculata* aecia on the underside of the leaf are orange, as compared with the dark brown of the telia of *P. xanthii.* This rust has been observed in Kansas in a sunflower field infested with nutsedge. Since the rust requires both hosts to complete its life cycle, elimination of the nutsedge effectively will limit this rust infection of sunflower.

C*oleosporium* species are commonly referred to as pine needle rusts and are heteroecious rusts (requiring two different hosts to complete their life cycle). *Coleosporium helianthi* has its uredial and telial stages on sunflower, and the remainder of its life cycle on two- and three-needle pines, such as Jack pine, Virginia pine and loblolly pine. The rust is of minimal economic importance in pine plantations and never has been observed on cultivated sunflower. On Jerusalem artichoke (and other perennial *Helianthus* species), *C. helianthi* infections can be quite severe and potentially cause yield losses. Preliminary greenhouse tests have shown that cultivated sunflower is susceptible, with little differences between commercial hybrids. The most effective way to prevent *C. helianthi* infection on sunflower is to avoid planting near shelter belts or areas with two-needle pines.

Albugo or "White" Rust

Description: White rust is one of the rarest sunflower diseases in North America, but is considered a potentially serious disease in countries such as South Africa and Argentina. Despite the word "rust" in the common name, this disease is caused by a pathogen more closely related to downy mildew. White rust has been recorded on sunflower in North America only in western Kansas, eastern Colorado and adjacent Nebraska during the late 1990s and seldom is seen in this area. In North Dakota, it has been recorded on ragweed *(Ambrosia* spp.*),* various sage and sagebrush *(Artemisia* spp.*)* and goatsbeard *(Tragopogon)*. White rust has not been recorded on either wild sunflower or cultivated sunflower in the northern Great Plains or in Canada on sunflower.

Foliar lesions, consisting of raised, chlorotic pustules up to 3/8 inch in diameter, are the most commonly seen symptom on sunflower in the U.S. (Figure 77). A dull, white layer of spores forms in these pustules on the underside of the leaf, which could be mistaken for local lesions caused by downy mildew. If the Albugo pustules are numerous enough, they will merge as they enlarge, and entire areas of the leaf will turn necrotic as secondary fungi colonize the pustules.

One striking feature often seen with *Albugo* is that a single horizontal "layer" of leaves in the crop canopy usually is affected, with a sharp demarcation of healthy leaves above and below the affected leaves. This delimited layer of infected leaves suggests that environmental conditions and *Albugo* spores were

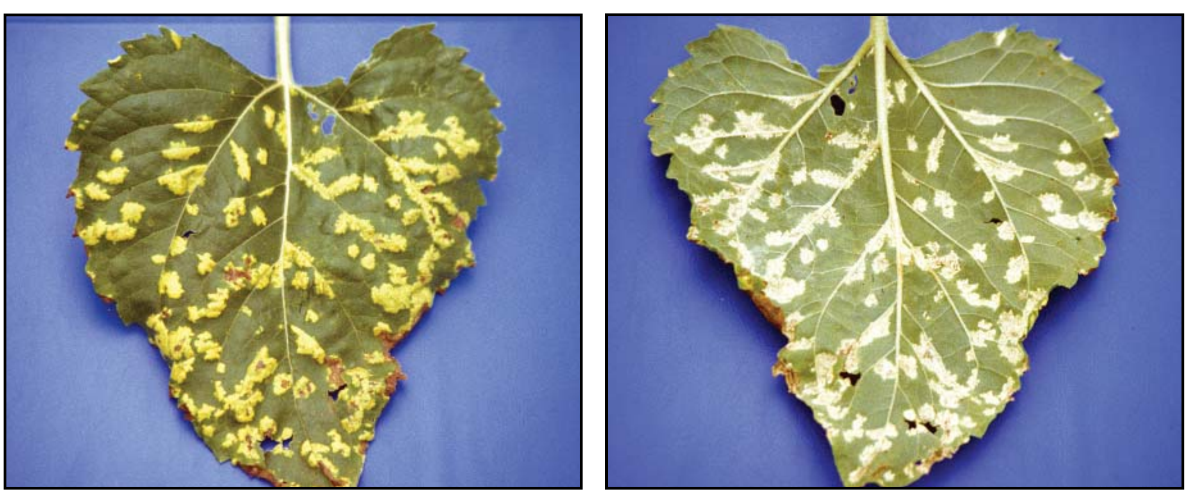


Figure 77. Albugo lesions on upper leaf surface (left) and lower leaf surface (right). (T. Gulya)

present for a very short time, thus only one layer of leaves shows symptoms. *Albugo* also can cause lesions on stems, petioles, bracts and the back of heads. The lesions on stems (Figure 78), petioles and the back of the heads are much different from those on leaves, and appear to be dark, bruiselike lesions. This appearance is due to the presence of black oopsores just beneath the epidermis. No white sporangia ever are seen in the stem or petiole lesions. Stem lesions often are colonized by other fungi and may lead to stalk rot and lodging by the secondary fungi. Petiole lesions may girdle the petiole and cause the affected leaf to wilt, thus causing considerable damage and yield loss.

Disease Cycle: The causal agent of white rust is the obligate fungus *Albugo tragopogonis,* which recently has been reclassified as *Pustula tragopogonis.* In addition to sunflower, this fungus infects cocklebur *(Xanthium),* groundsel *(Senecio),* marsh elder *(Iva),* ragweed *(Ambrosia)* and several other weedy Composites. The fungus appears to have host-specific races, however, so white rust occurring on one host genus may not infect other genera or cause only minimal infection. *Albugo* overwinters as oospores in infected plant debris. Rain splashes the oospores onto nearby seedlings, where they germinate to form motile zoospores that enter through stomates. The pustules that develop contain masses of dry, white asexual sporangia. The pustules rupture to release sporangia that are windblown to other plants to continue leaf infection. Sporangia also can initiate infection on stems, petioles and bracts. Optimal conditions for *Albugo* infection are cool nights (50 to 60 F) with rain or dew, but lesion development is favored by warm days (70 to 80 F).

Damage: Foliar infection by *Albugo* seldom causes yield loss, although the symptoms are quite noticeable. Lesions on stems and petioles, which fortunately are seen seldom in the U.S., are much more serious. Petiole lesions lead to defoliation, with significant yield losses, and stem lesions may become colonized by other fungi and result in lodging. *Albugo* infections on the head may result in seed infection, which would be of concern in seed production fields.

Management: Field trials have shown that sunflower plants can tolerate a high proportion of foliage infection by *Albugo* before yield losses are observed. Stem and petiole lesions caused by *Albugo* are more serious, as stem lesions can result in lodging and petiole lesions will result in defoliation. In countries where *Albugo* is serious, commercial seed companies have made the effort to develop resistant hybrids. In the U.S., no information is available regarding the reaction of hybrids to white rust. Evaluations of USDA breeding material have shown that resistance probably is controlled by several genes, each governing infection of leaves, stem, petioles and heads. Since *Albugo* is an Oomycete, like downy mildew, the same fungicides that control downy mildew have been effective against white rust. Thus, seed treatment with metalaxyl or mefenoxam will offer protection against both systemic infection and foliar infection for a limited time. Rotation is of limited use with *Albugo,* as the spores can be windblown from adjacent fields.

Figure 78. Albugo lesions on stems. (T. Gulya)

Alternaria Leaf and Stem Spot

Description: Alternaria leaf spot is a ubiquitous disease on senescing leaves and generally of little concern, but under warm, humid conditions it can be a serious defoliating disease. The Midwest has two main species of *Alternaria: A. helianthi* and *A. zinniae,* of which *A. helianthi* is the more prevalent and more serious. In addition, several other *Alternaria* species have been reported on sunflower, including *A. alternata, A. helianthicola, A. helianthinficiens* and *A. protenta. Alternaria helianthi* and *A. zinniae* both produce dark brown spots on leaves. These spots are irregular in size and shape with a very dark border and a gray center (Figure 79). The spots on young plants may have a yellow halo. Leaf lesions may coalesce, causing leaves to wither. Stem lesions begin as dark flecks that enlarge to form long, narrow lesions (Figure 80). These stem lesions often coalesce to form large blackened areas, resulting in stem breakage. Stem lesions are distributed randomly on the stem and are not associated with the point of attachment of the leaf petiole. Brown, sunken lesions also may form on the back of the head, especially following any mechanical damage such as that caused by hail or birds. The leaf and stem lesions caused by the various *Alternaria* species are similar and thus not diagnostic. Therefore, microscopic examination is required to distinguish which *Alternaria* species is present.

Disease Cycle: All *Alternaria* fungi overwinter on diseased stalks. They can be seed-borne at low levels, although seed is a relatively unimportant source of the inoculum under most conditions. Seedling blights caused by *Alternaria* may develop when sunflower plants emerge in rainy weather on *Alternaria*-infested soil. However, plants at the flowering to maturing stage are more susceptible than plants in the vegetative or budding stage. Safflower and cocklebur also can be alternate hosts of *A. helianthi.*

Disease development in *A. helianthi* is favored by 77 to 82 F temperatures and at least 12 hours of wet foliage. Extended wet periods of three to four days can cause serious losses as the spots enlarge.

Damage: The primary damage that all *Alternaria* species cause is the leaf blights that lead to defoliation which increases the potential for yield loss. In the northern Great Plains, the climate is usually not conducive for *Alternaria* epidemics, and *Alternaria* generally affects only the lower, senescing leaves. However, in warmer climates with plentiful rainfall, the potential for defoliation by *Alternaria* species and subsequent yield loss is much greater. In addition to the direct yield loss caused by foliar *Alternaria* infection, this fungus also has been noted to cause blemishes on the achenes. While this damage may be only superficial, if the achenes are on confection sunflowers destined for human consumption, the impact of "achene blemish" can be significant. This achene

Figure 79. Leaf lesions caused by *Alternaria hellanthi.* (B.D. Nelson)

Figure 80. Stem lesions caused by *Alternaria hellanthi.* (T. Gulya)

blemish, currently noted only on sunflower grown in Israel, looks very similar to "kernel black spot," which is caused by feeding by the tarnished plant bug *(Lygus),* with no involvement from *Alternaria.*

Management: *Alternaria* leaf blights are considered a major disease in subtropical sunflower growing areas, where yield losses may range from 15 percent to 90 percent, but are much less serious in temperate areas of the U.S. However, severe epidemics have been observed on sunflower in the eastern and southeastern portions of the U.S. Management practices to minimize *Alternaria* problems include crop rotation and burying of infested crop refuse to hasten decomposition. Consult university Extension publications, such as NDSU's PP-622, "Field Crop Fungicide Guide," for current recommendations of foliar fungicides registered for use on sunflower for *Alternaria* control. Seed treatments with metalaxyl or mefenoxam offer no control of *Alternaria* seedling blights.

Septoria Leaf Spot

Description: Septoria leaf spot develops first on the lower leaves and spreads to the upper leaves. The spots begin as water-soaked areas (greasy green in appearance). The spots become angular, with tan centers and brown margins (Figure 81). A narrow yellow halo often surrounds young spots. Mature leaf spots may contain tiny black specks, the fungal fruiting bodies (pycnidia), which are visible with a 5X to 10X hand lens. The presence of pycnidia is the best means of distinguishing leaf spots caused by *Septoria* from those caused by *Alternaria.*

Disease Cycle: Septoria leaf spot can be caused by two *Septoria* species, *S. helianthi.* and *S. helianthina,* of which the former is the major species in the U.S. *Septoria* can be seed-borne and also can survive on infected sunflower crop refuse. *Septoria* leaf spot may appear anytime during the growing season and is favored by moderately high temperatures and abundant rainfall. As such, the disease potentially is more severe in southern growing areas, compared with the northern Great Plains.

Damage: In the temperate climate of the Midwest, Septoria leaf spot usually causes little damage. Severe *Septoria* infection may cause some defoliation, but if this affects only the lower leaves on mature plants, the impact upon yield will be minimal.

Management: Crop rotation, incorporation of sunflower residue and clean seed are the best means of managing *Septoria* leaf spots. Although resistance to *Septoria* has been identified in breeding material, the infrequent occurrence of Septoria has not warranted the development of resistant hybrids.

Figure 81.Septoria leaf spot. Note small black pycnidia in lesions. (T. Gulya)

Powdery Mildew

Description: Powdery mildew, caused by the fungus *Erysiphe cichoracearum,* can be found in most fields after full bloom. The symptoms are distinctive and easy to recognize: a dull white to gray coating of the leaves, starting as individual circular spots and eventually merging to cover the entire leaf (Figure 82). This coating is the scant mycelial growth of the fungus on the leaf surface. Severely infected areas senesce prematurely and dry up. Normally the lower leaves are more heavily infected than the upper leaves. In other countries, two other powdery mildew fungi have been documented on sunflower: *Sphaerothecia fuliginea* and *Leveillula taurica.* These both exist in the U.S., but to date have not been documented on sunflower.

Disease Cycle: Powdery mildew seldom is seen until late in the growing season, as senescing leaves are most susceptible to infection. While leaves are the most common plant part affected, powdery mildew also will form on bracts and the backs of heads. The powdery coating seen is a combination of scant mycelia and spores of the asexual stage, which is referred to as *Oidium.* As the season progresses, the fungus forms small (pinhead-sized) black cleistothecia, the sexual fruiting bodies.

Damage: Powdery mildew generally occurs late enough in the season that control measures are not needed. Sunflower cultivars differ widely in reaction to powdery mildew. On ornamental sunflower, especially those grown in the greenhouse, powdery mildew is common. Although the main impact of the disease is cosmetic, this alone can cause economic losses.

Management: Powdery mildew is seldom a problem on cultivated sunflower in the Midwest, but may be of concern in more humid areas and on the southern Plains states. On ornamental sunflowers, powdery mildew can be minimized by adequate air movement, allowing the leaves to dry, and by the use of registered fungicide sprays specific for powdery mildew.

Diseases Caused by Viruses and Phytoplasmas

Description: Several viruses have been reported on sunflower from other countries and the warmer regions of the U.S. (Florida), but no reports of viruses occurring on sunflower in the northern Great Plains have been confirmed. Wild sunflower is a host of *Tobacco ring spot virus* in the Rio Grande Valley, and *Cucumber mosaic virus* has been reported on sunflower in Maryland. Viruses reported on sunflower outside the U.S. include *Tobacco streak virus, Tomato big bud virus, Sunflower rugose mosaic virus,* and *Tomato spotted wilt virus.* Confirmation/identification of a virus as the causal agent is based on observation of the viral particles using an electron microscope, detailed chemical analysis of the viral components or serological identification.

The only well-documented virus found on sunflower in the U.S. is *Sunflower mosaic virus (SuMV),* currently found only in southern Texas on both cultivated sunflower and wild *Helianthus* species. Symptoms of SuMV are a mottled pattern of light green and normal green areas on the leaf, referred to as mosaic (Figure 83). Affected plants may die in the seedling stage or live to maturity, with all leaves affected.

Aster yellows is a disease at first believed to be caused by a virus but which has since been identified as a phytoplasma. Phytoplasmas are living cells, in contrast to viruses, and are intermediate in size between viruses and bacteria. Symptoms on sunflower include yellowing of leaves and/or the head, which often occurs in sectors. A characteristic symptom is a wedge-shaped portion of the head that remains green and bears small leaves rather than floral parts (Figure 84), a condition termed "phyllody."

Figure 82. Powdery mildew with fungus producing white, powdery spores on leaf surface. (Reu V. Hanson)

■ **Figure 83. Sunflower mosaic virus.** (T. Gulya)

■ **Figure 84. Aster yellows. Note wedged shaped portion of head which remains green.** (Donald Henne)

Disease Cycle: SuMV is spread primarily by aphids but is also seed-borne to a small extent. Seedlings less than a month old are the most susceptible, and mosaic symptoms appear within a week after aphid transmission. Affected leaves will retain the mosaic pattern for the life of the plant, but no stunting due to the virus is discernible.

The aster yellows phytoplasma is transmitted only by the aster leaf hopper *(Macrosteles quadrilineatus)* and occurs on a wide variety of plants. Symptoms generally appear at flowering, and affected heads will show the symptoms for the remainder of the summer.

Damage: SuMV, which currently is found only in Texas, can substantially reduce yield in individual plants. No fields have been observed with high incidence. This disease is also of quarantine significance, and many countries will not accept seed from fields with any level of SuMV. Aster yellows, which occurs throughout the Midwest, is sporadic in occurrence and is generally more of a novelty than of economic consequence.

Management: As both SuMV and aster yellows are spread by insects, the easiest means of minimizing both diseases is to control their insect vectors. Varietal differences to aster yellows have been noted. In contrast, no resistance to SuMV is available in commercial hybrids, although resistance has been found in wild *Helianthus* species from Texas.

Other Miscellaneous Foliar Diseases

The diseases mentioned above are the most likely leaf diseases to be encountered in the main sunflower-producing areas of the Midwest. As sunflower production expands into other areas, a possibility exists of other fungi causing leaf spots. Some of the fungi recorded to cause leaf spots on wild sunflower in other areas of the U.S. include *Ascochyta compositarum, Cercospora helianthi, C. pachypus, Colletotrichum helianthi, Entyloma compositarum* (leaf smut)*, Epicoccum neglectum, Itersonilla perplexans, Myrothecium roridum, Phialophora asteris* (Phialophora yellows), *Phyllosticta wisconsinensis* and *Sordaria fimicola.* Check out the “Sunflower Diseases” chapter by Gulya et al. in “Sunflower Technology and Production,” published by the Agronomy Society of America, for more details on these minor foliar pathogens.

III. Stalk- and Root-infecting Diseases

Sclerotinia Wilt

Description: Sclerotina wilt usually is observed first as plants start to flower. The first symptoms include a sudden wilting (Figure 85) with no other leaf symptoms, and a characteristic stalk lesion at the soil line. The length of time from the first sign of wilt to plant death may be as little as four to seven days. The stalk lesions that form at the soil line are tan to light-brown and eventually may girdle the stem (Figure 86). Under very wet soil conditions stalks and roots may be covered with white mycelia and hard black structures called sclerotia (Figure 87). Sclerotia are irregular-shaped structures which range in size and shape from spherical and 1/8 inch in diameter to cylindrical or Y-shaped and up to 1 inch in length. Sometime a series of dark "growth" rings produced by the daily extension of the fungus can be observed.

Disease Cycle: *Sclerotinia sclerotiorum* overwinters as sclerotia in the soil or in plant debris. When sunflower roots grow near sclerotia, the sclerotia are stimulated to germinate, and the resulting mycelium infects the lateral roots. The fungus grows along the root system to the tap root and up into the stem, and the plant wilts and dies. Contact between roots of adjacent plants within rows allows the fungus to spread from plant to plant. The fungus does not move between conventionally spaced rows. Sunflower is the only crop that *S. sclerotiorum* consistently infects through the roots. Other susceptible crops are infected mainly by spores on above-ground parts of the plant.

Sclerotia are formed in the decayed stem pith and on the roots as the plant dies. These sclerotia then are returned to the soil during tillage operations and serve as sources of inoculum for the next susceptible crop. Sclerotia can survive in the soil for five or more years, with a portion of them dying each year if they fail to infect a host. The higher the inoculum density (i.e., the number of sclerotia in the soil), the longer the period a

Figure 85. Sudden wilting is a characteristic symptom of Sclerotinia wilt. (B.D. Nelson)

Figure 86. Basal canker formed from *Sclerotinia* wilt infection. (B.D. Nelson)

Figure 87. Dense white mold may form on the surface of the basal canker. Hard black bodies called sclerotia also form on the outside and the inside of stems. (D.E. Zimmer)

field will remain infested. Soil moisture and temperature during the growing season are not critical factors affecting wilt incidence. Plant population, in the range from 15,000 to 30,000 plants per acre on 30- or 36-inch rows, is not a factor affecting disease incidence, although solid seeding should be avoided. Lodging of wilted plants, however, increases at high plant populations due to smaller stem diameter.

Damage: Historically, wilt is the most prevalent of the Sclerotinia diseases, with the disease found in one out of two fields in the Dakotas, and about 3 percent of the crop affected. Wilt occurs whenever sunflower is planted on *Sclerotinia*-infested soil and can cause severe yield loss. Infected plants die rapidly, and if this occurs before the seed is fully mature, the result is a loss of seed yield accompanied by lower test weight and lower oil content. Since plant death occurs late in the season, healthy adjacent plants have little opportunity to compensate for the loss of the *Sclerotinia*-infected plant. On the average, infected plants yield less than 50 percent of healthy plants. Equally important, however, is that Sclerotinia wilt leads to increased numbers of sclerotia in the soil, thus contaminating the field for all susceptible crops that would be in the rotation.

Management: Sclerotinia wilt is a difficult disease to manage for several reasons. First, the fungus has a very broad host range and basically is able to infect all broadleaf crops to some extent. Rotation to minimize *Sclerotinia* is most effective with cereal grains and corn. Second, since the sclerotia can persist in the soil for long periods of time, long rotations away from broadleaf crops are necessary to minimize sclerotial populations in the soil. This may not be feasible because repeated cropping of cereal grains will lead to a buildup of cereal diseases, especially Fusarium head blight. Sunflower breeders have strived to increase the level of resistance to Sclerotinia wilt and tremendous improvements have been made, but no immune hybrids are on the market yet. Based on several years of tests with artificial inoculations, commercial hybrids with extremely good levels of resistance are available. Information on hybrid ratings for Sclerotinia stalk rot resistance is found in NDSU publication A-652, "Hybrid Sunflower Performance Testing."

