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

Insect Pest Identification and Control Photos

(see pages 13 through 16 for descriptions)

Photo 1.

Photo 2.

Photo 3.

Photo 4.

Photo 5.

Photo 6.

Photo 7.

Photo 8.

Insect Pest Identification and Control Photos *(Continued)*

(see pages 13 through 16 for descriptions)

Photo 9.

Photo 10.

Photo 11.

Photo 12.

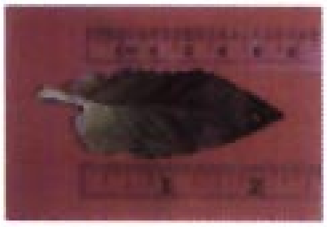
Photo 13.

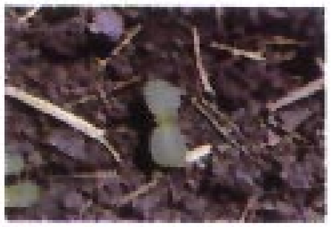
Photo 14.

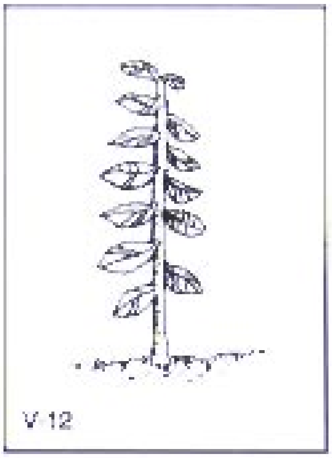
Photo 15.

Photo 16.

Vegetative Stages


True leaf-4cm


V-E


V 12


V-2


V-4

Stages of Sunflower Development
(See facing page for description.)

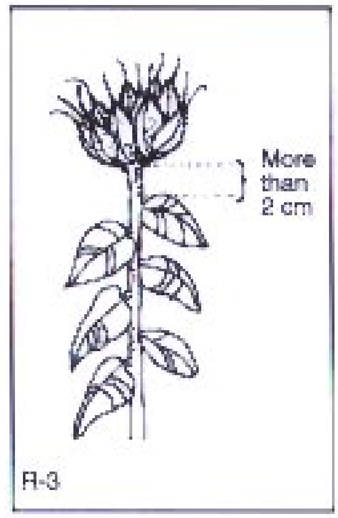
A.A. Schneiter, Professor; J.F. Miller, USDA-ARS; D.R. Berglund, Extension Agronomist

Reproductive Stages


R-1


R-2

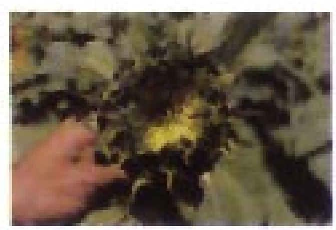
R-2



R-3


R-3


R-3 Top View

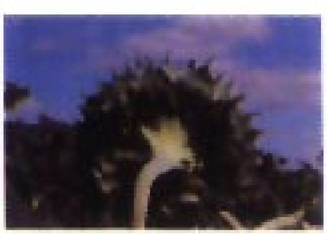

R-4 Top View

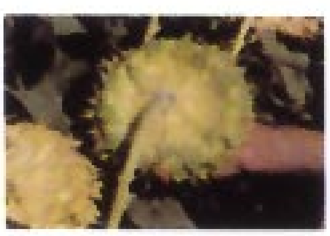

R-5.1


R-5.5


R-5.9


R-6


R-7


R-8


R-9

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.

Edited by: Ron Meyer, Cooperative Extension Agronomy Agent, Colorado State University; Dana Belshe, County Extension Agriculture Agent, Daniel O'Brien, Extension Agricultural Economist and Rebecca Darling, Office Professional, Kansas State University

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High Plains Sunflower Production Handbook was published at Kansas State University in cooperation with the following groups.

Colorado State University · K-STATE Kansas State University · University of Nebraska Lincoln · University of Wyoming · USDA ARS Agricultural Research Service

Agronomic Practices

Hybrid Selection

Successful High Plain's 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 Proso and Sunflower Variety Tests* (Nebraska Cooperative Extension Publication E.C. Annual-107). 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. Commercial seed companies also can provide specific hybrid performance information. Both oil type and confection type (also referred to as non-oil type) sunflower are produced in the region, each requiring specific crop management and marketing techniques.

When deciding to grow oil type sunflower, hybrids producing satisfactory seed yields and oil percentages should be selected. Domestic sunflower processors pay a premium for oil content higher than the 40 percent standard, while discounts are assessed for seed lots yielding oil content below this standard.

Test weight is important from a quality standpoint. USDA grade for oil type sunflower cannot be met with test weights less than 25 pounds per bushel. Confection-type sunflower normally have lower test weights than oil type sunflower because of larger seed sizes. To achieve satisfactory test weights, hybrids should be selected that will mature within the frost-free growing season. This is especially important for later summer plantings.

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. In addition, 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 and early maturity. The disadvantage is reduced yield potential in comparison to conventional height hybrids.

Hybrid Types

Sunflower can be classified into two categories: Confection (non-oil) and oil types. Both types have separate and distinct markets, and as a result cannot be mixed in storage.

Confection sunflower production is similar to oil type, with the exception of two areas: Population (confection fields should be planted slightly thinner than oil seed types) and, insect pest control (insect threshold levels are lower for confections). Lower plant populations per acre assist in increasing amount of large sized seeds, while insect-free confection seeds are necessary to meet market standards. Confection seeds brought to processors with high insect levels will be discounted. Confection growers should budget for at least one insecticide application with some fields requiring a second application at early bloom.

Oil 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 have been the predominant oil sunflower hybrid produced, but this is expected to decrease in the future.

Rather, NuSun is projected to become the predominant sunflower oil type. NuSun oil contains 20 percent lower saturated fats than traditional linoleic oil types, and 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. High oleic sunflower types produce a specialty oil used in lubricants (both food grade and industrial) and as food coatings. High oleic oil is a specialty oil that is very low in saturated fats.

Before choosing a sunflower hybrid type contact sunflower processors (oil crushing plants, confection processors, birdseed processors), as some types must be grown "identity preserved" only. In addition, pricing contracts exist for specific sunflower types, as well.

