High Plains Sunflower Production Handbook

Colorado State University • Kansas State University • University of Nebraska • University of Wyoming
USDA–ARS—Central Great Plains Research Station, Akron, Colorado

Weed Control Identification Photos

(see page 8 for descriptions)

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Photo 2c. *Yellow foxtail plant.*

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Weed Control Identification Photos *(Continued)*

(see page 8 for descriptions)

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Weed Control Identification Photos *(Continued)*

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Weed Control Identification Photos *(Continued)*

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Photo 20. *Spartan and Prowl H_20 tank mix giving season-long weed control in no-till sunflower.*

Photo 21. *Clearfield (center) and conventional (right) sunflower treated with Beyond 4 oz + NIS 0.25% v/v.*

Stages of Sunflower Development

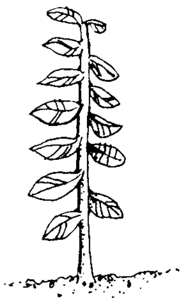
A.A. Schneiter, Professor
J.F. Miller, USDA-ARS
D.R. Berglund, Extension Agronomist

Vegetative Stages

True leaf — 4 cm, 1½ inch

V-E

V-2

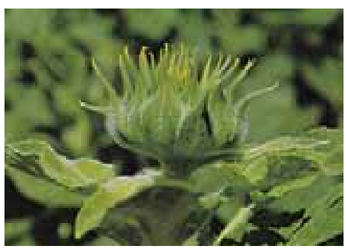


V-12

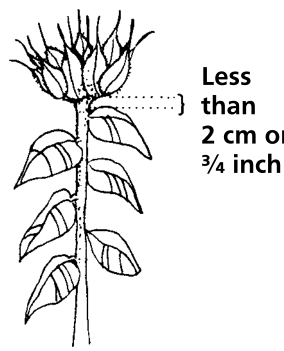
V-4

Reproductive Stages

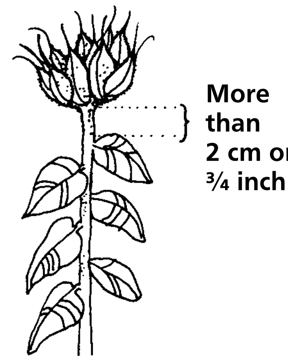
R-1



R-2



R-2



R-3

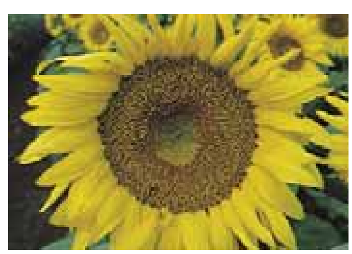
R-3

R-3 Top View

R-4 Top View

R-5.1

R-5.5



R-5.9

R-6

R-7

R-8

R-9

Vegetative Stages photos and information provided by North Dakota State University.

NDSU
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Description of Sunflower Growth Stages

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 the growing 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.

Stage		Description
VE	Vegetative Emergence	Seeding has emerged and the first leaf beyond the cotyledons is less than 4 cm long.
V (number) (i.e.) V-1 V-2 V-3 etc.	Vegetative Stages	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 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 form 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 2.0 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) (i.e.) 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 color.
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.

Acknowledgments

Stages of Sunflower Development, North Dakota State University, Cooperative Extension Service.

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High Plains Sunflower Production Handbook was published at Kansas State University in cooperation with Kansas Sunflower Commission, National Sunflower Association - High Plains Committee, Colorado Sunflower Administrative Committee, and the following groups.

Agronomic Practices

Hybrid Selection

Successful High Plains sunflower production reflects desirable yield, oil percentage, seed size, insect and disease resistance, and other hybrid characteristics. Correct hybrid selection is extremely important for top yields. Producers should use current performance tests when selecting a hybrid to plant. Sunflower varieties are tested annually in the High Plains region. Nebraska and Wyoming results are published in the Nebraska Seed Guide (Nebraska Cooperative Extension Publication E.C. Annual-101). Colorado results are available from the Variety Testing Program, Department of Soil and Crop Science, Colorado State University. Kansas results are published in the *Kansas Performance Tests with Sunflower Hybrids* and are available from K-State Research and Extension through local county extension offices (see Web site addresses at the end of this section). Commercial seed companies also can provide specific hybrid performance information. Both oil-type and confection-type (also referred to as non-oil type) sunflowers are produced in the region, each requiring specific crop management and marketing techniques.

When deciding to grow oil-type sunflowers, hybrids producing satisfactory seed yields and oil percentages should be selected. Domestic sunflower processors pay a premium for oil content more than 40 percent, while discounts are assessed for seed lots yielding less than 40 percent oil content.

Test weight is important from a quality standpoint. USDA grade for high-quality oil-type sunflowers require test weights of at least 25 pounds per bushel. Confection-type sunflowers normally have lower test weights than oil-type sunflowers because of larger seed sizes. To achieve satisfactory test weights from both oil and confectionary sunflowers, hybrids should be selected and planted so that they will mature within the frost-free growing season. This is especially important for late-summer plantings. Frost damage to sunflowers that have not matured will lower both test weights and yields.

Pest resistance is becoming more common in current sunflower hybrids. Hybrids with tolerance to rust, some races of downy mildew, and other pests are available. Additionally, strong stalk characteristics reduce lodging and allow easier harvesting. Seed companies will furnish hybrid-specific pest resistance information upon request.

Semidwarf sunflower hybrids are 25 to 40 percent shorter than conventional hybrids. The main advantage of planting semidwarf hybrids is reduced lodging potential and tendency for early maturity.

Hybrid Types

As stated earlier, sunflowers can be classified into two categories: oil type and confection (non-oil). Both types have separate and distinct markets, and as a result, cannot be mixed in storage.

Oil-type sunflower hybrids can be divided into three types: linoleic (regular oil type), NuSun (mid-oleic), and high oleic. Linoleic oil processed from sunflower oil is used as a low saturated fat cooking oil. Linoleic types were the predominant oil sunflower hybrid produced, but acreage of this type has decreased.

Rather, Nusun is currently the predominant oil-type sunflower planted. NuSun is a healthier oil and contains 20 percent lower saturated fats than traditional linoleic-type oil. NuSun does not have to be hydrogenated, which makes it an excellent frying oil with a long shelf life.

Lastly, high oleic sunflower hybrids also have been developed. This kind produces is a specialty oil very low in saturated fats used in lubricants (both food grade and industrial) and food coatings. It is grown by contract only. Local seed companies can sometimes make cantract arrangements, also.

Confectionary sunflower production is similar to oil type, with the exception of two areas: plant population and insect pest control. Confection hybrids should be planted slightly thinner than oil seed types and insect threshold levels are lower for confectionary sunflowers. Lower plant populations per acre assist in increasing the amount of large seeds produced. Insect threshold levels are lower for confections and insect-free confection seeds are necessary to meet market standards. Confection seeds brought to processors with high insect damage will be discounted or rejected. Confection growers should budget for at least one insecticide application with some fields requiring a second application, both during early bloom. Premiums exist for large-sized, insect-free seed delivered to confection processors.

Before choosing a sunflower hybrid type, contact sunflower processors (oil crushing plants, confection processors or birdseed processors), as some types must be grown "identity preserved" only. In addition, pricing contracts exist for specific sunflower types. Credible local seed representatives can assist with marketing opportunities.

Seed

Sunflower seed must be purchased from commercial seed companies every year because varieties are hybrids. Replanting hybrid seed from last year's crop will result in yield losses. Sunflower seed is sold either by weight (bag) or seeds per bag. Oil-type hybrid seed sizes are #2, #3 and, #4. Size #2 is the largest and size #4 the smallest, with the latter having more seeds per pound and per bag. Size #3 is most commonly used when planting oil-type hybrids.

Confection seed sizes are small, medium, large and extra large. Price is normally set per 1,000 seeds. The medium seed size is most commonly used for planting confection types. Regardless of sunflower type, larger seed sizes may have some advantages when it is necessary to plant deeply, but large seed may require slightly more soil moisture for germination. The size of sunflower seed at planting has not been proven to have an affect on either final sunflower yields or the size of seed produced. This is particularly true with respect to confectionary sunflower varieties.

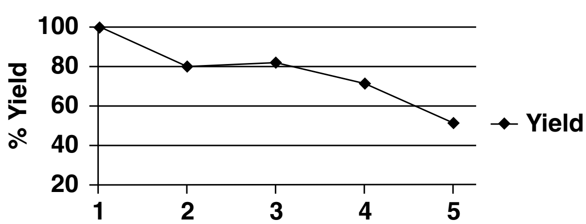
Planting

Good planting procedures will provide optimum seedling establishment. Errors at planting time will handicap the crop over the course of the growing season and will be reflected at harvest. Seedbed preparation, soil conditions, planting date, row width, and plant population should be managed as local conditions dictate.

Correct seedbed preparation involves creating an environment that allows seed germination and plant emergence to progress uniformly and rapidly. A moist, firm seedbed free of weeds is desirable. Sunflower seed should be planted into moist soil about 2 inches deep, but never more than 3 inches. Semidwarf hybrids should not be planted more than 1½ inches deep. Seed must be placed into moist soil for rapid germination to occur.

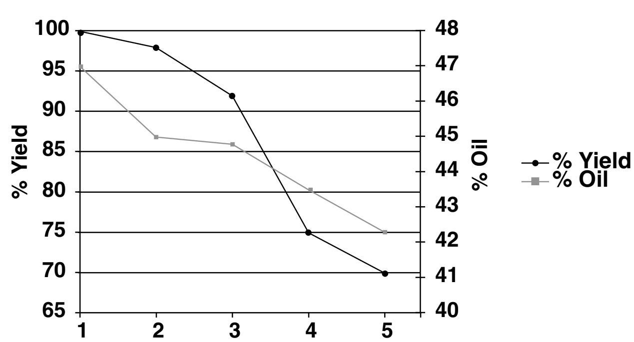
Sunflowers have trouble emerging through crusted soil. If soil crusting occurs before emergence, rotary hoe the field. Adjust the travel speed during rotary hoeing so that seedlings are not damaged.

Figure 1. *Planting Date Effect on Sunflower Production 3-year Average — Confection Type.*



Relative Planting Dates
Date 1 = May 20, Date 5 = June 30
Meyer, R.F., Pilcher, S., Peairs, F.
Colorado State University Cooperative Extension

Figure 2. *Planting Date Effect on Sunflower Production 3-year Average — Oil Type.*



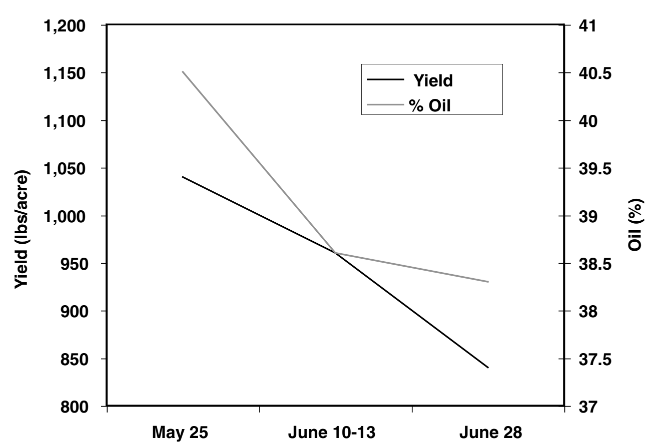
Relative Planting Dates
Date 1 = May 20, Date 5 = June 30
Meyer, R.F., Pilcher, S., Peairs, F.
Colorado State University Cooperative Extension

Sunflowers may be planted over a wide range of dates. Highest yields occurred with sunflowers in Kit Carson County, Colo., when planted during the last week in May (Figures 1 and 2). Sunflower yields were lower when planted after the second week in June; however, seed weevil counts were lowest for sunflowers planted later. The agronomic advantages in these studies indicate planting early outweighs the disadvantages of higher insect pest densities, provided fields are monitored for insect pests and treated accordingly. Seed quality (percent oil) also was highest from early planting dates (May 20). Additionally, test weight decreased, while harvest moisture increased, as planting dates were delayed. In Nebraska studies, sunflowers planted on May 25 resulted in 200 pounds higher seed yield per acre, 2 percent higher oil, 100 pounds per acre more oil, and 2 pounds per bushel higher test weight than sunflowers planted on June 28 (Figure 3). Further, gross income was reduced by $0.77 per acre for each day planting was delayed after May 25.

Early planting dates work well in the region, however, seeding sunflowers in soil cooler than 50 degrees Fahrenheit is not recommended. Planting sunflowers into soil averaging less than 50 degrees Fahrenheit will delay germination and increase the likelihood of seeding diseases, insects, and soil herbicide damage. Planting dates in early May yielded similar to late-May planting dates in Kit Carson County, Colo. Wyoming and northern producers may want to start with early-June planting dates to place seeds in warmer soils..

Colorado State University Cooperative Extension trial results indicate that mid-season hybrids planted during the first week of July will mature with 1,500 degree days (base 50 degrees Fahrenheit). Although later-planted sunflowers yield less than earlier planted, later plantings are effective under normal summer conditions if they become necessary due to weather or replanting delays. When planting midsummer, choose only early maturing hybrids.

Figure 3. *Oil and Yield Based on Relative Planting Date.*



University of Nebraska

Plant Populations

Row crop equipment available should dictate row spacing used. Both solid seeded and row-planted sunflowers have been produced successfully. Currently, 30-inch row spacing is most popular and considered standard. However, trials conducted by Colorado State University Cooperative Extension have found equal sunflower yields with 12-, 15-, and 30-inch row spacings.

Adequate plant population also is important for highest possible seed yields. Sunflowers, however, will compensate somewhat for differences in plant populations through adjustments in head size. Higher populations are generally planted for oil type than for confection type hybrids. Plant populations for oilseed hybrids grown under dryland conditions should be between 14,000 and 22,000 final plants per acre, adjusting for yield potential. In lower yield environment potentials, plant populations should be lowered slightly. In Nebraska studies, plant populations of 11,000 resulted in 1.2 ounce larger heads, 300 more seeds per head, 0.0004 ounce larger seed, and 2 pounds per bushel lower test weight than populations of 20,000 plants per acre. Nebraska yields were similar from 11,000 to 20,000 plants per acre, but higher populations may be helpful in weed competition and soil erosion prevention.

Moisture in the soil profile is regarded as the most important criterion for adjusting plant populations within this recommended range. Lower populations are recommended for lower yield potentials (drier soils). Plant populations for irrigated oil-type sunflowers should be between 17,000 and 22,000 final plants per acre. Irrigated oil-type sunflower plant population recommendations in Kansas range from 22,000 to 26,000 plants per acre, with western regions requiring lower populations than eastern regions. Confection hybrids should be planted between 12,000 (dryer soil conditions), and 18,000 (irrigated) final plants per acre. In central and eastern Kansas, irrigated confection population recommendations range from 15,000 to 18,000 plants per acre. Higher populations will allow faster preharvest drydown as head size will be smaller, but this also can result in smaller seed size. Thinner confection stands tend to produce a higher proportion of large seed.

Prior to flowering, sunflower heads follow the sun during the day, a phenomenon called nutation. However, at bloom, sunflower heads face east. As sunflower heads fill, they become heavy and may also face downward. Planting rows in north-south direction allows sunflower plants to face the next row and not the next plant, resulting in less head contact and thus, less seed shattering during storms.

Planting sunflowers into compacted soils must be avoided. Although a sunflowers have a deep taproot, it will not penetrate tightly compacted soil conditions. Often times, the compaction layer is found at the tillage layer, approximately 4 to 6 inches below the soil surface. If soil compaction is an issue, a ripping operation is needed. Rip as deep as the compacted layer, but not much deeper, when soil conditions are dry. Ripping wet soils allows smearing to take place and will not reduce soil compaction. Symptoms of soil compaction are sunflower lodging and “L” shaped tap roots.

Table 1. *Inches between seeds, assuming 90 percent germination.*

Desired Plant Population per Acre	Inches Between Each Seed	
	30-inch row spacing	12-inch row spacing
12,000	15.6	39
14,000	13.4	34
16,000	11.8	29
17,000	11.1	28
18,000	10.5	26
19,000	9.9	25
20,000	9.4	23
21,000	9.0	22
22,000	8.8	21

Bird Control

Sunflowers are susceptible to bird damage after seeds are formed. Under certain conditions, birds have been known to consume considerable quantities of seed in the field. Fields that are close to open water and have perch sites (trees or irrigation systems) can expect bird damage.

Following are some suggestions for dealing with birds that feed on the seed of standing sunflowers. These approaches have been used with varying degrees of success. However, some of these cultural practices may work in your situation.

1. Address a bird situation early. Fifty percent of the damage occurs within the first 10 days after petal drop.
2. Select varietal plant types with head types that face down after flowering.
3. Plant early hybrids at early planting dates, and harvest early.
4. Avoid planting sunflowers within a quarter mile of marshes or sloughs that consistently harbor large quantities of birds and contain water in later summer.
5. Leave at least a 100-yard buffer strip of a crop not as attractive to birds, such as small grains, adjacent to shelter belts, groves, or other wooded areas.
6. Do not plow or till earlier harvested sunflower fields in the vicinity, since these areas can act as alternative bird seed reservoirs. After harvest leave all stubble standing until the crop is harvested, as birds may be attracted to these areas in search of food.

Additionally, bird deterrent practices can be used. These practices fall into two categories: mechanical frightening and chemical agents. Sunflower protection by mechanical means, particularly on large acreage, is an especially formidable task and one likely to discourage the protector long before harvest. Frightening devices will likely be most effective if employed early in the season before flocks become "entrenched" in a field. Devices also should be more effective if they are employed at a time of day just prior to early morning or late afternoon feeding periods. Gas-powered propane and acetylene exploders are the most popular tools. Use one exploder per ten acres and plan on moving exploders frequently as birds will become accustomed to them. Other devices include guns with "cracker" loads and recorded amplified sound.

Starlicide ™ (an avicide) is currently registered for control of blackbirds in sunflowers. It is a cracked-corn bait, which four out of every 100 particles is treated with the active ingredient, 4-aminopyridine. The bait is applied by broadcasting along access lanes placed in the fields, at the rate of 1 pound per acre. When a blackbird eats one or more treated particles, it flies erratically and emits distress calls. This abnormal behavior often causes the remaining birds in the flock to leave the field. It usually kills the bird that eats the bait. Careful consideration must be given to the timing of initial and repeat baiting. The first baiting should be when the birds first initiate damage, and repeat baiting should occur as necessary, about 5 to 7 days apart. Weeds that hide bait, ground insects (e.g., crickets) that eat bait, and excessive rainfall can contribute toward making the product less effective. Instructions on the label, especially the avoidance of baiting field edges, should be carefully followed to avoid contacting nontarget birds. Contact your local county agent, state department of agriculture, or the National Sunflower Association for current registrations status and always read and follow label instructions.

Birdshield ™ is another product that may work for blackbird control. It is a biodegradable taste aversion product made from a grape extract and early results look promising for deterring blackbird feeding in sunflowers. Birds are not killed from this product. They stop feeding in treated sunflower fields as a result of unpleasant tastes when feeding.

Some companies now offer a new generation of electronic sound devices using digital technology to produce distress calls of specific birds. They are only effective against bird species whose distress calls are encoded on the microchip. Following are some companies on the Internet that market bird harassment products. The National Sunflower Association has not evaluated any of the products and cannot verify the success of their use.

www.reedjoseph.com
www.wildlifecontrolsupplies.com
www.birddamage.com
www.betterpestcontrol.com
www.birdbarrier.com
www.biconet.com

More Web Page Listings

National Sunflower Association
www.sunflowernsa.com

CSU Golden Plains Area
www.colostate.edu/Depts/CoopExt/GPA

Sunflower variety test results
www.colostate.edu/Depts/SoilCrop/
www.ianr.unl.edu/ianr/agronomy/varitest2.htm
www.csuag.com
www.ksu.edu/kscpt/
uwadmnweb.uwyo.edu/UWCES

Nutrient Management

Fertile, well-managed soils capable of producing good yields of other crops also can produce good yields of quality sunflowers. Nutrient uptake by sunflowers is influenced by many factors including stage of development, hybrid, and soil fertility. Sunflowers need an adequate supply of nutrients at each developmental stage for optimum growth. High-yielding sunflowers remove considerable amounts of nutrients from the soil. This should be taken into account when developing a nutrient management program. Table 2 summarizes typical nutrient content of sunflowers.

Sunflowers are considered to be efficient in using both nutrients and water from the soil because of a deep, expansive taproot system; however, profitable responses to fertilization can be expected on many High Plains soils.