Lastly, chemical control is not an option since the sclerotia are low in number and scattered throughout the soil. The most effective chemicals would be soil fumigants used for nematocide control, and even if the chemicals were registered on sunflower, the cost would be prohibitive. Two management strategies hold promise to minimize, but not eliminate *Sclerotinia.* One is the use of biocontrol. Various fungi, termed mycoparasites because they feed upon other fungi, have been shown to attack *Sclerotinia.* One such fungus is *Coniothryium minitans,* which is found in the registered product called "Contans." If this product is applied to the soil (and preferably to the crop before disking), the mycoparasite *Coniothryium* will colonize the sclerotia and kill the sclerotia in several months rather than years. This will allow shortened rotations to be used, but replanting a *Sclerotinia*-infested field to a susceptible crop (e.g., dry bean, canola, sunflower) the following year still is inadvisable.

Another management option is tillage, and this is at the center of two schools of thought. One opinion is that deep tillage (inversion of the soil profile via moldboard plowing) will put the sclerotia deep into the soil in an anaerobic environment where they are more prone to bacterial degradation and are out of the plant root zone. If deep tillage is used, producers should practice reduced tillage in the following years to prevent bringing the buried sclerotia back to the surface. The second school of thought is to let the sclerotia remain on the soil surface, where they are subject both to weathering and attack by other fungi. No conclusive evidence is available to show that either no-till or deep tillage produces significantly less Sclerotinia wilt with sunflower, although research on soybeans strongly favors no-till to reduce sclerotia numbers.

Sclerotinia Middle Stalk Rot and Head Rot

Description: Middle stalk rot is the disease least often caused by *Sclerotinia,* and is first observed in the middle to upper portion of the stalk at or before flowering. Midstalk rot begins with infection of the leaf, and the fungus progresses internally through the petiole until it reaches the stem (Figure 88). Symptoms of *Sclerotinia* leaf infection are not unique enough to identify the fungus, but once the stem lesion forms, the symptoms are identical with the lesion formed by root infection. The characteristic pith decay and formation of sclerotia both within the stem and sometimes on the exterior are highly diagnostic. The stalk usually lodges at the lesion site and the leaves above the canker die. With time, the fungus completely disintegrates the stalk, and the affected area will have a shredded appearance, as only the vascular elements of the stem remain.

The first symptoms of head rot usually are the appearance of water-soaked spots or bleached areas on the back of the heads. The fungus can decay the entire head, with the seed layer falling away completely, leaving only a bleached, shredded skeleton interspersed with large sclerotia (Figure 89). These bleached, skeletonized heads, which resemble straw brooms, are very obvious in the field, even from a distance. During harvest, infected heads often shatter and any remaining seeds are lost. The large sclerotia in the heads may be 0.5 inch (12 mm) or greater in diameter and many are harvested along with the seed (Figure 90).

Disease Cycle: If soil is very wet for seven to 14 days, sclerotia in the upper several inches of soil can germinate to form small mushrooms called apothecia. These apothecia produce ascospores for a week or more. The ascospores can originate within the sunflower field or can be blown in from adjacent fields. Thus, sunflower fields with no history of Sclerotinia can became affected by head and middle stalk rot. Apothecia are not usually observed until after the crop canopy has completely covered the rows. Apothecia are more likely to form in crops with dense canopies, such as small grains, and the resultant spores can be blown a distance to nearby sunflower fields (Figure 91). Ascospores require both free water (dew or rain) and a food base such as dead or senescing plant tissue to germinate and infect. The fungus cannot penetrate unbroken

Figure 88. Middle stalk rot occurs via ascospore infection. (B.D. Nelson)

Figure 89. Head rot showing skeleton head filled with sclerotia. (B.D. Nelson)

Figure 90. Sunflower seed contaminated with sclerotia.

Figure 91. Apothecia in field of soybean plants. (B.D. Nelson)

tissue. Midstalk infection may result from either leaf infection or infection at the leaf axil. Head infection actually starts as ascospores colonize the dead florets and pollen on the face of the head. Thus, when lesions are seen on the back of the head, several weeks have elapsed since infection took place.

Damage: Middle stalk rot is the least often seen phase of Sclerotinia diseases. Head rot incidence fluctuates dramatically, dependent entirely upon weather conditions. In dry years, head rot is entirely absent, while in years and locations where rainfall is frequent during and after flowering, head rot may be present in nearly all fields to some degree. Currently the incidence of head rot and wilt in the Dakotas is about equal, with approximately 3 percent of the crop affected by each disease. Yield loss from head rot on an individual plant may range from minimal to total loss since the affected head may disintegrate and drop all of the seed on the ground prior to harvest. Intact but diseased heads will have light and fewer seeds, with lower oil concentration, and also will shatter during harvest. The sclerotia that form in the diseased stalks and heads are returned to the soil at harvest, thus contaminating the field for subsequent broadleaf crops.

Management: The same comments made about Sclerotinia wilt also apply to head rot management, with some exceptions. Since ascospores that cause head rot can be blown into a field, rotation will have less consistent impact upon head rot, even though it may reduce the levels of sclerotia in the field. Anything that can minimize the crop canopy will help modify the environment necessary for ascospore infection. Thus, lower plant populations will facilitate more air movement and hasten leaf drying. Moderate levels of nitrogen fertilization also will minimize excessive foliage, but this needs to be counterbalanced with adequate fertilization to optimize yields.

One of the most important tools for managing all Sclerotinia diseases is monitoring the incidence of Sclerotinia diseases on any preceding crop. If *Sclerotinia* is observed on a crop, the grower then knows that planting any susceptible crop in that field the next year is imprudent. The number of years necessary to rotate away from susceptible broadleaf crops (while the population of sclerotia declines) depends upon the initial *Sclerotinia* incidence. As a general rule of thumb, most researchers suggest that four years away from broadleaf crops should reduce the sclerotial population to below a threshold level. Since sunflower is the only crop prone to root infection, and root infection can happen even in dry years, sunflower obviously would be the worst crop choice to plant in a known infested field, with dry bean and canola following closely behind. As stated earlier, the best crops to break the *Sclerotinia* cycle are monocots (small grains, corn, sorghum).

Sunflower hybrids do exhibit different degrees of susceptibility to head rot, but no totally resistant hybrids are available. An extensive testing program is under way to evaluate commercial hybrids for head rot resistance. Several university research centers have established mist-irrigated plots, which when coupled with artificial inoculations with ascospores, have produced high levels of infection to accurately assess hybrid disease response. After the most resistant hybrids have been tested in multiple locations, this information will be published in the NDSU publication "Hybrid Sunflower Performance Testing" (A652), also available online at www.ag.ndsu.edu/pubs/plantsci/rowcrops/a652.pdf. No chemical is registered for control of head rot in the U.S. Even if a chemical were registered, it would have to be applied as a preventative because when symptoms become visible, the infection already took place two to three weeks earlier and the fungus has become well-established in the head.

For more information on sclerotinia, consult NDSU Extension Service publication "Sclerotinia Disease of Sunflower" (PP-840), also viewable on the Internet at www.ag.ndsu.edu/pubs/plantsci/rowcrops/pp840w.htm.

Stem Rots Caused by *Sclerotinia Minor* and *Sclerotium Rolfsii*

Description: Stem rots caused by *Sclerotinia minor* or *Sclerotium rolfsii* are very similar in appearance and will be covered together. *Sclerotinia minor* on sunflower is seen in California and the southern Great Plains, but has not been reported in the northern Great Plains. Stem rot caused by *Sclerotium rolfsii,* also called Southern blight, primarily is observed on sunflower in warm climates such as California, Florida and irrigated fields in the southern Great Plains. *Sclerotium rolfsii* has not been observed on sunflower in the northern Great Plains, but has been noted in nursery stock in Minnesota, suggesting it could become established in the northern latitudes. Both fungi have a very broad host range encompassing many broadleaf crops.

The symptoms of both *Sclerotinia minor* and *Sclerotium rolfsii* are outwardly very similar to the root infection and wilt caused by *Sclerotinia sclerotiorum.* Affected plants have a water-soaked lesion on the stem at the soil line that turns light brown. Under humid conditions, white mycelium also may be found on the lesion. In some instances, the lesion also may have a series of dark rings due to the diurnal growth pattern of the fungus. Plants infected with either fungus wilt and die suddenly, without any distinctive foliar symptoms, within a week of the onset of wilting. The major field sign to distinguish S. *sclerotiorum* from *S. minor* is the size and shape of the sclerotia. In *S. minor,* the sclerotia are always round and generally less than 1/12 inch (2mm) in diameter (Figure 92), and thus much smaller than sclerotia of *S. sclerotiorum.* Sclerotia of *Sclerotium rolfsii* are also round and the same size (< 1/12 inch) as those of *S. minor,* but *Sclerotium rolfsii* sclerotia are tan to light brown. Sclerotia of these two fungi can be found within pith tissue and on the surface of the tap root.

Disease Cycle: Both fungi overwinter in infected plant debris or can persist for several years as free sclerotia in the soil. The sclerotia germinate in response to root exudates to form mycelia that infect roots of adjacent sunflower plants. As the fungus moves up the root system and reaches the tap root and the stem, it produces toxins and oxalic acid that cause the plant to wilt. Both fungi are capable of infecting adjacent sunflower plants by root-to-root spread. Neither fungus produces any spores to initiate leaf or head infection, in contrast to *S. sclerotiorum.*

Damage: Both *Sclerotinia minor* and *Sclerotium rolfsii* are as potentially damaging as *S. sclerotiorum,* with the caveat that the first two species only cause a root rot and subsequent wilt. Plants infected near anthesis will suffer substantial seed losses, and if the affected plants lodge, further yield losses occur. Additionally, the sclerotia produced by these two fungi will contaminate the field and make subsequent crops of other host plants prone to infection.

Management: Crop rotation, elimination of infected residue and weed control will help reduce disease caused by either fungus. Since both fungi are highly aerobic, deep plowing (>12 inches), especially if complete inversion of the soil profile is possible, will remove most of the sclerotia from the root zone and place the sclerotia where they are most vulnerable to attack by soil bacteria. Differences in hybrid susceptibility have not been investigated in the U.S. because neither disease is present in the major sunflower production areas.

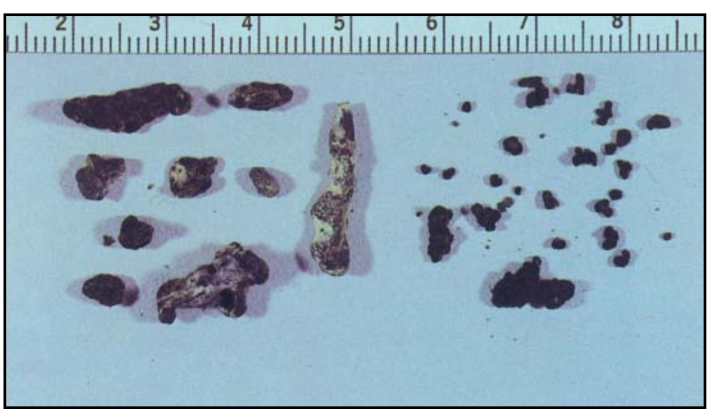


Figure 92. Sclerotia of *Sclerotinia sclerotiorum* (left) and *S. minor* (right) from sunflower stalks. Ruler at top in centimeters. (T. Gulya)

Charcoal Rot

Description: Charcoal rot is caused by *Macrophomina phaseolina,* a fungus that attacks about 400 plant species, including sunflower, dry bean, soybean, corn and sorghum. Charcoal rot is found throughout the Great Plains, but the disease is most common and severe in southern areas such as Texas, Kansas and Nebraska. Charcoal rot has been found on sunflower in western North Dakota and north-central South Dakota recently, and also on corn and soybean in both states. Charcoal rot generally appears after flowering but seedling blights have been reported. Symptoms on stalks appear as silver-gray lesions near the soil line (Figure 93), which eventually decay the stem and tap root, leaving a shredded appearance. Stems are hollow and rotted, and lodge easily. Plants show poor seed fill and undersized heads. Seed yield, test weight and oil concentration are reduced. Numerous tiny black fungus bodies, called microsclerotia, form on the outside of the stalk and in the pith. To the unaided eye, the microsclerotia look like pepper grains; with a 5X to 10X lens they are clearly distinguishable as black, spherical sclerotia. Another unique characteristic of charcoal rot is the compressing of pith tissue into horizontal layers, like a stack of separated coins (Figure 94). This is a diagnostic characteristic of the disease.

Disease Cycle: The primary source of inoculum is sclerotia in the soil, but *Macrophomina* also can be seed-borne. Upon stimulation by nearby root exudates, the sclerotia germinate to form mycelium that colonizes the roots. *Macrophomina* may colonize roots early in the season, but disease symptoms do not manifest themselves until anthesis. Once the root system is colonized, the fungus enters the stem and colonizes the vascular system, resulting in wilt and partial degradation of the pith. Disease development is favored by soil temperatures above 85 F. Moisture stress during the post-flowering period greatly favors disease development.

Damage: Post-flowering stresses due to high plant population or drought coupled with heavy applications of nitrogen fertilizer, hail or insect damage promote disease development and accentuate the impact of charcoal rot. Yield losses can be significant if disease incidence is high, as infected plants die before seed set is complete.

Management: Crop rotation, balanced fertilizer programs and practices to reduce moisture stress all help minimize the impact of charcoal rot. Certain hybrids offer some resistance, possibly through drought tolerance. Since the fungus also attacks corn, sorghum and soybeans, not growing sunflower and these crops in successive years on the same ground would be advisable if charcoal rot has been observed.

Figure 93. Silver grey discoloration of lower stem caused by charcoal rot compared with healthy green stalk (left). (T. Gulya)

Figure 94. Charcoal rot affected stalk split apart to reveal characteristic compression of pith into layers. (T. Gulya)

Texas Root Rot

Description: Texas root rot, or cotton root rot, is a soil-borne fungal disease found only in Texas, New Mexico, Arizona, southeastern California and northern Mexico. The causal agent, *Phymatotrichopsis omnivora* (synonym: *Phymatotrichum omnivorum*) has a very broad host range of more than 1,800 species of broadleaf herbaceous crops and weeds. On sunflower, as with most crops, the initial symptom is wilting followed quickly by death of affected plants. The disease in Texas develops in late spring and usually occurs in circular spots in the field, which enlarge after rain or irrigation. No diagnostic symptoms appear on leaves or stems, but white mycelial strands on roots, visible with a 5X to 10X hand lens, are characteristic of this fungus. Following rain or irrigation, the fungus may produce white mycelial mats up to 12 inches in diameter and up to ¾ inch thick on the soil surface.

Disease Cycle: The Texas root rot fungus survives for many years in the soil as sclerotia. These germinate to produce mycelial strands that can grow some distance in the soil until root contact is made. This ability also allows the fungus to spread from plant to plant in a row via overlapping root systems. The disease is most severe in moist, warm (80 F or higher at a 1-foot depth) soils that are high pH and high clay content. Sclerotia, at first white and turning tan to dark brown, are round and generally greater than 1/12 inch in diameter. Sclerotia may form in the soil away from plant roots. On roots, the sclerotia may form at irregular intervals, giving the appearance of a string of beads.

Damage: Like other root-infecting, stalk-rotting fungi, *Phymatotrichum* can cause considerable yield losses if plants are infected near bloom. Even if seed yield is not reduced, the fungal infection will lower oil content and result in lower test weight. In field trials in western Texas, disease incidences up to 60 percent were observed, which cut yields by at least half.

Management: The fungus persists in the soil for many years as sclerotia, which are the propagules that infect subsequent crops. Resistance has not been observed in sunflower. The best disease management is rotation with nonhosts, such as corn, sorghum, small grains or grass. Planting after cotton or alfalfa, especially where Texas root rot was observed, would be the worst-case scenario.

Phoma Black Stem

Description: Phoma black stem, caused by the soil-borne fungus *Phoma macdonaldii,* is characterized by large, jet black lesions on the stem, sometimes reaching 2 inches in length. In addition, the fungus produces lesions on the leaves, on the back of the head and at the base of the stalk. The typical stem lesions originate with leaf infections that progress down the petiole to the stalk. Under favorable conditions, the leaf wilts, the petiole turns uniformly black and the stem lesions expand to form a large, shiny, black patch with definite borders (Figure 95). Small circular fruiting bodies of the fungus are produced on the surface of the stem, but these are inconspicuous to the naked eye and require a hand lens to observe.

Disease Cycle: *Phoma* infection occurs throughout the growing season, although it usually is not noticed until the stem lesions become obvious later in the summer. The fungus overwinters in infected debris and conidia are spread by splashing rain. Insects such as *Apion* and *Cylindrocopturus* stem weevils also can carry *Phoma* spores both internally and externally. Adult weevils feeding on the leaves cause leaf lesions, while contaminated larvae spread the fungus as they tunnel throughout the stem. Disease transmission through infected seed is of minor importance.

Figure 95. Large black lesions associated with the point of attachment of the leaf to the stem is a characteristic symptom of Phoma black stem. (D.E. Zimmer)

Damage: *Phoma* black stem is the most widespread stalk disease noted on sunflower in the northern Great Plains, but yield losses attributable solely to *Phoma* generally are considered minimal. Infected plants may produce smaller heads with reduced seed yield and oil. *Phoma* stem lesions are generally superficial and do not result in pith damage or lodging. However, if stem weevil larva tunneling spreads *Phoma* spores in the pith, extensive pith degeneration can occur.

Management: No control measures are totally effective. A four-year rotation to other crops will minimize the concentration of *Phoma* within the soil. Control of stem weevils can help reduce transmission of the fungus. However, such control is not recommended solely for management of *Phoma.* No hybrids have been identified as being immune to the disease, but some hybrids are more tolerant than others.

Phomopsis Stem Canker

Description: *Phomopsis* stem canker, caused by *Phomopsis helianthi* (sexual stage = *Diaporthe helianthi*) is a serious disease that first was observed in Europe in the late 1970s and in the U.S. in 1984. The distinguishing feature of the disease is the large tan to light brown lesion or canker that typically surrounds the leaf petiole (Figure 96). Compared with *Phoma* black stem, the *Phomopsis* lesion is much larger, reaching 6 inches in some cases, is brown rather than black and typically has a sunken border. *Phomopsis* also causes more extensive pith degradation than *Phoma,* so the stalk may be crushed with moderate thumb pressure. Phomopsis-infected plants also are more prone to lodging than Phoma-infected plants.

Figure 96. Phomopsis is characterized by the large light brown lesion or canker which typically surrounds the leaf petiole. (T. Gulya)

Disease cycle: The fungus overwinters predominantly as perithecia of *Diaporthe* in infected plant debris. The ascospores released from the perithecia are rain splashed or windblown onto leaves. The infection starts on the margins of lower leaves. A brown necrotic area develops and may be bordered by a chlorotic margin. The infection spreads down through the veins to the petiole and finally to the stem. These symptoms look similar to those of *Verticillium* leaf mottle, but with *Verticillium,* the necrotic areas are **between** the veins. Stem lesions usually do not appear until flowering. Girdling stem lesions result in wilting and make the plant more prone to lodging. The disease may be difficult to identify when both *Phoma* and *Phomopsis* are present, in which case the stem lesion may be intermediate in color between the black lesion associated with *Phoma* and the brown typically associated with *Phomopsis.* In these cases, microscopic identification of the fungus is necessary.

Damage: Phomopsis stem canker has been found in both the central and northern areas of the Great Plains. Since the fungus is specific to sunflower, it likely would not be found in areas without a history of sunflower production. The disease is most severe under conditions of prolonged high temperatures and high rainfall. Yield losses result from smaller heads and lighter seed, and from lodging due to weakened stems, which can be quite extensive.