Seed

Sunflower seed must be purchased from commercial seed companies every year because varieties are hybrids. 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. Regardless of sunflower type, larger seed sizes may have some advantages when it is necessary to plant deep, but may require more moisture for germination. The size of sunflower seed at planting has not been proven to have any effect upon either final sunflower yields or the size of seed produced. This is particularly true with respect to confection sunflower varieties.

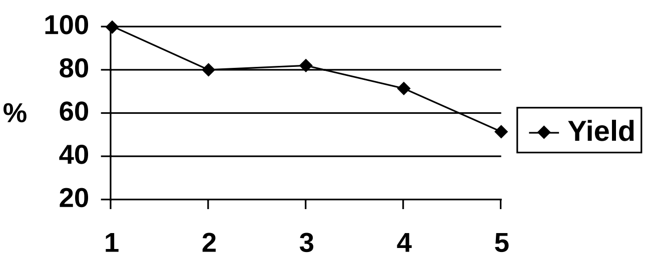
Planting

Best planting procedures will provide optimum seedling establishment. Errors at planting time will handicap the crop over the course of the growing season and will often 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 covered more than 3 inches. Semidwarf hybrids should not be planted more than 1.5 inches deep.

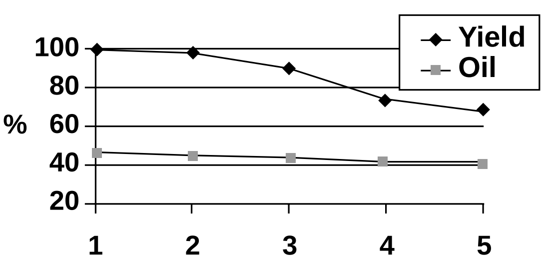
Sunflower may be planted over a wide range of dates. Highest yields occurred with sunflower in Kit Carson County, Colorado, when planted during the last week in May (Figures 1 and 2). Sunflower yields were lower when planted after the second week in June; however, seed weevil counts were also lowest for sunflower planted later. These studies indicate the agronomic advantages of planting early outweigh disadvantages of higher insect pest densities, provided fields are monitored for insect pests and treated accordingly. Seed quality (percent oil) also was higher from early planting dates (May 20). In addition, test weight decreased while harvest moisture increased as planting date was delayed. In Nebraska studies, sunflower 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 sunflower planted on June 28. Gross income was reduced by $0.77 per acre for each day of delay in planting after May 25.

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



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

Early planting dates work well in the region, however, seeding sunflower in soil cooler than 50 degrees Fahrenheit is not recommended. Planting sunflower into soils averaging less than 50 degrees Fahrenheit will delay germination and increase the likelihood of seedling disease, insects, and soil herbicide damage. Planting dates in early May yielded similar to late May planting dates in Kit Carson County, Colorado. Wyoming producers may want to consider early June planting dates.

How late in the season can sunflower be planted? 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 sunflower yields less than earlier planted, later plantings are effective under normal summer conditions if they become necessary in your operation. When planting midsummer, choose only early maturing hybrids.

Plant Populations

Available row crop equipment should dictate row spacing used. Solid seeded sunflower is feasible but yield performance has been best with row spacing at 30 inches. Currently, 30-inch row spacing is most popular, and is considered to be standard.

Adequate plant population also is important for highest possible seed yields. Sunflower, 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 18,000 final plants per acre, adjusting for yield potential.

Inches between seeds assuming 90 percent germination.

	Row Spacing	
Plants per Acre	**30"**	**12"**
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
ft per 1/1,000 acre	17.4	43.5

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 competing with weeds and preventing erosion. 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 sunflower should be between 17,000 and 22,000 final plants per acre. Irrigated oil-type sunflower plant population recommendations in central and eastern Kansas go to 4,000 plants per acre higher than the high end of this range. 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 may 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 face downward. Planting rows in a 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.

Bird Control

Sunflower is 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 such as trees and irrigation systems can expect bird damage.

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

1. Select varietal plant types with head types that turn down after flowering.
2. Plant early hybrids at early planting dates, and harvest early.
3. Avoid planting sunflower within a quarter mile of marshes or sloughs that consistently harbor large quantities of birds and contain water in later summer.
4. 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.
5. Do not plow or till earlier harvested sunflower fields in the vicinity, since these areas can act as alternative seed reservoirs. After harvest leave all stubble standing until all sunflower is harvested, as birds will be attracted to these areas in search of food.

In addition, bird deterrent practices have been used. These practices fall into two categories: 1) mechanical frightening and 2) 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 just prior to early morning or late afternoon feeding periods. Gas-powered propane and acetylene exploders probably have been used to the greatest extent. Use one exploder per 10 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.

Avitrol is currently the only chemical registered for control of blackbirds in sunflower. It is a cracked-corn bait in which 4 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 or state department of agriculture for current registrations status and always read and follow label instructions.

Web Page Listings

Information about sunflower can be found at the following web sites.

http://www.sunflowernsa.com
National Sunflower Association

http://www.ndsu.nodak.edu
North Dakota State University site

http://www.colostate.edu
Colorado State University

http://www.oznet.ksu.edu
Kansas State University

http://www.ianr.unl.edu
University of Nebraska-Lincoln

http://www.uwyo.edu
University of Wyoming

Nutrient Management

Fertile, well-managed soils capable of producing good yields of other crops also can produce good yields of quality sunflower. Nutrient uptake by sunflower is influenced by many factors including stage of development, hybrid and soil fertility. Sunflower needs an adequate supply of nutrients at each developmental stage for optimum growth. High-yielding sunflower removes considerable amounts of nutrients from the soil and this should be taken into account in developing a sound nutrient management program. Table 1 summarizes typical nutrient content of sunflower.

Sunflower is considered to be efficient in utilizing 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.

Nitrogen

Nitrogen (N) is the nutrient of greatest need for optimum sunflower production. Nitrogen recommendations vary with yield expectations associated with soil, climate, soil moisture, cropping sequence, and residual nitrogen in the soil.

Table 1. 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 (P205)	12	3	15
Potassium (K20)	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

Table 2. Nitrogen credit for legumes used in crop rotations.

Previous Legume	Nitrogen Credit lb/ac
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

Fertilizer nitrogen rates should be adjusted if legumes are grown in rotation with sunflower. Table 2 summarizes nitrogen credits for various legumes.