Fertilizer and lime needs are best assessed by soil testing, field history, and grower experience. Fertilizer rates are suggested for optimum yields, assuming yield potential is not restricted by other factors.

Table 2. *Nutrient content in a sunflower crop producing 1,000 lbs seed/acre.*

	Nutrient Removal lbs/acre		
Element	Seed	Stover	Total
Nitrogen (N)	30	18	48
Phosphorus (P_20_5)	12	3	15
Potassium (K_20)	8	28	36
Sulfur (S)	2	4	6
Magnesium (Mg)	2	5	7
Calcium (Ca)	1.2	18.5	19.7
Zinc (Zn)	0.05	0.04	0.09

Nitrogen

Nitrogen (N) is the nutrient of greatest accumulation in the aboveground portion of the sunflower crop. Nitrogen recommendations vary with yield expectations associated with soil, climate, soil moisture, cropping sequence, and residual nitrogen in the soil. The results of a 7-year study conducted at the USDA-ARS Central Great Plains Research Station (Akron, Colo.) indicated that sunflowers require 6 to 7 pounds of nitrogen for every 100 pounds of production. This has lead to an increase from a previous recommendation of 50 pounds of nitrogen for every 1,000 pounds of potential grain production, to 65 pounds of nitrogen for every 1,000 pounds of expected yield.

Fertilizer nitrogen rates should be lowered if legumes are grown in rotation before sunflowers. Table 3 summarizes nitrogen credits for various legumes.

Since sunflowers are efficient in recovery of residual nitrogen, a soil test for available nitrogen in the profile is strongly encouraged. Profile nitrogen samples should be taken to a depth of at least 2 feet. On deep, well-drained soils, deeper sampling may be justified to 4 feet.

Nitrogen recommendations can be calculated by using the following equation:

N Rec = {[YG × 0.065 pounds nitrogen per pound of yield] × STA } - PCA - PYM – PSNT – (Nmin)

N Rec Fertilizer nitrogen recommended in pounds per acre

YG A realistic yield goal in lbs per acre

STA Soil texture adjustment (1.1 for sandy soils less than 1.0 percent organic matter, 1.0 for other soils)

PCA Previous crop adjustment [use Table 2 for previous legumes, 20 pounds for fallow (if no profile N test) and 0 for all other previous crops]

PYM Previous years manure (50 pounds for last year, 20 pounds for 2 years ago and 0 for no manure history)

PSNT Profile nitrogen soil test results where:

Surface:
ppm nitrogen × 0.3 × depth, inches = pounds per acre

Subsoil:
ppm nitrogen × 0.3 × depth, inches = pounds per acre

Total Profile nitrogen = pounds per acre

Note: If profile nitrogen test is not run, use 30 pounds per acre as a default value for PSNT.

Table 3. *Nitrogen credit for legumes used in crop rotations.*

Previous Legume	Nitrogen Credit pounds per acre
Alfalfa > 80% stand	100–140
60–80% stand	60–100
< 60% stand	0–60
Second year after alfalfa	½ first year credit
Red Clover	40–80
Sweet Clover	80–120
Soybeans	30–60

Nmin Estimate of nitrogen mineralized from soil organic matter. Credit 30 pounds of nitrogen for every 1 percent of soil organic matter in the top 6 inches of soil.

Example:
Yield Goal = 1,800 pounds per acre
Soil Texture = Silty Clay Loam
Previous Crop = Wheat
Previous Manure = None
Soil Test Results:
0 - 6 inches = 8 ppm nitrogen, 6 - 24 inches = 6 ppm nitrogen, 1 percent soil organic matter
N Rec = ((1,800 pounds per acre × 0.065 pounds per pound) × 1.0) – 0 – 0 – 46.8* – 30 = 40
*(8 ppm × 0.3 × 6 inches) + (6 ppm × 0.3 × 18 inches) = 46.8

Under these conditions, 40 pounds of fertilizer N is recommended.

Subtract residual soil test results from following recommendations.

Yield Goal	1,000 lbs/a	1,500 lbs/a	2,000 lbs/a	2,500 lbs/a	3,000 lbs/a
Total Nitrogen Need	65 lbs N/a	98 lbs N/a	130 lbs N/a	163 lbs N/a	195 lbs N/a

The use of excessive nitrogen rates is not advisable. Research in North Dakota, Colorado, and Nebraska indicates that excessive nitrogen can result in decreased oil content and increased lodging.

If fertilizer is placed in contact with the seed, the starter material should contain no more than 10 pounds of actual nitrogen plus potash per acre. The nitrogen and potash can cause germination damage because of their high salt index when placed with the seed. Much higher amounts can be applied in a 2 × 2 band (2 inches deep and 2 inches away from the seed), or broadcast applied without seedling damage. These fertilizer placement statements hold true regardless of the crop.

Field comparisons of nitrogen sources conducted by K-State researchers indicate little agronomic difference between alternative nitrogen materials, when properly applied. Nitrogen source should be based on applied cost, availability, adaptability to your management system, and dealer services.

Nitrogen application for sunflowers can be made preplant, sidedress, or a combination of these methods with equal results. Applications should be timed so nitrogen is available for rapid plant growth and development.

Phosphorus

Phosphorus (P) application should be based on a soil test. Consistent sunflower response to phosphorus fertilization has generally occurred on soils testing very low or low in available phosphorus where yield potential is not restricted by lack of moisture or other environmental factors. With medium-testing soils, yield responses have been erratic and normally quite small. Phosphorus applications are recommended with medium and low soil tests for potential yield response and to maintain the soil in a highly productive condition. Table 4 shows phosphorus recommendations.

Phosphorus should be applied preplant-broadcast, preplant-knifed, or banded at seeding. Starter applications are most efficient, particularly when small amounts are applied on soils low in available phosphorus. Phosphorus can be placed in direct contact with the seed or to the side or below the seed with no restrictions in economical rates. If placed in contact with the seed, the starter material should contain no more than 10 pounds of actual nitrogen plus potash per acre. The nitrogen and potash can cause germination damage because of their high salt index when placed with the seed. Preplant applications can be made in the fall or spring and should be thoroughly incorporated because phosphorus does not move much in the soil.

Liquid and solid fertilizers, as well as varying chemical forms of phosphorus (ortho- and poly-phosphates), are available. Research conducted in several states indicates that, in general, all are agronomically equivalent. Selection of a phosphorus source should be made on the basis of cost, availability, and adaptability to the operation.

Potassium

Like phosphorus, a soil test is the best guide to potassium (K) need (Table 4). Potassium removal is much greater with silage than with grain production. Potassium deficiencies are not likely unless soil tests levels are low, which normally occur in sandy soils.

Potassium should be applied preplant-broadcast or as a starter. Remember, sunflowers are sensitive to fertilizer salts (N and K). When applying starter applications with the seed, limit application to no more than 10 pounds actual nitrogen plus potash per acre. Preferred fertilizer placement is 2 inches deep and 2 inches away from seed. Broadcast applications should be thoroughly incorporated to place the potassium in the root zone. The most common potassium source is muriate of potash (potassium chloride); however, potassium sulfate, potassium nitrate, potassium-magnesium sulfate, and mixed fertilizers are other sources. Little difference in potassium availability exists among these materials. Selection should be based on cost, availability, and adaptability to the farm operation.

Lodging of sunflowers at maturity has been a problem in some areas resulting in considerable harvest loss. Research has shown that many factors such as weather stress, insect and disease damage, hybrids, date and rate of planting, and nutrient imbalance can cause lodging. Adequate potassium is essential for sturdy stalks and may help reduce lodging on medium- to low-potassium test soils.

Liming

Acid soils are not common in the High Plains, but soil pHs less than 5.5 have been reported in northwest Kansas.

Lime recommendations are intended to maintain soils in a productive condition. Sunflowers are not the most responsive crop to lime, but liming of acid soils should not be ignored. Although yearly yield increases may be small, liming is a sound farming practice. Lime is recommended for sunflowers on all soils with a pH of 6.0 or less. If sunflowers are grown in a cropping system that includes legumes, liming to obtain a higher pH (6.2 to 6.5) should be maintained. However, most High Plains soils test quite high in pH and therefore, liming is not common.

Other Elements

Perhaps because of the extensive root system, reports of secondary and micronutrient deficiencies in field-grown sunflowers are rare. In most states in the region for example, sulfur, iron, and/or zinc deficiencies have been reported on other row crops, small grains, and forage crops. However, there have been no reported deficiencies of any of these nutrients in sunflowers. In fact, sunflowers are often suggested as an alternative crop on severely iron deficient soils. Likewise, there should be no problems with boron, copper, or manganese nutrition in sunflowers.

Soil Fertility and Micronutrients

Iron availability decreases with increasing soil pH. However, sunflowers are tolerant of low iron availability. Sunflower production is usually successful on soils that

Table 4. *Phosphorus and potassium recommendations for sunflowers.*

		Soil Test Phosphorus, ppm					Soil Test Potassium, ppm[1]				
		VL	L	M	H	VH	VL	L	M	H	VH
Yield	Bray-1 P	<5	6–12	13–25	26–50	>51	<40	41–80	81–120	121–160	>161
Goal	Olsen P	<3	4–7	8–12	13–16	>17					
lb/a		lb $P_2 0_5$/a					lb $K_2 0$/a				
1,000		30	20	15	0	0	50	40	15	0	0
1,500		40	30	20	0	0	60	50	25	10	0
2,000		50	40	25	10	0	70	60	35	15	0
2,500		60	45	30	15	0	80	70	45	20	0
,3000		70	55	35	20	0	90	75	55	25	0

[1] *When sunflowers are used for silage, add 40 lb $K_2 0$/a to recommendation in low-testing soils.*

cause deficiencies on sensitive crops such as corn, sorghum, or potatoes. Severe iron deficiency of sunflowers in the seedling stage shows interveinal chlorosis on the youngest leaves with stunted plants.

Zinc-deficient plants are stunted with distorted upper leaves. As the deficiency intensifies, leaves tend to wilt. Zinc deficiencies or responses to added zinc are not likely in the region.

When setting yield goals, considerations must include individual management skills, soils, and average weather conditions. Adequate fertilizer nutrients must be provided as required for selected yield goals. The most limiting factor, however, for yield on dryland sites, is often stored soil water and effective summer precipitation. Decisions for choosing yield goals therefore should be based on yield histories and future expectations.

Recent research with micronutrients applied foliarly two times during the season in a 2-year study at Akron, Colo. did not provide a return on investment that was great enough to pay for the micronutrient application. Although in one of the years, a significant increase in seed oil content was measured with micronutrient application.

Likewise, researchers at Colorado State University found no yield advantages to adding micronutrients to sunflowers applied either foliar applied or as a soil-applied granular regardless of soil moisture conditions.

Weed Control

Weed management is an important component of successful sunflower production. Sunflowers in the High Plains are grown in rotation with other crops. The weed control benefits associated with crop rotation can be realized only if good weed management was practiced in the preceding crop. Because sunflowers are usually planted at low densities and grow slowly during the first 2 weeks, weeds that emerge and establish during this time can be competitive and reduce sunflower yield. Sunflowers are strong competitors with weeds that emerge 3 or more weeks after sunflower emergence. Therefore, early season weed control is important to minimize yield losses.

Preplant Weed Control

It is essential that sunflower seeds be planted into a seedbed free of growing weeds. Weed control before planting can be accomplished with tillage, herbicides, or a combination of both. If tillage is the predominant method of weed control, implements such as the V-blade, tandem disk, or field cultivator may be used before planting. Soil that is warm and dry on the surface, and moist below, encourages rapid sunflower development and may delay weed seed germination. In double-cropped sunflowers, appropriate weed control must be practiced in the small grain crop. However, sunflowers should not be planted into wheat stubble if Glean, Ally, Ally Extra, Peak, Amber, Rave, Finesse, Maverick, Olympus, Beyond, or Tordon herbicides were applied in the preceding small grain crop because of the risk of sunflower injury from herbicide carryover. Nonselective burndown herbicides must be applied prior to sunflower emergence to avoid severe crop injury.

The use of a nonselective herbicide such as glyphosate (several) or paraquat (Gramoxone Max) is an alternative to preplant tillage for weed control. These foliar-applied herbicides can control seedling broadleaf weeds and grasses. Since paraquat is a contact (nontranslocated) herbicide, it may give incomplete control of grass plants that have tillered, or broadleaf plants with well-developed axillary buds. Glyphosate is a systemic (translocated) herbicide that controls a wide spectrum of grass and broadleaf weed species, but is weaker on certain species such as wild buckwheat, kochia, common lambsquarters, and marestail. Tank mixing glyphosate and sulfentrazone (Spartan) may antagonize glyphosate activity and require that additional glyphosate be added to the tank. It may be best to avoid tank mixing the two herbicides.

Applying glyphosate or paraquat before planting uses the “stale seedbed” technique. In contrast to the flush of new weed seedlings that usually follows tillage and rainfall, few weeds germinate following use of preplant burndown herbicides, because there is no tillage to bring a new supply of weed seed into germination position near the soil surface and weed seed lying on the surface is not buried into moist soil. In sunflower crops, where there are few herbicide options, alternative weed control techniques such as stale seedbed are especially important.

Glyphosate prepack or tank mixtures containing 2,4-D or dicamba have a high potential for causing crop injury when applied before sunflower planting and should not be used within 3 months of planting (refer to herbicide label guidelines).

Another alternative to tillage for weed control in double-crop sunflowers is to burn the small grain stubble ahead of sunflower planting. Fire can kill existing weeds, reduce the potential for volunteer wheat problems, and eliminate interference of residues with planting and cultivation equipment. Fire generally will not destroy weed seed in direct contact with the soil surface. The advantages of burning must be compared to the benefits of leaving the wheat stubble standing for control of soil erosion by wind and water. Burning may increase moisture loss from the profile and reduce moisture stored in the profile during the growing season because it leaves the soil surface exposed to wind and sunlight.

Delayed planting of sunflowers is sometimes used to allow weeds and volunteer wheat to germinate. This method can reduce weed populations and minimize problems with weed control strategies discussed above. Delaying planting may reduce sunflower yield potential and seed oil contents, thus, it is important to review the planting date section of this publication before implementing delayed planting strategies.

Weed Control in the Crop

Preplant incorporated herbicides available for weed control are EPTC (Eptam), ethalfluralin (Sonalan), pendimethalin (Prowl H_2O), trifluralin (Treflan and others), *S*-metolachlor (Dual Magnum), and Spartan. With the exception of Spartan, these herbicides primarily control grassy weeds such as crabgrass, foxtail, fall panicum, field sandbur, witchgrass, and barnyardgrass (see photos 1, 2, 3, 4, 5, and 6 for pictures of weeds). Additionally, these herbicides usually control some small seeded broadleaf weeds like pigweeds. Prowl H_2O can provide fair control of velvetleaf. Sonalan and Treflan can provide good kochia and Russian thistle control at the higher use rates.

Spartan will control many broadleaf weeds species including kochia, pigweed species, and Russian thistle (see photos 7, 8, 9, 10, and 11 for pictures of weeds). However, sunflower injury can occur from Spartan (Photo 13), so it is important to follow label guidelines. Soil texture, organic matter, and soil pH affect Spartan activity. Greatest risk of adverse crop response occurs on coarse textured soils with organic matter less than 1.5 percent and soil pH greater than 7.8. Spartan may be applied in the fall or spring up to 3 days after sunflower planting. If applying Spartan more than 3 weeks before planting, use the highest recommended label rate for the specific soil characteristics. Spartan, Prowl H_2O, and Dual Magnum may be surface applied to no-till planted sunflowers without incorporation to provide broad spectrum weed control (Photo 20).

Weeds that germinate and emerge before rainfall is received likely will not be controlled by a preemergence herbicide treatment. Receiving rainfall or irrigation immediately after application of all of these soil-applied herbicides will increase the level of weed control, but also will increase the risk of sunflower injury from preemergence applied Spartan.

Granular Sonalan or Treflan may be incorporated with a sweep plow to provide weed control in a reduced tillage system. This method provides consistent weed control that is not as dependent on rainfall as no-till preemergence herbicide applications at planting and conserves more residue than the traditional preplant incorporated treatments. Research in Colorado, Nebraska, and North Dakota found that Sonalan or Treflan granules applied and incorporated 1 to 2 weeks before planting provided greater than 85 percent control for 7 to 9 weeks after planting.

Clearfield sunflower, a non-GMO crop, was released in the High Plains in 2003. The resistance gene in Clearfield sunflowers was transferred into commercial sunflowers from a wild sunflower found in Eastern Kansas. Clearfield sunflowers may be treated with imazamox (Beyond) at 4 ounces of product per acre to sunflowers in the V-2 to V-8 growth stages. Addition of nonionic surfactant and liquid nitrogen fertilizer additives are required for adequate weed control. If treated with Beyond, conventional sunflower hybrids will be killed and Clearfield sunflowers often will exhibit subtle chlorosis (Photo 14). Beyond will control spring emerging susceptible grass species that have fewer than five leaves, including volunteer wheat (non-Clearfield), and broadleaf weeds before they exceed 3 inches. Beyond will control devilsclaw if treated at the true two-leaf stage or earlier (Photo 12). Populations of ALS-resistant kochia, Russian thistle, and Palmer amaranth are common in the High Plains and likely will not be controlled by Beyond. Stewardship guidelines provided with the grower contract should be studied and followed to reduce the risk of the Clearfield gene escaping into the wild sunflower population and to minimize additional development of ALS-resistant weed species. A survey conducted at Kansas State University suggests that the ALS-resistant gene is already present in wild sunflowers throughout much of the state of Kansas. To minimize the ALS-gene transfer into the wild population, stewardship guidelines recommend that the Clearfield sunflower system should not be used in fields where wild sunflowers are common.

Volunteer wheat can be a major problem in double crop sunflowers, especially where wheat has been shattered by hail or wheat stubble has been disked. Volunteer wheat and other grassy weeds can be controlled postemergence with sethoxydim (Poast), clethodim (Select), or Beyond. These herbicides most effectively control wheat that is less than 4 inches tall and is actively growing. Control of volunteer wheat can be reduced significantly if postemergence herbicides are applied when wheat is drought stressed.

Herbicide options for weed control in sunflowers have improved, especially for control of many broadleaf weed species, but this improved control comes at a cost. To reduce costs and provide broad-spectrum weed control, mechanical weed control in the crop may also be considered. A shallow tillage pass with a spring-tooth, or flexible harrow pulled diagonally to the planting direction can remove newly emerged seedling weeds. Use of a rotary hoe is another option and such tillage can be used before and just after sunflower emergence. Producers considering the use of these practices should increase planting rates to compensate for stand reductions due to tillage.

Shielded (hooded) sprayers may be used to apply glyphosate or Gramoxone Max. Extreme care must be exercised to avoid the nonselective herbicide coming into contact with the sunflowers. This treatment is most effective on weeds less than 6 inches tall and should not be used as a rescue treatment on large weeds.

Finally, between-row cultivation may be necessary to obtain adequate weed control in sunflowers and should always be available at least as a backup. Heavy-duty cultivators that combine disk hillers in front with single, wide, rear-mounted sweeps are especially useful where row crops are grown in heavy crop residues. The use of cultivator guidance systems can speed up cultivation and reduce operator fatigue. Cultivating sunflowers that have been planted into wheat stubble may reduce the moisture saving benefits associated with wheat stubble on the soil surface.

For specific herbicide and weed control recommendations, refer to the respective herbicide labels or weed management guides provided by your extension service.

Herbicide Injury

Sunflowers are susceptible to herbicide residual following application of several herbicides to previous crops. Additionally, sunflowers are susceptible to drift of several herbicides applied to adjacent crops.

Atrazine drift (Photo 15) on sunflowers results in leaf necrosis. Atrazine is a contact herbicide and can be translocated upward in the plant. Short-term symptoms may appear serious, however, if growing points are not destroyed, sunflowers may recover.

Glyphosate drift (Photo 16) on sunflowers will appear as chlorotic new growth and in some cases, chlorotic banding on leaf tissue. Sunflowers are sensitive to glyphosate and terminal growth will die when exposed to glyphosate.

Read and follow label instructions regarding the use of growth regulator herbicides ahead of planting sunflowers. Sunflowers injured by soil residues of growth regulator herbicides such as Tordon or dicamba (Photo 17) can appear near normal, however, the terminal bud can be chlorotic and distored or in some instances can be absent or nearly absent. Carryover injury from picloram or dicamba at relatively high rates can eliminate sunflower production.