Management: Since the fungus overwinters in infected sunflower debris on the soil surface, thorough disking in the fall to bury plant residue and crop rotation can reduce disease incidence and severity. Leaving crop residue on the soil surface would foster the best development of *Phomopsis.* Most U.S. sunflower companies are trying to incorporate some levels of Phomopsis resistance into their hybrids, using parental lines developed in Europe, where the disease is particularly severe. No U.S. commercial hybrids are immune to Phomopsis stem canker, nor are any fungicides registered in the U.S. for control of *Phomopsis.* Please consult NDSU publication A-652 for information on ratings of commercial hybrids to *Phomopsis.*

Verticillium Leaf Mottle

Description: Verticillium wilt, or more accurately, leaf mottle, is caused by the soil-borne fungus *Verticillium dahliae.* The fungus has a wide host range and causes wilt of several other cultivated plants and weeds. Potato is the other important crop host of *Verticillium* in the northern Great Plains. Verticillium leaf mottle typically causes necrosis between the main leaf veins with yellow margins. The contrast between the necrotic tissue surrounded by chlorosis and the healthy green leaf tissue is striking and quite diagnostic. Symptoms begin on the lower leaves and progress slowly upward (Figure 97) and may encompass all leaves. Affected leaves rapidly become completely dry, but do not wilt to the same degree as with *Sclerotinia* wilt. Thus, the term leaf mottle may be more appropriate than *Verticillium* wilt. Symptoms usually are not observed until flowering, but under severe conditions, they may occur as early as the six-leaf stage. The vascular system of infected plants may be discolored brown, visible as a brown ring in a cross-section of the stem. The pith of severely diseased plants is blackened with a layer of tiny black fruiting bodies (microsclerotia). These microsclerotia are much smaller than microsclerotia of charcoal rot and are not visible with a hand lens. Under a microscope, Verticillium microsclerotia are irregular to club-shaped (< 0.1 mm long), while charcoal rot microsclerotia are more uniformly spherical and larger (0.1 to 1.0 mm in diameter). Another fungus, *Phialophora asteris,* causes quite similar symptoms on sunflower. This fungus does not form microsclerotia, which is one way to distinguish it from *Verticillium.*

Life Cycle: *Verticillium* overwinters as mycelium or microsclerotia in infected plant debris. The microsclerotia germinate in response to root contact and colonize the root system. As the fungus reaches the tap root and lower stem, toxins produced by the fungus are translocated to the leaves to produce the chlorotic and necrotic areas between the veins. *Verticillium* remains within the stem tissue and cannot be isolated from symptomatic leaves. The fungus is isolated most easily from stems and petioles of infected plants. No involvement of conidia occurs in disease development, although the fungus does produce conidia in culture.

Damage: Sunflowers infected with *Verticillium* usually die before seeds are completely mature, and thus yield losses result from smaller head size, lighter test weigh and reduced oil concentration. The stems of *Verticillium*-infected plants are weakened as the pith shrinks, and are more prone to lodging.

Management: Resistance to *Verticillium dahliae* is controlled by a single dominant gene (V-1), and most U.S. oilseed hybrids contain this resistance. However, a new strain of *Verticillium* that is able to overcome the V-1 gene recently was identified both in the U.S. and Canada. Thus, hybrids that previously were considered resistant have shown symptoms of Verticillium wilt due to infection by this new strain. Confection hybrids as a group are more susceptible to *Verticillium* than are oilseed hybrids. Verticillium leaf mottle is a serious disease on lighter soils with a history of sunflower cropping, and is seen less frequently on heavy, clay soils. This disease will cause some yield loss each time a susceptible crop is planted, as the fungus can persists for five to 10 years as microsclerotia.

Figure 97. Plants infected with Verticillium wilt show interveinal necrosis with yellow margins. (T. Gulya)

Bacterial Stalk Rot

Description: Bacterial stalk rot occurs sporadically in the Great Plains and generally is not considered a major sunflower disease. The pathogen is *Erwinia carotovora,* a bacterium that causes soft rot on potato and other vegetables. Typical disease symptoms are stem discoloration (dark brown to black), often centered on a petiole axil, and a wet, slimy, soft rot of internal stem tissue. A pungent odor, reminiscent of rotting potatoes, is also characteristic. Due to pressure from the gas produced by the bacteria, the stem may be split open. Symptoms may extend down the stem into the roots. The bacterium also can infect the head, causing a wet, slimy rot of the receptacle. Infected stems are prone to lodging, and infected heads quickly fall apart. After the plant dies, the affected stalk or head dries up and may leave little indication of prior mushy rot.

Disease Cycle: The main source of the bacteria is infested plant residue on the soil surface. The bacteria enter the plant through wounds caused by insects, hail and windblown sand; they cannot penetrate unbroken epidermis like fungal pathogens. Extended wet and warm periods favor disease development. Most diseased plants are observed later in the season. Young plants are more resistant to stalk decay than plants nearing senescence. Varietal differences in susceptibility to bacterial stalk rot are reported.

Damage: Bacterial stalk rot is seen infrequently. Plants affected by this disease will be killed and produce little or no seed, but disease incidence within a field is generally low.

Management: While differences in resistance have been observed, little information is available on the resistance of current hybrids. Control of stem feeding insects will minimize the potential of insect transmission.

Nematode Diseases

Description: Nematodes are microscopic, nonsegmented roundworms that can cause serious damage to the roots of many crops. While many different types of nematodes have been found in sunflower fields, their economic impact on the plant is undocumented or highly variable.

Genera of nematodes that have been reported on sunflower in the northern Great Plains include *Heliocotylenchus, Tylenchrohynchus, Paratylenchus, Hoplolaimus* and *Xiphinema;* the first two genera are the most widely distributed in North Dakota, while *Paratylenchus* is the dominant nematode in South Dakota. All these nematodes are ectoparasites, meaning that they feed either on the root surface or burrow partially into the roots. Root-knot nematodes *(Meloidogyne* spp.), damaging pests of many crops, have been reported on sunflower in Florida and in warm areas of other countries but have not been recorded on sunflower in the upper Great Plains states. Sunflower is not a host for the soybean cyst nematode *(Heterodera glycines),* making sunflower suitable for rotation with soybean where the cyst nematode is a problem.

Disease Cycle: Nematodes overwinter in the soil as eggs and colonize plant root systems throughout the growing season. Symptoms caused by nematodes are not distinctive and mimic those due to drought and nutrient deficiencies. In severe infestations, the foliage wilts and turns yellow, and stunting may occur. The pattern of affected plants in the field may have little or no relationship with topography. Examination of roots is necessary to prove nematode damage. Identification of nematodes to genus requires their extraction from soil and roots, followed by microscopic examination.

Damage: High populations of nematodes have caused yield reductions in greenhouse studies.

Management: Applications of nematocides in field trials have produced variable yield responses. No nematocides are registered for use on sunflower, and the potential cost return makes their use questionable. Tolerance to nematode damage appears related to the extensive root system of sunflower.

IV. Head Rots and Diseases of Mature Plants

Head Rots, Other Than *Sclerotinia*

Description: Several head rots (other than *Sclerotinia*) occur on sunflower in the U.S., and these are caused by several fungi, including *Rhizopus, Botrytis* and the bacterium *Erwinia,* covered previously.

Rhizopus head rot, caused by *Rhizopus arrhizus* and *R. stolonifera,* was considered a sporadic disease in the Great Plains, but recent surveys have shown it to be the most widespread disease in the central Great Plains (Figure 98). Initial symptoms are brown, watery spots on the receptacle. *Rhizopus* species rot the soft tissues of the head, turning it brown and mushy. A threadlike, whitish fungal mycelium develops on and within the receptacle. Tiny black pinhead-sized fruiting structures (sporangia) form within the head tissue, giving the appearance of pepper grains.

Botrytis head rot is caused by the widespread fungus *Botrytis cinerea,* and is distinguished from *Rhizopus* by the gray "fuzz" on the heads (caused by mycelium and spores). Heads affected by *Botrytis* eventually will disintegrate and may contain small sclerotia, similar in size to those caused by *Sclerotinia.*

Bacterial head rot caused by *Erwinia carotovora* is rare in the Great Plains. This disease is characterized by a slimy, wet, brownish rot of the head with no fungus growth or spores in the tissues. Often such heads have a putrid odor.

Disease Cycle: *Rhizopus* enters the head through wounds caused by hail, birds and insects and has been associated with head moth and midge damage. The susceptibility of heads increases from the bud stage up to the full bloom and ripening stages. Disease development is most rapid in warm, humid weather. Once the head is fully colonized and all tissue killed, the head dries up and becomes hard and "mummified."

Botrytis infects sunflower heads during cool, wet weather and requires organic debris, such as flower parts or senescing tissue, to initiate growth. Late attacks start from the senescent petals and head bracts and may be serious during a wet fall and late harvesting. Head rot symptoms start as brown spots on the back of the head, which is identical to the initial symptoms of all head-rotting fungi. These spots become covered with gray powdery *Botrytis conidia,* giving the head a "fuzzy" appearance. These spores generally form on the surface tissues and not inside the tissues, as with *Rhizopus.* In wet weather, the infection spreads throughout the tissues, and the head becomes a rotten, spongy mass.

Bacterial head rot, as with bacterial stalk rot, is caused when windblown or rain-splashed bacteria fall on wounds in the head caused by hail, insects or birds. No fruiting structures are associated with bacterial diseases, but the putrid odor associated with bacterial rotting is distinctive enough for identification.

Damage: Disease incidence for all three described head rots is generally low throughout the northern Great Plains, while Rhizopus head rot is common in the High Plains. Individual heads affected by any of the head rots will have lighter test weight seed, lower oil content and reduced seed yield. In severe cases, the affected heads may be entirely lost. Seeds from heads infected by any of these fungi or bacteria will have higher free fatty acid content, resulting in a bitter taste. Thus, head rots of confection sunflower may cause losses due to lowered quality factors, even in cases where actual seed yield losses are minimal.

Management: Insect control may help minimize *Rhizopus* head rot, but will not offer as much disease reduction as fungicide sprays. In the U.S., no fungicides are registered for control of any head rot, except Sclerotinia. No practices are recommended to control bacterial head rot, other than to minimize head-feeding insects that might transmit the bacterium.

Figure 98. Rhizopus head rot is characterized by a dark brown, peppery appearance of tissues in the receptacle. (T. Gulya)

Weeds

(Richard Zollinger)

Weeds compete with sunflower, causing poor growth and yield losses. Yield loss from weed competition depends on weed species, time of infestation, weed density and climatic conditions. All weeds are competitors. However, in the northern region of the U.S., wild mustard, wild oats and kochia, which grow rapidly early in the season, appear more competitive than foxtail on a per-plant basis.

A comprehensive weed management program consisting of cultural and/or chemical controls is needed to maximize yields. Sunflower is a good competitor with weeds. However, this competitive advantage occurs only after plants are well-established. The first four weeks after emergence are most critical in determining weed competition damage, so early weed control is essential. Weeds competing longer than four weeks cause important yield loss even if they are removed. All chemical recommendations for weed control have a U.S. federal label unless otherwise specified. All recommended herbicides have federal registration at the time of printing, and rates listed are label rates at time of printing. Consult the current issue of NDSU Extension publication W-253, “North Dakota Weed Control Guide,” or appropriate Extension publications from other states for current labeled products, rates and method of application.

WILD MUSTARD *(Sinapis arvensis)* is a major weed that infests sunflower. Wild mustard is not controlled by most of the herbicides commonly used in sunflower. Wild mustard emerges early and appears to be most competitive with sunflower when the early season is cool. The cool condition favors wild mustard, but not sunflower growth. Late seeding with seedbed tillage to control early emerged wild mustard can reduce infestations. However, wild mustard may continue to emerge with timely rains and remain a problem even with late seeding. Assert (imazamethabenz) is the only herbicide registered for use in conventional sunflower to control wild mustard. Wild mustard can be controlled easily in Clearfield sunflower with Beyond (imazamox) and in Express-resistant sunflower with Express (tribenuron). Wild mustard is controlled effectively by herbicides used in other crops in the rotation. Wild mustard seed can remain viable in the soil for many years, so plants allowed to produce seed can cause an infestation for many subsequent years.

WILD OAT *(Avena fatua)* is another cool-season weed that is abundant in North Dakota and causes important yield losses, especially in early seeded sunflower. Wild oat germinates early in the spring, and germination and emergence generally stop when soil becomes warm. Delayed seeding reduces wild oat infestations. Wild oat can infest late-seeded sunflower when cool and moist conditions occur at or after seeding. Wild oat is controlled to various degrees by several registered herbicides (Table 12).

GREEN FOXTAIL *(Setaria viridis)* and YELLOW FOXTAIL *(Setaria lutescens)* are the most abundant grassy weeds in North Dakota. Both green and yellow foxtail occur throughout the state. Green foxtail has been more abundant, but yellow foxtail is the dominant species in many areas because herbicides giving less control of yellow foxtail have been used in crops. The two species have similar appearance, but yellow foxtail has a flat stem with long hairs at the base of the leaves, a more brushlike spike and a larger seed. Green foxtail has a round stem with no hair on the leaves. Foxtail is a warm-season plant, and germination and emergence do not occur until the soil reaches 60 degrees Fahrenheit. Many sunflower herbicides give excellent control of foxtail species (Table 12).

KOCHIA *(Kochia scoparia)* is considered the worst weed problem of sunflower in North Dakota. Kochia is a highly competitive weed that emerges during cool periods early in the spring or later with warm temperatures and adequate moisture. Most kochia has become resistant to ALS (acetolactate synthase) herbicides and no registered herbicides in sunflower give adequate control. Beyond herbicide in Clearfield sunflower is an ALS herbicide and will not control ALS-resistant kochia. Soil-applied Spartan (sulfentrazone) controls ALS-resistant and susceptible kochia when activated by sufficient moisture after application. Kochia seeds do not have a long residual life in the soil. Good control of kochia in the crop prior to sunflower emergence or control before seeding will reduce the kochia infestation.

RUSSIAN THISTLE *(Salsola iberia)* is most common in the drier western areas of North Dakota. Russian thistle germinates throughout the season. Germination is rapid, so light rains anytime will promote a new flush of Russian thistle growth. Competition data on losses from Russian thistle in sunflower are not available. The plants are normally small and competition usually is not expected. However, Russian thistle is drought tolerant and losses may be severe, even from a small number of plants under conditions of limited moisture.

OTHER WEEDS important in sunflower are wild buckwheat *(Polygonum convolvulus),* redroot pigweed *(Amaranthus retroflexus),* common lambsquarters *(Chenopodium album),* field bindweed *(Convolvulus arvensis),* Canada thistle *(Cirsium arvense),* cocklebur *(Xanthium strumarium),* marshelder *(Iva xanthifolia),* biennial wormwood *(Artemisia biennis),* nightshades *(Solanum spp.)* and wild sunflower. Some of these weeds are controlled partially by soil-applied triflualin or Sonalan (ethalfluralin), but these products cannot be used in no-till sunflower production because of

Table 12. Relative effectiveness of herbicides for various weeds.

Herbicide	Green/yellow foxtail	Wild oat	Wild buckwheat	Comn. cockle bur	Kochia	Comn. lambsquarters	Marshelder	Wild mustard	Nightshade spp.	R. root pigweed	Russian thistle	Bien. wormwood	Canada thistle
Preplant herbicides													
Glyphosate	E	E	F-G	E	F-E	P-E	G-E	E	F-G	E	G-E	G-E	G-E
Paraquat	G	G	F	F-G	G-E	E	G	E	G-E	E	E	-	P
Soil-applied herbicides													
Eptam (EPTC)	E	G-E	F	P	F	F	N	P	F	G	P	N	N
Prowl (pendimethalin)	G-E	P	P	N	F	G	N	N	N	G	F-G	N	N
Sonalan (ethalfluralin)	E	P-F	P-F	N	F	E	N	N	P	G-E	G-E	N	N
Dual Magnum (s-metolachlor)	G-E	P	P	N	P	P-F	N	P	P	F-G	P	N	N
Spartan (sulfentrazone)	P	N	P-F	N	E	E	P-G	P-F	E	E	G-E	G-E	N
Trifluralin	E	P	P	N	F	G	N	N	N	F-G	F-G	N	N
POST-applied herbicides													
Assert (imazamethabenz)	P	G-E	F-G	P	N	P	N	E	N	P	P-F	N	N
Beyond* (imazamox)	E	E	P	G-E	E1	F	G-E	E	E	E	G-E	P	N
Poast (sethoxydim)	E	G-E1	N	N	N	N	N	N	N	N	N	N	N
Select (clethodim)	E	E	N	N	N	N	N	N	N	N	N	N	N

* = Clearfield sunflower.
1 = Herbicides will not control resistant biotypes.
E = Excellent, G = Good, F = Fair, P = Poor and N = None.
The ratings in the table indicate relative effectiveness, with effectiveness of each herbicide varying with environment and method of application.

their soil incorporation requirement. Pre-emergence Spartan controls most small-seeded broadleaf weeds and suppresses wild buckwheat, marshelder and foxtail. However, no herbicides are available for selective control of wild buckwheat, Canada thistle, field bindweed, cocklebur, marshelder or wild sunflower. Beyond in Clearfield sunflower controls most annual grass and broadleaf weeds except ALS-resistant weeds, including kochia, but has no activity on perennial broadleaf weeds. Weeds for which no herbicides are available need to be controlled in previous crops in rotation, or through tillage or the use of herbicides in or between other crops in the rotation.

The sunflower yield loss from individual weeds varies with the weed species, environment and time of weed emergence relative to the crop. Sunflower yield losses from several weeds at various infestations are presented in Figure 99. The values are averages from several years and losses from an individual weed would vary with conditions. A weed that emerges before the sunflower would be more competitive than one emerging after sunflower establishment, and an environment that favored the growth of the weed would cause a greater loss than if the environment favored the sunflower.

Weed Management

(Richard Zollinger)

Cultural

Cultural weed control requires an integrated system of tillage operations. Weeds must be controlled in other crops in the rotation to reduce the potential infestation level in sunflower. Preplant, pre-emergence and postemergence tillage practices all must be followed for effective weed control using only tillage. Poor timing or missing any tillage operation can reduce the effectiveness of the cultural weed control program drastically.

Preplant tillage can control one or more weed flushes. Sunflower should be planted immediately after the last tillage operation so the crop can germinate rapidly and compete more favorably. Weeds frequently emerge before sunflower, especially during cool weather. These weeds can be controlled by pre-emergence harrowing.

Postemergence mechanical weed control consists of harrowing and cultivating. Small weeds can be controlled by harrowing after the sunflower is in the four- to six-leaf stage (V-4 to V-6) and can resist burial and breaking (Figure 100). Postemergence harrowing should be done across rows and preferably on a warm, clear day to assure sufficient weed kill with the least damage to the sunflower. Sunflower seedlings, which are strongly rooted, can be harrowed three to five times during the four- to six-leaf stage (V-4 toV-6). The harrow should be kept free of trash. Spring tooth harrows are recommended; solid spike-tooth harrows should not be used, as excessive damage may result.

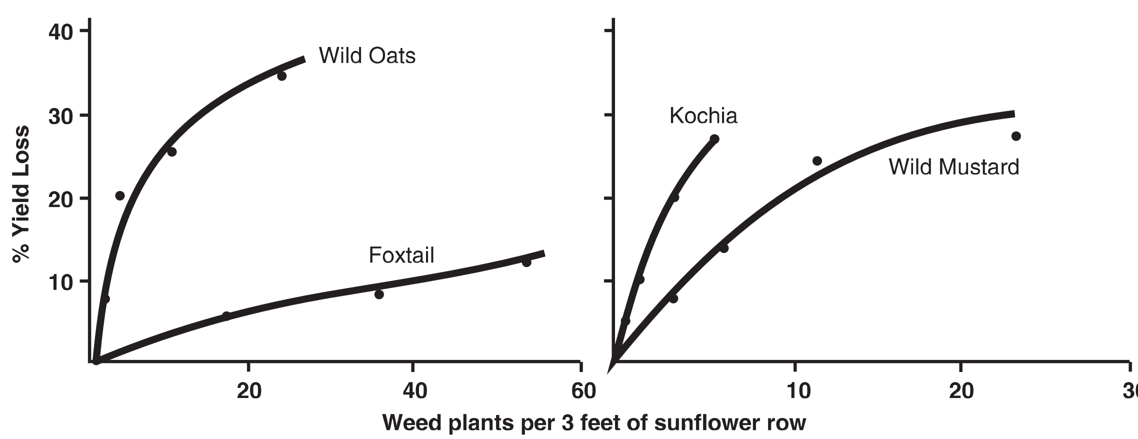


Figure 99. Percent reduction in sunflower seed yield from several weeds. (J.D. Nalewaja)

Figure 100. This field was harrowed before sunflower emergence and was being harrowed at about the four leaf stage to control seedling weeds. (GTA-Farmers Union)

The direction of travel during harrowing is determined by considering the stand, weed growth and herbicide treatment. Harrowing diagonally to the rows will give better in-the-row weed control than with the row harrowing. However, sunflower damage will occur from the tractor wheels with diagonal harrowing. Harrowing may be necessary if a soil-applied herbicide was not activated by rainfall, if a field previously treated with a herbicide has weeds resistant to the herbicide or if adverse climatic conditions reduce herbicide effectiveness. If the herbicide is band-applied, harrowing should be parallel to the rows to prevent dilution with untreated soil. A rotary hoe also is effective for postemergence weed control, but weeds must be just emerging for good control. Setting the harrow or "weighting" the rotary hoe to do the most damage to weeds and the least damage to sunflower can be accomplished on a "try-and-adjust" system. Postemergence harrowing will kill some sunflower (5 percent to 8 percent loss can be expected), so if this system of weed control is planned, the sunflower should be seeded at higher rates than normal.

After postemergence harrowing, weed control for the remainder of the season depends on the row-crop cultivator. During the first cultivation, producers must take care not to cover the sunflower. One to three or more cultivations may be necessary, depending on the weed situation in the field. Lateral sunflower roots are shallow and can be damaged easily by cultivating too deeply and too closely to the plants. Cultivation should be no closer to the row center than the leaf spread of the plants. During later cultivations, soil may be thrown into the row to bury weed seedlings and provide the sunflower extra support.