A general guideline is to provide 50 pounds of nitrogen per 1,000 pounds of expected yield.

Since sunflower is 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.

Nitrogen recommendations can be calculated by using the following equation:

N Rec = [YG × 0.05 lbs ÷ lb of yield] STA - PCA - PYM - PSNT

N Rec—Fertilizer nitrogen recommended in pounds per acre

YG—A realistic yield goal in pounds 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 N × 0.3 × depth, in.= pounds per acre

Subsoil:

ppm N × 0.3 × depth, in. = pounds per acre

Total Profile N = pounds per acre

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

Example:

Yield Goal = 1,800 pounds per acre

Soil Texture = Silty Clay Loam

Previous Crop = Wheat

Previous Manure = None

Soil Test Results:

0–6" = 8 ppm N, 6–24" = 6 ppm N

N Rec = (1,800 lb/a × .05 lbs/lb) 1.0 - 0 - 0 - 47* = 43

*(8 ppm × 0.3 × 6" + 6 ppm × 0.3 × 18")

Under these conditions, **43** lbs of fertilizer N is recommended.

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

Field comparisons of nitrogen sources conducted by Kansas 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 sunflower can be made preplant, sidedress, or a combination of these 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 responses by sunflower to phosphorus fertilization have 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 3 shows phosphorus recommendations.

Phosphorus should be applied either preplant-broadcast, preplant-knifed, or banded at seeding. Starter applications are most efficient, particularly when small amounts are applied on acid soils low in available phosphorus. Phosphorus can be placed in direct contact with the seed or to the side and below the seed. 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 equal. Selection of a phosphorus source should be made on the basis of cost, availability, and adaptability to the operation.

Potassium

As with phosphorus, a soil test is the best guide to potassium (K) need (Table 3). 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, sunflower is 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 the 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 materials. Selection should be based on cost, availability, and adaptability to the farm operation.

Lodging of sunflower 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 the northwest Kansas region.

Lime recommendations are intended to maintain soils in a productive condition. Sunflower is 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 sunflower on all soils with a pH of 6.0 or less. If sunflower is 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 Region soils test quite high in pH.

Other Elements

Perhaps because of the extensive root system, reports of secondary and micronutrient deficiencies in field grown sunflower are rare. In most states in the region for example,

Table 3. Phosphorus and potassium recommendations for sunflower.

		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 P205/a ------------					------------ lb K20/a ------------				
1000		30	20	15	0	0	50	40	15	0	0
1500		40	30	20	0	0	60	50	25	10	0
2000		50	40	25	10	0	70	60	35	15	0
2500		60	45	30	15	0	80	70	45	20	0
3000		70	55	35	20	0	90	75	55	25	0

[1] When sunflower are used for silage, add 40 lb K_20/a to recommendation in low-testing soils.

sulfur, iron, and zinc deficiencies have been reported in other row crops, small grains, and forage crops. However, there have been no reported deficiencies of any of these nutrients in sunflower. In fact, sunflower is often suggested as an alternative crop on severely iron deficient soils. Likewise, there should be no problems with boron, copper, or manganese nutrition in sunflower.

Soil Fertility and Micro Nutrients[1]

Iron availability decreases with increasing soil pH. However, sunflower is tolerant of low iron availability. Sunflower production is usually successful on soils that cause deficiencies on sensitive crops such as corn, sorghum or potatoes. Severe iron deficiency of sunflower 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 past yield histories and future expectations.

References

1. Ron Meyer, author, Colorado State University

Weed Control

Weed management is an important component of successful sunflower production. Sunflower in the High Plains is nearly always grown in rotation with other crops. The weed control benefits associated with crop rotations can best be realized if good weed management was practiced in the preceding crop. Because sunflower is usually planted at low densities and grows slowly during the first 2 weeks, weeds that emerge and establish during this time period can be very competitive and reduce sunflower yield potential tremendously. However, sunflower is a strong competitor with weeds that emerge 3 or more weeks after sunflower emergence. Therefore, maintaining sunflower weed free for the first 3 to 4 weeks after planting will minimize yield losses from weeds.

Preplant Weed Control

It is essential that sunflower seed 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 predominate weed control method, implements such as the V-blade, tandem disk, or field cultivator may be used before planting sunflower. Soil that is warm and dry on the surface, and moist below, encourages rapid sunflower development and will delay weed seed germination. In double-cropped sunflower, good weed control also must be practiced in the small grain crop first. However, sunflower should not be planted in wheat stubble if Glean, Ally, Peak, Amber, Finesse, Canvas, Maverick, or Tordon herbicides were applied for weed control within the growing wheat because of the sunflower injury risk from herbicide carryover.

The use of a nonselective herbicide such as glyphosate (Roundup Ultra or Roundup RT) or paraquat (Gramoxone Extra) is an alternative to preplant tillage for weed control. These foliar-applied herbicides can control seedling broadleaf weeds and grasses that have emerged. Since paraquat is a contact (non-translocated) 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 broadleaf species such as wild buckwheat and kochia.

Applying glyphosate or paraquat before planting utilizes 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 seeds lying on the surface are not buried into moist soil. In crops such as sunflower, where there are few herbicide options, alternative techniques such as the stale seedbed method may be utilized. Alternatives may be utilized in any situation, but they gain in importance when traditional techniques (herbicides) are not available.

Glyphosate mixtures containing 2,4-D (Landmaster BW) or dicamba (Fallow Master) have high potential for causing crop injury when applied ahead of sunflower planting and should not be used within 3 months prior to planting.

Another alternative to tillage for weed control in double-crop sunflower is to burn the small grain stubble ahead of sunflower planting. Fire can kill some 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 weighed against the benefits of leaving the wheat stubble standing for control of soil erosion from wind and water. Burning also may increase moisture loss from the soil profile and reduce stored moisture in the profile during the growing season because it leaves the soil surface more exposed to wind and sunlight.

Delayed planting of sunflower is sometimes used to allow weeds and volunteer wheat to germinate. This method can reduce weed population 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 currently available for weed control are EPTC (Eptam), ethalfluralin (Sonalan), pendimethalin (Prowl), and trifluralin (Treflan and others). These herbicides primarily control grassy weeds such as crabgrass, foxtail, fall panicum, field sandbur, witchgrass, and barnyard grass. The most economical and consistent grass control is often provided by Treflan, followed by Prowl, and Sonalan, in that order. All these herbicides usually control pigweeds and lambsquarters, and at higher rates can provide acceptable control of kochia and Russian thistle. Prowl may be surface applied to no-till planted sunflower without incorporation. However, best control is obtained when rainfall is received within 7 days of application.