Sprayer contaminations or drift from applications of dicamba, 2,4-D, or other growth-regulator herbicides will cause epinasty (twisting) of the growing sunflower tissues and chlorosis in the whorl (Photo 18). Sunflowers are sensitive to growth regulator herbicides and yields often can be reduced. Very low rates can cause chlorosis in the whorl without the new growth showing epinasty.

Sulfonylurea residual can result in sunflowers being severely stunted, with chlorotic leaf tissue, crinkled leaves, and death of the terminal bud in severe cases (Photo 19). Planting Clearfield sunflowers may not overcome the residue from sulfonylurea herbicides.

Water Requirements

Water Use and Yield

Sunflowers are a drought and heat tolerant crop adapted to a High Plains environment. The amount of water used by sunflowers varies with the amount of water available from the soil and rainfall during the growing season. As available water increases, so does water use. For sunflowers to grow all season with no water stress in the central High Plains, approximately 34 inches of water is required. This could come as a combination of stored soil water, growing season rainfall, and irrigation. Reports of water use by sunflowers range from 8 to 38 inches per year. The higher values come from irrigated studies or high rainfall conditions. Sunflowers grown where the soil water profile is full will use greater amounts of water. Dryland sunflowers are almost always grown under water-deficit conditions in the central High Plains; hence, yields are almost always lower than the maximum attainable.

Sunflower yield generally increases with crop water use, when other factors such as fertility, weeds, insects, and diseases are not limiting to yield. This relationship, generated at Akron, Colo., shows that about 150 pounds per acre of seed are produced for every inch of water use after the first 7 inches (water use is defined as the sum of stored soil water use, growing season precipitation, and irrigation). This yield increase, with increasing water use (150 pounds per acre-inch), is the same as reported in studies conducted in the panhandles of both Nebraska and Texas.

However, it has been found that fully irrigating sunflowers can have a negative influence on seed oil content as compared to proper timing of water application during key reproductive time periods. Work conducted at Akron, Colorado found that irrigating during the vegetative and early reproductive periods (R-1 to R-3) had similar oil content as dryland production (Table 5). Irrigation only during the R-3 to R-7 periods increased oil content. Unger (1982) found similar results in Texas. Yields when irrigating during the R-3 to R-5 period were similar to full water management.

Table 5. *Oil Content as affected by irrigation timing.*

Irrigation	2003 Oil Average [1]	
Growth Stage	%	
Rainfed	43.9	B
R-6 – R-7	47.3	A
R-4 – R-5	47.7	A
R-1 – R-3	41.3	C
R-1 – R-5	43.4	BC
Full Water	42.5	BC

[1] Numbers followed by the same letter are not statistically different, and therefore should be considered not different from each other. Numbers followed by different letters are considered not equal to one another.

Water-Sensitive Growth Stage

As with many other crops, sunflower yield is most sensitive to water stress (due to low stored soil water or lack of rainfall) just before flowering through seed development. In the central High Plains, these growth stages occur during August and early September. Data collected at Akron, Colo., show that sunflower yield is highly related to rainfall during August and early September. Yield increases by about 158 pounds per acre for every inch of rainfall during this time period. Research at other locations has shown that water stress earlier in the growing season, during vegetative development, does not affect sunflower seed yield as much as stress during the reproductive growth stages. When rainfall patterns are normal, growers who can irrigate should be able to successfully employ limited irrigation strategies by delaying their first irrigation until just before flowering. However, during extremely dry periods, limited irrigation amounts may be needed during sunflower vegetative stages.

Soil Water Extraction and Rooting

Sunflowers have an extensive root system, which is capable of using large amounts of available soil water from deep in the soil profile. In a detailed study of sunflower root development and soil water use in Kansas, researchers found 87 to 96 percent of observed roots in the sampled soil profile were above 65 inches, although some roots were found as deep as 106 inches. Other studies in the central and southern High Plains have shown that most of the soil water use by sunflowers comes out of the top 6 feet of soil. Some studies have shown dry growing season conditions can stimulate the production of a deeper root system than occurs under wetter conditions.

Proso millet extracts about 4 inches from the top 3 feet of soil, whereas sunflowers extract about 5 inches from the top 3 feet and 7½ inches from the 6-foot profile. About 1½ inches more soil water is used by sunflowers out of the lower half of the profile than corn or wheat.

Impact on Yield of Subsequent Rotational Crops

Because of the dry soil profile condition following sunflower production, producers need to consider the effect of sunflowers on subsequent dryland crop yields. Research results from 3 years of a crop-rotation study at Akron, Colo., show reduced average yields in winter wheat and proso millet when these crops followed sunflowers in rotation compared with rotations without sunflowers when rainfall was low. This is a result of the lower soil water content left following sunflower production, which still exists at wheat and millet planting time if no significant soil water recharge occurs. Wheat yields are reduced by 3 bushels per acre for every inch less of available water at planting. Millet yields are reduced by 6 bushels per acre for every inch less of available water at planting. The yield reductions due to sunflowers in rotation are greater for both wheat and millet when growing season rainfall is below normal. In dry years, the starting soil water profile following sunflowers is not offset by rain during the growing season. Water stress is greater in the rotations that include sunflowers. In wet years, the effect of sunflowers on subsequent crop yields is not a factor. Sunflowers were found to increase yields of subsequent crops when soil moisture is adequate.

While it is clear that average yields of both wheat and millet are reduced by the presence of sunflowers in rotation during dry seasons, the yield of the total rotation must be considered when making decisions about diversifying and intensifying cropping systems. It has been an observation that in larger sunflower production fields with good standing residue following harvest, and with normal to above normal snowfall, 4 to 6 inches of soil water recharge can occur.

This soil water recharge by snow catch in standing sunflower stalks can reduce the influence of sunflowers on subsequent wheat and millet yields from what has been observed in small plot experiments. Other factors, including production costs, market prices, and weed and pest pressures, also must be considered as producers make decisions regarding the benefit of including sunflowers in their rotational cropping systems.

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Irrigation Management

Sunflower irrigation in the High Plains sates of Colorado, Kansas, Nebraska, and Wyoming is becoming of increasing interest to producers. This is due to the fact that supplementary irrigation in dry years help produce good yields. Systems with limited irrigation capacity may produce a good yield if properly timed with the peak water use period of bud formation to petal fall. During the 2003 growing season the United States planted 2.3 million acres of sunflowers. Confectionary sunflower produced under irrigation tend to produce better seed quality and size.

Like other field crops, sunflowers do best with adequate water and, contrary to popular belief, use as much or more water than other crops during their growing season. The reason for this misconception about sunflower water use is that sunflowers do well under field conditions where other crops fail due to dry weather, but it does well in such circumstances because it has a deep and aggressive root system.

If growers would sample soil water to depths of 5 or 6 feet, they would discover that the sunflower crop had removed water to a greater extent than other crops. Crop water-use studies have shown that during the time of its peak use rate, sunflowers use as much water as corn, soybeans, grain sorghum, or alfalfa. However, total seasonal water can be less, because of late planting dates and shorter time to maturity. Reports of sunflower water use range widely from 8 to 38 inches per season. The higher values come from irrigated studies that produced higher yields.

The seasonal water needs of sunflowers are typically around 22 inches under well-watered conditions. However, yields of a fully watered crop, as compared to yields of sunflowers with only two-thirds of full water, are similar during favorable seasons. In general though, yield is directly related to water availability. A conservative estimate is that each inch of available water will produce about 100 pounds of seed. Yield variability, however, can be high. The Central Great Plains Research Station, Akron, Colo., has developed a water use/yield function using both dryland and irrigated sunflower yield. The results indicate that about 150 pounds per acre of seed are produced for every inch of water use after the first 7 inches of water use. Dryland sunflower yield at Akron, Colo., has ranged from 100 pounds per acre to 2,000 pounds per acre. Dryland sunflower yield is very responsive to rainfall received during August and early September or just prior to flowering and through seed filling (Figure 4).

Adequate soil water is needed to obtain uniform germination. A full soil profile that holds about 8 inches of root zone water, (a typical amount for loess soils in the High Plains) and rainfall of 4 to 6 inches after germination, should be adequate for sunflowers to reach bud stage. A single 4-inch irrigation at either bud or full bloom produces the same yield. Thus waiting until full bloom, if possible, is a more conservative method to schedule if only one irrigation is possible or desired. If two irrigations are made, the first should be near early bud stage and the other at full bloom. With a sprinkler system, which uses smaller application amounts, irrigation should start just prior to bud formation and if sufficient water is available, continued until petal drop, unless there is adequate rainfall. Sunflowers can use up to 70 percent of the available soil water from the upper 4 to 6 feet of soil profile by harvest time without adversely influencing yield. Because the soil profile can be very dry after a sunflower crop, a significant water recharge prior to planting the next crop in rotation may be required. In most years, limited irrigation will produce yields similar to full irrigation.

Sunflower stalks should be left standing in good condition to allow snow trapping, which can occur during storms with strong winds. Tall stalks will trap more snow than short stalks. A study done at Akron, Colo., has shown that a population of 14,000 stalks per acre, one inch in diameter, and 16.7 inches tall would trap 4 inches of soil water under the snow condition that prevails in Akron, Colo.

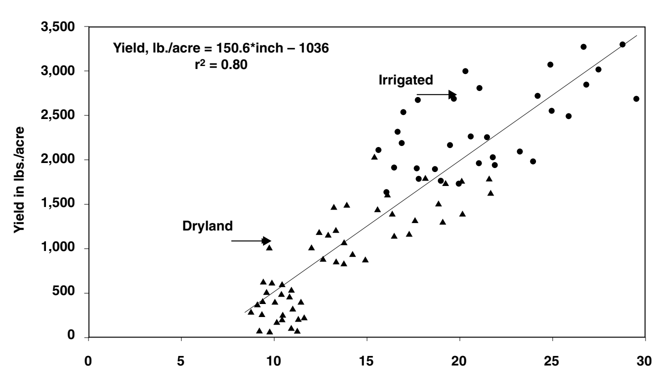
A summary of sunflower yields and water-use data from a 3-year irrigation study at the Northwest Research-Extension Center, Colby, Kan., is presented in Tables 6 and 7. Irrigation treatments ranged from no irrigation (dryland) to irrigation need based on evapotranspiration (ET) or crop water use rates up to 140 percent of actual ET. In two of these years, the sunflower response to irrigation was poor. Yields in 1987 were extremely low because of leaf diseases. Table 3 shows results from a limited irrigation study at Tribune. In this study, a single in-season irrigation at either bud or bloom stage was equally effective.

Kansas State University Research and Extension also conducted studies in 2001 and 2002, both considered to be drought years in the region. In 2001, oil-type sunflowers were grown in eastern Sherman County. Seasonal 2001 precipitation and irrigation data are shown in Table 9. Sunflower yield components are shown in Table 10. Dryland yield was 1,510 pounds per acre, while the irrigated yield produced 2,700 pounds per acre using 8.3 inches of irrigation water applied through a center pivot.

In 2002, plots were established on the Northwest Research and Extension Center at Colby, Kan. The seasonal precipitation and irrigation amounts are shown in Table 11. Table 12 contains the sunflower yield components. The data in Table 12 also contains yield data adjusted to account for lodging and predation problems within the plots to better account for irrigation effect. Two irrigation levels and sunflower hybrids were used. The adjusted dryland yield of the two hybrids were 1,259 and 2,010 pounds per acre, while the highest level of irrigation yield for the two hybrids were 2,720 and 2,941 pounds per acre.

In 2000 and 2001, a study at the Northwest Research Extension Center in Colby, Kan., investigated the effect of water deficits on oil-type sunflowers development, seed yield and quality, and water use. The irrigation treatments were dryland; water during grain fill (R-6 to R-9); water during reproduction development (R-1 to R-5); and water throughout the growing season. The results are summarized in Table 13. Lower yields in 2001 were attributed to insect damage. The yield response to irrigation was less than expected, probably because of insect pressure. Other study

Figure 4. *Sunflower Yield Function.*



results indicate crop water use may be reduced when the soil water content of the wettest soil layer is less than 60 percent of the water holding capacity (Figure 5). The available soil water also can effect canopy development as indicated by Figure 3, the R-5 leaf area index (LAI) (flowering) as compared to soil water content at R-3 (mid-bud) with low soil water at R-3 resulting in reduced LAI at R-5. There is about a 2-week time period between R-3 and R-5.

An irrigation timing study for irrigated sunflowers was conducted at the Central Great Plains Research Station in Akron, Colo. Below normal precipitation for the 2002 and 2004 growing seasons and hailstorms caused yield reductions. Normal precipitation was recorded in 2003. Both oil-type and confectionary sunflowers had a positive yield response to irrigation (Table 14 and 15). Irrigation management of confectionary sunflowers tended to have greater yields and seed size with irrigation during the early reproductive growth stages (before R-5). Irrigating during the R-1 to R-5 growth stage produced yields and seed size similar to that of full water management (Table 16). Irrigating during those growth stages reduced irrigation demand by 3.6 inches of water as compared to Full water (Table 17). Ending irrigation after the R-3 growth stage reduced yield and seed size as compared to irrigating up to the R-5 growth stage.

Timing of irrigation of oil sunflowers influenced both yield and oil content. Full water management, R-1 to R-5 and R-4 to R-5 irrigation strategies average grain yields for 2003-2004 were similar (Table 15). Beginning irrigation after R-5 or ending irrigation by R-3 significantly reduced grain yields of oil-type sunflowers. When irrigation was started prior to R-4, oil percentage tended to be lower than if irrigation was started at R-4 or R-6 growth stages except for 2004, which was a cooler than normal summer. When irrigation was started prior to R-4, continuing irrigation into the later growth stages did not increase oil content, but did have a tendency to reduce oil content as compared to dryland. Ending irrigation by the R-3 growth stage decreased oil content as compared to all other irrigation strategies all three years. Irrigating oil sunflowers during the R-4 to R-5 growth stages had gross returns of $20 per acre less than full water management (data not shown). However, 6 inches of irrigation water were saved by timing irrigation during the R-4 to R-5 growth stage as compared to full water management.

On sandy soils, irrigation normally will be needed earlier and more frequently. Holding the available soil water in the upper one-half of the range of availability until petal drop is a scheduling irrigation goal. Soil water monitoring devices, such as tensiometers or resistance blocks at 1, 3, and possibly 5 feet in two or more representative locations in the field should form an adequate basis for deciding when to irrigate. The irrigator also could use a soil probe to monitor soil water. Irrigations could be scheduled based on crop water-use information. The water-holding capacity of sandy soils in limited (1 inch of water per foot of soil). Consequently, maintenance of adequate soil water is extremely important for producing reasonable yields.

Under irrigation, full-season hybrids are normally recommended (110+ days), with seeding rates of 17,000 to 22,000 seeds per acre. If water is limited, the seeding rate should be reduced to provide an adequate volume of water for each plant. Full irrigation of sunflowers in western Kansas has produced about a 40 percent increase in yield, but during the best seasons with adequate rainfall, nonirrigated yields were comparable to the best long-term average yields with irrigation.

Figure 5. *Water uptake by sunflowers (relative to maximum observed uptake) in relation to the available soil water in the wettest soil layer (relative to available water capacity).*

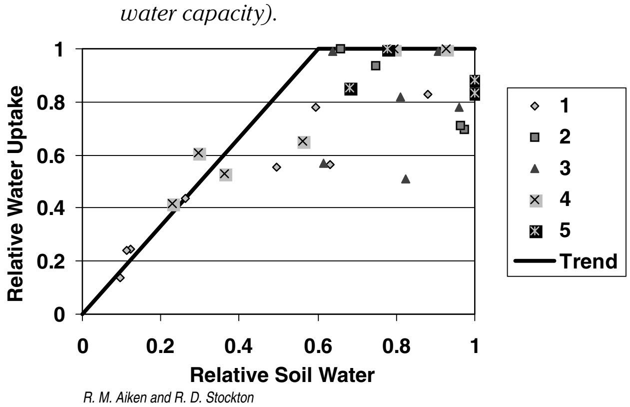


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Figure 6. *Sunflower leaf area at flowering (R-5) in relation to available soil water at mid-bud (R-3) growth stage.*

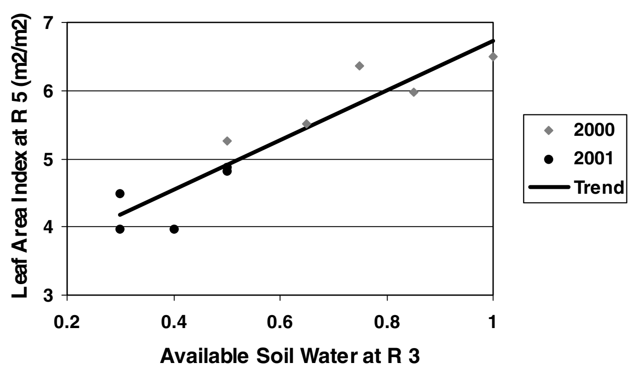

Table 6. *Summary of sunflower yield and irrigation application from an irrigation scheduling study, KSU, Northwest Research Extension Center 1986-1988.*

ET Factor	Yield lb/a	Irrigation inches	Yield lb/a	Irrigation inches	Yield lb/a	Irrigation inches	Yield lb/a	Irrigation inches
	1986	1986	1987	1987	1988	1988	1989	1989
1.40	2.,385	17.19	1,365	17.15	3,759	16.55	2,503	16.96
1.20	2,279	14.25	1,534	12,44	3,015	13.35	2,276	13.35
1.00	2,402	10.40	1,385	11.10	3,328	9.90	2,372	10,47
0.75	2,432	7.12	1,341	7.80	3,065	6.10	2,279	7.01
0.50	2,292	3.00	1,117	3.10	2,998	3.10	2,136	3.07
No Irrigation	2,328	0.00	1,165	0.00	2,568	0.00	2,020	0.00

Table 7. *Summary of sunflower water use and water-use efficiency data from an irrigation scheduling study, KSU, Northwest Research Extension Center 1986-1988.*

ET Factor	Water use inches	WUE[1]	Water use inches	WUE	Water use inches	WUE	Water use inches	WUE
	1986	1986	1987	1987	1988	1988	Mean	Mean
1.40	23.3	103	25.9	53	27.5	137	24.6	78
1.20	21.4	106	23.1	66	24.8	121	22.3	86
1.00	18.5	130	21.9	63	23.0	145	20.2	97
0.75	16.2	151	19.6	69	19.6	157	17.9	110
0.50	13.6	170	15.3	73	18.4	163	14.5	122
No Irrigation	11.4	204	13.6	86	15.4	167	12.5	145

[1] *WUE (Water-Use Efficiency) is defined as yield in pounds per acre divided by total water use in inches.*

Table 8. *Summary of limited water sunflower study. Tribune Branch Agricultural Experiment Station, 1979-1985.*

Treatment	1979	1980	1982	1983	1984	1985	6-Year Average
				Yield (lb/a)			
Preplant only	1,966	1,575	1,400	1,198	2,722	2,540	1,900
PP & Bud	2,405	1,839	1,400	2,190	2,698	2,698	2,205
PP & Bloom	2,436	1,842	1,617	1,661	2,926	2,727	2,202
PP & Bud & Petal Drop	2,667	2,240	1,360	2,831	3,324	2,597	2,512
				Total Water Use (in/a)			
Preplant only	18.0	11.2	15.8	16.1	15.4	14.1	15.1
PP & Bud	22.4	18.6	16.3	21.2	19.3	19.8	19.6
PP & Bloom	23.9	16.5	18.2	17.7	18.0	17.3	18.6
PP & Bud and Petal Drop	19.2	21.4	16.7	23.4	23.0	22.9	21.1

Table 9. *2001 Seasonal precipitation and irrigation for eastern Sherman County, Kan.*

Month	May	June	July	August	September	October	Total
Rain	3.35 [1]	0.5	3.0	1.5	2.0	0.5	10.85
Irrigation	0.6	1.75	4.0	2.0	0	0	8.35

[1] *2.35 received prior to May 10*

Table 10. *Effect of irrigation on sunflower yield components, Sherman County, KS, 2001*

Treatment	Head diameter[1] Range (in.)	Test Weight lb/bu	Yield lb/a	Oil %
Dryland (avg)	3.5-5.5	28.85	1510	51.2
Irrigated (avg)	6.5-8.5	31.9	2780	44.75

[1] *Range in diameter in inches of 10 consecutive heads at a random location in plot.*

Table 11. *Seasonal precipitation, irrigation and ET at NWREC, Colby, Kan.*[1]