Registration of Spartan and Clearfield sunflower will allow and encourage no-till sunflower production. No-till farming increases dependence on chemicals and increases selection pressure for resistant weeds.

Chemical

The most effective weed management is accomplished by an integrated system that uses both cultural and chemical control. Preplant cultural practices to reduce weed seed populations, pre-emergence tillage and postemergence cultivation may be needed to supplement the herbicides under adverse climatic conditions and to control late-emerging weeds or weeds that are not controlled by herbicides. Herbicides vary in their effectiveness against various weeds (Table 12).

Preplant and Pre-emergence

GLYPHOSATE at 1 to 2 pt/A of 3 lb/gal concentrate (0.38 to 0.75 lb ai/A) is registered for the control of emerged weed seedlings before, during or after planting but before the crop emerges. Glyphosate is a nonselective, systemic, nonresidual herbicide, so treatment must be made before sunflower emergence and after weeds emerge. Several formulations are available, so follow label directions for rates, weed sizes, application volume and addition of nonionic surfactant.

PARAQUAT at 2.5 to 4 pt/A (0.63 to 1 lb ai/A) is registered for the control of emerged weed seedlings before, during or after planting but before the crop emerges. Paraquat is a nonselective contact herbicide, so treatment must be before sunflower emergence. However, application must be after weed emergence, as paraquat has no soil residual to control late-emerging weeds. A nonionic surfactant at 0.25 percent v/v should be added to the spray solution to increase spray droplet contact with the leaf surface and retention by the leaf. Spray should be applied at 20 gallons per acre by ground equipment or 5 gallons per acre by air. Paraquat is a restricted-use herbicide.

EPTAM (EPTC) at 2.5 to 3.5 pt/A (2 to 3 lb ai/A) applied before planting or at 4.5 to 5.25 pt/A or 20 to 22.55 lb 10G per acre applied after Oct. 15 controls some annual grass and broadleaf weed species. Eptam is degraded within three weeks after application. The 3 pound- per-acre rate spring applied occasionally has caused sunflower injury on coarse-textured, low organic matter soils. The risk of sunflower injury can be reduced by using lower rates on these soils. Immediate and thorough incorporation is essential, as the herbicide is volatile. A 15-minute delay in incorporation during warm weather with moist soil may result in significant vapor loss and poor weed control. Proper incorporation can be accomplished by tandem disking twice in cross directions (4 to 6 inches deep) or by any other method that thoroughly mixes the chemical within the top 3 inches of soil. Eptam generally gives good short-term weed control but is weak on wild mustard, Russian thistle, common cocklebur, smartweed and all perennial broadleaf weeds. Wild oat control is good.

PROWL or PROWL H20 (pendimethalin) at 2.4 to 3.6 pt/A EC, 2.1 to 3 pt/A ACS preplant incorporated or pre-emergence in no-till sunflower is registered for control of most grass and certain broadleaf weeds in sunflower. Prowl can be applied in the fall at 2.4 to 4.25 pt/A and incorporated when soil temperature is less than 45 degrees. Prowl is registered only as an incorporated treatment for conventionally tilled sunflower because of greater consistency of weed control and greater crop safety. Prowl plus Spartan controls many grass and broadleaf weeds in no-till sunflower. No-till sunflower is treated with higher rates of Prowl than conventionally tilled sunflower. The higher rates help overcome the reduced control from pre-emergence vs. PPI treatment and from Prowl being absorbed on the crop residue. Prowl is registered at 2.4 pt/A in no-till sunflower for coarse-textured soils with less than 3 percent organic matter and 3.6 pt/A for all other soils, including coarse-textured soils with greater than 3 percent organic matter.

Prowl may be applied up to 30 days before seeding no-till sunflower. Spray volume greater than 20 gallons per acre should be used to aid penetration to the soil in fields with high amounts of crop residue. Prowl does not control emerged weeds, so either glyphosate or paraquat would be needed to control emerged weeds in no-till sunflower prior to planting. Prowl has state registration for no-till sunflower in North Dakota, South Dakota and Minnesota.

SONALAN (ethalfluralin) at 1.5 to 3 pt/A (0.55 to 1.15 lb ai/A) preplant incorporated in the spring is registered for the control of annual grass and some small-seeded broadleaf weeds in sunflower. The granular formulation (Sonalan 10G) can be applied in the spring or fall between Oct. 10 and Dec. 31 at 5.5 to 11.5 lb 10G/A. Sonalan does not control wild mustard. The first incorporation into the soil may be delayed no longer than two days after application. The second incorporation should be delayed three to five days after the first. Sonalan has a shorter soil residual than trifluralin and is slightly more effective in controlling wild oats, Russian thistle and a few other broadleaf weeds. Sonalan is registered for tank mixtures with Eptam.

Recent labeling allows use of Sonalan in reduced-tillage systems for suppression of foxtail species. Sonalan 10G may be applied at 7.5 to 12.5 pounds per acre in the fall to small-grain stubble and incorporated once in the fall and once in the spring with a V-blade prior to planting sunflower. Sonalan 10G may be applied in the spring and incorporated twice using a V-blade. For spring applications, a delay of at least three weeks between incorporations should be observed unless a minimum of 0.5 inch of precipitation occurs after the first incorporation. The delay then may be shortened to 10 days. The incorporations should be made at approximately 5 mph using a V-blade implement with 12- to 32-inch-wide sweeps. Both incorporations should be no deeper than 2 to 2.5 inches.

DUAL MAGNUM (s-metolachlor) at 1 to 2 pt/A (0.95 to 1.9) preplant incorporated or preplant will control green foxtail and several other weeds, such as pigweed and lambsquarters. It will not control wild mustard or wild oats. Incorporation improves weed control and consistency of control. It requires soil moisture for activation and better weed management. Use higher rates for clay soils high in organic matter.

SPARTAN (sulfentrazone) at 3 to 8 fl oz F (1.5 to 4 oz ai/A) applied pre-emergence controls most annual small-seeded broadleaf weeds, such as kochia, pigweed species, lambsquarters, nightshade, smartweed, Russian thistle and biennial wormwood, and may suppress buckwheat, mustard, ragweed and Russian thistle. Spartan may provide some grass but no perennial weed control. Adjust rate based on organic matter and use higher rates if applied up to 30 days prior to planting. Sunflower has good tolerance to Spartan on medium to fine-textured soils with organic matter above 3 percent. Crop injury may occur on soils with low organic matter and soil pH greater than 8.0, especially on calcareous outcropping. Do not use on coarse-textured soils with less than 1 percent organic matter. Closely furrow at planting to avoid injury. Poor growing conditions at and following sunflower emergence, cold temperatures, soil compaction or a rate too high based on soil type and organic matter may result in sunflower injury. Consistent weed control greatly depends on at least 0.75 inch rainfall shortly after application and before weeds emerge. Spartan is a PPO inhibitor mode-of-action herbicide in which no weed resistance has been documented.

TRIFLURALIN at 1 to 2 pt/A or 5 to 10 lb 10G/A (0.5 to 1 lb ai/A) is a preplant incorporated herbicide for grass and certain broadleaf weed control in sunflower. Incorporation should be by tandem disk or field cultivator twice in cross directions (4 to 6 inches deep) at about 6 mph. Thorough incorporation is essential for optimum, consistent weed control. Trifluralin is less volatile than EPTC (Eptam). Immediate soil incorporation is preferred, but with cold, dry soil and low wind, incorporation may be delayed up to 24 hours. The lower rate should be used on soils of coarse texture and low organic matter. Trifluralin gives seasonlong control of some annual grass and broadleaf weeds. Wild mustard is not controlled, and wild oat control is poor.

Postemergence

ASSERT (imazamethabenz) at 0.6 to 0.8 pt/A (0.19 to 0.25 lb ai/A) controls wild mustard in sunflower. Assert should be applied before sunflower exceeds 15 inches in height. Wild mustard should be in the rosette stage but prior to bloom. Sunflower injury may occur from Assert if applied during high temperatures and humidity.

POAST (sethoxydim) at 0.5 to 1.5 pt/A (0.1 to 0.3 lb ai/A) applied postemergence in sunflower controls annual grasses and suppresses quackgrass. Oil adjuvant should be included at 1 qt/A. Poast at 0.5 pt/A controls wild proso millet; at 1 pt/A controls volunteer corn, green and yellow foxtail, and barnyardgrass; and at 1.5 pt/A controls wild oats and volunteer cereals.
Quackgrass that is 6 to 8 inches tall can be suppressed with Poast at 1.5 pt/A. Quackgrass regrowth should be treated at 1 pt/A. Cultivation between 14 to 21 days after application will improve quackgrass control. The addition of 2 to 4 quarts per acre of liquid nitrogen solution or 2.5 pounds per acre of ammonium sulfate in addition to the oil adjuvant may increase control of volunteer corn, cereal grains and quackgrass. Sunflower should not be harvested before 70 days after application.

CLETHODIM (several trade names) at 6 to 8 fl oz or SELECT MAX (clethodim) at 9 to 32 fl oz/A (1 to 3.9 oz ai/A) applied postemergence in sunflower controls annual grasses, volunteer cereals and perennial grasses, including quackgrass. See label rates to control individual type of grasses. Oil adjuvant should be included at 1 qt/A. oz/A. Cultivation between 14 and 21 days after application will improve quackgrass control. The addition of 2 to 4 qt/A of liquid nitrogen solution or 2.5 lb/A of ammonium sulfate in addition to the oil adjuvant may increase grass control. Sunflowers should not be harvested before 70 days after application.

Herbicide-resistant Sunflower

Clearfield sunflower

BEYOND (imazamox) at 4 fl oz/A (0.5 oz ai/A) applied postemergence to Clearfield sunflower varieties from the two- to eight-leaf stage controls most annual grass and broadleaf weeds. Apply with NIS at 0.25 percent v/v alone or with UAN liquid fertilizer at 1 to 2 qt/A. Beyond will not control wild buckwheat, biennial wormwood, large common lambsquarters, Canada thistle or ALS-resistant weeds, including kochia. Clearfield sunflower can be planted on land previously treated with Assert or Pursuit to reduce or eliminate injury from long residual sulfonylurea herbicides. Clearfield sunflower may facilitate no-till sunflower production.

EXPRESS (tribenuron) at 0.25 to 0.5 oz/A (0.188 to 0.38 oz ai/A) applied postemergence to Express Sun sunflower varieties will control annual broadleaf weeds, including wild mustard. It will not control ALS-resistant weeds, including kochia or grass weeds.

Control or suppression of Canada thistle can be expected at the higher rate. Apply early postemergence to Express-resistant sunflower in the one-leaf stage but prior to bud formation. Broadleaf weeds should be 3 inches or less in height. Apply with MSO-type oil adjuvants at 1 percent v/v. NIS or petroleum oil adjuvants are not prohibited.

Sequential applications are allowed but observe a 14-day interval between applications and do not exceed 1 oz/A during any growing season. Allow a 70-day preharvest interval. Express Sun application may help facilitate no-till sunflower production.

Preharvest Application

GRAMOXONE INTEON (paraquat) at 1.5 to 2 pt/A (0.375 to 0.5 lb ai/A) can be used as a harvest aid in oilseed sunflower. Application should be made when the backside of the sunflower heads is yellow, bracts are turning brown and seed moisture is less than 35 percent. Paraquat can be used on both confectionary and oilseed hybrid cultivars. Apply with a nonionic surfactant at 1 to 2 pints per 100 gallon of water. A seven-day interval must elapse between application and harvest. Paraquat is a restricted-use herbicide.

DREXEL DEFOL (sodium chlorate) at 1 to 2 gal/A (6 to 12 lb ai/A) can be used as a desiccant with both oilseed and confectionary sunflower. Application should be made when the backside of the sunflower heads is yellow, bracts are turning brown and seed moisture is less than 35 percent. Apply at 20 to 30 gallons per acre by ground and 5 to 10 gallons per acre by air.

Roundup Preharvest Application in Sunflower

Monsanto has issued a Supplemental label allowing certain applications of glyphosate (Roundup) for control of annual and perennial weeds in sunflower. Apply no more than a total of 22 fl oz of the 4.5 lb. acid equivalent/gal formulation at preharvest. See label for rates suggested.

For preharvest use in sunflower, apply for weed control, NOT crop desiccation when sunflower plants are physiologically mature. Apply when the backsides of sunflower heads are yellow and bracts are turning brown and seed moisture is less than 35%. Generally the dry chaffy material from the disk flowers on the head can be easily rubbed off by hand and expose the seeds at this stage of maturity. Allow a minimum of 7 day preharvest interval (PHI) for sunflower following application.

For post-harvest weed control, the products may be applied after harvest of sunflower. Higher rates may be required for control of large weeds, which were growing in the crops at the time of harvest. Tank mixtures with 2,4-D or dicamba may be used after harvest.

Always follow the pesticide label when applying any product to sunflower.

Control of Volunteer Sunflower in Crops

Crops following sunflower often are infested with volunteer sunflower plants. In small grains, 2,4-D and MCPA at rates of at least 1 pt/A are needed for consistent control. Bromoxynil plus MCPA at 0.5 pt/A + 0.5 pt/A has given excellent, consistent volunteer sunflower control. Dicamba plus MCPA at 4 fl oz/A + 0.5 pt/A has given good control. Several sulfonylurea herbicides plus 2,4-D or MCPA, and Curtail or Curtail M also control sunflower. Sunflower can emerge from deep in the soil, and these late-emerging plants may escape an early herbicide application. However, delaying treatment until all sunflower emerge may result in poor control and some yield loss from competition. Some judgment is needed to determine the proper time for application, and two applications may be needed in some situations.

In corn, preplant Hornet (flumetsulam plus clopyralid), postemergence bromoxynil, Basagran (bentazon), dicamba, Distinct (dicamba + diflufenzopyr), Hornet, Callisto (mesotrione), Permit (halosulfuron), NorthStar (dicamba + primisulfuron) and Option (foramsulfuron) control volunteer sunflower. Volunteer sunflower also can be controlled with glyphosate in Roundup Ready corn.

In soybean, preplant Pursuit Plus (imazethapyr + pendimethalin), Gangster (flumioxazin + cloransulam), postemergence bentazon, Result (bentazon + sethoxydim), FirstRate (cloransulam), Pursuit (imazethapyr), Raptor (imazamox) and glyphosate in Roundup Ready soybean will control volunteer sunflower.

Refer to the herbicide label or the most current edition of the "North Dakota Weed Control Guide," NDSU Extension publication W-253, for rates, adjuvants and application guidelines.

Birds

(George M. Linz and Jim Hanzel)

Sunflower, due to the easy accessibility and high nutritional value of its seed, is particularly vulnerable to damage by birds (Figure 101). Seeds are exposed and the large head serves as a perch during feeding. Sunflower seed is a preferred bird food because the seed contains many proteins and fats essential to their growth, molt, fat storage and weight maintenance processes. Although many species of birds feed in maturing sunflower fields, the greatest losses are caused by migrating flocks of red-winged blackbirds, yellow-headed blackbirds and common grackles (Figure 102). Significant losses can occur in fields near cattail marshes.

Figure 101. Sunflower may be depredated by birds. Birds perch on sunflower heads and pluck the seeds. (Reu V. Hanson)

Migrating and Feeding Habits of Blackbirds

The adult male blackbird is the first of his species to arrive in the spring. He establishes a territory and awaits the arrival of the females. As females arrive, they disperse to the males' territories and breeding takes place. Each female produces a clutch of three or four eggs. Nests are built in dense vegetation, most often in cattails, which have an abundant food supply. Their diet throughout the nesting season includes insects, weed seeds and waste grains.

Following nesting in July, blackbirds form large flocks and begin feeding in grain fields. Blackbirds start feeding on sunflower seed soon after the petals begin to wilt and cause most of the damage during the following three weeks. Peak concentrations of blackbirds occur in mid-September in the northern growing area (Figure 103). This period coincides with the time that sunflower nears physiological maturity. Most often, the birds roost in the cattail marshes at night and move to the field for feeding during the day.

Blackbirds feed on insects and weed seeds in small grain, corn or sunflower fields before these crops are vulnerable to damage. They become used to feeding in a certain location and include sunflower seeds in their

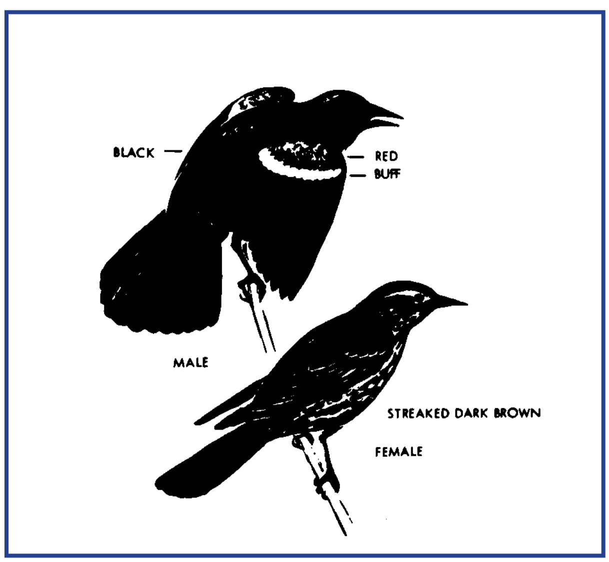


Figure 102. The red-winged blackbird is the most serious bird pest of sunflower in the northern Plains. (Reu V. Hanson)

Figure 103. Blackbirds cause the most damage in early to mid-September. (Reu V. Hanson, George Linz)

diets as the crop matures. Efforts made by the producer to move birds from a field often are unsuccessful because the birds are in the habit of feeding there.

Management

Blackbirds are protected under the Migratory Bird Treaty Act. However, Section 21.43, Title 50 CFR, provides: “A federal permit shall not be required to control yellow-headed, red-winged, tri-colored red-winged, and Brewer’s blackbirds, cowbirds, all grackles, crows and magpies when found committing or about to commit depredations upon ornamental or shade trees, agricultural crops… .” Cultural practices in combination with mechanical and chemical harassment practices should be used to control blackbirds.

Cultural Control

A combination of cultural practices may be used to reduce the risk of bird damage to sunflower. If possible, sunflower should not be planted near cattail marshes or woodlots. Unplanted access trails allow easier access to fields while scaring blackbirds from the center of the field. Planting should be done at the same time as neighbors because earlier and later ripening fields take more damage.

Weed and insect control should begin early. Insects and weeds in the crop are often an attractive food source for blackbirds before the crop reaches a susceptible stage. Once blackbirds have developed patterns in insect-infested or weedy fields, they will begin to include the maturing cultivated crops in their diet. The plow-down of harvest stubble should be delayed until after sunflower harvest. Crop stubble serves as an alternate feeding area for harassed birds and other wildlife. Sunflower should be harvested as early as possible to avoid prolonged exposure to bird damage. Desiccation to advance harvest will reduce exposure to birds.

Cattail Management

Dense cattail marshes serving as roosting sites for blackbirds can be managed with a registered aquatic herbicide (e.g., glyphosate) to remove cattails used by these birds (Figure 104). Generally, cattails must be treated one year before sunflower is planted in the vicinity of the marsh to allow time for the cattails to decompose. However, herbicide applications made in mid-July might reduce blackbird use of the marsh in the year of application. The herbicide should be applied from mid-July to late August to at least 70 percent of the marsh with an agriculture spray plane or helicopter (Figure 105). Use 2 quarts of herbicide per acre. Managing these marshes reduces blackbird use and improves the habitat for other more desirable wildlife, such as waterfowl. North Dakota/South Dakota Wildlife Services, telephone (701) 250-4405, is a unit within the U.S. Department of Agriculture’s Animal and Plant Health Inspection Service. It operates a cost-share cattail management program in North Dakota and South Dakota.

Decoy Crops

Blackbirds can be attracted readily to small plots of oilseed sunflower or other desirable crops planted near traditional wetland and tree roost sites. This strategy can be effective for the protection of high-valued confectionery and oilseed varieties. The plots must produce sufficient seeds to feed the expected population of blackbirds. Each bird can eat about 1 pound of sunflower seeds. Thus, if a grower expects 30,000 blackbirds, then a 20-acre plot must produce about 1,500 lb/acre to feed the birds for a season. These plots also provide essential food and cover for other migrating and game birds. The North Dakota/South Dakota Wildlife Service’s National Wildlife Research Center, at telephone (701) 250-4469, is developing and refining the decoy crop concept. A cost-share program is available to sunflower growers.

Birds are kept out of sunflower fields most successfully by starting methods to frighten them as soon as the birds are seen in the vicinity, regardless of their diet. Various ways of moving birds mechanically are listed.

Use of .22-caliber Rifle

This method should be used only where legal and safe. One rifleman can protect 100 acres by firing from a high position into the midst of settling birds. Several more rounds fired into the lifting flock often will send them on their way. Riflemen must use extreme care with the use of rifles since the bullet may carry a mile or more. Sometimes good results can be obtained with this method if used consistently.