Weeds that germinate and emerge before rainfall is received will not be controlled. Formulations of Lasso and Dual herbicides are currently being evaluated for registration in sunflower. The chloracetamide herbicides provide good control of grass and some broadleaf weeds, especially pigweed species. These herbicides can be surface applied in a no-till system. Receiving rainfall or irrigation immediately after application of these soil applied herbicides will increase the level of weed control.

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 Prowl applications and conserves more residue than traditional PPI treatments. Research in Colorado, Nebraska, and North Dakota found that Sonalan or Treflan granules applied and incorporated 1 or 2 weeks before planting, or in a split application with half of the herbicide applied and incorporated the previous October, provided greater than 85 percent weed control for 7 to 9 weeks after planting. Because winters in the High Plains are warmer than in the Northern Plains and snow seldom covers the ground all winter, fall and surface applications of granular herbicides break down more rapidly and do not work as well in the High Plains.

Volunteer wheat can be a major problem in double crop sunflower, especially where wheat has been shattered by hail or wheat stubble has been disked. Treflan can provide some wheat control, but generally is not satisfactory. Volunteer wheat and other grassy weeds can be controlled postemergence with sethoxydim (Poast or Poast Plus). Poast is most effective for control of wheat that is less than 4 inches tall and is actively growing. Herbicide screening trials at the North Central Kansas Experimental Field, Belleville, Kansas, have shown sunflower yields and weed control were better where preplant incorporated herbicides were used, as opposed to postemergence herbicides. These results were based on responses of redroot pigweed and fall panicum.

Herbicide options for weed control in sunflower are limited, especially for control of many broadleaf weed species. Thus, to reduce costs and provide broad spectrum weed control, mechanical weed control in the crop also should be considered. A shallow tillage pass with a springtooth, or flexible harrow pulled diagonally to the planting direction can remove many 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 Gramoxone Extra as a directed spray between the rows of sunflower. Extreme care must be exercised to avoid contact of the nonselective herbicide and the sunflower. 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 sunflower and should be available 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 sunflower that have been planted into wheat stubble may reduce the soil moisture saving benefits associated with wheat stubble on the soil surface.

For specific herbicide and weed control recommendations, refer to pesticide control or herbicide guides provided by your extension service.

Water Requirements and Potential Impacts on Following Crops

Water Use and Yield

Sunflower water use amounts vary with the amount of water available to the plant from the soil and how much comes as rainfall during the growing season. As available water increases, so does sunflower water use. For sunflower to grow without water stress in the central High Plains, approximately 34 inches of water would be required. This could come as a combination of stored soil water, growing season rainfall, and irrigation. Reports of sunflower water use range widely from 8 to 38 inches per year. The higher values come from irrigated studies or high rainfall conditions. Sunflower grown where the soil water profile is full will use greater amounts of water. Dryland sunflower 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 (Fig. 3), when other factors such as fertility, weeds, insects, and diseases are not limiting to yield. This relationship, generated at Akron, Colorado, shows that about 150 pounds per acre of seed are produced for every inch of water use after the first 7 inches of water use (water use is defined at the sum of stored soil water use, growing season precipitation, and irrigation). This yield increase with increasing water use (150 pounds per acre per inch) is the same as reported in studies conducted in the panhandles of both Nebraska and Texas. Also, it has generally been found that sunflower oil concentration in seed increases with increases in available water and crop water use.

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 prior to flowering through seed development. In the central High Plains, these growth stages occur during August and early September. Data collected at Akron, Colorado, 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 more of rainfall during this time period (Fig. 4). 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. Growers with the option to irrigate should be able to successfully employ limited irrigation strategies by delaying their first irrigation until just prior to flowering.

Soil Water Extraction and Rooting

Sunflower has an extensive root system that 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 sunflower 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.

Figure 5 compares typical soil water extraction by depth in the soil for proso millet, corn, winter wheat, and sunflower under dryland production systems at Akron, Colorado. Proso millet extracts about 4 inches from the top 3 feet of soil, whereas sunflower extracts about 7.5 inches from the 6 foot profile. About 1.5 inches more soil water is used by sunflower out of the lower half of the profile than is used by corn or wheat.

Effect on Yield of Subsequent Rotational Crops

Because of the dry soil profile condition following sunflower production, producers need to consider the impact of sunflower on subsequent crop yields. Research results from 3 years of a crop rotation study at Akron, Colorado, (Fig. 6)

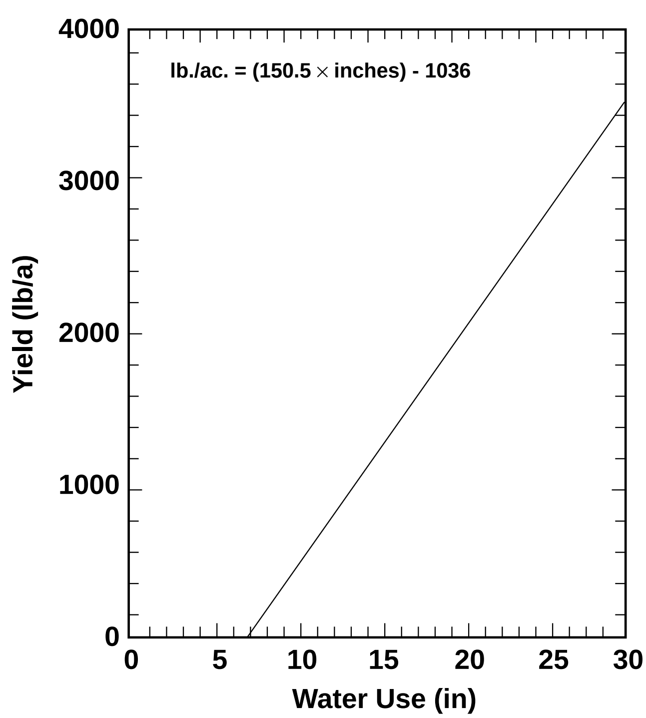


Figure 3. Sunflower yield as influenced by water use, Akron, CO

show reduced average winter wheat and proso millet yields when these crops are grown following sunflower in rotation compared with rotations without sunflower. This is a result of the lower soil water content left following sunflower production, and 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, and millet yields are reduced by 6 bushels per acre for every inch less of available water at planting (Fig. 7). The yield reductions due to sunflower in rotation are greater for both wheat and millet when growing season rainfall is below normal. In dry years, the dry starting soil water profile following sunflower is not offset by rain during the growing season, and water stress is greater in the rotations that include sunflower. In wet years, the impact of sunflower on subsequent crop yields is low.