Month	May	June	July	August	September	Total
Rain	1.31	1.26	1.49	4.17	1.6	9.39
Irrigation	0.00	1.50	1.50	6.60	1.10 [2]	9.6/10.7 [2]
Reference ET	5.48	10.8	10.91	9.00	5.73	41.92
Corn ET	1.24	6.05	10.26	8.13	2.15	27.83

[1] *May 12, 2002 to Sept. 24, 2002*

[2] *Late irrigation treatment only*

Table 12. *Effects of irrigation on sunflower yield components at NWREC, Colby, Kan., 2002.*

Treatment	Head diamenter[1] Range (in.)	Yield lb/a	Oil %	Adjusted yield[2] lb/a
Dryland (avg)				
545A	3.5-5.5	708	46.5	1259
567DW	3.5-5.5	1,719	37.5	2010
9.6 inches Irrigation (avg)				
545A	6.5-8.5	1,205	45.8	2143
567DW	8 - 9	2,356	37.3	2756
10.7 inches irrigation (avg)				
545A	6.5-8.5	1,530	46.2	2720
567DW	8 - 9	2,515	35.9	2941

[1] *Range in diameter in inches of 10 consecutive heads at a random location in plot.*

[2] *Yield adjusted to compensate for lodging and predation to better evaluate effect of irrigation. Lodging was 25 percent (545A) or 5 percent (567DW) and predation was 25 percent (545A) and 10 percent (567DW).*

Table 13. *Water supplement effects on sunflower yield components. NWREC, Colby, Kan.*

Watering Regime	Stand plants/a	Harvested Seeds/Plant	Seed Weight g/1,000 seed	Seed Yield lbs/a[1]	Oil %	Biomass lbs/a
			2000			
Dryland	14,875	1,897	46	2,119	37.7	6,193
R-1 – R-9	15,750	1,799	54	2,602	40.0	7,572
R-6 – R-9	15,250	1,814	53	2,703	40.6	7,247
R-1 – R-5	14,875	1,784	51	2,541	38.3	6,943
Seasonal V-12 – R-9	14,500	1,945	50	2,348	40.2	6,590
			2001			
Dryland	23,375	873	43	1,237	36.8	4,911
R-1 – R-9	23,125	1,001	48	1,705	38,3	5,905
R-6 – R-9	23,125	964	45	1,544	39.0	5,451
R-1 – R-5	23,250	984	41	1,419	36.6	5,543
Seasonal V-12 – R-9	21,750	1,062	47	1,722	37.2	5,837

[1] *Yield is adjusted to 10 percent moisture content*

Table 14. *Grain yield for Confectionary Sunflowers at Akron, Colo.*

	Average Grain Yields			2002-2004	2003-2004
	2002	2003	2004	Overall Avg	Overall Avg
Irrigation	lbs/acre	lbs/acre	lbs/acre	lbs/acre	lbs/acre
Dryland	299	2,550	1,193	1,347	1,871
R-6 – R-7	688	2,249	1,778	1,572	2,014
R-4 – R-5	883	2,875	2,063	1,940	2,469
R-1 – R-3	1,137	2,847	1,797	1,927	2,322
R-1 – R-5	1,192	3,139	2,173	2,168	2,656
Full Water	1,335	2,617	2,463	2,138	2,540

Table 15. *Grain yield for oil sunflowers at Akron, Colo.*

	Average Grain Yields			2002-2004	2003-2004
	2002	2003	2004	Overall Avg	Overall Avg
	lbs/acre	lbs/acre	lbs/acre	lbs/acre	lbs/acre
Dryland	468	2,387	967	1,274	1,677
R-6 – R-7	771	2,540	1,956	1,756	2,248
R-4 – R-5	1,022	3,031	2,297	2,117	2,664
R-1 – R-3	1,327	2,530	1,803	1,887	2,166
R-1 – R-5	1,287	2,701	2,411	2,133	2,556
Full Water	1,981	2,728	3,147	2,619	2,938

Table 16. *Seed size for confectionary sunflower and oil content for oil sunflowers at Akron, Colo.*

	Confection Seed Size						Oil Content		
	2002		2003		2004		2002	2003	2004
Irrigation	% Large	% Jumbo	% Large	% Jumbo	% Large	% Jumbo	%	%	%
Dryland	0.37	0.00	70.29	30.90	29.5	3.6	48.53	43.88	36.80
R-6 – R-7	9.51	0.24	70.79	31.76	32.8	6.5	49.70	47.33	41.35
R-4 – R-5	22.85	0.49	74.95	44.65	78.0	35.9	47.21	47.70	35.08
R-1 – R-3	55.0	16.6	80.91	43.52	45.5	14.4	43.29	41.32	34.45
R-1 – R-5	64.18	30.16	82.08	49.63	85.7	60.1	45.18	43.35	34.80
Full Water	72.25	48.50	85.64	61.77	78.3	50.7	45.30	42.52	37.90

Table 17. *Irrigation amount for irrigation strategies at Akron, Colo.*

Irrigation Year	Dryland	R-6 – R-7	R-4 – R-5	R-1 – R-3	R-1 – R-5	Full Water
2002	0	2.6	3.7	4.5	6.4	9.0
2003	0	1.8	3.0	3.8	5.3	9.3
2004	3.0 [1]	7.0 [1]	6.7 [1]	6.0 [1]	9.3 [1]	13.5 [1]
Average	1.0	3.8	4.5	4.8	7.0	10.6

[1] *3-inch preseason irrigation*

Insect Pest Management

Cultivated sunflowers in the High Plains host a wide variety of insects. Some of these species are beneficial, others are harmless, and some are pests. Those that are pest species are not always present in densities capable of causing economic loss. When significant insect damage occurs, it may result from leaf, stem, root, or seed feeding.

Wild sunflowers also serve as a host for some insect pests in the High Plains. Their varied flowering dates increase the chance that the presence of one or more pest species will coincide with susceptible development stages of cultivated sunflowers. However, some insects specialize in attacking cultivated sunflower plants, rather than wild ones. Species that attack both types usually survive better and become more abundant on cultivated plants. Furthermore, some pest species attack cultivated sunflowers only in particular regions of their geographic range.

Many sunflower insects overwinter in or near residue from the sunflower plants in which they developed. Crop rotation, modified planting dates, control of wild sunflowers, or deep plowing may reduce the risk of economically important insect infestations. However, deep tillage operations such as plowing to control stem-infesting insects may be incompatible with moisture and soil conservation practices in the High Plains region.

Identifying the pest damaging the crop, or those with potential to have economic impact, is an important first step in pest management. The appropriate pest management strategy cannot be determined without proper identification of the insects present in the field.

Planting date modifications often are recommended for reducing insect pest problems in sunflowers. However, the optimum planting date varies with the pest. Also, late planting dates are associated with reduced yield and oil content. A useful compromise is to select a planting date that minimizes stem weevil problems, because treatment for this insect is separate from other key insects, all of which are treated after heading. Planting after 500 accumulated degree days (using 43 degrees as the base temperature) reduces the risk of stem weevil damage, but it is still early enough to allow for good yield and oil content. However, it may still be necessary to treat at heading to control head moths and seed weevils.

Because insecticide registrations frequently change, complete insecticide recommendations are not provided in this publication. Insecticides currently registered for use against sunflower pests can be found in the *High Plains Integrated Pest Management Guide for Colorado, Western Nebraska, Montana and Wyoming* (*www.highplainsipm.org*) or in the Kansas publication: *Sunflower Insect Management* (*www.oznet.ksu.edu/library/ENTML2/MF814.PDF*).

Economically sound management of sunflower insect pests in our region is often dependent on the judicious use of insecticides, carefully timed to coincide with insect activity or a particular plant growth stage. The need for an insecticide treatment should be determined by scouting a field at least once a week. Optimal scouting patterns may vary from pest to pest. A general procedure is to cross the field on a diagonal or zigzag pattern, stopping to check for insects a minimum of 10 times. At each stop, examine five to 10 plants for insects and their damage. Use this scouting information and the action thresholds given below to determine if an insecticide treatment is necessary. The treatment thresholds suggested below should be used only as general guidelines that sunflower producers should adjust to fit their individual conditions. For example, a lower action threshold might be used for situations when higher crop values are expected or for fields with high yield potential. Conversely, higher action thresholds may be used when the crop is expected to be of lower value or for lower yield potential situations such as dryland production.

Key Pests of Sunflower

In this chapter, pests are arranged by the plant growth stages they attack, regardless of how important they are. Regionally, the sunflower stem weevil, sunflower moth, and red sunflower seed weevil are considered to be key pests. These are the pests most likely to cause significant losses and should be the main focus of pest management planning, scouting and treatment.

Seed and Seedling Pests

Cutworms

Several cutworms may be encountered throughout the sunflower growing region, but the following are common species:

Darksided cutworm (Photo 22): *Euxoa messoria* (Harris). This cutworm is grayish-brown with a narrow dark gray stripe on either side just above the spiracles. The mature larvae can be up to 1½ inch (38 millimeters) in length. It overwinters in the egg stage and is an early season pest that has one generation per year. The grayish-brown colored adult moths are found in late summer and autumn.

Dingy cutworm complex: (*Feltia spp*). Larvae have a dull, dingy-brown body with mottled pigmentation. A broad gray stripe runs along the back with light gray V-shaped patterns on each segment. Partially grown larvae overwinter in the soil. Fully developed larvae are 1 to 1½ inch (25 to 38 millimeters) in length. The forewings of the adult moth are dark brown with bean-shaped markings.

Pale western cutworm: *Agrotis orthogonia* Morrison. Larvae are uniformly grayish in color without spots or stripes, but the body has fine, flat granules. The adults emerge in August and September and are active during September. The females are attracted to loose, newly tilled soil for egg laying. The eggs will overwinter and begin hatching in early spring. Larvae can survive long periods without food and can be present when summer crops emerge. The larvae are quite destructive. They damage plants by cutting them off below the ground.

Sandhill cutworm: *Euxoa detersa* (Walker): The sandhill cutworm is light-tan, semi-translucent, and has several pale, longitudinal stripes. This cutworm has one generation per year, it hatches in the fall then overwinters as a partially-grown larvae. Feeding resumes again in the spring and continues until midsummer. Adults emerge in August and lay their eggs in the field. Soil texture is one of the important physical factors that determine the distribution of this cutworm. Sandhill cutworms will only be found in fields with very sandy soil.

Management: Check fields early in the growing season and treat if there is one cutworm per square foot or if stand losses are approaching the lower limit for optimum plant populations. Consider sieving the surface of 5 square feet of soil through coarse screening as a way of improving the detection of cutworm larvae. Treatment should be applied when economic levels are detected, unless a majority of larvae are fully grown (1¼ to 1½ inch long). These larvae have finished feeding and will soon pupate. Several pyrethroid insecticides registered for use in sunflowers are effective against these pests.

Wireworm

Many species of wireworm attack sunflower and other row crops. These insects overwinter mainly in the larval and adult stages in the ground. In the spring, the adults become active. The beetles are hard shelled, brownish, grayish, or nearly black in color and somewhat elongated with the body tapering more or less toward each end. They are referred to as click beetles because when they are placed on their backs, they snap the middle part of the body against the ground and throw themselves several inches in the air. This snapping makes an audible "click." The larval stage is spent in the soil and lasts 2 to 6 years. The larvae are usually hard, yellow to dark brown, smooth, "wirelike" worms, varying from ½ to 1½ inches in length when mature (Photo 23).

False wireworm larvae are similar in appearance and biology to wireworms, but they are slightly lighter in color, somewhat softer and have longer legs. False wireworm adults are darkling beetles and do not right themselves by clicking. These dark-colored, long-legged beetles are frequently seen scurrying about with their rear end held up in the air.

Management: Wireworms are most damaging to sunflower when the crop is planted in wheat stubble because the adults are attracted to grasses to lay their eggs. Generally false wireworms are concentrated in the highest residue areas of the field and may be more common as no-till increases in popularity. Larvae typically follow the drill row, feeding on seeds or germinated seedlings. The larvae kill plants by feeding directly on the seed and preventing germination or by feeding on the stem between the seed and the soil line. There is no known rescue treatment. Some soil insecticides and seed treatments are useful in reducing wireworm injury, but the sporadic nature of the of the problem makes using insecticides hard to justify unless there is a history of problems or when replanting a field because of previous wireworm injury.

Defoliators

Insect Defoliation Damage to Sunflowers

A number of insects cause defoliation damage to sunflowers during the course of the season (e.g., palestriped flea beetle, sunflower beetle, painted lady caterpillar, and grasshoppers). The effect of these insects on sunflower yield varies with the extent of defoliation and the growth stage at the time of defoliation.

The percent yield loss resulting from various levels of defoliation are shown in Table 18. These values can be used to estimate treatment thresholds for defoliating insects. Economic losses would fall in the range of about 5 to 10 percent yield loss, as these losses would generally equal the cost of an insecticide treatment. For example, 10 percent yield loss of a 1,200 pound yield on oil-seed types would equal 120 pounds and at $0.10 per pound the loss would be $12, the approximate cost of an insecticide treatment. Higher yields or crop value would result in a lower threshold yield loss.

During vegetative growth stages, defoliation effects are not severe with 5 to 10 percent yield losses not occurring until defoliation reaches 50 to 80 percent. Damage during the early reproductive stages (R-2 to R-5) will have the greatest effect on yield. During this time, defoliation thresholds vary from 15 to 40 percent, and before and after these stages, thresholds are not reached until more than 40 percent of the leaf area has been lost.

Painted Lady

Vanessa cardui (L.). The painted lady larva also is known as the thistle caterpillar because of its preference for feeding on thistles. This butterfly has a wingspread of 2 inches (51 millimeters). Its upper wing surface is brown with red and orange mottling and white and black spots with a lot of individual color variation possible (Photo 24). The green, barrel-shaped eggs are laid singly on plant leaves. More than one generation per year occurs. Larvae are light brown to black, spiny, with a pale yellow stripe on each side (Photo 25). Adults are present in May and June with larvae appearing shortly thereafter. Larvae skeletonize leaves and produce substantial webbing.

Management: The need to take action is based on yield loss estimates associated with defoliation levels given in Table 18 if larvae are smaller than 1¼ inch in length. Larger larvae will soon stop feeding.

Table 18. *Approximate percent yield reduction from defoliation occurring at various sunflower growth stages (table modified from North Dakota State Univ. Extension Bulletin #25).*

	Percent Defoliation									
	10	20	30	40	50	60	70	80	90	100
Plant Stage	Approximate percent yield loss									
V-4 to V-5	0	1	2	2	4	4	5	9	14	21
V-9 to V-11	0	2	3	4	5	5	7	11	17	24
R-1	2	4	6	6	7	9	16	24	34	47
R-3	2	8	15	19	24	32	44	59	78	99
R-5	1	3	7	10	16	25	37	49	67	90
R-7	0	1	3	7	10	13	16	18	20	22
R-8	0	1	2	3	5	7	8	9	10	11

Sunflower Butterfly

Charidryas nycteis (Doubleday). The sunflower butterfly, also known as the silvery checkerspot, is similar in appearance and biology to the painted lady, except there is more yellow on the wings and eggs are laid in clusters. When these egg clusters hatch on plants at the four- to six-leaf stage, whole plants may be defoliated. Larvae then disperse and feed on neighboring plants. When plants are larger, typically only single plants are affected. Larvae are similar in appearance to painted lady, but are usually darker with a more pronounced yellow band down each side.

Management: Determine defoliation threshold from Table 18, and follow treatment guidelines for painted lady.

Sunflower Beetle

Zygogramma exclamationis (F.). Adults are about ¼ to 5⁄16 of an inch (6 to 8 millimeters) long and have a reddish-brown head and cream-colored back. They have three dark, reddish-brown stripes on each wing cover (Photo 26), and the lowest strip is discontinuous, resembling an exclamation point. Larvae are yellowish-green and humpbacked in appearance (Photo 27). The adults overwinter in the soil and become active during June and July, when they mate and deposit eggs on stems and leaves. Larvae may be found soon afterwards. Both adults and larvae are defoliators, but larvae are considered to be more economically significant.

Management: Adults attack sunflowers early in the season by defoliating seedlings (Photo 28). An infestation of one adult per plant is considered to be an economic action threshold. The larvae feed later in the season on larger plants. Fifteen larvae per plant, or a threshold based on the yield loss estimates from defoliation levels given in Table 18, would justify an insecticide application.

The Palestriped Flea Beetle

Systena blanda Melsheimer is common in some areas of the High Plains. The beetles are cream colored. Each wing cover has two dull light brown stripes. When wing covers are closed, the beetle appears to have three light brown stripes alternating with two cream-colored stripes of about the same width as the darker ones. Flea beetle larvae overwinter in the soil and pupate in the spring. Adult flea beetles emerge and begin to feed on plants in June. The damage is characterized by tiny shot-hole feeding on seedlings. They will remain active for the first half of the summer.

Management: Seedling sunflowers are most vulnerable to damage from this pest. Water loss from beetle feeding can rapidly dry stressed seedlings and cause stand loss. Early-season treatment decisions should be based on preventing serious plant stress and stand loss. Later, threshold can be determined based on the yield loss estimates from defoliation levels given in Table 18.

Head Infesting Insects

Sunflower Moth

Homoeosoma electellum (Hulst) can cause substantial economic loss to commercial sunflower. The buff to gray colored moths are about ⅜ inch (10 millimeters) long with ¾ inch (19 millimeters) wingspan (Photo 29). Larvae (Photo 30) have brown head capsules with alternate dark and light lines running longitudinally. Adults migrate from southern areas and are attracted to sunflowers beginning to bloom. The annual northward dispersal is aided by southerly winds, and adults first appear in the region in late June or July. Large numbers of immigrating moths may descend on fields of blooming sunflowers. Sunflowers in early bloom stages are most attractive, in part, because sunflower pollen stimulates egg-laying by female moths. Eggs are laid at the base of florets and newly emerged larvae feed first on these florets, later burrowing into individual seeds. Larvae mature over 2 to 3 weeks and each larva can destroy three to 12 seeds during its development. Sunflowers infested with sunflower moth larvae are more susceptible to *Rhizopus* head rot, particularly under more humid or wet conditions. Mature larvae descend to the soil to pupate. Generation time is approximately 30 days during hot weather. In warmer years, sunflower moths from early planted fields may infest later-planted fields, but the extent of damage is generally less than that in early planted fields. Moth numbers, hence larval pressure in a given year varies from site to site and depends on the success of earlier generations to the south and weather conditions that aid northerly adult movement.

Management: If moth flights do not coincide with early bloom sunflower (stages R-5.1 to R-5.5), damage will be minimal. Planting after June 1 will reduce, but not eliminate, the potential for sunflower moth damage, because moth activity will be decreasing when the sunflowers begin blooming. Most planting date studies indicate that early planted fields (fields that bloom before late July) stand the greatest chance of developing significant infestations. However, when moth populations are high, the risk potential for later fields will be increased.

Use pheromone traps that capture male adults to monitor flights of the sunflower moth. When the plants are in the late bud stage (R-3), place two to four traps located 20 to 30 feet or about 10 rows into the field on the south and north borders. Traps should be placed on posts slightly above the canopy height. Both trap types (milk jug or wing) work equally well. Check traps two to three times per week, until plants have nearly finished flowering (R-5.9). If an average of fewer than one moth per night is caught, the risk of a significant infestation is low. If an average of one to four moths are caught, the risk of infestation is moderate, and control decisions should be based on further field scouting. If the trap catch averages more than four per night per trap, the risk of significant damage is high and an insecticide treatment should be considered. Remember to make sure that all traps function properly throughout the moth flight.

Field scouting also can be used to monitor moth flight or as a supplement to pheromone trapping. Begin scouting by stage R-4 (buds beginning to open) so that populations can be carefully assessed as flowering begins (R-5.0 to R-5.1). Moths are best scouted in the late evening when they are active on the heads. They spend most of the daylight hours resting on the undersides of leaves and other vegetation and often fly off when disturbed, thus they can be difficult to locate and identify unless populations are very heavy. Count moths on five sets of 20 plants scattered across the field. Consider an insecticide treatment if scouting results average two or more sunflower moths per five plants at early bloom. Since large numbers of moths can enter a field very quickly, scouting should be repeated at 2- to 3-day intervals until the R-5.9 stage is reached.