Figure 104. Cattails used by roosting blackbirds can be removed by aquatic herbicide (e.g. glyphosate). (George Linz)

Automatic Exploders (Figure 106)

Automatic exploders or bird-scaring cannons automatically detonate a gas to produce an extremely loud explosion. These devices range from relatively simple mechanisms to deluxe models with photoelectric regulators and programmable firing sequences. The device should be operated before birds begin to arrive from their roosting area at sunrise and continued as long as birds are in the field. It should be shut off at night. The exploder should be placed on a stand above the crop. It should be adjusted to fire slowly, about every four to five minutes. The exploder should be moved every two or three days, as birds will become accustomed to the noise if operated in the same location day after day. One exploder can protect 10 to 20 acres, especially if used with other mechanical devices and shooting.

Electronic Frightening Devices

Devices that broadcast distress calls of blackbirds are marginally effective and their application is somewhat limited because of their high cost and limited broadcast range. Furthermore, because they make extensive use of batteries, sophisticated electronic equipment and loud speakers, they are subject to vandalism and theft.

Pyrotechnic Devices

These include cracker-shells, flares, whistlers (fired or pistol launched) and firecrackers. Most of these products are effective in startling birds and are used commonly by many growers. These devices must be used with care, however, because of the potential for

Figure 105. An aquatic herbicide such as Rodeo (glyphosate) should be applied by airplane or helicopter. (James Hanzel)

Figure 106. Gas exploder, when properly located and moved within the field every 2 to 3 days can reduce bird damage. (Reu V. Hanson)

mishaps. Safety glasses and hearing protectors are strongly recommended since these devices occasionally detonate prematurely. They also may be a fire hazard during dry periods.

Shotgun

This tool is costly and ineffective as a direct control device. Killing a few birds has little if any direct effect on the rest of the flock. However, shotguns can be used to reinforce automatic exploders and pyrotechnic devices.

Airplane Hazing

Harassing feeding blackbirds with airplanes sometimes can be a marginally effective method of chasing flocks from sunflower fields. This technique is especially effective if combined with other mechanical methods, such as shotguns and pyrotechnic devices. Check with local authorities for permits needed to conduct low-level flying.

Repellents

Avitrol, a chemical frightening agent, and Bird Shield, a chemical repellent, are the only chemicals registered for management of blackbirds in sunflower. Avitrol is a cracked-corn bait in which one out of every 100 particles is treated with the active ingredient 4-aminopyridine. The bait is applied by airplane or ground vehicle along access lanes placed in fields. When a blackbird eats one or more treated particles, it flies erratically and emits distress calls. This abnormal behavior sometimes causes the remaining birds in the flock to leave the field. Bird Shield is a newly registered product that is formulated with the active ingredient methyl anthranilate. Research results to date indicate that the efficacy of both Avitrol and Bird Shield are inconsistent.

Best results are obtained by using an integrated pest management system that includes controlling insects and weeds that might attract blackbirds prior to sunflower ripening and by using a combination of harassment devices. Any device used must be operated when the birds are in the field.

Other Pests and Damage

(Duane R. Berglund)

Several sources of sunflower injury exist. Some of them are confused with damage from insects or diseases.

Rabbits

Rabbits will start foraging soon after seedling emergence, especially near the edges of fields. They will tend to concentrate on one row and apparently eat their fill, then leave until the next feeding period. Continued feeding by rabbits has been observed until the plants are 8 to 10 inches tall. Rabbit feeding on such large plants may be confused with deer. However, deer can be detected by their tracks.

Deer

Deer begin foraging on sunflower plants when the plants reach 8 to 10 inches and continue through harvest. They feed in areas near cover, such as wooded areas. All leaves of young plants will be consumed below the growing point. Heads will be foraged until near maturity and seeds until harvest. Often deer will knock down the stalk to facilitate foraging.

Gophers and Mice

Gopher and mouse damage usually is seen just after planting. It generally occurs next to overgrazed pastures, grassland recently converted to cropland and fields next to abandoned areas. The seed will be dug up, split open with the kernel consumed and the hull left on the soil. Several seeds in a row will be eaten. Seedlings are eaten occasionally when they are 2 to 3 inches tall. If the growing point is consumed, the seedling gradually dies. Shooting or rodenticide-treated oats will control gophers and mice.

Lightning

Lightning damage sometimes is mistaken for a disease. It is distinguished from disease damage by the sudden death of the plants in the affected area and the fact that both sunflower and weeds (not grass, however) are killed (Figure 107). Near the edge of the area, plants are wilted but not dead, and the stalks may have a brown to blackened pith. The area may be as large as 50 to 100 feet in diameter. The affected area usually is circular and does not increase in size after the first two weeks. Flags may be placed at the edges of the affected area to observe if the damage gradually progresses beyond the flags. If damage does gradually extend beyond the flags, this could indicate damage from a source other than lightning.

Flooding

Soils should have good drainage for sunflower production, but the crop doesn't differ greatly from most other crops. In flooded sunflower, research found that ethylene increased in the stems and roots below the water. Later, chlorophyll breakdown and leaf epinasty resulted. Sunflower plants flooded longer than three days may not recover. Cool, cloudy days during the flooding period reduce the damage, whereas hot and sunny days may hasten the death of plants.

Heat Canker

Warm temperatures and sunny days can result in heat canker injury to young sunflower seedlings growing in black or dark, moist soils. Hot temperatures at the soil line cause cell death in the young stem and the plants will show bands of yellowing and constricting. In severe cases, the constricted area completely girdles the stem at the soil line and the plant topples over. The sunflower seedling will not recover since the growing point is above this site. Plant populations can be reduced significantly in some cases.

Frost Damage

Sunflower seedlings in the cotyledonary stage (VE) can withstand temperatures down to 26 degrees Fahrenheit when just emerging from the soil. Sunflower in the V-1, V-2 and V-3 stages become less tolerant to frost as they grow and develop. The terminal bud can be frost damaged in seedlings with two, four and six true leaves. This early frost damage and killing of the terminal bud can result in excessive branching as the sunflower grows and develops.

Sunflower is most susceptible at the bud (R-4) and pollination stages (R-5.0 to R-5.9) of development. Temperatures of 30 F or less can cause damage to the anthers and stigmas of the pollinating disk flowers. (See Figure 108 for frost-damaged sunflower head).

Sunflower has a composite type flower. Several rows of showy yellow ray flowers encircle the head and commonly are called the "petals," although each is an individual flower. The center portion of the head, and by far the greater part, is composed of inconspicuous individual flowers, one for each seed that may develop. These disk flowers mature in circles from the outside

Figure 107. Two spots in sunflower field damaged by lightening. (Terry Gregoire)

Figure 108. Frost damage in the center third of sunflower head. (Duane Berglund)

of the flower head to the center, so that at various stages, the disk flowers ready for pollination appear as a yellow circular band in the brownish or dark center of the head. These disk flowers are sensitive to frost.

The result of the frost damage in the flowering period is circular bands of undeveloped seed that would vary with individual flower heads from a band around the outside edge to an area in the center. Unopened buds are less susceptible to frost than the opened flower heads. Growers can determine the extent of injury by cutting the surface of the flower head.

Once pollination is completed and 10 to 14 days after petal drying occurs, the sunflower plants can withstand frost temperatures as low as 25 F and have only minor damage. Twenty-five degrees Fahrenheit at the bud stage often will damage the stalk below the bud and seeds will not develop. If hard frosts do occur, many times only the seed in the center of the head (the last to pollinate) will be affected.

When sunflower heads start to turn yellow on the backside and the bracts are drying and turning brown, most risk of frost damage is very minimal.

In nonoilseed sunflower, frost damage can cause quality problems by causing a dark brown to blackened nutmeat to result during the roasting process. For the birdseed market, light-weight sunflower seed and brown seeds are the result of frost damage and will be discounted.

For oilseed sunflower, reduced test weight per bushel and lower oil percent may result from a frosted immature sunflower crop.

Hail Injury

(Duane R. Berglund)

Hail storms can and will cause different types of sunflower plant injury. Plant death, damage to the terminal bud, physical injury to the stalk and head, and defoliation are all types of injury that can influence yield. Variables such as hailstone size and degree of hardness, speed and density, storm duration and plant environmental status, such as whether the leaves are flaccid or turgid, influence the type and degree of crop injury. The stage of plant development is also an important factor. Figures 109 and 110 illustrate two distinct types of hail damage. As shown in Figure 109, almost all heads have been destroyed, while plants shown in Figure 108 have a high level of defoliation with the heads still attached.

One of the major factors causing differential growth and yield response is the stage at which the injury occurred. Data were obtained from a sunflower date-of-planting study at Carrington, N.D. Five sunflower hybrids sown at six planting dates between May 1 and June 20 were damaged by a hail storm on Aug. 6. Stages of plant development at the time of the storm were from R-1 to R-7. Data were taken approximately one week after the storm. Average percent defoliation from all planting dates was similar at about 26.4 percent. An average of 4.7 stalk and head stone bruises occurred per nondestroyed plant. The percent of plants destroyed and the percent of the remaining plants with heads broken off or bent over but attached decreased with plant maturity (Table 13).

Defoliation: Reduced yield as a result of defoliation depends on the amount of leaf loss and the stage at which it occurs. Stages R-1 through R-6 appear to be the most sensitive to defoliation since much of the photosynthate produced at this time is directed to head development. At early and late stages of plant development, high levels of defoliation may not have a major impact on seed yield. Approximate yield reductions due to varying degrees of random defoliation

Figure 109. Heads destroyed by hail stones.
(A.A. Schneiter)

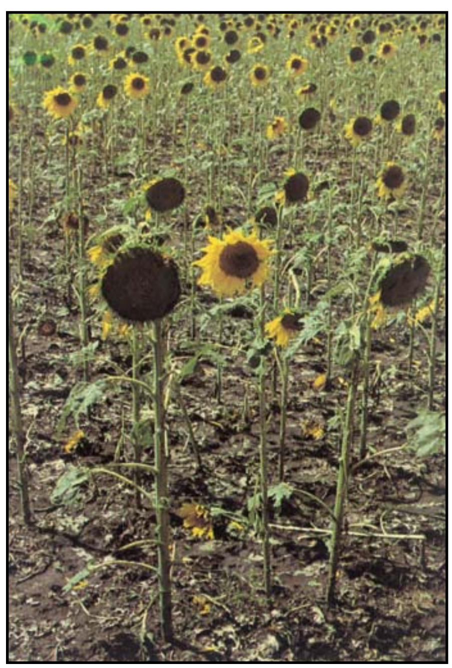


Figure 110. Sunflowers defoliated by hail.
(A.A. Schneiter)

Table 13. Effect of hail injury on sunflower at several stages of plant development.

Date planted	Approx. development stage when injured	% Plants destroyed	Injury on nondestroyed plants		
			% Heads broken off	% Heads broken over but still attached	% Attached heads
May 1	R-7	19.2	7.6	14.3	78.0
May 9	R-6	24.1	6.3	17.1	76.6
May 21	R-5	23.9	17.1	17.8	65.2
May 30	R-3	29.6	16.1	17.0	66.9
June 10	R-2	55.7	36.4	23.7	39.9
June 20	R-1	60.7	39.9	22.6	37.6

at several stages of growth are presented in Table 14. These values are based on investigations conducted at Fargo and Carrington and are the best estimates available on the effect of defoliation for average growing conditions.

Stand Reduction: Plant death as a result of hail injury is a common occurrence, especially at early stages of development when plants are small. At early stages of plant development, before plants begin competing with each other, yield losses due to stand reduction caused by hail are not different than those that would occur due to reduced seeding rates. If the amount of stand reduction is significant and/or occurs when the plant has begun to develop and compete with neighboring plants, the remaining uninjured plants cannot compensate enough and yields will be reduced. Losses due to stand reduction increase as the plant matures since it decreases the time for remaining plants to compensate.

Approximate yield reductions from variable levels of random stand reduction at several stages of plant development are presented in Table 15. These values are based on studies conducted at Carrington and Fargo. These values represent direct stand reduction where the plants have been destroyed and no longer are competing with uninjured plants for light, water or nutrients.

Injured Plants: In addition to stand reduction and defoliation, injuries such as terminal bud removal or injury and stem breakage or bruising may occur as a result of hail. An example of a living but severely injured plant is the gooseneck shown in Figure 111.

Plants that are injured but living sometimes may reduce total crop yield more than if they had been completely destroyed since they continue to compete with uninjured plants for space, light and nutrients but do not produce an equal yield. Competition from injured plants may reduce the ability of noninjured plants to compensate for the hail-damaged plants.

The response of plants to a hail injury, such as terminal bud removal, varies depending on the stage

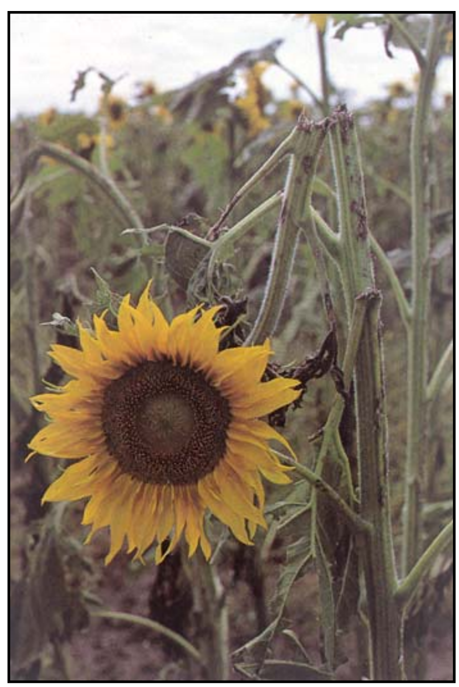


Figure 111. Goose-neck and stem bruising caused by hail injury. (A.A. Schneiter)

at which the injury occurs. When plants are injured in this manner at vegetative (V) stages, they usually develop branches that produce small seed-bearing heads. When injury to the terminal bud occurs during the early reproductive (R) stages, a greater percentage of the plants may die. When injury occurs near or after flowering, the plants usually remain green and continue to live but do not produce seed. A similar type of response can be evident when plants have been injured by the head-clipping weevil; however, the injury from the head-clipping weevil is a straight cut across the stalk.

The effect of bruising by hailstones is difficult to determine. If the amount of stalk bruising is such that the plant does not weaken or break during the remainder of its development prior to combine harvest, the effects on yield may be minimal. Stalk injury of such magnitude or at a specific location on the plant

Table 14. Approximate percent yield reduction from the indicated percent total leaf area destroyed at several stages of sunflower plant development.

	Percent Leaf Area Destroyed																			
Stage *	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**	**45**	**50**	**55**	**60**	**65**	**70**	**75**	**80**	**85**	**90**	**95**	**100**
	- Approximate percent yield loss -																			
V-E to V-3 (6-26 days)	0	0	0	1	1	1	2	2	2	3	3	3	4	4	5	7	8	10	12	15
V-4 to V-5 (27-29 days)	0	0	0	1	2	2	2	2	3	4	4	4	5	5	7	9	12	14	17	21
V-6 to V-8 (30-34 days)	0	0	0	1	2	2	2	2	3	4	4	5	6	6	8	10	14	16	19	22
V-9 to V-11 (35-39 days)	0	0	1	2	3	3	4	4	4	5	5	5	5	7	9	11	14	17	21	24
V-12 to V-(N) (40-43 days)	0	1	2	3	4	4	5	5	5	6	7	7	9	12	15	18	22	26	31	35
R-1 (44-51 days)	0	2	3	4	5	6	6	6	7	7	8	9	13	16	20	24	29	34	40	47
R-2 (52-58 days)	0	2	3	4	6	8	9	10	11	12	13	14	16	18	23	30	37	45	55	65
R-3 (59-67 days)	0	2	5	8	10	15	17	19	21	24	28	32	38	44	51	59	68	78	88	99
R-4 (68-75 days)	0	2	4	5	7	10	12	12	15	18	22	27	34	39	45	53	61	72	85	99
R-5 (76-84 days)	0	1	2	3	5	7	8	10	13	16	20	25	32	37	43	49	55	67	78	90
R-6 (85-92 days)	0	0	1	1	3	3	4	8	11	15	19	24	29	35	41	46	53	63	72	80
R-7 (93-102 days)	0	0	1	1	1	3	5	7	8	10	11	13	14	16	17	18	19	20	21	22
R-8 (103-110 days)	0	0	1	1	1	2	2	3	4	5	6	7	7	8	9	9	10	10	10	11
R-9 (111-maturity)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

*Number of days after planting for development to a specific stage will vary significantly depending on environmental conditions and the hybrid. Interpolating percent of loss between stages may be necessary.

resulting in nonharvestable heads certainly would have an effect on yield. Physical injury by hailstones on the back of a sunflower head at or near anthesis can result in Rhizopus head rot, especially if wet or humid conditions are present. Physical injury can occur as a result of bird, insect or hailstone damage. Increased dead plant tissue resulting from a hail storm, especially on the back of a head, may increase the chance of white mold infection.

Table 15. Approximate percent yield reduction from the Indicated percent stand reduction at several stages of sunflower plant development.

	Percent Stand Reduction																			
Stage *	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**	**45**	**50**	**55**	**60**	**65**	**70**	**75**	**80**	**85**	**90**	**95**	**100**
	- - - Approximate percent yield loss - - -																			
V-E to V-3 (6-26 days)	0	1	2	3	4	8	10	11	12	12	13	14	16	18	24	32	43	58	77	100
V-4 to V-5 (27-29 days)	0	1	2	3	4	8	10	11	12	12	13	14	16	18	24	32	43	58	77	100
V-6 to V-8 (30-34 days)	0	1	2	3	4	8	10	11	12	12	13	14	16	18	24	33	43	58	77	100
V-9 to V-11 (35-39 days)	0	1	2	3	4	8	10	11	12	12	13	14	16	19	25	33	44	59	77	100
V-12 to V-(N) (40-43 days)	0	1	2	3	4	8	10	12	12	13	14	15	17	21	27	35	46	60	78	100
R-1 (44-51 days)	1	2	5	9	12	14	15	16	17	18	19	21	25	29	35	43	53	66	81	100
R-2 (52-58 days)	2	3	7	9	13	17	19	21	23	24	26	28	31	35	40	47	57	68	83	100
R-3 (59-67 days)	4	7	11	13	15	17	21	24	27	29	31	34	37	41	46	53	61	72	84	100
R-4 (68-75 days)	5	10	14	18	20	22	25	27	29	32	35	38	42	47	53	60	68	77	88	100
R-5 (76-84 days)	5	10	14	19	20	24	28	31	35	39	42	45	49	54	60	66	73	81	90	100
R-6 (85-92 days)	5	10	15	19	22	26	31	35	39	44	48	52	56	62	68	73	79	85	93	100

*Number of days after planting for development to a specific stage will vary significantly depending on environmental conditions and hybrid. It may be necessary to interpolate percent of loss between stages.

Herbicide Drift and Chemical Residue

Herbicide Drift

Herbicide drift is the movement of herbicide from target areas to areas where herbicide application was not intended. Herbicide drift generally is caused by movement of spray droplets or by movement of herbicide vapors. Herbicide granules or dried particles of herbicide may move short distances in high winds but are not considered important sources of herbicide drift.

Sunflower is susceptible to many of the postemergence herbicides commonly used on crops grown in proximity to sunflower. Herbicides that may damage sunflower include most all ALS (acetolactate synthase) herbicides (Accent, Ally, Amber, Beacon, Express, Affinity, Pursuit and Raptor), atrazine, dicamba, bentazon, Bronate, Buctril, Curtail, glyphosate, MCPA, paraquat, Stinger, 2,4-D and Tordon.

Sunflower yield may be severely reduced by 2,4-D or dicamba (Figure 112). The amount of loss varied from 25 percent to 82 percent, depending on the sunflower growth stage when the herbicide was applied in tests. Sunflower yield loss averaged from three rates each of 2,4-D and dicamba to simulate spray drift was greatest when the herbicides were applied in the bud stage and least when applied during bloom. Sunflower in the V-2 to V-4 leaf stage was affected less than larger prebloom sunflower.

Only a small portion of an applied herbicide drifts from the target area. However, some nontarget areas can receive rather high doses of herbicide since herbicide drift can accumulate in the nontarget areas. Herbicide accumulated in downwind areas occasionally may exceed the rate applied to the target field. A small portion of the herbicide applied with each sprayer pass may accumulate in an adjoining field. Also, a taller crop, such as sunflower, may intercept more spray drift than a shorter crop, such as wheat or barley. The amount of herbicide that contacts the sunflower and the environment during and following application influences the yield loss caused by herbicide drift. For example, experiments at North Dakota State University showed that 2,4-D at 0.5 ounce per acre applied to 12- to 14-leaf sunflower caused a 5 percent loss in 1973 and 93 percent loss in 1978. Low but equal levels of drift may cause very different effects on sunflower yield, depending on environment. Sunflower injury from herbicide drift will be greatest with warm temperatures and good soil moisture.