While it is clear that average yields of both wheat and millet are reduced by the presence of sunflower in rotation, the yield of the total rotation must be considered when making decisions about diversifying and intensifying cropping systems. The rotation yield averaged over 1995, 1996 and 1997 (Fig. 8, top) shows M-W-C, W-C-F, W-C-Sun-F, and W-M-Sun-F to be the top producing rotations (based upon total pounds of grain produced), and M-Sun to be the lowest producing rotation. When these yields are expressed on an annualized basis (Fig. 8, bottom) (which accounts for the average yield across all crops in the rotation and the fallow year when it occurs), M-W-C and W-C-F are the top yielding rotations (1,992 to 1,913 pounds per acre per year), followed by W-F, M-C, W-C-Sun-F, and W-M-Sun-F (1612 to 1371 pounds per acre per year). The lowest yielding rotations are W-Sun-F and M-Sun (930 to 771 pounds per acre per year). These two rotations may be too demanding of water to be successfully used in the central High Plains. However, it has been our observation that in larger sunflower production fields with good standing residue following harvest, and with normal to above normal snowfall, soil water recharge of 4 to 6 inches can occur.

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

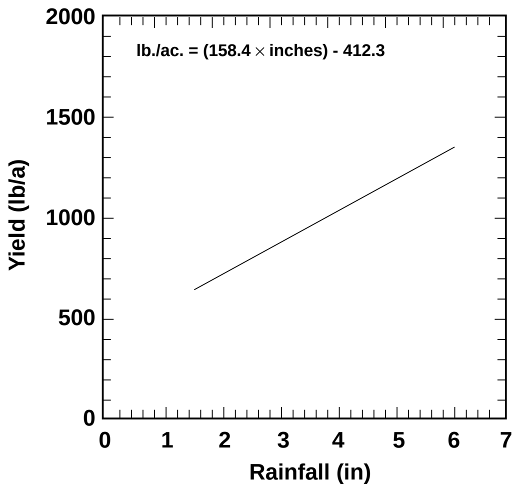


Figure 4. Sunflower yield as by August and September rainfall, Akron, CO.

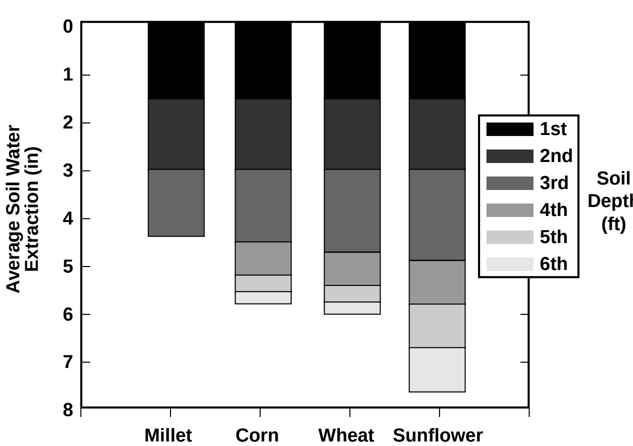


Figure 5. Typical soil water extraction by depth for proso millet, corn, winter wheat, and sunflower, Akron, CO.

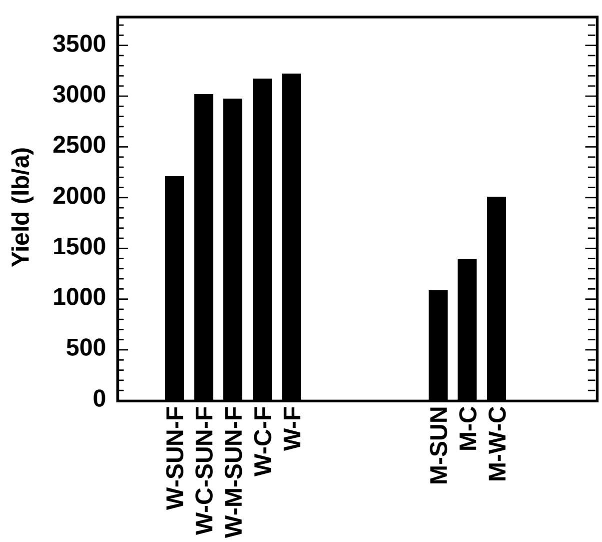


Figure 6. Average winter wheat and proso millet yields with and without sunflower as previous crop, Akron, CO.

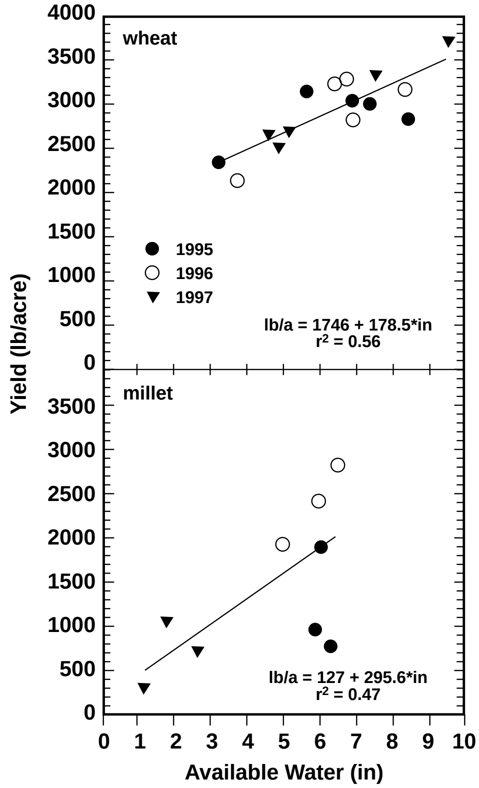


Figure 7. Relationship between available soil water at planting and wheat (top) and millet (bottom)