Regional differences in sunflower moth problems have been observed. Producers in more southern and eastern areas generally experience more sunflower moth activity than those to the north and west, and thus are more likely to need a second treatment to achieve acceptable levels of control. The need for a second treatment is more likely if the first was made early (R-4 to R-5.1). The first treatment targets the adult to prevent egg laying, but it provides little residual activity, and the second treatment targets larvae. Larval control can be inconsistent because it is very difficult to get good coverage of sunflower heads and larvae may already have moved away from the surface. Care should be taken to avoid killing bees and other beneficial insects that may be present. Evening or early morning treatments may be helpful in this regard.

Banded Sunflower Moth

Cochylis hospes Walsingham, is a small straw colored moth about ¼ inch (7 millimeters) long (Photo 31) with a wingspan of ½ inch (13 millimeters). The front wings are yellowish and have a dark brown triangular band near the middle.

Adults emerge from early July to August. Females lay off-white to pale orange eggs singly on the bracts of sunflower buds in growth stage R-2 through R-4. The newly hatched larvae are off-white, about 1/16 inch (1.6 millimeters) long and have dark-brown head capsules. Larvae feed in the heads, first on pollen and florets, later on developing seeds. As larvae grow, there is a gradual color change to light pink or yellow, then to reddish or purplish and finally to green at maturity when they reach 5/16 to ½ inch in length (Photo 32). Larvae feed on sunflower seeds through late September to early October then overwinter in the soil. They pupate in June of the following year. In more southern areas, banded sunflower moth has more than one generation per year and, for unknown reasons, is less likely to attack cultivated sunflower. It is most problematic in northern regions where it has only a single generation.

Management: Research in North Dakota has demonstrated that delayed planting of sunflower until late May or early June will help reduce infestation levels of banded sunflower moth. However, late planting may increase damage by the red seed weevil. Growers attempting to use planting dates to control a given sunflower insect should be aware of the effect of all potential insects. They should also consider the effect of planting date on yield potential and quality of crop.

Pheromone traps can be used to monitor populations and flight times of banded sunflower moths. However, a pheromone trap based economic threshold is currently not available for this species.

Field scouting should include weedy field margins and adjacent crops bordering the sunflower field. Moths are best scouted in the early morning or late evening when they are active. Research is continuing into accurate economic thresholds, so check with local extension specialists for current threshold information.

The best plant stage to treat for banded sunflower moths is early bloom or the R-5.1 growth stage, or when the plant has just begun to shed pollen. This is the time when banded sunflower moth eggs have hatched and larvae are present, but before seed formation. At this time the larvae are beginning to feed on the disk flowers are exposed on the head and are susceptible to insecticide treatment.

Sunflower Seed Weevils

Red sunflower seed weevil, *Smicronyx fulvus* LeConte adults are about ⅛ inch (2.5 to 3 millimeters) long and covered with reddish-orange scales (Photo 33). As the weevils age, the scales rub off and weevils become darker. Gray sunflower seed weevils, *Smicronyx sordidus* LeConte (Photo 34) are about ⅛ to ¼ inch (2.5 to 6 millimeters) long.

Table 19. *Conversions to be used with "DEET" scouting method to estimate absolute red sunflower seed weevil density in the head from actual weevil counts in the field.*

Weevil Count in Field	Absolute Density	Weevil Count in Field	Absolute Density
1	1.4	11	19.5
2	2.9	12	21.3
3	4.4	13	23.1
4	5.8	14	24.9
5	7.3	15	26.6
6	10.7	16	29.3
7	12.4	17	31.1
8	14.2	18	32.9
9	16.0	19	34.7
10	17.8	20	36.6

Females lay eggs between the pericarp and developing achene (seed), usually one egg per seed. Gray sunflower seed weevil female lays eggs during the later bud stages (R-4) and the red sunflower seed weevil begins laying eggs early in the flowering stages (R-5.1). Since females must feed on pollen before their eggs are ready to be laid, red sunflower seed weevil eggs are not laid until pollen shed. Larvae feed on the inner meat of seeds (Photo 35). Red sunflower seed weevil larvae only consume about half the meat in the seed while the gray sunflower seed weevil larvae consume nearly all the seed contents. When growth is completed in August to early October, larvae chew a hole, exit the seed, and drop to the ground to overwinter in belowground cavities. Pupation occurs in June, lasting 8 to 10 days. Adults may be found from June to September. There is a single generation each year.

Management: Scouting for red sunflower seed weevils can be difficult because of its spotty distribution in the field and its habit of hiding in sunflower heads. Start scouting at the late bud stage (R-4.0) and stop when the majority of the plants in the field have passed 70 percent pollen shed (R-5.7), or when the action threshold has been exceeded in oil-type sunflowers (see below for calculations). Avoid making seed weevil counts from plants in field margins as they tend to congregate in these areas and counts will not be representative of the entire field. A set of five flower heads should be sampled at random (without regard for growth stage) at each of five different sites within a field, each at least 75 feet from the field edge.

Red sunflower seed weevils can be counted by rubbing the face of the head. This causes the weevil to back out and move around the face of the head. An alternative is to spray the head with an aerosol containing the insect repellent "DEET." This will flush the insects from their hiding places, allowing them to be counted easily. If the insect repellent method is used, use Table 19 to convert from total weevils flushed from a head to an absolute count to compare to calculated threshold shown in Step 3.

Steps for calculating a red sunflower seed weevil action threshold in oil type sunflower

Step 1: Break-even threshold = Per acre cost of treatment per pound market value of crop.

Example: $7.00 ÷ $0.09 = 77.8 pounds loss per acre to break even on an insecticide application when sunflower price is $0.09 per pound.

Step 2: Female weevils per acre required for this loss (0.00056 pound loss per female red seed weevil).

Example: 77.8 pounds per acre ÷ 0.00056 = 138,930 female weevils.

Step 3: Weevils per plant to cause break-even loss = female weevils x 2 (to account for males) ÷ plant population.

Example: (138,930 x 2) ÷ 20,000 = 13.9 weevils per plant. This is the number of red seed weevils per plant expected to be present per sunflower plant in order to cause the calculated break-even loss.

In this example, an action threshold of 13.9 (use 14 for simplicity) weevil adults per plant will justify treatment with a break-even return. This figure will go up or down depending on control costs and crop market value. (Scouting and threshold information were taken from McBride, D.K., G.J. Brewer, and L.D. Charlet. 1992. *Sunflower seed weevils*. North Dakota State University Cooperative Extension, Bulletin E-817.)

Insecticide applications are made to prevent adults from laying their eggs; therefore, treatments should be timed early in the flowering period when about 30 percent of the plants have reached the R-5.1 stage. Insecticide applications made against sunflower moth also may provide adequate control of seed weevils.

Confection sunflower should be treated even earlier to avoid quality penalties. If less than 10 to 15 percent of the plants have reached R-5.1 and one to two red sunflower seed weevils can be found per head, treatment should be considered.

Because the action threshold for gray sunflower weevils is not well defined, the thresholds described for the red sunflower weevil is generally used on oil type sunflowers, keeping in mind the following differences between the species. The gray sunflower seed weevil feeding causes the seed to enlarge during its development. The larvae consume most of the seed contents so that at harvest the seeds pass through the combine and do not contribute to dockage. Treatments for gray sunflower seed weevil should be made earlier, when 10 to 15 percent of the plants have reached the R-4 stage.

Sunflower Bud Moth

Suleima helianthana (Riley). This moth has a wingspan of 11⁄16 of an inch (17 millimeters) and is gray-brown in color with two dark transverse bands on the forewings (Photo 36). The larva is cream colored with a brown head (Photo 37). First generation adult moths emerge from overwintering pupae from May to mid-June. There is a second generation in July or August. First generation larvae bore into stems of both wild and cultivated sunflowers, leaving characteristic lumps of black excrement at their entrance holes. This damage can result in deformed plant growth, including branching. Second generation larvae usually feed in the pith area of the head.

Management: Significant yield losses have not been demonstrated with this insect. Insecticide treatments are not considered necessary under most conditions.

Sunflower Headclipping Weevil

Haplorhynchites aeneus (Boheman). The adult is shiny black, measuring about about 5⁄16 of an inch (8 mm) from the tip of the snout to the rear of the abdomen (Photo 38). Larvae are cream colored, somewhat C-shaped and grub-like in appearance. Adults emerge in mid-July and may be found on plants for a 2- to 3-week period. The females feed on pollen and nectar of flowering heads. Damage to sunflower occurs because the female makes a circle of feeding punctures on the upper stalk that partially sever the head (Photo 39). Eggs are then laid in the sunflower head, which subsequently falls to the ground. The larvae develop and overwinter in the fallen head. The percent of "clipped-heads" is usually very low but may reach 20 percent in some fields. Damage is often limited to field margins.

Management: The economic threshold for this pest is not well defined, but consider insecticide treatment if more than half of the plants examined have sunflower headclipping weevils present and head clipping exceeds 5 percent on average across the field.

Sunflower Seed Maggot

Neotephritis finalis (Loew). The adult fly is about ¼ of an inch (6 millimeters) long, with a wingspan of about ⅜ inch (9 millimeters). The wings have a brown lace-like appearance. The larvae attain a length of 3⁄16 inch (5 millimeters) at maturity. Adults emerge during early July and egg deposition occurs on the corolla (flower petals) of developing disk flowers. The total larval period is 14 days. Two generations generally occur. The first generation pupates in the head, whereas, the second generation overwinters in the soil as pupae. Larval damage is largely dependent upon the state of larval and seed development. Seed sterility occurs when newly hatched larvae tunnel into young blooms. A single larva feeding on immature flowers can destroy up to 12 ovaries, while larvae feeding on more mature flowers may destroy only one to three seeds during development.

Management: Significant yield losses have not been demonstrated with this insect. Insecticide treatments are not considered necessary under most conditions.

Sunflower Receptacle Maggot

Gymnocarena diffusa (Snow). The adult fly is about ½ inch (13 millimeters) in length with a wingspan of about ¾ inch (19 millimeters). Its eyes are bright green and wings have a yellowish-brown mottled pattern (Photo 40). Adults emerge in late June to early July. Eggs are laid on bracts of developing sunflower heads. Upon hatching, larvae tunnel into the spongy tissue of the receptacle and upper stem (Photo 41). After about 30 days, the mature larvae cut small emergence holes on the underside of the receptacle. Most larvae then drop to the soil to pupate in late August or early September, although some larvae pupate in the head. There is one generation per year in the region.

Management: Significant yield losses have not been demonstrated with this insect. Insecticide treatments are not considered necessary under most conditions.

Stem Feeders

Sunflower Stem Weevil

Cylindrocopturus adspersus (LeConte). Adults are about ⅛ to 3⁄16 inch (4.5 millimeters) long and grayish-brown with variable white spots on the wing covers and thorax (Photo 42). Larvae are creamy white with a small, brown head capsule and are ¼ inch (5 to 6 millimeters) long when mature. Larvae appear C-shaped when observed in the vascular and pith tissue of the lower stalk (Photo 43).

This pest has only one generation per year. Most adults emerge in late May and early June, making early plantings more susceptible to attack. Adults can be found on plants in June and July feeding on the epidermal tissue of sunflower foliage. This feeding does not affect plant vigor. Once emergence occurs, 10 to 14 days are required before egg deposition begins. Eggs are deposited individually in the epidermal tissue of the lower stem. Drought stressed plants are most susceptible. Plants under irrigation typically contain fewer larvae than adjacent dryland plants, suggesting that well-watered plants may be able to partially resist the establishment of small weevil larvae. The presence of numerous larval chambers weakens the stalk, causing infested plants to lodge when plants dry down. Additionally, this insect is a vector of Phoma black stem disease. Adults pick up spores of the fungus as they emerge from old stalks and inoculate young plants with the disease as they lay eggs. Larval feeding appears to enhance subsequent proliferation of the fungus within the stalk. Mature larvae form overwintering chambers in the woody stem tissue near the base of the stalk (Photo 44) in the fall. Pupation of overwintered larvae begins in April.

Management: Cultural control methods that are useful for managing sunflower stem weevil include delayed planting to avoid the major egg laying period (plant after 500-degree days, base 43 degrees Fahrenheit), planting lower plant population to allow large stalks (lodging was lower at both 9,000 and 18,000 plants per acre than 36,000 plants per acre in studies from North Dakota), and tillage. Cultivation of crop residues may provide some control of overwintering larvae and pupae, if this is compatible with soil and water conservation practices. A combination of disking to break up stalks and moldboard plowing to bury them at a depth of 6 inches (15 centimeters) can cause larval/pupal mortality and severely impact the emergence of adult stem weevils.

To estimate their population, it is important to monitor for sunflower stem weevils. However, adults are difficult to see on the plants because of their small size, cryptic coloration, and tendency to drop to the ground and "play dead" when disturbed. Field scouting for adults should start at about 600-degree days (Base 43 degrees Fahrenheit, starting January 1) and continue until mid-July. Select sampling sites 70 to 100 feet in from field margin. Count the number of adults on five plants at five randomly selected sites throughout the field for a total of 25 plants. Calculate the average number of weevils per plant. Consider treatment if average counts exceed one adult sunflower stem weevil per three plants as plants enter the V-8 stage of development and continue to monitor fields through V-14. This level of stem weevils can result in about 40 larvae per stalk at the end of the season. Larval populations of 25 to 30 or more per stalk can weaken the stem tissues and cause lodging.

Stem weevil can be controlled by either a preventive application of Furadan 4F at planting time or with a foliar application to control the adults after the economic threshold is reached. Since Furadan has good systemic activity, applications to irrigated fields can be followed by watering to encourage uptake of the material by the plants. Early planted dryland fields in regions with a history of stem weevil problems generally benefit from treatment. Seed treatments generally do not have the residual activity to control stem weevils.

Black Sunflower Stem Weevil

Apion occidentale (Fall). The black sunflower stem weevil is only 1⁄8 to 3⁄16 of an inch (2.5 to 5.0 millimeters) long with a long, curved snout. Larvae are small and yellowish. Unlike the sunflower stem weevil, black stem weevils overwinter as adults, not larvae. They are rarely as abundant as the sunflower stem weevil, and their mechanical injury is considered negligible. They have been implicated as vectors of Phoma black stem disease.

Treatment: This insect usually does not require specific management, but treatments directed at controlling sunflower stem weevil will also control black stem weevils.

Longhorned Beetles

Dectes texanus texanus LeConte, is native to the High Plains and is a member of the beetle family known as the longhorn beetles or roundheaded borers. The adult (photo 45) is a bluish gray beetle about 3⁄8 inches (7 to 10 millimeters) in length with black and gray banded antennae that are somewhat longer than the body. Eggs are usually laid in the petioles of lower leaves where the early instar larvae feed, boring down into the main stalk as they grow. Fully grown *Dectes* larvae (Photo 46) are creamy white, legless, somewhat corrugated in appearance and taper toward the tail end. When mature, the larvae girdle the inside of the stalk from the interior (Photo 47) and create an overwintering chamber at the base of the stalk. This insect also is known as the soybean stem borer and is a pest of soybeans in southern and central US productions areas. It also feeds on several weedy hosts, including cocklebur and ragweed.

A much larger (5⁄8 inch (13 to 17 millimeter)) species, *Ataxia hubbard* Fisher, (Photo 48) is similar in biology and damage, with the very important exception that the larvae of this species do not girdle the stem. Larvae of *Ataxia* (Photo 49) are blunter in shape and covered with tufts of bristles on the terminal segments.

Management: Options for stem borer management are limited. Resistant varieties and effective chemical controls are not available. Deep plowing has been recommended in the past, but is inconsistent with current soil and water conservation recommendations. Since larval feeding is confined to the central pith of the stalk and has little or no effect on yield in healthy plants, management should focus on reducing losses due to lodging. Reducing plant populations to encourage thicker stems and harvesting severely infested fields early may help minimize lodging losses.

Root Feeders

Carrot Beetle

Ligyrus gibbosus (DeGeer). A moderate size, 1⁄2 to 5⁄8 inch (13 to 17 millimeters) and oblong-ovate, dark reddish-brown to black beetle. The larvae are similar in appearance to white grubs and attack the root system.

Management: Significant yield losses have not been demonstrated with this insect. Insecticide treatments are not considered necessary under most conditions. Insect-feeding mammals may damage some plants in localized areas as they dig up these larvae in their search for food.

Sunflower Root Moth

Pelochrista womonana (Kearfott). The sunflower root moth is similar in appearance to the sunflower bud moth, but darker gray with less clearly defined bands on the forewings. Unlike the bud moth, there is one generation per year, and the adults emerge in late spring. Eggs are laid directly into upper portions of the stem and the larvae (Photo 50) tunnel downward to the roots late in the season where they overwinter. Multiple larval galleries may be formed around the root crown, seriously weakening the plant.

Management: Because the effect of this pest on yield is unknown, there is no established action threshold for sunflower root moth. Harvest early if lodging is observed.

Sunflower Root Weevil

Baris strenua (LeConte). The black adults are oval shaped, almost 1⁄4 inch (7 millimeters) in length, with a short downward pointing snout (Photo 51). Adults appear in fields by June, and they are often found near the roots at the soil surface. Adult feeding at the bases of the plant causes the development of callous tissue. The bright yellow eggs are laid in this tissue and hatching larvae feed on the roots. By September and early October larvae form a "soil cocoon" near the roots at a depth averaging 2 to 5 inches, where they overwinter. Numerous larvae in the stalk result in wilting and lodging. Adults are known vectors of charcoal rot and Phoma black stem disease.

Management: Heavy larval feeding can result in some wilted plants and contribute to lodging, but the damage is usually quite localized and no action threshold has been determined. Insecticide treatments are not considered necessary under most conditions.

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Suppliers of Sunflower head moth sampling equipment and supplies

- Phero Tech Inc., 7572 Progress Way, Delta, B. C. V4G 1E9, phone (604) 940-9944 or 1-800-665-0076; fax: (604) 940-9433
- Sentry Biological, 610 Central Avenue, Billings, MT 59102, phone: (800) 735-5323
- Great Lakes IPM, 10220, Church Rd. NE, Vestaburg, MI 48891, phone: (517) 268-5693 or (517) 268-5911; fax: (517) 268-5311
- Gempler's Inc., 211 Blue Mounds Rd., Mt. Horeb, WI 53572, phone: (800) 382-8473

Cost-Return Prospects

Sunflowers are an economically viable crop alternative for growers in the High Plains region, including Kansas, Colorado, and Nebraska. It is well adapted agronomically to both irrigated production and dryland cropping systems in the region and is a viable "double crop" option where growing season length permits. The profitability of dryland sunflower production has been comparable to other summer crops in High Plains cropping systems. Irrigated sunflowers also have a competitive economic niche in parts of the High Plains where groundwater supplies are sometimes too limited to support fully irrigated corn production. Most of the sunflower production in the High Plains is located in sections of the three state region of northwestern and west central Kansas, east central and northeast Colorado, and southwest and the panhandle sections of Nebraska. The existence of a number of major sunflower processing plants in the High Plains region provides area sunflower producers with local market outlets for the crop and helps ensure the long-run viability of the sunflower enterprise in the region.

Markets exist in the High Plains region for three differentiated sunflower products — oil, confectionary seed, and birdseed sunflowers. Oil-type sunflower varieties have a shiny black coat and are crushed to produce a high-quality vegetable oil used in cooking. Sunflower meal is a by-product of the crushing process for oil sunflowers and is used as high protein livestock feed. Discarded sunflower parts from the crush process are also used in livestock feed with sunflower meal. Confectionary sunflowers have larger seeds that are black colored with white stripes. Confectionary sunflowers are grown to produce food products for baking or direct consumption. Sunflowers are also produced in the High Plains for birdseed. Birdseed sunflower sales represent a small, but fast growing, portion of sunflower production, with some sunflower varieties grown specifically to meet birdseed contract specifications. Additionally, some oil-type sunflower producers deliver their crop to birdseed plants if the price relationships are favorable. Some small sunflower nut meats from hulled sunflowers also go into the birdseed market. Confectionary sunflowers that are too small to meet market specifications for human consumption are often sold as birdseed by processors. Contracting of confectionary sunflower production between producers and processors is prevalent, which points to the need for an understanding of sunflower contract grade and quality specifications on the part of area sunflower producers.

Since the late 1990s, the U.S. oil sunflower industry has been in a process of transition toward the use of mid-oleic varieties. The sunflower oil produced by these mid-oleic sunflower varieties is commonly referred to as "NU-SUN," a title originating with the National Sunflower Association. Mid-oleic sunflower varieties have oleic acid contents of 55 to 75 percent, a linoleic acid level of 30 percent, and a saturated-fatty acid content of 8 percent or less. Mid-oleic sunflower oil has performed as well as cotton oil (i.e., the industry standard) in consumer frying tests, with the added benefit of having low saturated fat levels, making it attractive to health conscious consumers and consequently the U.S. food processing industry. There is optimism in the sunflower industry that mid-oleic sunflower oil can fulfill U.S. consumer demand for a nonhydrogenated and reasonably priced frying oil in coming years, both in the U.S. snack food and the fast food industry. This transition toward mid-oleic sunflower oil production could coincide with a shift in U.S. sunflower demand away from volatile world export markets toward stable and potentially lucrative domestic markets.