Sunflower may exhibit herbicide injury symptoms without a yield loss. Experiments at North Dakota State University indicated that sunflower height reduction, as compared with undamaged sunflower, caused by 2,4-D, MCPA or dicamba was significantly correlated with sunflower yield loss. Drift of 2,4-D,

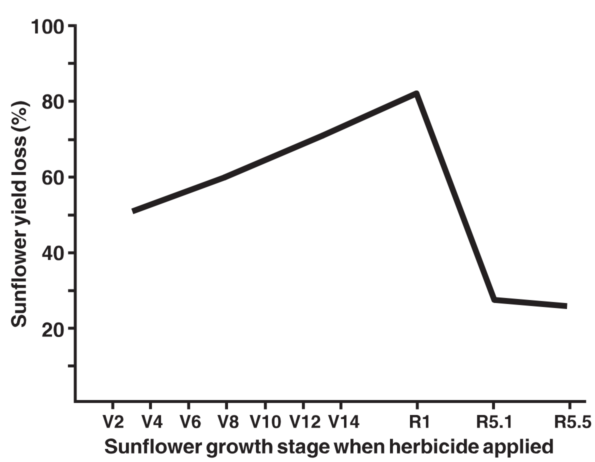


Figure 112. Sunflower yield loss from herbicides applied at various growth stages averaged over 2,4-D rates of 0.5, 1 and 2 oz./A and dicamba at 0.1, 0.5 and 1.0 oz/A. (A. Dexter)

MCPA or dicamba, which causes a sunflower height reduction, also would be expected to reduce yield. However, typical injury symptoms can occur without height reduction and this would not be expected to reduce yield.

MCPA, 2,4-D, dicamba and Tordon are growth-regulator herbicides and all produce similar symptoms on sunflower. Sunflower exhibits epinasty, which is an abnormal bending of stems and/or leaf petioles, shortly after contact with a growth-regulator herbicide. Figure 113 shows the bending of sunflower only 24 hours after 2,4-D application while Figure 114 shows the abnormal twisting of leaf petioles several days after 2,4-D application. Sunflower growth often is slowed or stopped by growth-regulator herbicides.

Leaves that develop after contact with a growth-regulator herbicide often are malformed. Leaves may have more parallel vein patterns and abnormal leaf shapes (Figure 115). A higher degree of injury from a growth-regulator herbicide may stop plant growth totally. Some plants die without further growth, some will remain green and not grow the rest of the season, and some plants will begin growing later after the herbicide is partially metabolized. Sunflower in Figure 116 did not grow for several days and then produced a stalk and flower.

Affected plants also may branch and produce multiple heads when growth resumes (Figure 117). Root

Figure 113. Bending of sunflower only 24 hours after 2,4-D application. (A. Dexter)

Figure 115. Growth regular herbicides may cause leaves of sunflower to have more parallel vein patterns and abnormal leaf shapes. (A. Dexter)

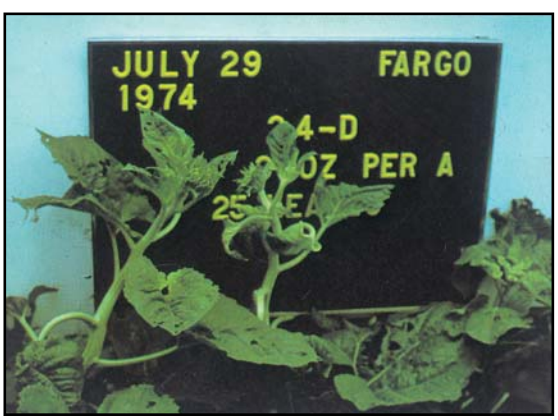


Figure 114. Abnormal twisting of leaf petioles several days after 2,4-D application. (A. Dexter)

Figure 116. Interrupted growth of sunflower due to exposure to growth regulator herbicide. (A. Dexter)

growth may be retarded by growth-regulator herbicides and abnormal lumps or knots may develop on sunflower roots (Figure 118). Sunflower contacted by growth-regulator herbicides during the bud or flowering stage may develop malformed heads or heads with sterility (Figure 119).

Figure 117. Multiple branching and heading of sunflower due to exposure to growth regulator herbicides. (A. Dexter)

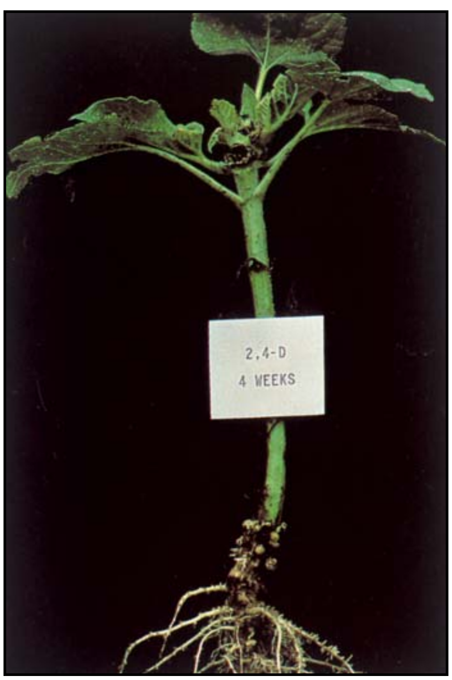


Figure 118. Abnormal lumps and knots on sunflower roots developed after exposure to growth regulator herbicides. (A. Dexter)

Sunflower plants contacted with a growth-regulator herbicide will not develop all of the symptoms shown in Figures 112 through 117. Considerable variation in symptomology can occur, depending on herbicide rate, sunflower stage and environment.

Symptoms similar to those shown in Figures 114 to 119 also may be produced by soil residues of herbicide. MCPA and 2,4-D have very short soil residual, but damage to sunflower could occur if they were applied just before planting or emergence. Tordon has a long soil residual and can carry over from the previous year and cause sunflower injury. Dicamba at rates used in small grains would not be expected to carry over to the next year. Dicamba used in the fall at rates necessary to control certain perennial weeds may persist in the soil and damage sunflower the next year. Accent, Ally, Amber, atrazine, Beacon and Pursuit are long residual herbicides that may persist for more than one year at levels that can injure sunflower. The length of persistence can be affected by pH (high pH causes longer residue of some herbicides), application rate and soil moisture.

The symptoms from these herbicides are not similar to symptoms from growth-regulator herbicides. Sunflower affected by Accent, Ally, Amber, Beacon or Pursuit emerge and become well-established. Chlorosis starts on the young leaves often with a distinct yellowing. Top growth and roots may be severely stunted. Plants may remain small for several weeks or they may die.

Figure 119. Sunflowers contacted by growth regulator herbicides during bud or flowering stage developed malformed heads or heads with sterility. (A. Dexter)

Low doses may cause temporary stunting and plants later may begin to grow normally. Sunflower affected with atrazine emerge and look normal for a short time. Leaf burn starts on the outer edges of the oldest leaves and progresses toward the middle of the leaf. Veinal areas are the last to turn brown in an affected leaf.

The risk of sunflower injury from herbicide drift is influenced by several factors.

Spray particle size: Spray drift can be reduced by increasing droplet size since larger droplets move laterally less than small droplets. Droplet size can be increased by reduced spray pressure; increased nozzle orifice size; use of special nozzles, such as "Raindrop," "LFR," "XR" or "LP;" use of additives that increase spray viscosity; rearward nozzle orientation; and increased nozzle pressure on aircraft. Research has shown that increasing nozzle pressure in a rearward-oriented nozzle in a high-speed air stream will produce larger droplets and less fines. This is due to less secondary wind shear, and does not happen with ground sprayers.

Spray pressure with standard flat-fan nozzles should not be less than 25 pounds per square inch (psi) because the spray pattern from the nozzles will not be uniform at lower pressures. The "XR" and "LP" nozzles are designed to give a good spray pattern at 15 to 50 psi. Operating at a low spray pressure results in larger spray droplets. Some postemergence herbicides, such as bentazon, require small droplets for optimum performance, so techniques that increase droplet size may reduce weed control with certain herbicides. Herbicides that readily translocate, such as 2,4-D, MCPA, dicamba and Tordon, are affected little by droplet size within a normal droplet size range, so drift control techniques would not be expected to reduce weed control with these herbicides. Glyphosate is translocated readily, so droplet size has minimum effect on weed control. However, glyphosate is inactivated partially by increased water volume and spray volume recommendations on the label should be followed.

Herbicide volatility: All herbicides can drift in spray droplets, but some herbicides are sufficiently volatile to cause plant injury from drift of vapor or fumes. The ester formulations of 2,4-D and MCPA may produce damaging vapors, while the amine formulations are essentially nonvolatile. Dicamba is a volatile herbicide and can drift in droplets or vapor.

Herbicide vapors may cause crop injury over greater distances than spray droplets. However, spray droplets can move long distances under certain environmental conditions, so crop injury for a long distance does not necessarily result from vapor drift. A wind blowing away from a susceptible crop during herbicide application will prevent damage from droplet drift, but a later wind shift toward the susceptible plants could move damaging vapors into the susceptible crop.

Herbicide volatility increases with increasing temperature. The so-called high-volatile esters of 2,4-D or MCPA may produce damaging vapors at temperatures as low as 40 degrees Fahrenheit, while low-volatile esters may produce damaging vapors between 70 and 90 F. The soil surface temperature often is several degrees warmer than air temperature, so a low-volatile ester could be exposed to temperature high enough to cause damaging vapors, even when the air temperature was less than 70 F.

Wind velocity and air stability: Wind, or the horizontal movement of air, is widely recognized as an important factor affecting spray drift. However, vertical movement of air also has a large influence on damage to nontarget plants from spray drift. An air mass with warmer air next to the ground and decreasing temperature with increasing elevation will be unstable. That is, the warm air will rise and the cool air will sink, providing vertical mixing of air. Stable air, often called an inversion, occurs when air temperature increases or changes little as elevation increases. With these temperature relationships, very little vertical movement of air occurs since cool air will not rise into warmer air above. Spray droplets or vapor are carried aloft and dispersed away from susceptible plants with unstable air conditions. With stable air (inversion), small spray droplets may be suspended just above the ground in the air mass, move long distances laterally and be deposited on susceptible plants.

Low wind velocity in combination with unstable air generally will result in very little damaging spray drift. However, low wind velocity with stable air (inversion) can result in severe damage over a long distance. Crop injury has been observed two miles or more from the site of application with 10 mph or slower winds, small spay droplets, stable air, highly susceptible crops and nonvolatile but highly active herbicides. Long-distance drift can occur with particle drift as well as vapor drift.

Stable air usually can be identified by observing dust off a gravel road or smoke from a fire or smoke bomb. Smoke or dust moving horizontally and staying close to the ground would indicate stable air. Fog also would indicate stable air. Herbicide application should be avoided during stable air conditions unless spray drift is not a concern.

Distance between nozzle and target (boom height): Less distance between the droplet release point and the target will reduce spray drift. Less distance means less time to travel from nozzle to target, so less drift occurs. Small spray droplets have little inertial energy, so a short distance from nozzle to target increases the chance that the small droplets can reach the target. Also, wind velocity often is greater as height above the ground increases, so reduced nozzle height will reduce the wind velocity affecting the spray droplets.

Shielded sprayers: Shielded sprayers utilize some type of shielding to protect spray droplets from wind. The effectiveness of the shields varies, depending on the design of the shield, wind velocity and wind direction relative to the sprayer. Drift from shielded sprayers has varied from about 50 percent to more than 95 percent less than from similar nonshielded sprayers in experiments with various shield designs and conditions.

Herbicide drift can reduce sunflower yield severely. The risk of herbicide drift can be reduced greatly by increasing droplet size, reducing nozzle height, using nonvolatile herbicides, avoiding spraying during temperature inversions, using shielded sprayers and spraying when the wind is blowing away from a susceptible crop.

Chemical Residue in the Tank and Sprayer Cleanout

Crop injury from a contaminated sprayer may occur when a herbicide not registered on sunflower was used previously in the sprayer. The risk of damage is greatest when the previous herbicide is highly phytotoxic to sunflower in small amounts. Rinsing with water is not adequate to remove all herbicides. Some herbicides have remained tightly adsorbed in sprayers through water rinsing and even through several tank loads of other herbicides. Then, when a tank load of solution including an oil adjuvant or nitrogen solution was put in the sprayer, the herbicide was desorbed, moved into the spray solution and damaged susceptible crops. Highly active herbicides that have been difficult to wash from sprayers and have caused crop injury include ALS herbicides (Accent, Ally, Beacon, Express, Pursuit and Raptor), and growth-regulator herbicides (2,4-D and dicamba).

Herbicides that are difficult to remove from sprayers are thought to be attaching to residues remaining from spray solutions that deposit in a sprayer. The herbicide must be desorbed from the residue or the residue removed in a cleaning process so the herbicide can be removed from the sprayer. Sprayer cleanout procedures are given on many herbicide labels and the procedure on the label should be followed for specific herbicides. The following procedure is given as an illustration of a thorough sprayer cleanup procedure that would be effective for most herbicides.

Step 1. Drain tank and thoroughly rinse interior surfaces of tank with clean water. Spray rinse water through the spray boom. Sufficient rinse water should be used for five minutes or more of spraying through the boom.

Step 2. Fill the sprayer tank with clean water and add a cleaning solution (many herbicide labels provide recommended cleaning solutions). Fill the boom, hoses and nozzles and allow the agitator to operate for 15 minutes.

Step 3. Allow the sprayer to sit for eight hours while full of cleaning solution. The cleaning solution should stay in the sprayer for eight hours so that the herbicide can be fully desorbed from the residues inside the sprayer.

Step 4. Spray the cleaning solution out through the booms.

Step 5. Remove nozzles, screens and filters and clean thoroughly. Rinse the sprayer to remove cleaning solution and spray rinsate through the booms.

Common types of cleaning solutions are chlorine bleach, ammonia and commercially formulated tank cleaners. Chlorine lowers the pH of the solution, which speeds the degradation of some herbicides. Ammonia increases the pH of the solution, which increases the solubility of some herbicides. Commercially formulated tank cleaners generally raise pH and act as detergents to assist in removal of herbicides. Read the herbicide label for recommended tank cleaning solutions and procedures. **WARNING: Never mix chlorine bleach and ammonia, as a dangerous and irritating gas will be released.**

Sprayers should be cleaned as soon as possible after use to prevent the deposit of dried spray residues. If a sprayer will remain empty overnight without cleaning, fill the tank with water to prevent dried spray deposits from forming. A sprayer kept clean is essential to prevent damage from herbicide contamination.

Harvesting

(Vern Hofman)

Maturity

Sunflower in the northern Great Plains production area usually is ready for harvest in late September or October, with a growing season of approximately 120 days. The growing season may vary in length, depending on summer temperatures, relative moisture distribution and fertility levels. The sunflower plant is physiologically mature when the back of the head has turned from green to yellow and the bracts are turning brown (Stage R-9), about 30 to 45 days after bloom, and seed moisture is about 35 percent.

Desiccants can be applied to the crop after physiological maturity to speed the dry-down process. The chemical compounds act much like a frost to kill the green tissue on the plant and accelerate its drying. After applications of a desiccant, dry down of the seed is not as rapid as the dry down of the plant. Growers often are tempted to apply desiccants too early when potential loss factors are present. Application of a desiccant before the plant reaches physiological maturity will reduce yield and lower oil percentage. Drying is facilitated in most years by a killing frost, but if frost occurs too early, yield and oil percentages are reduced.

Seed shattering loss during harvest and loss from birds may be reduced by harvesting sunflower at moisture contents as high as 25 percent. Sunflower seed from the combine then is dried in a grain dryer to 9.5 percent, which is considered a safe storage level.

Harvesting Attachments

Combines suitable for threshing small grains can be adapted to harvest sunflower. A variety of header attachments are available, with many operating on a head stripper principle.

The attachments are designed to gather only the sunflower heads and eliminate as much stalk as possible. Major components of this attachment are catch pans, a deflector and a small reel. Long catch pans extend ahead of the cutter bar to catch the seed as it shatters. The deflector mounted above the catch pans pushes the stalk forward until only the heads remain above the cutter bar. As the heads move below the deflector, the stems contact the cutter bar and are cut just below the head. A small reel, mounted directly behind the deflector, pushes the heads into the combine feeder.

Catch pans are available in various widths. These range from narrow 9-inch pans spaced on 12-inch centers (Figure 120) to 37-inch pans spaced on 40-inch centers (Figure 121). The narrow 9-inch pans can operate on any row spacing, while the wider and more efficient 30- to 40-inch spaced pans are limited to a fixed-row spacing.

The deflector consists of a curved piece of sheet metal the full width of the combine head. It is attached to the reel support arms above the catch pans. The reel for the unit is mounted directly behind the deflector and usually consists of three or four arms. The reel is usually 16 to 20 inches in diameter and mounted 4 to 5 inches above the catch pans, so when the heads come in contact with the reel, they are pushed back into the feeder. The shield and reel can handle tall plants while taking only a minimum length of stalk with the head, allowing harvest when the seed is dry but stalk moisture may remain above 50 percent. Cleaner threshing also is accomplished when only the head enters the machine.

Optional forward rotating stalk-walker shafts, introduced from Argentina and used mainly in the southern Plains, can be mounted under the cutter bar to reduce plugging of stalk slots between pans. The stalk-walker pulls sunflower stalks and weeds down so that only the sunflower head is fed into the combine. Stalk-walkers are reported to be especially useful in fields with tall weeds.

A rotating drum with metal projections that replaces the deflector bar and reel often is used (Figure 122). The projections are triangular-shaped pieces of strap iron welded to its surface. As the drum rotates, the projections pass through the slots between the catch pans to remove any stalks that may cause clogging. The smooth drum acts as a deflector bar to strip stalks until one of the projections catches a head and pushes it into the cutter bar and into the combine header.

Row-crop units mounted on combine headers have been used successfully to harvest sunflower seed (Figure 123). One unit uses gathering belts, one on each side of the row, to draw the stalk into the cutting unit and the header. A large quantity of stalk passes through the machine with this unit and may increase the foreign matter in the seed, but this unit works well picking up lodged sunflower and getting the heads into the machine.

Another type of header uses a short section of screw conveyor to pull the stalks into the cutter bar and the combine header. This unit also works well for picking up lodged sunflower.

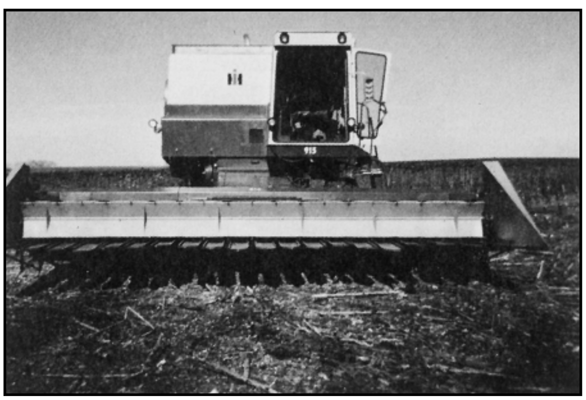


Figure 120. Catch pans in narrow 9 inch pans spaced on 12 inch centers. (V. Hofman)

Figure 122. Rotating drum with metal projections. (V. Hofman)

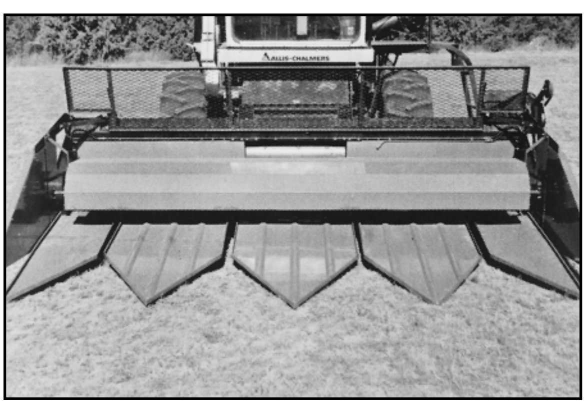


Figure 121. Catch pans in wide 37 inch pans spaced on 36 inch centers. (V. Hofman)

Figure 123. All crop header used to harvest sunflower. (V. Hofman)

Combine Adjustments

Forward Speed: A combine's forward speed usually should average between 3 and 5 miles per hour. Optimum forward speed usually will vary depending upon moisture content of the sunflower seed and yield of the crop. Forward speed should be decreased as moisture content of the seed decreases to reduce the shatter loss as the heads feed into the combine. Faster forward speeds are possible if the moisture of the seed is between 12 percent and 15 percent. The higher speeds should not overload the cylinder and the separating area of the combine except in an extremely heavy crop. Seed having 12 percent to 15 percent moisture will thresh from the head very easily as it passes through the cylinder.

Cylinder Speed: After the sunflower heads are separated from the plant, they should be threshed at a cylinder speed operating as slow as possible. The normal cylinder speed should be about 300 revolutions per minute (rpm), depending upon the condition of the crop and the combine being used. This cylinder speed is for a combine with a 22-inch-diameter cylinder to give a cylinder bar travel speed of 1,725 feet per minute. Combines with smaller cylinders will require a faster speed and combines with a larger cylinder diameter will require a slower speed. Rotary combines, as well as conventional machines, should have similar cylinder travel speeds. A rotary combine with a 30-inch cylinder will need to be operated at 220 rpm to have a cylinder bar speed of 1,725 feet per minute. A combine with a 17-inch cylinder will need to operate at 390 rpm to have a cylinder bar speed of 1,725 feet per minute.