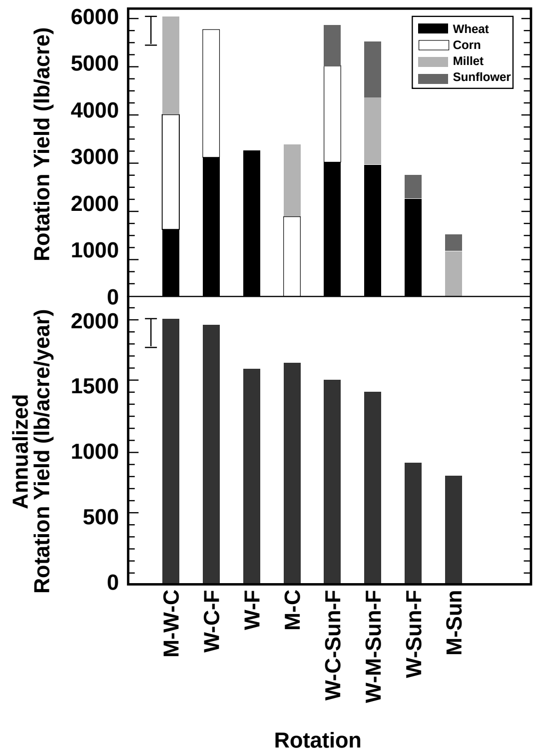


Figure 8. Average total rotation yield by crop (top) and average annualized rotation yield (bottom) for rotations at Akron, CO.

Irrigation Management

Irrigation of sunflower is not common in High Plains states of Colorado, Kansas, Nebraska, and Wyoming. Less than one-half percent of the 16 million irrigated acres are planted to irrigated sunflower (80,000 acres). Confection sunflower often is irrigated to ensure good seed quality and size. Sunflower is a deep-rooted crop, but will respond to irrigation if properly timed with the peak water use period of bud formation to petal fall.

Like other field crops, sunflower does best with adequate water and, contrary to popular belief, uses more water than most other crops during their growing season. The reason for misconception about sunflower water use is that it will 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 for soil water to depths of 5 or 6 feet, they would discover that the sunflower crop removed water to a greater extent than other crops. Crop water-use studies have shown that during the time of its peak use rate, sunflower uses 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 sunflower is typically around 22 inches of water use under well watered conditions. However, yields of a fully watered crop as compared to yield of sunflower with only two-thirds of full water is 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, Colorado, 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 is produced for every inch of water use after the first 7 inches of water use. Dryland sunflower yield at Akron, Colorado, 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. (Fig. 9)

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 within the High

Plains) and rainfall of 4 to 6 inches after germination, should be adequate for sunflower to reach bud stage. (Fig. 10) 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, one 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. Sunflower may 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 affecting yield. Because the soil profile can be very dry after a sunflower crop, 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 such that snow trapping can occur during storms with strong winds. Tall stalks will trap more snow than short stalks. A study done at Akron, Colorado, has shown that a population of 14,000 stalks per acre (3.57 stalks per 1,600 square inch), one inch in diameter, and 16.7 inches tall would trap 4 inches of soil water under the snow condition that prevails in Akron, Colorado.

A summary of sunflower yields and water-use data from a 3-year irrigation study at the Northwest Research–Extension Center, Colby, Kansas, is presented in Tables 4 and 5. 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 6 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.

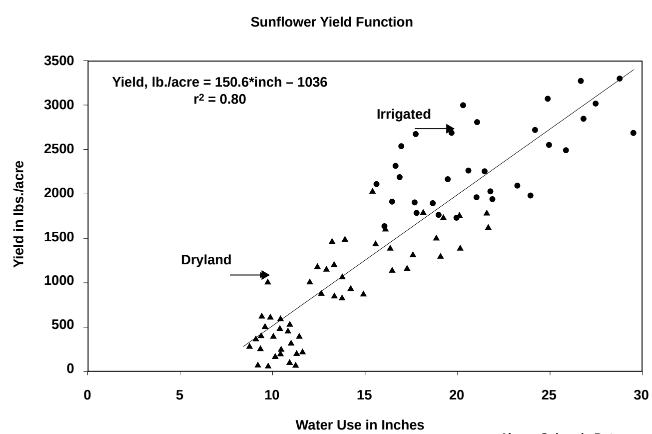


Figure 9. Sunflower Yield Function

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 should be the goal in scheduling irrigation. 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 is 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 sunflower in western Kansas has produced about a 40 percent increase in yield, but during the best seasons with fully adequate rainfall, nonirrigated yields were comparable to the best long-term average yields with irrigation.

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Table 4. 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	Mean	Mean
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 5. 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 6. 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 & Petal Drop	19.2	21.4	16.7	23.4	23.0	22.9	21.1

Insect Pest Identification and Control

Cultivated sunflower in the High Plains hosts a wide variety of insects. Not all these insects are damaging, and the problem species are not always present in densities capable of causing economic loss. When significant insect damage does occur, it may result from leaf, stem, root, or seed feeding.

Several species of native sunflower may serve as plant hosts 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 sunflower. Many sunflower insects overwinter in or near plant residue from the sunflower plants in which they developed. Crop rotation, modified planting dates, wild sunflower control, or deep plowing may reduce the likelihood of economically important insect infestations. However, deep tillage operations such as plowing may be incompatible with moisture and soil conservation practices in the High Plains region. Experience has shown that judicious use of insecticides often is required for successful sunflower production in the High Plains region.

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 5 to 10 plants for insects and damage. Use this scouting information and the action thresholds given below to determine if an insecticide treatment is necessary. The following treatment thresholds 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.

Because insecticide registrations change constantly, complete insecticide recommendations are not provided in this publication. Insecticides currently registered for use against a given sunflower pest can be found in insect control recommendation guides provided annually by the university extension services in the High Plains region. A summary of important sunflower insect pests and control recommendations follows.