The High Plains region presently has three major sunflower plants: one oilseed crush plant (near Goodland, Kan.) and two confection processors (one in Colby, Kan., and one in Goodland). In the United States, three other major oil sunflower processing plants exist, two in North Dakota (Enderlin and West Fargo) and one in Minnesota (Red Wing). Additionally, a number of smaller sunflower processing and birdseed packaging plants exist in Kansas, Colorado, and Nebraska. Because of the geographic location of the U.S. High Plains region, it holds a transportation cost advantage over the sunflower production areas in the northern United States for many domestic markets and for the export market to Mexico.

Mexico was the largest importer of U.S. sunflower oil during the 19990 to 2003 calendar year period with an annual average of 72,023 metric tons valued at $39,346,000 annually. These figures amounted to 30.6 percent and 30.2 percent of total U.S. sunflower seed oil quantity and dollar value of exports during the 1999 to 2003 period. Average total U.S. sunflower seed oil exports for the same period were 214,366 metric tons per year valued at $114,714,000 annually. Other major consistent U.S. sunflower seed oil importers during the 1999 to 2003 time period include Canada, Egypt, Japan, Saudi Arabia, and Taiwan.

In addition to the sunflower processors who contract and buy from High Plains producers, many local elevators also handle sunflowers. Most of these elevators are located in the western third and North Central parts of the Kansas and in eastern Colorado and typically handle oil sunflower. Elevators typically compare oil-type sunflower seed bids from competitive sunflower crushers, exporters, and birdseed packagers and then make sales to the sunflower seed user that offers them the highest price net of transportation and handling costs.

Figure 7 graphically depicts the increase in sunflower acreage over the past 16 years in this region. The trend has been to increase acres, even though a few years have been short due to price, weather, and crop disease concerns. In 6 of the past 10 years, there have been in excess of 400,000 acres of sunflower in the region, with a high of nearly 630,000 acres harvested in 1999.

Sunflower Cost-Return Prospects

A farmer's decision to produce either oilseed or confectionary sunflowers should be based on the expected profitability of sunflowers relative to competing crops. In any particular year, that decision will depend on the relative expected returns over selected variable costs for each of the cropping alternatives. In the following dryland and irrigated crop budgets, all costs are accounted for except land and management. Table 19 shows average cost estimates for nonirrigated oil-type and confectionary sunflowers in Western Kansas, Northeastern Colorado, and Western Nebraska. Table 20 shows cost estimates for irrigated sunflowers and some primary alternative crops. Western Kansas dryland and irrigated cost estimates are based on 2002-03 projections. Northeastern Colorado dryland and irrigated cost estimates and are taken from 2003 farm records. The western Nebraska cost estimates are based on 2003 projections.

Production cost estimates for northeastern Colorado irrigated and dryland crop enterprises are taken, with permission, from Golden Plains Area Agricultural Handbooks. The northeastern Colorado budgets are intended to be "typical" rather than "average," as they represent a group of individuals each with unique management techniques, machinery, chemical applications, market timing, and uncontrollable fortune with frost, hail, rain, and insects. Cost estimates for western Kansas irrigated and dryland crop enterprises are taken from Kansas State University Farm Management Guides. The western Kansas budgets are designed to provide Kansas farmers, farm managers, and agribusiness with annual crop cost projections for planning purposes. Each of the Kansas dryland crop enterprise budget projections were assumed to be part of a wheat-summer crop-fallow rotation (Table 20). Center pivot irrigation systems are assumed for each of the irrigated crop budget estimates in Table 23. Tables 21 and 22 represent yield sensitivity analysis for dryland and irrigated enterprise costs. Production cost estimates for Nebraska are taken from the 2003 Nebraska Crop Budgets. This sunflower budget is based on an ecofallow system after wheat with a two crops in 3 years system.

Farmer's sunflower marketing opportunities in the High Plains region are closely tied to the presence of an oilseed sunflower processing plant and at least two confectionary sunflower buyer-processors in the area. The birdseed market offers a secondary market for many oilseed growers. Specific information about sunflower grade requirements, oil content price premiums, confectionary seed size premiums and discounts, market supply-demand factors influencing sunflower prices, and example sunflower contract specifications are found in the K-State Research and Extension publication *Sunflower Marketing in the High Plains*, L-887 (Revised in September 2001).

Figure 7. *Harvested sunflowers acres in Colorado, Kansas, and Nebraska (1988-2003).*

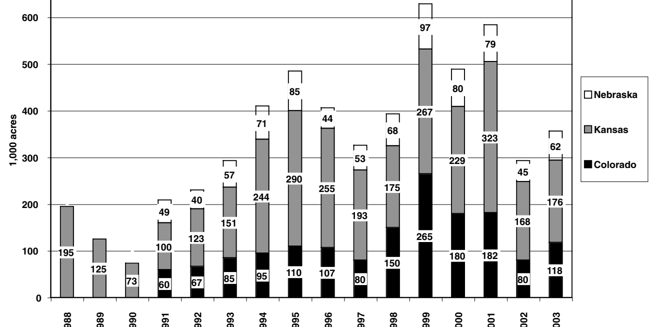

Table 20. *Three-year average dryland crop comparisons, estimated production costs and breakeven prices for Colorado (2001-2003) and Kansas (2002-2004).*[1]

Dryland Crop Budgets for Western Kansas (2002-2004 Average) and Northeastern Colorado (2001-2003 Average)	Oil-Type Sunflowers	Oil-Type Sunflowers	Oil-Type Sunflowers	Confection Sunflowers	Winter Wheat	Winter Wheat	Dryland Corn	Dryland Corn	Millet	Sorghum
	KSU cwt/acre	Nebraska cwt/acre	CSU cwt/acre	KSU cwt/acre	KSU bu/acre	CSU bu/acre	KSU bu/acre	CSU bu/acre	CSU cwt/acre	KSU bu/acre
Yield per Acre	15.0	15.0	5.5	13.5	40.0	38.8	80.0	25.4	16.5	75.0
Direct Costs										
Seed	$15.67	$11.25	$13.12	$16.21	$5.42	$5.26	$29.07	$17.63	$1.77	$7.23
Fertilizer	24.10	17.56	16.13	21.74	16.49	15.46	32.76	17.16	10.49	31.40
Herbicide	28.63	40.84	18.94	30.63	16.95	11.75	38.86	22.86	9.04	37.28
Insecticide	15.45	2.10	6.56	15.45	0.00	0.00	1.00	0.00	0.00	0.00
Machinery Operating Costs (CSU)[2]	-	9.79	29.67	-	-	27.64	-	21.90	26.53	-
Crop Insurance	0.00	3.50	4.60	0.00	0.00	8.03	0.00	7.56	0.92	0.00
Custom Spray/Hire	0.00	3.30	6.83	0.00	0.00	4.00	0.00	0.00	4.00	0.00
Drying Expense	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Crop Consulting	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Miscellaneous Expenses	5.50	5.50	0.00	5.50	5.50	0.00	5.50	0.00	0.00	5.50
Interest Expense	5.83	3.47	0.00	5.83	4.45	0.00	6.49	0.00	0.00	5.53
Total Direct Costs	$95.19	$97.31	$95.85	$95.36	$48.82	$72.14	$113.68	$87.12	$52.75	$86.94
Fixed Costs										
Machinery Ownership Costs[3]	63.41	29.91	37.80	63.10	71.28	39.02	62.95	30.37	32.72	63.68
General Farm Overhead	-	4.00	12.89	-	-	12.13	-	12.21	12.03	-
Total Fixed Costs	$63.41	$33.91	$50.69	$63.10	$71.28	$51.15	$62.95	$42.58	$44.75	$63.68
Total Costs Excluding Land	$158.60	$131.22	$146.54	$158.47	$120.09	$123.29	$176.63	$129.70	$97.50	$150.62
Breakeven Price to Cover All Costs Excluding Land	$10.57	$8.75	$26.64	$11.74	$3.00	$3.17	$2.21	$5.10	$5.90	$2.01

[1] *One Nebraska oil-type dryland sunflower oil budget is also included.*

[2] *Includes Operating Interest Expense on Variable Inputs.*

[3] *For KSU Budgets, Machinery Ownership Costs are based on Kansas Custom Rates, including all machinery, labor, fuel, maintenance, insurance and any other costs associated with Custom Rate Operations. Nonmachinery labor is also included.*

Table 21. *Yield Sensitivity Analysis for Dryland Crop Breakeven Cost (Excluding Land Cost).*

Dryland Crop Budgets for Western Kansas and Northeastern Colorado 2001 - 2003 Average	Oil-Type Sunflowers	Oil-Type Sunflowers	Confection Sunflowers	Winter Wheat	Winter Wheat	Dryland Corn	Dryland Corn	Millet	Sorghum
	KSU cwt/acre	CSU cwt/acre	KSU cwt/acre	KSU bu/acre	CSU bu/acre	KSU bu/acre	CSU bu/acre	CSU cwt/acre	KSU bu/acre
Yield per Acre	15	8	14	40	39	80	25	17	75
Sensitivity to Yield Changes									
75% of Average Yields	14.72	23.68	16.33	4.58	4.23	3.14	6.80	7.86	2.85
90% of Average Yields	12.26	19.74	13.61	3.82	3.53	2.62	5.67	6.55	2.38
100% of Average Yields	11.04	17.76	12.25	3.44	3.17	2.36	5.10	5.90	2.14
110% of Average Yields	10.03	16.15	11.14	3.13	2.89	2.14	4.64	5.36	1.94
125% of Average Yields	8.83	14.21	9.80	2.75	2.54	1.88	4.08	4.72	1.71

Table 22. *Yield Sensitivity Analysis for Irrigated Crop Breakeven Cost (Excluding Land Cost).*

Irrigated Crop Budgets for Western Kansas (2002-2004 Average) and Northeastern Colorado (2001-2003 Average)	Oil-Type Sunflow-ers	Oil-Type Sunflow-ers	Confec-tion Sunflow-ers	Winter Wheat	Winter Wheat	Corn	Corn	Pinto Beans	Grain Sorghum	Soy-beans	Alfalfa	Alfalfa
	KSU cwt/acre	CSU cwt/acre	KSU cwt/acre	KSU bu/acre	CSU bu/acre	KSU bu/acre	CSU bu/acre	CSU cwt/acre	KSU bu/acre	KSU bu/acre	KSU tons/ acre	CSU tons/ acre
Yield per Acre	22.7	18.5	21.7	60.0	63.7	178.3	199.0	28.0	105.0	55.0	6.2	6.1
Sensitivity to Yield Changes												
75% of Average Yields	17.53	19.12	18.22	5.66	5.41	3.35	2.90	16.51	4.11	7.31	74.66	85.55
90% of Average Yields	$14.61	$15.93	$15.19	$4.72	$4.51	$2.79	$2.42	$13.76	$3.43	$6.09	$62.21	$71.29
100% of Average Yields	13.15	14.34	13.67	4.24	4.06	2.51	2.18	12.38	3.09	5.48	55.99	64.16
110% of Average Yields	11.95	13.04	12.42	3.86	3.69	2.29	1.98	11.26	2.80	4.98	50.90	58.33
125% of Average Yields	10.52	11.47	10.93	3.40	3.24	2.01	1.74	9.91	2.47	4.39	44.79	51.33

Table 23. *Irrigated Crop Production Cost Estimates for the Central Great Plains States.*

Irrigated Crop Budgets for Western Kansas (2002-2004 Average) and Northeastern Colorado (2001-2003 Average)	Oil-Type Sunflowers KSU cwt/acre	Oil-Type Sunflowers CSU cwt/acre	Confectionary sunflowers KSU cwt/acre	Winter Wheat KSU bu/acre	Winter Wheat CSU bu/acre	Corn KSU bu/acre	Corn CSU bu/acre	Pinto Beans CSU cwt/acre	Grain Sorghum KSU bu/acre	Soybeans KSU bu/acre	Alfalfa KSU tons/acre	Alfalfa CSU tons/acre
Yield per Acre	22.7	18.5	21.7	60.0	63.7	178.3	199.0	28.0	105.0	55.0	6.2	6.1
Direct Costs												
Seed	$18.33	$19.20	$17.83	$7.50	$8.55	$34.80	$38.98	$27.00	$8.50	$24.50	$9.22	$17.16
Fertilizer	27.69	16.63	26.58	24.41	16.41	54.57	51.53	24.90	30.10	10.56	22.44	40.62
Herbicide	10.03	23.63	10.03	5.21	19.50	31.03	25.31	19.80	27.38	21.64	15.16	12.00
Insecticide	15.45	12.25	15.45	0.00	0.00	38.89	18.06	5.42	2.67	0.00	9.27	14.33
Machinery Operating Costs (CSU)[1]	-	19.83	-	-	38.78	-	60.84	47.63	-	-	-	86.76
Irrigation Energy	33.03	31.35	33.03	33.03	24.50	57.40	58.20	34.71	46.25	52.85	62.76	68.33
Irrigation Repair	3.30	10.00	3.30	3.30	10.00	5.72	10.00	10.00	4.62	5.28	6.27	10.00
Sprinkler Lease[2]	86.54	60.00	86.54	86.54	60.00	86.54	60.00	60.00	86.54	86.54	86.54	60.00
Crop Insurance	0.00	5.40	0.00	0.00	8.47	0.00	13.52	9.00	0.00	0.00	0.00	0.00
Custom Spray/Hire	0.00	12.50	0.00	0.00	0.00	0.00	4.17	9.50	0.00	0.00	0.00	8.00
Drying Expense	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Crop Consulting	6.50	7.00	6.50	6.00	0.00	6.50	6.67	6.67	6.25	6.25	6.50	0.00
Miscellaneous Expenses	10.00	0.00	10.00	10.00	0.00	10.00	0.00	17.81	10.00	10.00	10.00	0.00
Interest Expense	8.98	0.00	8.91	7.38	0.00	14.52	0.00	0.00	9.94	9.13	13.06	0.00
Total Direct Costs	$219.86	$217.79	$218.19	$183.38	$186.21	$339.97	$347.27	$272.44	$232.26	$226.75	$241.23	$317.21
Fixed Costs												
Machinery Ownership Costs[3]	78.14	29.88	77.93	71.26	56.29	108.37	69.90	58.70	91.72	74.72	168.01	56.36
General Farm Overhead	-	17.60	-	-	15.73	-	15.78	16.01	-	-	-	16.73
Total Fixed Costs	$78.14	$47.48	$77.93	$71.26	$72.03	$108.37	$85.68	$74.71	$91.72	$74.72	$168.01	$73.09
Total Costs Excluding Land	$298.00	$265.27	$296.12	$254.64	$258.23	$448.34	$432.95	$347.15	$323.97	$301.48	$409.23	$390.31
Breakeven Price to Cover All Costs Excluding Land	$13.15	$14.34	$13.67	$4.24	$4.06	$2.51	$2.18	$12.38	$3.09	$5.48	$66.01	$64.16

[1] *Includes Operating Interest Expense on Variable Inputs*

[2] *Sprinkler Lease includes an estimate of actual irrigation sprinkler lease expenses in CSU budgets, and the total of Sprinkler Irrigation Depreciation (well and equipment), Interest (equipment), and irrigation labor for K-State budgets*

[3] *For K-State Budgets, Machinery Ownership Costs are based on Kansas Custom Rates, including all machinery, labor, fuel, maintenance, insurance and any other costs associated with Custom Rate Operations. Both field related machinery labor and nonmachinery labor are included in these custom rate based cost estimates.*

Diseases

Sunflower production in the High Plains has been increasing as the sunflower oil and confection seed industry have established local markets. As with other crops, as planted acreage increases, the probability of disease problems also increases. The problem is compounded by native, weedy sunflowers that serve as a reservoir for diseases and pathogen-carrying insects.

Disease problems affecting sunflowers can generally be divided into two types, nonparasitic and parasitic. Nonparasitic diseases include problems such as hail injury, herbicide damage, nutritional deficiencies, and weather related problems. Parasitic diseases include problems caused by fungi, bacteria, viruses, phytoplasmas, and nematodes. There are about a dozen diseases known to occur in the High Plains region, all of which are caused by fungi. These fungi may attack the roots, stems, leaves, or heads, but only a few of these diseases cause significant economic loss.

Many disease problems are more severe under irrigated conditions, especially with center pivots. The most effective controls for sunflower diseases are the use of resistant or tolerant hybrids, and when a particular disease has caused problems in a field, a minimum rotation of 4 years between sunflower crops. (Refer to the Crop Rotations and Residue Management section in this publication.) Seed treatments are available for the control of seed rots and seedling blights. Currently, no foliar-applied fungicides are registered, although emergency exemptions have been granted in recent years for the control of sunflower rust.

Nonparasitic Problems

Bract Necrosis

High temperatures (greater than 100 degrees Fahrenheit) may cause a brown discoloration of disk flowers and bracts. This discoloration often becomes black after rain. When bract necrosis occurs during the bud stage, buds may not open. Injured buds that do open may produce only a few or no disk flowers and little pollen. Some hybrids may be more susceptible to this problem than others, otherwise, there is no known control.

Hail Injury

Severe wind, rain, and hail storms may defoliate or destroy sunflower plants. Damage and yield loss depend on the stage of plant development at the time the injury occurs. Partial or complete defoliation, stem bruising or breakage, and stand reduction can occur because of storm damage. When injury to the terminal bud occurs during the early reproductive stages, plants often die. When the injury occurs at or after flowering, the plants usually remain green, but do not produce seed. Physical injury on the back of the sunflower head, coupled with wet or humid conditions, can result in the development of Rhizopus head rot, a serious plant disease in the High Plains region.

The sudden death of plants (both sunflowers and weeds) following a storm is usually an indication of lightning damage. Dead plants usually occur in a circular area from 50 to 100 feet in diameter. Near the outer edge of the circle, plants may wilt but not die. The stalks of lightning damaged plants often have a brown to black pith. The affected area does not increase in size after the first 2 weeks.

Herbicide Damage

Damage from herbicides can occur from drift, carryover from a preceding crop, application of the wrong chemical, application of approved chemicals at excessive rates, or when applied immediately before extended periods of low temperature or high rainfall. (See the Weed Control Section of this publication) Drift is caused by the movement of windblown spray droplets applied in the proximity of a sensitive crop, or by movement of herbicide vapors during times of high wind and hot temperatures. Volatilized herbicides can damage sensitive crops many miles from the point of application. Sunflowers are susceptible to drift from many postemergent applied herbicides such as 2,4-D, MCPA, picloram (Tordon), dicamba (Banvel), bromoxynil (Buctril), bentazon (Basagran), glyphosate (Roundup), and paraquat (Gramoxone). Drift from a growth regulator type herbicide such as 2,4-D or dicamba is most common. These materials may reduce sunflower yields by as much as 25 to 80 percent, depending on the growth stage when the drift occurred. Damage is greatest when sunflowers are at the bud stage. Symptoms from herbicides such as 2,4-D, dicamba, MCPA, and picloram, (especially ester formulations) usually consists of abnormal bending or twisting of stems or leaf petioles within 24 to 48 hours after contact. Sunflower growth is often slowed or stopped, and young leaves that emerge after exposure to the herbicide are often cupped or elongated (Photos 13a through 19). Some plants may die without further growth, while others remain green but with no further growth for the remainder of the season. If damage is less severe, growth may begin again after the herbicide is partially metabolized by the plant. Other symptoms include the development of multiple heads or heads that are malformed or partially filled.

The other major type of chemical damage in sunflowers is carryover from herbicides in the amino acid synthesis inhibitor group. Some commonly used herbicides in this group include chlorsulfuron (Glean), metsulfuron (Ally), prosulfuron (Peak), imazethapyr (Pursuit), chlorimuron (Classic) and thifensulfuron (Harmony, Pinnacle). Many of these materials have long residual life in the soil, especially where soil pH is high and rainfall is limited. Injury symptoms include stunting, yellowing of leaves, purple veins, root pruning, and gradual death.

Most herbicide drift and carryover problems can be managed by careful crop rotation, avoiding application of herbicides near sensitive crops such as sunflowers, and by avoiding spraying during periods of high winds and hot temperatures. Aerial applicators should be made aware of sunflower field locations.