If a combine cylinder operates at speeds of 400 to 500 rpm, giving a cylinder bar speed of more than 2,500 feet per minute, very little seed should be cracked or broken if the moisture content of the seed is above 11 percent. Cylinder bar speeds of more than 3,000 feet per minute should not be used because they will cause excessive broken seed and increased dockage. Excess dockage and broken seed may overload the sieves and the return elevator.

Concave Adjustment: Sunflower threshes relatively easily. When crop moisture is at 10 percent or less, conventional machines should be set wide open to give a cylinder-to-concave spacing of about 1 inch at the front of the cylinder and about 0.75 inch at the rear. A smaller concave clearance should be used only if some seed is left in the heads. If the moisture percentage of the crop is between 10 percent and 12 percent, rather than increase the cylinder speed, the cylinder-to-concave clearance should be decreased to improve threshing. If seed moisture exceeds 15 percent to 20 percent, a higher cylinder speed and a closer concave setting may be necessary, even though foreign material in the seed increases. Seed breakage and dehulling may be a problem with close concave settings. Make initial adjustments as recommended in the operator's manual. Final adjustments should be made based on crop conditions.

Rotary combines should be set to have a rotor-to-concave spacing of about 0.75 to 1 inch. Making initial settings as recommended in the operator's manual usually is best. Final adjustments should be made based on crop conditions.

Fan Adjustment: Oilseed and nonoilseed sunflower weigh about 28 to 32 pounds per bushel and 22 to 26 pounds per bushel, respectively. The seed is relatively light compared with other crops, so excessive wind may blow seed over the chaffer and sieve. Seed forced over the sieve and into the tailings auger will be returned to the cylinder and may be dehulled. Only enough wind to keep the trash floating across the sieve should be used. The chaffer and sieve should be adjusted to minimize the amount of material that passes through the tailings elevator.

When the combine is adjusted correctly to thresh sunflower seed, the threshed heads will come through only slightly broken and with only unfilled seed remaining in the head. Cylinder concaves and cleaning sieves usually can be set to obtain less than 5 percent dockage. Improper settings will crush the seed but leave the hull intact. Proper setting is critical, especially for nonoilseed sunflower that is used for the human food market. The upper sieve should be open enough to allow an average seed to pass through on end, or be set at a ½- to 5/8- inch opening. The lower sieve should be adjusted to provide a slightly smaller opening, or about 3/8 inch wide. The final adjustments will depend on the amount of material returning through the tailings elevator and an estimation of the amount of dockage in the grain tank. Some operators are able to adjust and operate their machine to allow only 2 percent to 3 percent dockage in the seed.

Field Loss

The harvested yield of sunflower can be increased by making necessary adjustments following a determination of field loss. Three main sources of loss are: (a) loss in the standing crop ahead of the combine, (b) header loss as the crop enters the machine and (c) threshing and separating loss. The loss found in any of these three areas will give the combine operator a good estimate of sources of seed loss and the adjustments necessary to minimize seed loss.

Loss occurring in any of these areas may be estimated by counting the seed on the soil surface in a square-foot area. Ten seeds per square foot equal approximately 1 hundredweight (cwt) per acre loss if seed loss is uniform throughout the entire field.

The loss in the standing crop is estimated by counting the seed in a 1-square-foot area ahead of the machine at several different places in the field. Header loss can be calculated by counting seed in a 1-square-foot area behind the head under the combine and subtracting the standing crop loss. The loss in combine separation can be found by counting the seed in a 1-square-foot area directly behind the rear of the combine and subtracting the shatter loss and the header loss found under the machine. The count made directly behind the combine will be concentrated, so an adjustment must be made to equalize the loss over the entire width of cut. The result should be divided by the ratio:

$$\frac{\textbf{Width of Header Cut (feet)}}{\textbf{Width of Rear of Combine (feet)}}$$

The answer is the adjusted separator loss for the width of cut. This result must be divided by 10 to obtain the combine separator loss in cwt per acre. The total loss in cwt per acre is determined by adding the seed loss in the standing crop, header loss and separator loss and dividing this answer by 10. The percentage loss can be found by dividing the total cwt per acre by the yield in cwt per acre.

Harvest without some seed loss is almost impossible. Usually a permissible loss is about 3 percent. Loss as high as 15 percent to 20 percent has occurred with a well-adjusted combine if the ground speed is too fast, resulting in machine overload.

Drying and Storage

(Kenneth Hellevang)

Harvesting sunflower at higher moisture contents normally results in higher yields and less field loss. Early harvest also reduces exposure to late-season wet and cold weather. Frequently, mechanical drying is required so harvesting can be completed.

Natural-air, low-temperature and high-temperature bin, batch (Figure 124) and continuous-flow dryers can be used to dry sunflower.

Natural-air and low-temperature bin drying is energy efficient if designed properly and permits rapid harvest since bins can be filled at the harvest rate. Drying will take three to six weeks, depending on the initial moisture content, airflow rate and outdoor temperature. Required airflow rates and drying time for drying oil sunflower at various moisture contents using air at 47 degrees Fahrenheit and 65 percent relative humidity (average North Dakota conditions for October) are shown in Table 16. Drying times will be twice as long at 27 degrees due to the reduced moisture-holding capacity at colder temperatures. Heating the air more than about 5 degrees normally causes overdrying.

Figure 124. A high temperature column dryer used for drying sunflower. (K. Hellevang)

Table 16. Recommended airflow rates and drying times for natural-air drying oilseed sunflower in October. (47 F and 65 percent relative humidity).

Moisture Content	Airflow (cfm/bu)	Fan Time hours	Fan Time days
17%	1.00	648	27
15%	1.00	480	20
	0.75	720	30
	0.50	960	40
13%	1.00	336	14
	0.75	504	21
	0.50	672	28

Add enough heat when needed to dry the sunflower to the safe storage moisture content. Generally, enough heat to warm the air about 5 degrees is the maximum amount required. As a rule of thumb, about 2 kilowatts (kW) of heater will be required per fan motor horsepower. The equation for calculating the heat requirement in Btu is: Btu/hr = cfm x 1.1 x temperature increase. Convert Btu to kW by dividing by 3,413 Btu/kW. Refer to NDSU Extension Service publication EB-35, "Natural Air and Low Temperature Crop Drying," and publication AE-701, "Grain Drying," for more information on drying sunflower.

A perforated floor is recommended. Since air does the drying, making sure air reaches all the sunflower is imperative. The uniform airflow distribution required for drying is more difficult to achieve with ducts than with perforated floors. However, drying can be done successfully if ducts are spaced no more than one-half the grain depth apart and the distance from the duct to bin wall does not exceed one-fourth the grain depth. Provide 1 square foot of duct or floor perforated surface area for each 25 cubic feet per minute (cfm) of airflow. One square foot of bin exhaust opening should be provided for each 1,000 cfm of airflow.

Drying temperatures up to 220 F do not appear to have an adverse effect on oil percentage or fatty acid composition. High drying temperatures for the nonoil varieties may cause the kernels to be steamed, wrinkled or even scorched.

Column batch and bin batch dryers should be operated at 180 and 120 F, respectively. Continuous-flow and recirculating batch dryers may be operated at temperatures up to about 200 F. Temperatures in excess of 110 F should not be used to dry sunflower seed for seeding purposes.

Fire hazards exist in dryers used for sunflower. Very fine hairs or fibers from the seed are rubbed loose during handling and commonly are found floating in the air around the dryer. These hairs or fibers or other plant materials may be ignited when drawn through the drying fan and open burner. A fire hazard is present unless these ignited particles burn themselves out before contacting the sunflower seed.

The fire hazard is decreased if the fans of a portable dryer are turned into the wind to draw clean air that does not contain fine hair or fibers and by pointing stationary dryers into the prevailing wind. A moveable air intake duct may be placed on the burner intake to draw clean air away from the dryer. However, the duct must be large enough to not restrict the airflow because drying speed will be reduced if the airflow is reduced.

Clean the dryer, air ducts and area around the dryer at least daily. Frequently remove the collection of sunflower lint on the dryer column and in the plenum chamber, as this material becomes extremely dry and can be ignited during dryer operation. A major concern is that some sunflower seeds will hang up in the dryer or be stopped by an accumulation of fines and become overdried. Make sure the dryer is completely cleaned out after each batch, and check a continuous-flow dryer regularly (at least hourly) to see that the sunflower seed is moving.

High-speed dryers are like a forge when a fire gets going. However, fires can be controlled if they are noticed immediately, which makes constant monitoring necessary. Many fires can be extinguished by just shutting off the fan to cut off the oxygen. A little water applied directly to the fire at the early stages may extinguish it if shutting off the fan fails to do so. A fire extinguisher for oil-type fires should be used for oil sunflower fires. Many dryers are designed so that sunflower can be unloaded rapidly in case of a fire, before the dryer is damaged. In some dryers, just the part of the dryer affected by the fire needs to be unloaded.

Measuring Moisture Content

Measuring the moisture content of sunflower immediately after removal from the dryer results in only an estimation. As moisture is removed from the sunflower seed, the hull dries first and the kernels dry last. Moisture testers used by local grain elevators and farm operators generally result in a reading that is lower than the actual moisture percentage when moisture is measured while the moisture variation exists. The initial moisture content of the sunflower and the temperature of the drying air influence the amount of error. A number of operators have reported that sunflower removed from the dryer at 9 percent to 10 percent moisture (according to the moisture tester) would be up to 12 percent moisture later. The moisture rebound can be estimated by placing a sample from the dryer in a covered jar and then rechecking the moisture after 12 hours.

Guidelines for drying sunflower are:

- The area around the dryer and the plenum chamber should be cleaned thoroughly.
- The fan must be fed clean air without seed hairs.
- A continuous flow in all sections of recirculating batch and continuous-flow dryers should be maintained. Uneven flow will cause overdried spots and increase fire hazard.
- Drying equipment must not be left unattended day or night.
- The dried sunflower should be cooled to air temperature before storing.

Storage

Farm structures that are structurally adequate to store other grains are adequate for storing sunflower due to sunflower's light test weight, Figure 125.

Seed should be cleaned for storage. Fines tend to concentrate in the center of the bin if a distributor is not used. Since this material tends to be wetter, this area is more prone to storage problems. Also, airflow will be restricted by the fines, limiting cooling by aeration in the center of the bin. Large pieces of head, stalk and corolla tubes, which frequently adhere to the seed, should be removed because they are higher in moisture than the seed.

Oil sunflower should not be stored above 10 percent moisture during the winter and 8 percent during the summer. Nonoilseed sunflower should not be stored above 11 percent moisture during the winter and 10 percent during the summer. Sunflower can be stored for short periods in the fall at 12 percent with adequate airflow to keep the seeds cool. Resistance of oilseed sunflower to fungal infection during storage at 10 percent moisture is equal to wheat resistance at 15 percent stored moisture.

Figure 125. Structures adequate to store other grains are adequate for sunflower. (K. Hellevang)

Aeration to control seed temperature is essential. Aeration fans normally are sized to provide 0.05 to 0.2 cfm/bu. (0.15 to 0.6 cfm per cwt) of sunflower (Figure 126). Sunflower should be rotated between bins during the storage period when aeration is not available.

Cooling sunflower reduces the potential for sunflower deterioration from insects and mold. Sunflower should be cooled to 40 degrees or below before or soon after it is put in the bin and to about 25 degrees for winter storage. Insects become dormant and will not cause damage or multiply if seed temperature is below about 40 F.

Moisture and heat accumulate in the peak due to moisture migration, which results in crusting, spoilage and increased possibility of insect infestations (Figure 127). This can be prevented by cooling the sunflower using aeration.

Bins should be checked initially every two weeks for moisture condensation on the roof, crusting and changes in temperatures within the pile. Any of these conditions could indicate the presence of mold or insects. If the sunflower has started to heat, it should be cooled immediately. The sunflower should be checked at least monthly after the seeds have been cooled to about 25 F for winter storage and a history of temperature and moisture content has been developed.

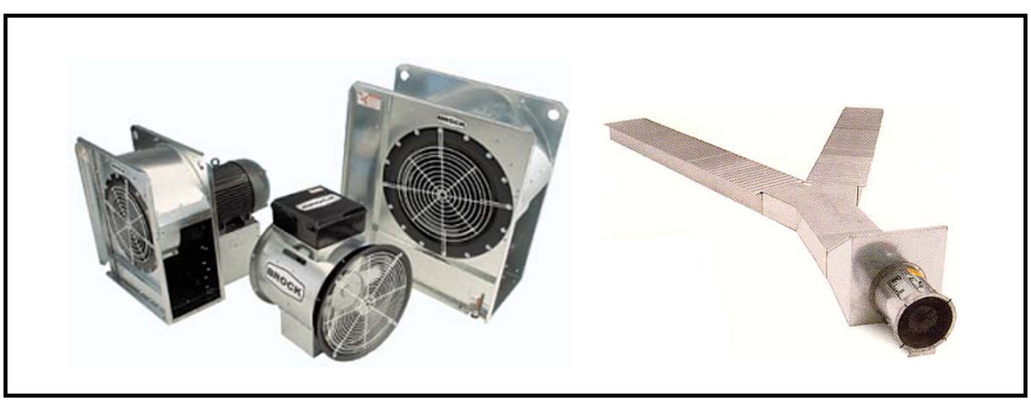


Figure 126. Aeration is critical for proper storage. (K. Hellevang)

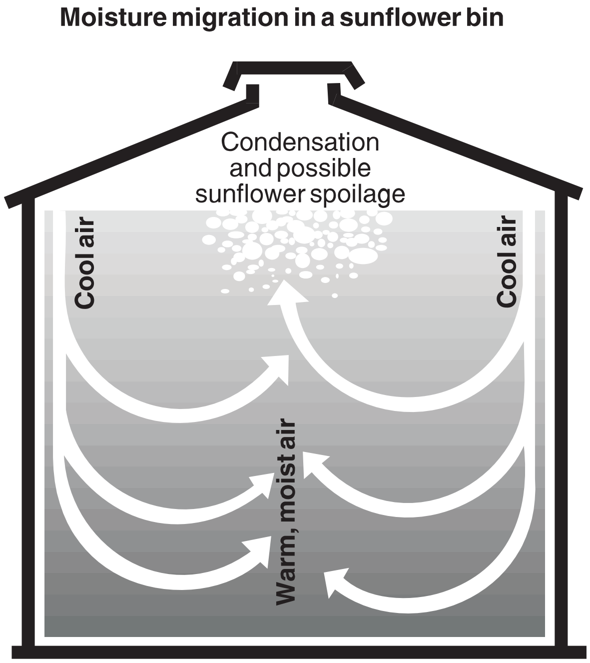


Figure 127. Moisture migration leads to increased moisture in top center of stored sunflower.
(K. Hellevang)

Seed lots containing a high percentage of hulled seed or immature seed, such as seed resulting from an early frost, tend to deteriorate in storage, affecting oil quality.

Refer to NDSU Extension Service publication AE-791, "Crop Storage Management," for more information on aeration and storage management.

Feeding Value of Sunflower Products in Beef Cattle Diets

(Greg Lardy)

Sunflower Meal

Nutrients in sunflower meal can vary depending on several factors. The amount and composition of meal is affected by oil content of the seed, extent of hull removal and efficiency of oil extraction. The proportion of hull removed before processing differs among crushing plants. In some cases, a portion of the hulls may be added back to the meal after crushing. The amount of hull or fiber in the meal is the major source of variation in nutrients (Table 17).

Pre-press solvent extraction of whole seeds with no dehulling produces meal with a crude protein content of 25 percent to 28 percent, partial dehulling yields 34 percent to 38 percent crude protein content and completely dehulled sunflower meal commonly yielding 40-plus percent crude protein. Sunflower meal is marketed and shipped as meal or pellets. Protein required by rumen microbes can be provided in the form of rumen-degradable protein from sunflower meal. Heat treatment or toasting of meal from the solvent extraction process may increase the proportion of undegradable protein. Sunflower meal is more ruminally degradable (74 percent of crude protein) than either soybean meal (66 percent) or canola meal (68 percent; Table 18).

Sunflower meal has a lower energy value than either canola or soybean meal (Table 18). Energy varies substantially with fiber level and residual oil content. Higher levels of hulls included in the final meal product lower the energy content and reduce bulk density. The mechanical process of oil extraction leaves more residual oil in the meal, often 5 percent to 6 percent or more, depending on the efficiency of the extraction process. Elevated oil content in mechanically extracted meals provides greater energy density. Pre-press solvent extraction reduces residual oil to 1.5 percent or less.

Table 17. Nutrient content of solvent-extracted sunflower meal based on amount of hulls retained.

	No Hulls Removed	Partially Dehulled	Dehulled
Dry Matter, %	**90.0**	**90.0**	**90.0**
	Percent, Dry Matter Basis		
Crude Protein	28.0	34.0	41.0
Fat	1.5	0.8	0.5
Crude Fiber	24.0	21.0	14.0
Ash	6.2	5.9	5.9
Calcium	0.36	0.35	0.34
Phosphorus	0.97	0.95	1.30
Potassium	1.07	1.07	1.07
Magnesium	0.80	0.79	0.79

Hesley (ed), National Sunflower Association, 1994.

Sunflower Meal in Beef Cattle Diets

Sunflower meal can be used as the sole source of supplemental protein in beef rations. In trials comparing sunflower meal with other protein sources, equal animal performance commonly is observed based on isonitrogenous diets from different sources.

Cows consuming low-quality forages, such as winter range, crop aftermath or other low-quality forages, can utilize supplemental degradable protein to increase total intake, forage digestibility and performance. Protein can be supplemented with a number of feeds, coproducts or oilseed meals. Least costly sources are critical to profitability, and sunflower meal often is very competitively priced per unit protein. Sunflower meal has been used widely in beef cow supplementation programs but few research trials document comparative animal performance.

Table 18. Protein and energy fractions for sunflower meal, soybean meal and canola meal.

Item	Sunflower Meal	Soybean Meal	Canola Meal
		Dry Matter Basis, %	
Crude Protein	26.0	49.9	40.9
		Crude Protein, %	
Rumen Degradable	74.0	66.0	68.0
Rumen Undegradable	26.0	34.0	22.0
		Dry Matter Basis, %	
Crude fiber	12.7	7.0	13.3
Neutral Detergent Fiber	40.0	14.9	27.2
Acid Detergent Fiber	30.0	10.0	17.0
Net Energy, Maintenance, Mcal/lb	0.67	0.93	0.73
Net Energy, Gain, Mcal/lb	0.40	0.64	0.45
Total Digestible Nutrients	65	84	69

Adapted from NRC, 1996.

Sunflower Silage

Sunflower silage can make a suitable feed for beef cows; however, high moisture levels can be a challenge since sunflowers typically don't dry down well. Consequently, dry feed must be added to the silage pile to reduce the moisture level to a point where seepage is not a major problem.

Table 19 gives the estimated nutrient content of sunflower silage produced from either low-oil or high-oil varieties of sunflower. Depending on what other feeds are mixed in the silage pile, nutrient contents may change.

Blending corn and sunflower silages together can help alleviate the moisture problem. Producers also may consider waiting seven to 10 days following a killing frost to facilitate dry down. Blending dry forage into the silage pile also can reduce moisture content. To minimize seepage problems, the moisture level should be 65 percent or less.

Whole Sunflower Seeds

When economical, whole sunflower seeds can be used as a source of energy and protein in beef cattle diets (Table 19). Fat levels can be quite high in whole seeds; consequently, amounts fed should be restricted based on fat content of the seed. Typically, no more than 4 percent supplemental fat should be added to cow diets to reduce the potential for any detrimental effects on fiber digestion. This will result in inclusion levels of approximately 10 percent of the diet.

Sunflower Residue

Sunflower residue is useful for aftermath grazing by beef cows. Nutritional value of the head is greater than the stalk. Supplementation may be required if the volume of residue is limited and nutrient quality decreases rapidly after head material is consumed.

Sunflower Screenings

Sunflower screenings from both confection and oil seed plants are often available at competitive prices. Nutrient content varies widely with the amount of meats, which are high in fat and protein, and hull, which is low in nutrient content and digestibility. Screenings are best used in modest growing or maintenance diets when animal performance is not critical. The presence of sclerotia bodies does not appear to be a problem for palatability, nutrient content or animal performance.

Sunflower Hulls

Sunflower hulls are low in protein and energy and should be used only as a bedding source.

Summary

That sunflower meal is a useful protein source for growing and finishing cattle is apparent from the limited research. Similarly, beef cows can be provided supplemental protein effectively with sunflower meal. Sunflower meal may be especially useful in diets where degradable protein is required, such as lower-quality forage or high corn finishing rations. The increased bulk of this relatively high-fiber meal may affect logistics, but ruminants are positioned to be more tolerant of high fiber levels than other species. Other sunflower products can be used effectively in ruminant diets, given appropriate performance expectations.

Table 19. Nutrient content of sunflower products.