Key Insect Pests of Sunflower

Sunflower Moth

Homoeosoma electellum (Hulst). The tan or gray adults are about a of an inch long with ¾ inch wingspread (Photo 1). Larvae (Photo 2) have brown head capsules with alternate dark and light lines running longitudinally. Adults apparently migrate from southern areas and are attracted to sunflowers beginning to bloom. The annual northward dispersal is aided by southerly winds, and adults appear in the region from late June to July. Earlier adult migrations utilize wild sunflowers and other host plants. Larvae begin to tunnel into seeds and other head tissue from July to August and each larvae can destroy 4 to 6 seeds during development. Sunflowers infested with sunflower moth larvae are more susceptible to Rhizopus head rot.

When to treat: Scouting should start when plants reach the R-3 stage of development. Moths are best scouted in the evening when they are active. Count moths on five sets of 20 plants distributed in an X pattern across the field. Consider an insecticide treatment if scouting results average two or more sunflower moths per five plants at early bloom. Continue scouting through the R-5.9 stage for reinfestation. Another method to determine the economic action threshold utilizes pheromone traps. Four traps should be used in each field. The traps should be located ten rows into the field on the south and north borders. Traps should be placed on T posts slightly above the canopy height. Both trap types (Jug or Wing Type) work equally well. The traps should be monitored daily from the R-3 stage through the R-5.9 stage. Treatment should be considered if the traps in a field exceed 4 moths per trap per day during the R-3 to R-5.9 growth stage. Research results are not clear when average moth counts per night are between 1 and 4. If counts are in this range, field scouting should be utilized to determine the economic action threshold. Moth trap catches averaging less than 1.0 per night usually result in non-economic infestations. Effective insecticide treatments currently used against sunflower moth include: Asana XL, Baythroid 2E, Furadan 4F, Lorsban 4E, and Warrior 1E. Most planting date studies indicate that early planted fields (fields that bloom before late July) stand the greatest chance of developing significant infestations.

Banded Sunflower Moth

Cochylis hospes (Walsingham). Adults (Photo 3) have a ½ inch wingspan. The front pair of wings are yellowish and have a dark brownish-black band near the middle. Young larvae are cream colored, whereas mature larvae (⅓ to ½ inches) range from pink to reddish brown with a brown head (Photo 4). Adults begin to emerge in the region from June to early July. Peak egg laying coincides with the late bud crop growth stage (R-3 and R-4). Larvae feed on sunflower heads through late September to early October. Larvae overwinter in the soil and pupate in June of the following year (Photo 5).

When to treat: Applications are made to prevent moths from laying eggs. Moths are best scouted in the early morning or late evening when they are active. Scouting should include weedy field margins and adjacent crops bordering the sunflower field. Use an X pattern, counting moths on 20 heads per sampling site for a total of 100 heads. Research is continuing into accurate economic thresholds, however one moth per two plants is considered a reasonable economic threshold level if it occurs in the late bud stage (R-3.0 to R-4.0). Infestations can be substantiated by examining bract leaves on late bud stage flowers for eggs. The eggs are singular, opaque and oval. Pheromone traps can be used to determine when scouting should be started, however a pheromone based economic threshold is currently not available. Treat for banded sunflower moth at early bloom stage. Treatments should include field margins where adults congregate when they are not active in the field. Effective insecticide treatments currently used against banded sunflower moth include: Asana XL, Baythroid 2E, Furadan 4F, Lorsban 4E, and Warrior 1E.

Sunflower Seed Weevils

Red sunflower seed weevil, *Smicronyx fulvus* (LeConte) are reddish brown (Photo 6) and gray sunflower seed weevil, *Smicronyx sordidus* (LeConte) (Photo 7) are gray. Adults range from 1⁄10 to 1⁄5 of an inch long. Females lay eggs between the pericarp and developing achene, usually 1 per seed. Larvae feed on the inner meat of seeds (Photo 8). When growth is completed, larvae exit the seed and drop to the ground from August to early October and overwinter in below-ground 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.

When to treat: Applications are made to prevent adults from laying their eggs. The action threshold for gray sunflower seed weevil is not well defined. The gray 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. Use the formulas that follow to determine action thresholds for red sunflower weevil on oil types. Application of treatments should be timed when about 30 percent of the plants have reached the R-5.1 stage. *Confection types* should be treated 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. Treatments for gray sunflower seed weevil should be made earlier, when 10 to 15 percent of the plants have reached the R-4 stage. Effective insecticide treatments currently used against seed weevils include: Asana XL, Baythroid 2E, Furadan 4F, Lorsban 4E, and Warrior 1E.

Scouting for red sunflower seed weevil can be difficult because of its distribution in the field and because of its habit of hiding in the 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 (see below for calculations). Avoid taking 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. 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. Count five sets of five plants, distributed across the field in an X pattern. If the insect repellent method is used, counts will need to be converted to absolute numbers before comparing them to the economic threshold calculations described below. Use Table 7 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 lbs., or loss per acre to break even on an insecticide application when sunflower price is $0.09 per lb.

Step 2: Female weevils per acre required for this loss (0.00056 lb. loss per female red seed weevil).
Example:
77.8 lbs. per acre ÷ 0.00056 = 138,930 female weevil
This number of female weevils per acre will cause break-even loss.

Step 3: Weevils per plant to cause break-even loss = female weevils × 2 (to account for males) ÷ plant population.
Example:
(138,930 × 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)

Sunflower Stem Weevil

Cylindrocopturus adspersus (LeConte). Adults are about 3⁄16 of an inch long and grayish-brown with varying shaped white spots on the wing covers and thorax (Photo 9). Mature larvae are 3 inch long. They are creamy white with a small, brown head capsule. Larvae appear C-shaped when in the vascular and pith tissue of the stalk (Photo 10). Adults can be found on plants in June and July. Newly hatched larvae feed on leaf tissue, but latter stages move into the stalks from July to late September. A chamber is formed by mature larvae (4th instar) near the base of the stalk where they remain all winter (Photo11). The presence of larval chambers can weaken the stalk, causing infested plants to lodge as plants dry down. Pupation occurs in to May to June of the next year.

Table 7. Conversions to be used if the "deet" scouting method is employed to count red sunflower seed weevil.