Parasitic Problems
Root and Stalk Diseases

Seedling Blight and Seed Rot

Sunflower seed may be attacked by various soilborne and seedborne pathogens. Affected seeds may rot before emergence or seedlings may be killed within a week or two following emergence. Such seedlings often exhibit a symptom known as damping-off, which is a collapsing of the stem at or below the soil surface that causes a plant to fall over and die. Other symptoms may include darkened, rotted roots or stem discoloration. *Pythium* and *Rhizoctonia* species are the most common fungi associated with such diseases, but other fungi may occasionally cause problems as well.

Seedling diseases are best managed by making sure there is good contact between the soil and seed at planting, and that soil temperature (above 50 degrees Fahrenheit) and moisture are favorable for rapid germination and growth. When planting or germination conditions are less than ideal, there are several recommended planter box seed treatments available.

Downy Mildew

The downy mildew fungus, *Plasmopara halstedii*, is a soilborne pathogen that can systemically infect roots within the first few weeks after emergence. It is favored by poorly drained clay soils. Typical symptoms include dwarfing and a chlorosis that starts as a light green or yellowish area near the midribs of leaves and expands outward (Photo 52). During periods of high humidity or dew, a white, cottony growth (fungal spores and mycelium) develops on the underside of the leaf (Photo 53). These spores can be blown to other leaves and plants to begin new infections. As plants continue to grow, leaves become wrinkled and distorted and the entire plant may be stunted. Infected plants usually produce normal-sized heads that remain upright and contain mostly empty seeds (Photo 54). There are at least nine races of the downy mildew fungus in North America. Commercial hybrids currently available have resistance to several races, but no commercial hybrid is resistant to all of them. Chemical control in the High Plains relies mainly on treating seed with metalaxyl (Apron). Seed treatment protects against root infection, but will not protect against foliar infection. Additional management practices include extended rotations, eradication of volunteer sunflowers, avoiding poorly drained fields, and delaying planting until soil temperatures favor rapid seedling growth.

Verticillium Wilt

Verticillium wilt or leaf mottle is caused by the fungus *Verticillium dahliae*. Symptoms are most obvious at flowering when infected plants occur singly or in groups. Symptoms appear on lower leaves first and gradually progress up the plant. Tissue between leaf veins becomes yellowed, then brown, giving the leaf a mottled appearance (Photo 55). Black areas occur on the stem, particularly near the soil line. The vascular system of the stem is brown to black when cross-sectioned (Photo 56). Severely infected plants are stunted and may ripen prematurely or die before flowering.

Verticillium wilt occurs only occasionally in the High Plains Region. Management is by a 3- to 4-year rotation with small grains or other nonhost crops, and avoiding fields with a history of Verticillium wilt.

Phoma Black Stem

Phoma black stem, caused by the fungus *Phoma macdonaldii*, appears as large black lesions on the stem, sometimes reaching several inches in length. Infection is favored by moist conditions during and after flowering. Lesions usually appear where the leaf petioles attach to the stem (Photo 57). Eventually, leaves wilt and dry up and stalks often turn dark brown to black. Small black spots (pycnidia) may be observed in mature lesions with the use of a hand lens. Infected plants are weak and more susceptible to lodging. Heads may be smaller with reduced seed yield and oil content.

When *Phoma* girdles the stem base, symptoms of premature ripening can occur, including early dying and blackening of plants. Plants affected by *Phoma* girdling have black to brown roots and a black to brown lesion at the soil line. Premature ripening results in sunflowers with small heads, and seeds toward the center of the head do not fill properly or may be empty.

The fungus overwinters in infected debris and is spread by splashing rain or insects. While no control measure is totally effective, crop rotation will reduce the population of *Phoma* in the soil. A good insect control program also will limit disease spread. Although no hybrids are immune to the disease, some seem to have more resistance than others. Resistance in hybrids is best identified by observing the incidence and severity of the disease in hybrid demonstration plots.

Phomopsis Stem Canker

Phomopsis stem canker, caused by *Phomopsis helianthi*, is similar in appearance to Phoma black stem. Compared with Phoma black stem, the *Phomopsis* lesion is much larger, sometimes reaching 6 inches in length. It is also lighter in color being a tan-to-brown color (Photo 58). *Phomopsis* causes more pith degradation than Phoma, so that the stalk is easily crushed when thumb pressure is applied to the lesion. Like Phoma black stem, plants infected with *Phomopsis* ripen prematurely and have a reduced oil content. No specific control measures are reported, but since the disease overwinters on crop debris, long rotations should be effective.

Charcoal Rot

Charcoal rot is caused by the soilborne fungus *Macrophomina phaseolina.* Charcoal rot is favored by high temperature (greater than 90 degrees Fahrenheit) and low soil moisture. Infection can occur early in the season, and then remain latent until environmental conditions are more favorable for disease development.

Symptoms usually begin to appear after flowering. The first symptoms are a general wilting of the plant during the midday heat followed by a recovery in the evenings as temperatures decline. Eventually the wilt becomes permanent and the plant dies. Since charcoal rot restricts the flow of water and nutrients to the head, reduced seed size, and light test weights usually occur. The stalks of infected plants eventually take on a gray discoloration at the base (Photo 59). Internally, the pith decays leaving only the water conducting vascular bundles. This gives the internal stem a shredded appearance. In the final stage of disease development, the vascular bundles become covered with small, black flecks, which are the reproductive structures of the fungus known as sclerotia (Photo 60). With the use of a hand lens, sclerotia also can be observed embedded in the outer surface of the lower stem and roots.

As infected crop residue decays, the sclerotia fall back into the soil where they can survive for several years. More than 200 plant species serve as a host for *M. phaseolina* including soybeans, dry beans, corn, and grain sorghum. Therefore, crop rotation has minimal effects on disease control unless small grains are used. Resistant hybrids are not available, but hybrids and planting dates can be selected to avoid flowering and seed fill in the hottest part of the summer. The best management system for charcoal rot is to avoid drought stress. Any cultural practice that conserves soil moisture will reduce losses to charcoal rot. These include irrigation, weed control, reduced plant population, and conservation tillage practices.

Foliar Diseases

Alternaria Diseases

Two species of *Alternaria* are known to cause leaf spots, stem lesions, or head rot in the High Plains region. They are *A. helianthi* and *A. zinniae*. Both pathogens can be seedborne and overwinter in stem residue on and near the soil surface. Infection is favored by warm, humid conditions that promote extended periods of leaf wetness. Early planted fields can be more severely diseased than later-planted ones. Plants are most susceptible at flowering and during the seed-fill stages. Dark brown, oval, necrotic spots can occur on the heads, leaves, petals, petioles, and stems (Photos 61, 62, and 63). Stem lesions start as black flecks or streaks that later enlarge to cover large areas of the stem, which may be girdled. Plants may be defoliated and die prematurely, and lodging frequently occurs. Yield losses occur from reduced head diameter, number of seeds per head, and oil content. The disease may be satisfactorily managed through crop rotation and tillage practices that hasten residue decomposition.

Red Rust

Red rust, caused by the fungus *Puccinia helianthi*, is one of the most common diseases found on sunflowers in the High Plains region. Yield losses are limited when it occurs late in the growing season, but in recent years, development has begun early in the season and significant losses have occurred, particularly in the confectionary seed crop. Recent surveys have detected many new races of rust. Good resistance is available to these new races in many oil hybrids, and a few newer confectionary hybrids.

Rust may first appear as pale yellow spots on the upper surface of the leaf. As it develops, cinnamon-colored spots will form on the underside of the leaf (Photo 64). Later, these spots will turn black. Changes in color coincide with the different stages of fungal development. Severely diseased leaves dry up and die.

No fungicides are currently registered for use in the United States, but emergency exemptions have been granted for tebuconazole (Folicur) in recent years. Besides resistant hybrids, destruction of volunteer sunflowers, controlling wild sunflowers near commercial fields, and avoiding high nitrogen rates and high plant populations will aid in disease management. Choose rust resistant hybrids when planning seed purchases.

White Rust

White rust, also known as white blister, is a relatively new disease to the High Plains region. It is caused by the fungus *Albugo tragopogonis*. Although it is called a rust because of its rust-like symptoms, it is actually more closely related to downy mildew. It overwinters as oospores in residue in soil, or as mycelium or sporangia on weeds, and wild and volunteer sunflowers in milder climates. Infection is favored by temperatures below 90 degrees Fahrenheit and high rainfall.

The first noticeable symptom is a raised, yellowish-green spot on the upper surface of a leaf (Photo 65). A creamy white, blisterlike pustule forms below this spot on the underside of the leaf (Photo 66). The lowest leaves in the canopy are infected first, and then the disease moves upward. No yield losses have yet been recorded for this disease in the United States, but a systemic phase of the disease occurs in southern Africa with significant losses sometimes occurring. Management of this disease has not yet been necessary, but extended rotations and weed management should reduce inoculum levels.

Head Diseases

White Mold (Sclerotinia Diseases)

Worldwide, white mold, caused by the fungus *Sclerotinia sclerotiorum*, is the most destructive disease of sunflowers. It occurs on sunflowers in the High Plains region where cool nights and irrigation favor its development.

Symptoms of the disease can include wilting, middle stalk rot, and head rot. The wilt symptom is most common because the fungus survives in the soil and first attacks the roots. A dark canker forms at the base of the plant and eventually girdles the stem (Photo 67). In advanced stages, the pith decays and the stalk becomes shredded. Also, hard, black resting structures of the fungus, know as sclerotia, form at or near the stem base. They can be found in the pith or outside on the stem, and are an excellent identification aid for the fungus.

The fungus also produces mushroom structures known as apothecia that release windblown ascospores that can colonize dead tissues on the stalk, leaves, or heads. Apothecia formation occurs during times of high moisture, usually after the crop canopies over. Middle stalk rot and head rot usually begin as gray water-soaked lesions on the upper stem and fleshy part of the head, respectively. In the stalk, a dense snowy white fungal growth and some sclerotia will often be produced, especially during wet weather (Photo 68). On the head, the entire seed layer falls away leaving only a bleached, shredded skeleton interspersed with large sclerotia (Photo 69). Sclerotia are about the size and density of the seed and are difficult to remove in the threshing and cleaning operations, and therefore may be a common contaminant in seed stocks. Presence of the sclerotia with the harvested seed confirms that a field had head rot.

Once *Sclerotinia* becomes established in a field, growing a nonsusceptible crop becomes very difficult. The best way to control *Sclerotinia* is prevention. This is done principally by planting on noninfested fields, or using long rotations of nonhost crops (wheat, corn, sorghum) to prevent buildup in infested fields. Sunflowers should not be rotated with dry beans, soybeans, or canola in fields infested with *Sclerotinia*. Numerous weed species are also hosts of *Sclerotinia*, and if not controlled, can maintain the level of the disease during rotation with nonhost crops. Excessive nitrogen rates, which promote denser canopies, should be avoided. Neither resistant hybrids nor chemical controls are available.

Rhizopus Head Rot

Two fungal species, *Rhizopus arrhizus* and *R. stolonifer*, have been implicated in disease development. The disease first becomes noticeable when the back of the head turns brown and becomes soft and mushy (Photo 70). During periods of wet weather, or when examining the internal hollow part of the flower head, you may see threadlike strands of the fungal mycelium (Photo 71). Small, black fruiting structures the size of a pinhead develop later, giving the mycelium a grayish appearance. In later stages of disease development as the head dies, the tissue begins to shred and occasionally the head may fall to the ground. Losses to Rhizopus head rot in some fields have been near 100 percent.

Although no chemical controls are available, disease development is strongly correlated with sunflower head moth infestations. It has been demonstrated that a good insect control program will limit infection and yield losses due to Rhizopus head rot. Infection also can occur through wounds created by birds and hail.

Photo Credits

52–53 Tom Gulya
54* Downy mildew. M.L. Straley, Cargill Inc.
55* Verticillium wilt leaf symptoms. R. R. Urs, Dahlgren & Co.
56* Verticillium wilt stem symptoms. D. W. Zimmer, USDA–ARS.
57 Doug Jardine
58 Unknown
59* Charcoal rot symptoms on stem. W. E. Sackston, McGill University.
60* Charcoal rot—sclerotia and internal symptoms. J. S. Baumer, University of Minnesota.
61* Alternaria Symptoms on head. G. N. Fick, Sigco Research
62* Alternaria Symptoms on leaf. G. N. Fick, Sigco Research
63* Alternaria Symptoms on stem. G. N. Fick, Sigco Research
64 Red rust on sunflower leaf. Howard F. Schwartz, Colorado State University.
65-66 Doug Jardine
67* Sclerotinia wilt (white mold). B. D. Nelson, North Dakota State University.
69* Sclerotinia wilt in head. B.D. Nelson, North Dakota State University.
70* Rhizopus head rot. M. L. Straley, Cargill Inc.
71 Doug Jardine
* Used with permission from American Phytopathological Society, Slide Set #41.

Harvesting

Combines used to harvest High Plains grain crops are readily adapted to harvesting sunflowers, although machine settings and adjustments will differ. Sunflower crop conditions can change very rapidly. Because of this, producers should prepare early to harvest sunflowers and to make combine adjustments as warranted by field conditions.

As with any grain, some harvest loss will occur during combining, even under the most favorable conditions. Efficient combine operation is simply a matter of minimizing harvest losses. Additionally, natural factors contribute to crop loss before harvesting begins. For sunflowers this means that total losses should not exceed 5 percent of yield; this includes preharvest, header, threshing, and cleaning losses. Birds, plant heads jostled together by winds, and lodged plants due to wind, insects, or disease all contribute to preharvest loss. Preharvest loss is minimized by being prepared to harvest the crop when it is ready and finishing harvest in a timely manner. Header loss consists of seed and heads lost at the combine header and depends on operator skill, crop condition, and type of header being used. Threshing loss occurs at the combine cylinder or rotor and is usually minimal in sunflowers. Cleaning loss consists of seed that is carried over cleaning shoes. Cleaning loss is minimized by proper adjustment of chaffer openings and air flow.

What are typical grain losses in sunflowers? One study found losses as follows:

Preharvest loss	2.2%
Header loss	5.3%
Threshing loss	0.1%
Cleaning loss	1.8%
Total	9.4%

Assuming a yield of 1,500 pounds per acre, the total loss in this study amounts to 141 pounds per acre. At 8 cents per pound, that translates to more than $11 per acre.
Even a 5 percent loss can represent a significant profit loss. A 5 percent loss in this example equals a $6 per acre loss.
It is easy to see the value of efficient harvesting.

A Successful Harvest Begins at Planting

Decisions made as early as planting will affect harvest efficiency. Variety and fertility decisions can effect harvest losses. A uniform stand is important from the harvesting viewpoint because uniform stands will feed into the combine easier. As well, a uniform stand will result in uniform plant height and head size, which will reduce head loss and the amount of stalk that enters the combine.

Headers for Harvesting Sunflowers

Three types of combine headers are used in the High Plains: row crop, corn, and small grain platform head. All can be used to harvest sunflowers, although some require modification. Considerations in selecting which head type to use are availability, cost, convenience, and performance. If available equipment can be used, the cost of owning and operating that item can be spread over more acres and hours. Thus the cost of owning and operating an additional piece of equipment is reduced. If two or more crops are ready to harvest at the same time, using the same head for both crops could make switching between crops at harvest easier. Sunflowers can lodge and seed shattering can occur, so the ability to collect lodged heads and get them into the threshing mechanism with minimal shattering is crucial to harvest efficiency.

Because getting sunflowers into the combine is probably the biggest problem when harvesting, header performance can often dictate combine efficiency. Header performance can sometimes be dramatically improved simply by operating at a slower ground speed. Being patient during harvest will pay dividends because there is a great deal of seed in one sunflower head. Header losses may reduce efficiency, but gathering excess stalks could cause threshing and cleaning problems. The main objective is to gather heads with minimal stalk entering the combine and minimal seed loss from shattering.

Row Crop Heads

A row crop head is commonly used to harvest crops such as grain sorghum and soybeans planted in row spacings from 30 to 42 inches. It has been used successfully without modification to harvest sunflowers. Row crop head advantages include no need for modification, minimal additional cost incurred if this type of header is readily available, a positive feeding mechanism, and efficient operation in lodged crop. Low-cost row crop head attachments (pans) are also available for small grain platforms. Row crop heads do have a disadvantage because a large amount of stalk enters the threshing mechanism and must be removed from the seed by the cleaning shoe. Row crop heads are typically high maintenance items and also can be an expensive piece of equipment.

Corn Heads

The corn head is the newest attachment being used to harvest sunflowers. This requires the addition of a stationary knife to cut sunflower stalks. Operational advantages and disadvantages are similar to those of the row crop head. The difference is the cost of the knives and the time required to attach and remove knives when switching between corn and sunflower harvest.

Small Grain Platforms

The small grain platform is the most common head used in Kansas. It can be used to harvest sunflowers without modification. However, it has a tendency to cause considerable shatter loss and the loss of whole heads. To minimize these problems, special sunflower harvesting attachments have been developed (pans). Test results in Tennessee showed header losses were about 5 percent with attachments compared to 46 percent without attachments.

Although sunflower attachments vary in design and mounting, they generally consist of pans 3 to 5 feet long extending in front of the cutterbar and a modified reel and/or deflector. The pans guide the crop into the cutterbar. Many designs also catch shattered seeds as the heads move toward the cutterbar. In addition, some designs are better adapted to picking up lodged heads.

The modified reel and/or deflector shield replace the conventional reel. They push stalks into cutting position and deliver heads to the combine platform. Little stalk enters the combine threshing mechanism. In operation, this attachment acts like a head stripper. The stems are pushed forward by the deflector shield in the slot between the pans. As the heads pass under the lower edge of the shield, they are drawn to the knife by the reel, cut off, and thrown into the feeding auger. The pans guide the stems and catch most of the seed that is shattered from heads as they move to the feeding auger.

Some machines use forward rotating stalk-walker reels mounted under the cutterbar to reduce plugging of stalk slots between pans. The stalk-walker pulls sunflower stalks and weeds down so only the sunflower head is fed into the combine. Stalk-walkers are reported to be particularly useful in fields with tall weeds.

Pan spacing varies, with some being the width of conventional row spacings, 20 to 30 inches, and others being much narrower at 9 to 15 inches. The slot between the pans is usually 2 to 3 inches wide. The narrow-spaced pans work in both conventional rows and solid-stand planting and also allow cutting at any angle to the row direction. This is beneficial sometimes due to the pendulous nature of many sunflower varieties (hybrids) and the direction in which sunflower plants are leaning if lodged.

As with most crops, reel speed should be coordinated with ground speed for satisfactory performance. A variable speed reel drive allows matching reel speed to the ground speed best suited to the harvesting conditions. In general, the reel should operate slightly faster than ground speed.

The pans and a modified reel normally attach to the small grain head. This equipment is often difficult to attach and may take two people a half day or more and nearly as much time to remove. As a result, some producers with large sunflower acreage purchase an additional small grain head and leave the sunflower harvesting equipment permanently attached.

Advantages of using this system included reduced cost if a small grain platform is available, collecting shattered seed and harvesting less stalk, resulting in cleaner seed. Some disadvantages are lack of positive feeding mechanism, time required to attach pans, bunching between pans, and possible reduced performance in lodged crops. Also, little cost savings are realized when an additional small grain platform is purchased so that attachments are permanent.

Threshing

Again, variables abound, depending on the kind of combine and field conditions at harvest. As with headers, there are differing perspectives on how efficient various models and types (conventional versus rotary cylinders, for example) are in sunflowers.

Overthreshing has traditionally been the most prevalent machine problem. There is a tendency to break heads badly if the cylinder is improperly set for the conditions. Consequently the cleaning shoe is overloaded with small pieces of heads and trash. The goal is to get a completely threshed head onto the straw walker in one piece. This is done by keeping cylinder speed slow, concaves well open, combining at reasonable speeds and harvesting when seed moisture is in the low teens. When properly set, most machines can harvest the crop adequately. The two adjustments for the threshing mechanism are cylinder speed and concave spacing.

Cylinder Speed: Sunflowers thresh relatively easily. The cylinder speed should be set only fast enough to thresh seeds out of the head. On conventional cylinders, this is generally 250 to 450 rpm. A speed of 300 rpm on a 22-inch diameter cylinder has a peripheral speed of 1,725 feet per minute. Cylinders with a smaller diameter could require a faster speed and those with a larger cylinder will likely require a slower speed. Excessive cylinder speed causes considerable dehulling and breaking of seeds, and the chaffer, sieve, and tailings return may become overloaded with small pieces of broken heads.