	DM, %	TDN, %	NE_m, Mcal/lb	NE_g, Mcal/lb	CP, %	ADF, %	Ca, %	P, %
Sunflower Hulls*	90.0	40.0	0.41	0.00	5.0	63.0	0.00	0.114
Sunflower Screenings*	87.0	64.0	0.66	0.39	11.1	29.0	0.72	0.42
Sunflower Seed, Confectionary*	94.9	83.0	0.93	0.63	17.9	39.0	0.18	0.56
Sunflower Seeds, Oil Type*	94.9	121.0	1.42	1.03	17.9	39.0	0.18	0.56
Sunflower Silage, Low-oil Variety**	30.0	61.0	0.61	0.69	11.1	42.0	0.8	0.3
Sunflower Silage, High-oil Variety**	30.0	66.0	0.35	0.42	12.5	39.0	1.50	0.3

*Adapted from Lardy and Anderson, 2003.
**Adapted from Park et al., 1997.

U.S. Grades and Standards for Sunflower

(Duane R. Berglund)

Definition of Sunflower Seed

Grain that, before the removal of foreign material, consists of 50 percent or more of cultivated sunflower seed (Helianthus annuus L.) and not more than 10 percent of other grains for which standards have been established under the U.S. Grain Standards Act.

Definition of Other Terms

Cultivated sunflower seed - Sunflower seed grown for oil content. The term seed in this and other definitions related to sunflower seed refers to both the kernel and hull, which is a fruit or achene.

Damaged sunflower seed - Seed and pieces of sunflower seed that are badly ground-damaged, badly weather-damaged, diseased, frost-damaged, heat-damaged, mold-damaged, sprout-damaged or otherwise materially damaged.

Dehulled seed - Sunflower seed that has the hull completely removed from the sunflower kernel.

Foreign material - All matter other than whole sunflower seeds containing kernels that can be removed from the original sample by use of an approved device and by handpicking a portion of the sample according to procedures prescribed in the USDA's Federal Grain Inspection Service instructions.

Heat-damaged sunflower seed - Seed and pieces of sunflower seed that are materially discolored and damaged by heat.

Hull (husk) - The ovary wall of the sunflower seeds.

Kernel - The interior contents of the sunflower seed that are surrounded by the hull.

Basis of Determination

Each determination of heat-damaged kernels, damaged kernels, test weight per bushel and dehulled seed is made on the basis of the grain when free from foreign material. Other determinations not specifically provided for in the general provisions are made on the basis of the grain as a whole, except the determination of odor is made on either the basis of the grain as a whole or the grain when free from foreign material.

Table 20 lists the U.S. grade requirements for sunflower according to the Federal Grain and Inspection Service. These requirements became effective Sept. 1, 1984. The table lists the minimum limit for test weight and the maximum for damaged and dehulled seed. U.S. grades for both oilseed and nonoilseed classes of sunflower are determined with the requirements listed below.

Table 20. Grade and grade requirements for sunflower.

Grade	Minimum test weight per bushel	Maximum limits of damaged sunflower seed: Heat damage	Total	Dehulled seed
	(pounds)	- - - - - (percent) - - - - -		
U.S. No. 1	25.0	0.5	5.0	5.0
U.S. No. 2	25.0	1.0	10.0	5.0

U.S. Sample grade – U.S. sample grade shall be sunflower seed that:

(1) Does not meet the requirements for the grades U.S. Nos. 1 or 2; or

(2) In a 600-gram sample, contains eight or more stones that have aggregate weight in excess of 0.20 percent of the sample weight, two or more pieces of glass, three or more crotalaria seeds (Crotalaria spp.), two or more castor beans (Ricinus Communis), four or more particles of an unknown substance(s), or 10 or more rodent pellets, bird droppings or an equivalent quantity of other animal filth; or

(3) Has a musty, sour or commercially objectionable foreign odor; or

(4) Is heating or otherwise of distinctly low quality.

Source: Federal Grain and Inspection Service-USDA

Other Information Sources

Major Organizations and Information Sources

Public Research and Nonprofit Associations

Supporting the efforts of private companies in the development of the sunflower industry are public-supported research institutions and nonprofit associations. The following is a list and brief description of the functions and purposes of such groups:

State Agricultural Experiment Stations and Cooperative Extension Service

The Agricultural Experiment Stations, which conduct research, and Cooperative Extension Services, which deliver adult education programs in the major sunflower production areas, are at:

Colorado State University, Fort Collins, CO 80523
Kansas State University, Manhattan, KS 66506
North Dakota State University, Fargo, ND 58105
South Dakota State University, Brookings, SD 57006
Texas A & M University, College Station, TX 77843 (branch stations at Lubbock and Bushland)
University of California, Davis, CA 95616
University of Minnesota, St. Paul, MN 55108, and Crookston, MN 56716

Extension Publications

Many Extension publications giving specific information on sunflower production, insect pests, diseases, herbicide use, marketing and food use are available. These are readily available through your county or state Extension offices.

Federal Research

The Agricultural Research Service (ARS) of the USDA, working with state agricultural experiment stations and cooperative Extension personnel in the major sunflower-producing areas, have developed inbred lines for hybrids, conducted research and provided information on production, utilization and marketing aspects. The main USDA-ARS sunflower unit is at the Northern Crops Science Laboratory on the campus of North Dakota State University, Fargo, ND 58105, www.fargo.ars.usda.gov.

Agriculture and Agri-Food Canada

Unit 100-101 Route 100
Morden, Manitoba, R6M 1Y5 CANADA
www.agr.gc.ca/

The National Sunflower Association

4023 State St. N.
Bismarck, ND 58502-0690
Tel: (888) 718-7033 or (701) 328-5100
http://sunflowernsa.com/

The National Sunflower Association was organized in 1975 to promote the sunflower industry and to solve common problems. This association is intended to represent the interest of growers, processors and seed companies, including country elevators, exporters and other merchandisers. It publishes The Sunflower magazine and sponsors The Sunflower Research Forum, a meeting devoted to scientific reports and topics of general interest.

National Sunflower Association of Canada

Box 1269
Carman, MB R0G 0J0
Phone: (204) 745-6776
info@canadasunflower.com
www.canadasunflower.com/

The International Sunflower Association

12 Avenue George V
75008 Paris, France

The objective of the International Sunflower Association is to improve international cooperation and to exchange information in the promotion of research of agronomics, processing techniques and nutrition associated with the production, marketing, processing and use of sunflower. This objective is accomplished by sponsoring and publishing the proceedings of international conferences and by publishing the Sunflower Newsletter, a quarterly periodical.

Sources of Information of General Interest

Governmental Statistical Reporting Services

Sunflower production and farm price statistics are released by the following state and federal offices of Economics, Statistics and Cooperative Extension Service, USDA:

North Dakota Agricultural Statistics Service
P.O. Box 3166
Fargo, ND 58108-3166

South Dakota Agricultural Statistics Service
Box 31 Drawer V
Sioux Falls, SD 57101

Minnesota Agricultural Statistics Service
Seventh and Roberts Street
Metro Square, Suite 270
St. Paul, MN 55101

Texas Agricultural Statistics Service
Box 70
Austin, TX 78767

National Agricultural Statistics Service
U.S. Department of Agriculture
Washington, D.C. 20250

Sunflower Technology and Production

ASA Monograph 35. 1997, 834 pages. Albert A. Schneiter, editor. This monograph text is the extensive revision of the original Agronomy Monograph 19 Sunflower Science and Technology. The monograph has many contributing authors addressing and reporting all the scientific work on sunflower that is in the literature. It has become the "bible of knowledge and information" for all who wish to read and study about the sunflower plant, its origin, development, production and utilization.

The Sunflower

(by C.B. Heiser Jr. from Univ. of Oklahoma Press, Norman, OK 73069, for $10.95)
This 200-page book, authored by a botanist and written in layman's language, covers historical development, the distribution and interrelationships of sunflower species. It describes sunflower as an international commercial crop, as ornamentals and as weeds.

The Sunflower

(4023 State St. N., Bismarck, ND 58501-0690)
The Sunflower magazine is published nine times a year by the National Sunflower Association of America. It is intended for growers, merchandisers, processors, hybrid seed companies, researchers and other legitimate interests in the sunflower industry.

Sunflower Directory

(4023 State St. N., Bismarck, ND 58501-0690, $10)
The directory includes more than 150 companies, in addition to several trade organizations, government agencies and universities, which have a unique function in the sunflower industry. More than 400 individuals having expertise in sunflower also are listed.

High Plains Sunflower Production Handbook

2005, 44 pages. (Kansas State University- Agric. Experiment Station and Cooperative Extension Service). Joint publication of Kansas State University, Colorado State University, University of Nebraska, University of Wyoming and USDA-ARS Central Plains Research Center, Akron, Colo. Also supported by: Kansas Sunflower Commission, National Sunflower Association – High Plains Committee and Colorado Sunflower Administrative Committee.

Glossary

Achene — The sunflower fruit consisting of hull and "seed;" a small, dry, one-seeded fruit that does not open at maturity.

Apothecium (pl. apothecia) — Cup- or saucer-shaped fruiting structure of some fungi.

Ascospore — Fungal spore borne in a structure within the apothecium.

Annuala — Plant in which the entire life cycle is completed in a single growing season.

Bract — Modified, reduced leaf structure beneath ray flowers on sunflower head.

Canker — Sharply defined dead area of tissue on stem.

Corolla — Collective term for petals of the sunflower.

Cytoplasmic Male Sterility — Male sterility inherited through hereditary units in the cytoplasm, rather than through nuclear inheritance.

Defoliate — To remove leaves of a plant.

Dehull — Removal of outer seed coat (hull) from the "seed."

Depredation — A plundering or despoiling; robbery.

Desiccant — A dry-down or defoliating chemical.

Disk Flower — Tubular flowers that compose the central part of the sunflower head; produce the seeds.

Fungicide — A chemical or physical agent that kills fungi.

Fungus (pl. fungi) — A group of organisms that lack chlorophyll and that obtain food through absorption, frequently from plants.

Herbicide — A chemical or physical agent that kills plants.

High Oleic — Oilseed sunflower that contains a trait for high oleic fatty acid content in its oil. A premium oil used in the snack food industry.

Host — The organism affected by a parasite or disease.

Hybrid — The offspring of two unlike parents.

Insecticide — A chemical or physical agent that kills insects.

Instar — Any stage of insect development; larval growth stage.

Involucral Bract — An individual bract within a distinct whorl of bracts that subtend the flowering part of a plant.

Kernel — Term used for true seed in processing, preferred to "nutmeat." The sunflower seed is neither "nut" nor "meat."

Larva (pl. larvae) — The preadult form of an insect.

Nonoilseed — Preferred term, equivalent to nonoil sunflower or confectionery sunflower.

NuSun — Term that describes the new mid-oleic sunflower oil. It is lower in saturated fat (less that 10 percent) than linoleic sunflower oil and has higher oleic levels (55 percent to 75 percent) with the remainder being linoleic (15 percent to 35 percent)

Oilseed — Preferred term, equivalent to oil sunflower.

Open Pollinated — Naturally pollinated by selfing or crossing between two related strains.

Perennial — A plant that continues its growth from year to year, not dying after once flowering.

Petiole — The stalk of the leaf.

pH — Expression of acidity or alkalinity of soil or water.

Physiological Maturity — Stage at which a seed has reached its maximum dry weight.

Pollinator — Insect that carries pollen from plant to plant.

Pupa (pl. pupae) — The stage between larva and adult in some insects.

Ray Flower — Flattened, ray shaped flowers on margins of sunflower head. Commonly referred to as the petals. These are sterile and do not produce achenes.

Receptacle — Fleshy, thickened part of sunflower head just above the stem that bears the flower parts.

Sclerotium (pl. sclerotia) — The hard, resting bodies of certain fungi.

"Seed" — True seed in sunflower is the kernel; however, "seed" commonly is used to describe the kernel plus hull, which is equivalent to the achene.

Self Compatability — Production of fruits and normal seeds following self pollination.

Sporea — Reproductive structure of fungi.

Sunflower — The preferred term, equivalent to sunflowers.

Sun Oil — The preferred term, equivalent to sunflower oil, sunflower seed oil.

Variety — A subdivision of a species; a distinct group of organisms.

Volunteer Plant — Plant arising from seed dispersed from a previous crop.

Appendix 1

Diseases of Sunflower (Oilseed, Confection and Ornamental)

(Helianthus annuus L.)

BACTERIAL DISEASES

Apical chlorosis	*Pseudomonas syringae pv. tagetis* (Hellmers) Young et al.
Bacterial leaf spots	*Pseudomonas syringae pv. aptata* (Brown and Jamieson)Young et al. *P. cichorii* (Swingle) Stapp *P. syringae pv. helianthi* (Kawamura) Young et al. *P. syringae pv. mellea* (Johnson) Young et al.
Bacterial wilt	*Pseudomonas solanacearum* (Smith) Smith
Crown gall	*Agrobacterium tumefaciens* (Smith and Townsend) Conn
Bacterial stalk rot	*Erwinia carotovora* subsp. *carotovora* (Jones) Bergey et al. *E. carotovora* subsp. *atroseptica* (van Hall) Dye

FUNGAL DISEASES

Alternaria leaf blight, stem spot and head rot

	Alternaria alternata (Fr.:Fr.) Keissl. = *A. tenuis* Nees *A. helianthi* (Hansf.) Tub. and Nish. = *Helminthosporium helianthi* Hansf. *A. helianthicola* Rao and Rajagopalan *A. helianthinficiens* Simmons et al. *A. protenta* Simmons *A. zinniae* M.B. Ellis
Charcoal rot	*Macrophomina phaseolina* (Tassi) Goidanich = *Sclerotium bataticola* Taubenhaus = *Rhizoctonia bataticola* (Taubenhaus) E.J. Butler
Downy mildew	*Plasmopara halstedii* (Farl.) Berl. and De Toni in Sacc.
Fusarium stalk rot	*Fusarium equiseti* (Corda) Sacc. = (teleomorph: *Gibberella intricans* Wollenweb.) *F. solani* (H. Mart.) Sacc. = (teleomorph: *Nectria haematococca* Berk. and Broome) *Microdochium tabacinum* (Van Beyma) Arx = *Fusarium tabacinum* (Van Beyma) Gams = (teleomorph: *Monographella cucumerina* (Lindfors) Arx)
Fusarium wilt	*Fusarium moniliforme* J. Sheld. = (teleomorph: *Gibberella fujikuroi* (Sawada) Ito in Ito and K. Kimura) *F. oxysporum* Schlechtend.:Fr.
Gray mold	*Botrytis cinerea* Pers.:Fr. = (teleomorph: *Botryotinia fuckeliania* (de Bary) Whetzel)

Leaf smut	*Entyloma compsitarum* Farl. = (anamorph: *Cercosperella columbrina* Ell. and Ever.
Myrothecium leaf spot	*Myrothecium roridum* Tode:Fr. *M. verrucaria* (Albertini and Schwein.) Ditmar:Fr.
Petal blight	*Itersonilia perplexans* Derx.
Phialophora yellows	*Phialophora asteris* (Dowson) Burge and Isaac
Phoma black stem	*Phoma macdonaldii* Boerema = (teleomorph: *Leptosphaeria lindquistii* Frezzi) = *P. oleracea Sacc.* var. *helianthi-tuberosi* Sacc.
Phomopsis stem canker	*Phomopsis helianthi* M. Muntanola-Cvetkovic et al. = (teleomorph: *Diaporthe helianthi* M. Munt.Cvet. et al.)
Phytophthora stem rot	*Phytophthora* spp. *P. drechsleri* Tucker
Powdery mildew	*Erysiphe cichoracearum* DC. = (anamorph: *Oidium asteris-punicei* Peck) *E. cichoracearum* DC. var. *latispora* U. Braun (anamorph: *Oidium latisporum* U. Braun) *Leveillula compositarum* Golovin *f. helianthi* *L. taurica* (Lév.) G. Arnaud (anamorph: *Oidiopsis sicula* Scalia) *Sphaerotheca fuliginea* (Schlechtend.:Fr.) Pollacci
Pythium seedling blight	*Pythium* spp. *P. aphanidermatum* (Edson) Fitzp. *P. debaryanum* Auct. non R. Hesse *P. irregulare* Buissman
Rhizoctonia seedling blight	
	Rhizoctonia solani Kühn (teleomorph: *Thanatephorus cucumeris* (A.B. Frank) Donk)
Rhizopus head rot	*Rhizopus arrhizus* A. Fischer = *R. nodosus* Namyslowski *R. microsporus* Tiegh. *R. stolonifer* (Ehrenb.:Fr.) Vuill = *R. nigricans* Ehrenb.
Rusts	
(common sunflower rust)	*Puccinia helianthi* Schwein.
(cocklebur rust)	*P. xanthii* Schwein.
(nutsedge rust)	*P. canaliculata* (Schw.) Lagerh.
(unnamed rusts)	*P. massalis* Arthur, *P. enceliae* Diet. and Holw.
Pine needle rust	*Coleosporium helianthi* (Schwein.) Arth.
Sclerotinia basal stalk rot and wilt, mid-stalk rot, head rot	
	Sclerotinia sclerotiorum (Lib.) de Bary
Sclerotinia basal stalk rot and wilt	
	Sclerotinia minor Jagger
Southern blight	*Sclerotium rolfsii* Sacc. (teleomorph: *Athelia rolfsii* (Curzi) Tu and Kimbrough)
Septoria leaf spot	*Septoria helianthi* Ellis and Kellerm. *S. helianthina* (Petrov and Arsenijevic)
Texas or cotton root rot	*Phymatotrichopsis omnivora* (Duggar) Hennebert = *Phymatotrichum omnivorum* Duggar
Verticillium leaf mottle	*Verticillium dahliae* Kleb.
White rust	*Albugo tragopogonis* (Pers.) S.F. Gray = *Pustula tragopogonis* (Pers.) Thines

Misc. foliar pathogens	*Ascochyta compositarum* J.J. Davis *Cercospora helianthi* Ell. and Ever. *C. pachypus* Ell and Kellerman *Colletotrichum helianthi* J.J. Davis *Epicoccum neglectum* Desm. *Phyllossticta wisconsinensis* H.C Green *Sordaria fimicola* (Rob. ex Desm.) Ces. and Not.

NEMATODES, PARASITIC

Dagger, American	*Xiphinema americanum* Cobb
Pin	*Paratylenchus projectus* Jenkins
Lesion	*Pratylenchus* spp. *P. hexincisus* Taylor and Jenkins
Reniform	*Rotylenchulus* spp. *Rotylenchulus reniformis* Linford and Oliviera
Root knot	*Meloidogyne arenaria* (Neal) Chitwood *M. incognita* (Kofoid and White) Chitwood *M. javanica* (Treub) Chitwood
Spiral	*Helicotylenchus* sp.
Stunt	*Tylenchorhynchus nudus* Allen *Quinisulcius acutus* (Allen) Siddiqi

VIRUS and PHYTOPLASMA DISEASES.

Aster yellows

Sunflower mosaic potyvirus (SuMV)

Sunflower chlorotic mottle virus (SuCMoV)

Cucumber mosaic virus (CMV)

Tobacco mosaic virus (TMV)

Tobacco ringspot nepovirus (TRSV)

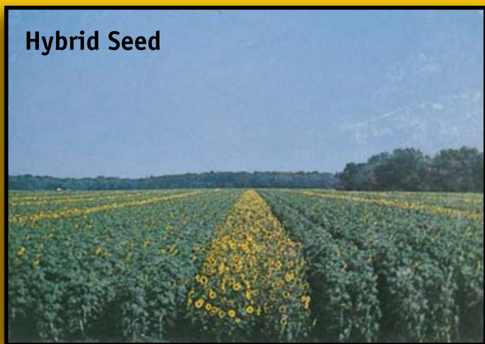
Tobacco streak lilarvirus (TSV)

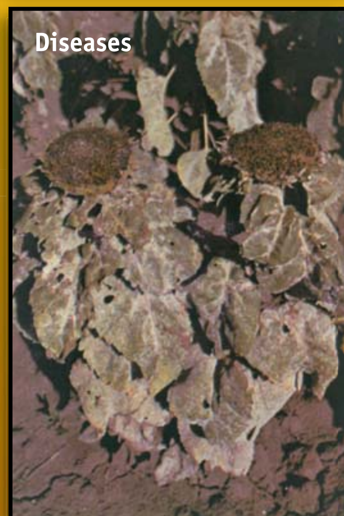
Tomato spotted wilt tospovirus (TSWV)

Featuring


Bird Damage


Weed Control

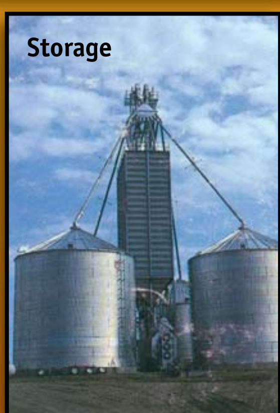

Hybrid Seed


Diseases


Grading


Herbicide Drift


Production


Storage


Harvesting


Hail Injury


Insects

For more information on this and other topics, see: www.ag.ndsu.edu

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