Concave Spacing: When the crop is dry (10 percent or less moisture), the concave should be open wide. A lower concave clearance should be used only if some seed is left in the head after threshing. Improper settings can crush the seed but leave the hull intact. Under most conditions, it is best to decrease the concave clearance rather than increase cylinder speed to get more complete threshing. It is usually possible to set cylinder, concaves, and cleaning shoe to obtain less than 5 percent trash dockage. Under abnormally wet conditions, it may be necessary to use higher cylinder speeds and closer concave settings. Ideally, whole sunflower heads should leave the combine without seeds in them. Machine adjustments should be attempted if sunflower heads are leaving the combine in small pieces.

Cleaning

Sunflower seed is relatively light — 24 pounds per bushel — compared to other crops, so excessive air 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 potentially dehulled or cracked. Only enough air flow should be used to keep trash floating across the sieve. This is sometimes difficult to do because stalks might have a higher moisture content than the seeds. Consequently, broken pieces of stalk can be heavier than the seed and, therefore, more difficult to blow out. 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 unbroken with only unfilled seed remaining in the head. If the cylinder/concave area is not properly threshing the crop, the cleaning shoe will be overloaded and cannot perform properly. Proper setting is critical, especially for confectionary sunflower seed.

The upper sieve should be sufficiently open to allow an average seed to pass through on end or be set at ½- to ⅝-inch opening. The lower sieve should be adjusted to provide a slightly smaller opening about ⅜-inch wide. Final adjustments will depend upon the amount of material returning through the tailings elevator and an estimate of the amount of dockage in the grain tank. Under ideal harvest conditions, and with proper machine adjustment, harvest losses can be reduced to less than 5 percent and dockage to less than 2 percent of yield.

Checking Losses

Preharvest losses and harvesting losses can be estimated by making counts of seeds on the ground. The most effective way to estimate losses is counting the number of seeds in a one-square-foot area. Make sure that you are counting seeds only. Sometimes hulls may not have a seed in them. The rule of thumb is that 10 seeds per square foot represents a loss of 100 pounds per acre.

Adjust seed counts taken directly behind the combine discharge for the concentrating effect from the width of cut down to separator width. Do this by dividing the number of seeds found by four. In other words, in the discharge area, 40 seeds per square foot represent a loss of 100 pounds per acre.

Desiccants

Sunflower fields can be desiccated when they have reached physiologic maturity (backs of heads well-yellowed). Desiccation allows an earlier harvest. Keep in mind, however, that physiological maturity (R-9) must be reached or test weight and seed quality will be reduced.

Storing and Drying

Like most grain crops, sunflowers can be stored safely if proper management practices are followed. The most critical aspects of storing sunflowers are to place dry, clean seed into storage, to apply adequate aeration when needed, and to inspect them frequently (every 3 to 4 weeks).

Steps to Successful Storage

Clean the storage facility. Thoroughly clean the facility, aeration fan, ducts, and handling system by removing trash and old grain, which can harbor insects or fungi. Seal cracks and crevices that allow insects, fungi, or moisture to enter the storage.

Consider using an approved bin treatment for insects. Treat the inside of the facility and beneath the plenum floor with a residual spray for insect control. Use only approved chemicals, follow label instructions, and make sure the chemical is registered for sunflowers.

Clean sunflowers. Sunflowers stored with excessive trash, florets, broken seeds, or other foreign material is more susceptible to fungi and insect problems. This trash is normally at higher moisture content and will cause heating. Cleaning the seeds also will improve the airflow through the sunflowers.

Store at safe moisture content. Sunflowers should be stored at 10 percent or less moisture if marketing within 6 months after harvest. Sunflowers held through the spring or summer should be stored at 8 percent or less for oil seed and 10 percent or less for non-oil seed.

Don't peak sunflowers in the top of the bin. Peaking results in uneven airflow through a bin and inadequate cooling in the top of the bin. The peaked portion of the bin is an ideal place for insects and fungi to survive during storage and cause excessive damage.

Aeration systems are a key to stored sunflower management. Remember, an aeration fan is used to cool sunflowers, not for drying or moisture removal. The target storage temperature is 40 degrees Fahrenheit. Fans should be operated when the outside air temperature is 15 to 20 degrees Fahrenheit less than the seed temperature. If the seed temperature is below the targeted storage temperature at harvest, the aeration fans still should run 24 to 48 hours to equalize the temperature and moisture inside the storage structure. Fans should run continuously, even during periods of intermittent high humidity. They can be turned off during rainy or damp weather. A fan should be covered after it is turned off. Spring rewarming of sunflowers is not necessary. In most bins, 2 to 3 days will be required to cool sunflowers.

Check the seed. Sunflowers should be sampled weekly the first 6 weeks after harvest or until seed temperatures are below 60 degrees Fahrenheit. Then sample the sunflowers every 3 to 4 weeks during winter and weekly through the spring and summer. Do not bring the stored grain temperature below freezing with aeration during the winter months. Many storage problems will appear during the first 6 weeks of storage or in the spring and summer as weather conditions begin to change.

Check the sunflowers, not the bin! When sampling, probe the sunflower seed pile and be observant for temperature, moisture, insect, fungi, and odor differences from the previous inspection. If the probe is hot, immediate action is necessary. Remember to feel, smell, or walk around the bin and probe the sunflowers and not just peer through a roof opening and assume there is no storage problem. Always write down the results of your inspection for future reference.

Act quickly to stabilize problems. If a problem is detected, try to stabilize it with aeration. If this fails, move the sunflowers to market immediately as the problems will only increases.

Although some cooperators experience problems when storing sunflowers, most are able to store seed successfully with good management. Growers who adequately dry seeds (8 to 9 percent), use aeration wisely and periodically inspect their product do not have problems. Generally, High Plains sunflower fields are harvested near 5 percent because of our arid climate. However, with proper management, seeds harvested at high moisture can be dried and stored easily.

Drying

In cases where sunflowers have been harvested at higher moisture (greater than 10 percent), they can be dried using any drying system. There is a tendency by operators accustomed to drying other grains to overdry sunflowers. Removing 10 points of moisture from corn requires evaporating approximately 6 pounds of water, whereas with sunflowers, only 3 pounds has to be removed when drying from 20 to 10 percent. The sunflower seed flow rate through nonbatch dryers must be increased in comparison to corn to avoid overdrying.

Temperatures in the plenum of a dryer should be 160 degrees Fahrenheit or lower in continuous-flow and recirculating-batch dryers with non-oil seeds. Excess heat will cause nutmeats to be steam wrinkled, or even scorched. Plenum temperatures for confectionary sunflowers in batch and bin dryers should be less than 140 degrees Fahrenheit and 110 degrees Fahrenheit, respectively. Plenum temperatures for oil-type sunflowers are 180 degrees Fahrenheit in column dryers and 120 degrees Fahrenheit for bin dryers.

Operators should recognize the fire potential when drying sunflowers. Hair or fibers on the seeds rub loose during handling and tend to float in the air. These fibers will ignite rapidly when drawn through a drying fan and open burner. Dryers should never be left unattended when drying sunflowers. Daily cleaning around and inside the dryer, uniform flow of seeds through a dryer, and providing clean intake air by attaching an extra length of duct to the fan inlet or facing the fan into the wind will reduce fire hazards when drying. The duct must be large enough to not restrict the air flow. Collected trash is a major fire hazard and should be disposed of properly.

If a fire occurs, stop the fan immediately. Many times this will extinguish a small fire in a dryer.

Moisture Meters

Moisture meters should be calibrated following the manufacturers' guidelines. The meter should be checked against an elevator or processor meter to make sure your meter is consistent with the buyer's meter. Seeds that are dried tend to "fool" a moisture meter if taken straight from a drier and tested. False readings (too low) after drying are common and can lead to storage problems if an accurate measurement is not known. Samples should be placed in an airtight bag and held for 12 hours at room temperature. Then recheck the moisture content to obtain a second reading. Compensation may be needed for sunflowers with high oil content.

Crop Rotation and Residue Management

Crop Rotations

As with any other crop, sunflowers respond to good management practices, including desirable placement within the crop rotation. While sunflowers grow well on summer-fallowed land, their deep root system allows them to perform well when planted in rotation following shallower-rooted cereals such as winter wheat or proso millet. The deep-rooted, full-season nature of sunflowers often results in significant soil water depletion. Therefore, it may be necessary to use summer fallow, or several years of shallow-rooted crops, to refill the soil water profile.

Research conducted by the USDA-Agricultural Research Service at Akron, Colo., showed that available soil water at winter wheat and proso millet planting was significantly affected by the presence of sunflowers in a crop rotation.

At Colby, Kan., research suggests that a winter wheat-corn-sunflowers-grain sorghum-fallow rotation is worth considering. Corn has shown more year-to-year yield variation than either sunflowers or grain sorghum – mostly because of variation in rainfall received. Since there is a greater probability for soil moisture to accumulate after wheat harvest than after a summer crop, the additional moisture stored favors corn following wheat. With soil moisture likely to be somewhat depleted after corn, sunflowers have shown the potential to extract water that is positionally unavailable to either corn or grain sorghum, which favors sunflowers after corn. Grain sorghum requires the least amount of available soil moisture to maintain small year-to-year yield variation and produced high amounts of crop residue. This suggests that grain sorghum, where the season allows its production, follow sunflowers as the last crop before seeding wheat, not only to provide another cash crop, but also to provide additional crop residue cover during the extended fallow period. This rotation potentially offers a combination of no-till and conventional-tillage options. With available herbicides for no-till, corn is easily planted into wheat stubble, grain sorghum into sunflower stubble, and wheat into sorghum stubble.

If the winter annual grasses, for example, downy brome, jointed goatgrass, or rye, are a problem in winter wheat fields, sunflowers in the rotation provide the producer with additional opportunities to exercise control. The control may be provided by additional tillage opportunities and/or the use of effective grass herbicides not available for use in a wheat-fallow or wheat-proso-fallow rotation. Clearfield™ sunflowers are now an option for controlling annual grasses. Volunteer sunflowers, and other broadleaf weeds, that can be problematic in sunflowers are easily controlled in the alternate small grain crop.

Sunflowers are susceptible to triazine, Aatrex, and sulfonylurea (Ally, Amber, Peak), herbicide residues in the soil. Oats, wheat, proso, barley, and soybeans all exhibit greater tolerance to these herbicides than sunflowers. Therefore, sunflowers should not be planted where chemical carryover may be a problem. Rotation restrictions for sunflowers with some sulfonylurea herbicides may be as long 36 months.

Sunflower diseases and insect and weed pests also are minimized through the use of proper crop rotation. Sclerotinia stalk and head rot (white mold), Verticillium wilt, Phoma and premature ripening are the primary diseases resulting from a failure to rotate crops. Rotations of 4-year spacings between sunflower crops, two of which must be cereals, are recommended to help prevent and control these diseases. Sunflowers are also a host for diseases found in other crops. Verticillium wilt is found in potatoes, safflowers, and sunflowers. White mold is a disease found in dry edible beans, flax, rapeseed, soybeans, mustard, sugarbeets and sunflowers. No more than one of these crops should be grown in the same rotation cycle in fields infested with these diseases. (Refer to the Diseases section in this publication for a more thorough discussion.)

Crop rotations help reduce populations of insects that overwinter in the soil or in sunflower residue. Insects that migrate into an area from other geographic regions, or from fields planted to sunflowers the previous year that are in close proximity to current season fields, are not effectively controlled by crop rotation. If possible, avoid planting sunflowers next to a sunflower field from the previous year since most overwintering sunflower insects can easily migrate to adjoining fields. Rotation spacings recommended above for disease prevention should minimize the potential for insect populations. (This is discussed in the Insect Pest identification and Control section of this publication.)

Suggested sunflower rotations for the High Plains include:

- winter wheat-sunflowers-fallow
- winter wheat-proso-sunflowers-fallow
- winter wheat-corn-sunflowers-fallow
- winter wheat-corn-sunflowers-grain sorghum-fallow

It may be desirable from a pest management and soil water storage standpoint to alternate the winter wheat-sunflowers-fallow rotation with a winter wheat-proso or corn-fallow rotation.

Residue Management

Standing sunflower residue is effective at reducing wind speeds at the soil surface, reducing soil erosion potential, and in capturing windblown snow. However, sunflower residue is fragile and decomposes rapidly after tillage. Research conducted for 3 years by the University of Nebraska at Sidney, Neb. found sunflower residue to decline during summer fallow from 3,900 pounds per acre and 39 percent ground cover after harvest to just 510 pounds per acre and 4 percent ground cover after winter wheat planting (Table 24). Tillage operations included a late May sweep tillage operation followed by a late June chisel operation with 9-inch sweeps and two operations with a rodweeder.

Research conducted at the USDA-ARS, Central Great Plains Research Station, Akron, Colo., indicated an advantage in surface residue amounts when sunflowers are managed with no-till. Two experimental sites, each with a different stalk harvest height of 18 or 25 inches, were used to study the disappearance of sunflower residues under no-till and reduce-till fallow. Weeds were controlled using a sweep-plow (32-inch V-blade) in the tilled plots. Glyphosate

Table 24. *Sunflower residue weights and ground cover at five sampling times between sunflower harvest and winter wheat seeding the following year at Sidney, Neb. from 1993 through 1995.*

Sampling time [1]	Residue weight	Ground cover
	lbs/acre	%
After harvest	3,900	39
Early spring	3,020	26
Late spring	1,290	11
Summer	1,160	9
Wheat seeding	510	4

[1] *After harvest = fall within 2 weeks after mechanical harvest; early spring = within 2 weeks of winter wheat green-up and prior to first tillage operation; Late spring = within 2 weeks after sweep tillage operation; Summer = prior to the first rodweeding operation; and Wheat seeding = within 2 weeks after planting winter wheat.*

Table 25. *Sunflower residue cover and residue mass at sunflower harvest and approximately one year later at wheat planting time. Average values for a two year study at Akron, Colo.*

Fallow system	Initially at sunflower harvest		A year later at wheat planting time	
	Residue weight	Ground cover	Residue weight	Ground cover
	lbs/acre	%	lbs/acre	%
Sweep-till	2,730	46	1,710	15
No-till	2,440	45	980	29

(Roundup) was used to control weeds in no-till plots. In no-till, the taller-stalk-harvest height (25 inch) lost 75 percent of the initial number of standing-stalks by that fall. Whereas, with shorter stalks (18 inch), only 27 percent of the initial amount was lost. In 1996, better durability of shorter stalks was again observed, but the advantage of the shorter stalk height in maintaining standing stubble was not as great. By wheat planting time both the tall and the short stalks had less than 50 percent of the initial stalk amount still standing. By late September, only 11 percent of the taller stalks were standing with nearly 43 percent of the shorter still standing that year. Part of the reason for the increased loss with taller stalks is mechanical damage from spray booms and tractor axles, which don't always clear the taller stalks. Also, a taller stalk has greater surface area exposed to the wind, hence greater force is available to blow it down.

No-till resulted in 1,700 pounds per acre of residue on the soil surface at wheat planting time (mid September) and maintained 29 percent residue cover during summer fallow season (Table 25). Sweep-plow managed summer fallow contained only 980 pounds per acre of surface residue at wheat planting time and only 15 percent residue cover.

Over two seasons at Colby, Kan., an average of 30 percent of sunflower residue was lost by spring time. With two sweep tillage operations during the summer, 80 percent of the original crop residue had been lost by wheat seeding time. With no-till, initial wheat and sunflower crop residue amounts at sunflower harvest were increased by approximately 30 percent and, at wheat seeding, three times as much crop residue remained compared to conventional tillage.

Residue management can begin as early as selecting the summer crop and row spacing for an intensified rotation. Average crop residue amounts over a 3-year period for 30-inch rows and conventional tillage at Colby, Kan., were 5,812 pounds per acre for corn, 5,350 pounds per acre for grain sorghum and 3,823 pounds per acre for sunflowers. For the first 2 years of the study, when 30-inch rows were compared to 15-inch rows, the narrower row spacing increased corn residue amounts by 933 pounds per acre, grain sorghum by 250 pounds per acre, and sunflowers by 621 pounds per acre. In another study under conventional tillage, 15-inch rows increased sunflower crop residue only an average of 240 pounds per acre over a 4-year period and increased oilseed yield an average of 327 pounds per acre.

Other practical solutions to incorporating sunflowers into High Plains while minimizing the risk of soil erosion cropping systems include strip cropping, or following sunflowers with a shallow-rooted summer crop such as proso millet.

Insect Pest Identification and Control Photos

(see pages 16 through 18 for descriptions)

Photo 22. *Darksided cutworm.*

Photo 23. *Wireworm.*

Photo 24. *Painted lady butterfly.*

Photo 25. *Painted lady larva.*

Photo 26. *Sunflower beetles.*

Photo 27. *Sunflower beetle larva.*

Photo 28. *Adult sunflower beetles defoliating a seedling sunflower.*

Photo 29. *Adult sunflower moths.*

Photo 30. *Sunflower moth larva.*

Insect Pest Identification and Control Photos *(Continued)*

(see pages 19 through 21 for descriptions)

Photo 31. *Banded sunflower moth.*

Photo 32. *Banded sunflower moth larva.*

Photo 33. *Adult red sunflower seed weevil.*

Photo 34. *Adult gray sunflower seed weevil.*

Photo 35. *Red sunflower seed weevil larva.*

Photo 36. *Adult sunflower bud moth.*

Photo 37. *Sunflower bud moth larva.*

Photo 38. *Headclipping weevil.*

Photo 39. *Sunflower headclipped by headclipping weevil.*

Insect Pest Identification and Control Photos *(Continued)*

(see pages 21 through 22 for descriptions)

Photo 40. *Adult sunflower receptacle maggot.*

Photo 41. *Sunflower receptacle maggot larva.*

Photo 42. *Adult sunflower stem weevil.*

Photo 43. *Sunflower stem weevil larva.*

Photo 44. *Overwintering galleries of sunflower stem weevil larva.*

Photo 45. *Dectes longhorned borer.*

Photo 46. *Dectes longhorned borer larva.*

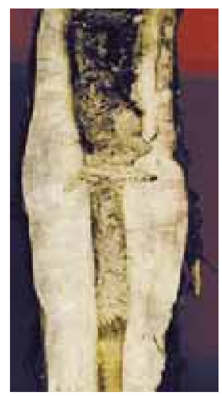

Photo 47. *Overwintering chamber of Dectes longhorned borer.*

Photo 48. *Ataxia longhorned borer.*

Photo 49. *Ataxia longhorned borer larva.*

Insect Pest Identification and Control Photos *(Continued)*

(see page 22 for descriptions)

Photo 50. *Sunflower root moth larva.*

Photo 51. *Sunflower root weevil.*

Disease Photos

(see page 26 for descriptions)

Photo 52. *Downy mildew.*

Photo 53. *Downy mildew.*

Photo 54. *Downy mildew.*

Photo 55. *Verticillium wilt leaf symptoms.*

Photo 56. *Verticillium wilt stem symptoms.*

Photo 57. *Phoma black stem.*

Disease Photos *(Continued)*
(see pages 26 through 27 for descriptions)


Photo 58. *Phomopsis stem canker.*

Photo 59. *Charcoal rot.*


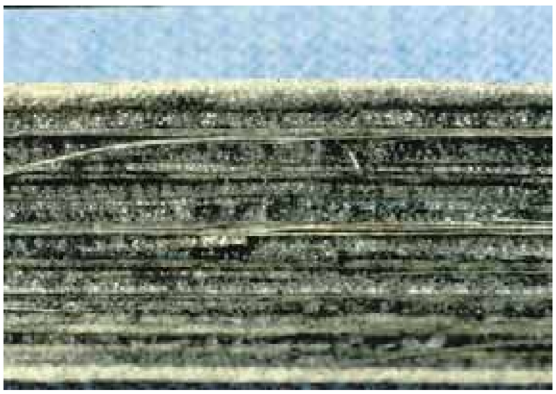
Photo 60. *Reproductive structures of charcoal rot.*


Photo 61. *Alternaria.*


Photo 62. *Alternaria.*

Photo 63. *Alternaria.*



Photo 64. *Red rust.*


Photo 65. *White rust.*

Disease Photos *(Continued)*

(see pages 27 through 28 for descriptions)

Photo 66. *White rust.*

Photo 67. *White mold.*

Photo 68. *White mold.*

Photo 69. *White mold.*

Photo 70. *Rhizopus head rot.*

Photo 71. *Rhizopus head rot.*

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