Weevil count in field	Absolute weevil count	Weevil count in field	Absolute weevil count
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

When to treat: Stem weevil can be controlled by a preventive application of Furadan 4F at planting time or by scouting and controlling the adults and larvae (prior to the larvae entering the stem) with a foliar application after the economic threshold is reached (one adult weevil per two plants). If small diameter stalks exist due to drought conditions or high plant populations, one adult weevil per three plants may be a more suitable economic threshold. Stem weevil adult emergence is highly influenced each spring by the preceding late fall, winter and early spring weather. However, once emergence occurs, 10 to 14 days are required before egg deposition begins. The female then selects plants with six or more leaves for egg laying. This means that early planted flowers are targeted for egg laying. Emergence studies based on degree day accumulation (Degree Day—6 degrees Celsius base temperature) conducted at Hays, Goodland, and St. Francis, Kansas (1996–97), Akron, Colorado (1995–97) and Scottsbluff, Nebraska (1996–1997) indicate planting date risk as follows: High relative risk if sunflower is planted prior to an accumulation of 449 degree days; low to moderate risk between 450 and 599 degree days and no risk after 600 degree day accumulation.

Other Insect Pests of Sunflowers

Seed & Seedling Pests

Cutworms and Armyworms

Caterpillar-like larvae, usually cream color to gray-brown, often with dark mottling or stripes. Mature larvae range in length from 1 to 1½ inches. Several species may be encountered throughout this sunflower growing region:

Army cutworm: *Euxoa auxilaris* (Grote)
Darksided cutworm (Photo 12): *Euxoa messoria* (Harris)
Dingy cutworm complex: *Feltia ducens* (Walker)
Pale western cutworm: *Agrotis orthogonia* (Morrison)
Sandhill cutworm: *Euxoa detersa* (Walker)

When to treat: Check fields early and treat if there is one cutworm per square foot or if plant losses are resulting in stands near the lower limits for optimum plant populations. Effective insecticides include Asana XL, Baythroid 2E, and Warrior 1E.

Wireworm

There are many species of wireworm that attack sunflower. The winter of this insect is passed mainly in the larval and adult stages in the ground. In the spring the adults become active. The beetle are hard shelled, brownish, grayish, or nearly black in color and somewhat elongated with the body tapering more or less toward each end. The joint just in front of the wing covers is loose and flexible and when beetles are placed on their backs, they snap the middle part of the body against the ground in such a matter as to throw themselves several inches in the air. This snapping makes an audible "click." The larvae stage is spent in the soil and lasts 2 to 6 years. The larvae are usually hard, dark brown, smooth, "wirelike" worms, varying from ½ to 1½ inches in length when mature. Some species are cream to yellow in color.

When to treat: Wireworms are most damaging to sunflower when the crop is planted in wheat stubble. Generally wireworms are concentrated in the highest residue areas of the field. The larvae either feed on the seed preventing germination or after germination they feed on the stem between the seed and the soil line. In both cases they kill the plant. There is no known rescue treatment. Seed damage can be prevented with a seed treatment utilizing Lindane. This will not prevent stem damage, however, it should reduce overall stand loss.

Head Infesting Species

Sunflower Bud Moth

Suleima helianthana (Riley). Wingspread ⅔ of an inch, gray-brown color with two dark transverse bands on forewings (Photo 13). The larva is cream colored with a brown head (Photo 14). First generation adult moths emerge in May to mid-June from overwintering pupae. There is a second generation in July or August. Larvae from first generation generally only damage terminals and stalks, whereas second generation larvae usually feed in the pith area of the head.

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

Sunflower Head Clipping Weevil

Haplorhynchites aeneus (Boheman). The adult is shiny black, measuring about ⅓ of an inch in length (Photo 15). 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 that partially sever the head from the stalk. An egg is 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.

When to treat: An action threshold has not been determined for this pest. Consider insecticide treatment if more than half the plants examined have weevils present and head clipping exceeds 5 percent on average across the field.

Sunflower Seed Maggot

Neotephritis finalis (Loew). Adult is ⅓ of an inch long, with a wingspan of about ¼ inch. The wings have a brown lace-like appearance. The larvae attain a length of ⅕ inch at maturity. Adults emerge during early July and egg deposition occurs on the corolla of incompletely opened sunflower inflorescence. 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 the corolla of young blooms. Young larvae can destroy up to 15 ovaries. Larger larvae can destroy up to three seeds during development.

When to treat: 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 in length with a wingspan of about ¾ inch. The eyes are bright green and wings have a yellowish-brown mottled pattern (Photo 16). 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 17). After about 30 days, the mature larvae cut a small emergence hole on the underside of the receptacle and drop to the soil to pupate in late August or early September. Overwintering pupae are found more than 6 inches deep. Some larvae will pupate in the sunflower head. There is one generation per year in the region.

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

Foliage Feeders

Painted Lady

Vanessa cardui (L.). The Painted Lady also is known as the Thistle Caterpillar. This butterfly has a wingspread of 2 inches, upper wing surface brown with red and orange mottling and white and black spots (Photo 18). Larvae are light brown to black, spiny, with a pale yellow stripe on each side (Photo 19). Adults appear in May and June with larvae appearing shortly thereafter. Larvae feed on leaves and can often be detected by the presence of webbing.

When to treat: Insecticide treatments are only recommended for larvae under 1¼ inch in length, because larger larvae are about to stop feeding. Consider a treatment if defoliation averages 25 percent on randomly selected plants.

Sunflower Beetle

Zygogramma exclamationis (F). Adults are about ¼ to ½ of an inch long and have a reddish-brown head, cream colored back with 3 dark, reddish-brown stripes on each wing cover (Photo 20). Larvae are yellowish-green, and humpbacked in appearance (Photo 21). The overwintering adults become active in the region in June and July to 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.

When to treat: Adults attack early in the season, defoliating seedlings (Photo 22). An infestation of one adult per plant is considered to be an economic action threshold. Later the larval stage feeds on larger plants. Fifteen larvae per plant or 25 percent defoliation would justify an insecticide application.

Root Feeding Species

Sunflower Root Weevil

Baris strenua (LeConte). The black adults of *B. strenua* are oval shaped, almost ¼ inch in length, and have a snout. Adults appear in fields by June in the region. Adults are often found in numbers around the root zone at the soil surface. Larvae can be found in stalks by mid-July. By September and early October larvae form a "soil cocoon" around roots at a depth averaging 2 to 5 inches and where they overwinter. Numerous larvae in the stalk will cause serious stalk breakage. Adults are known vectors of such fungal diseases as charcoal rot and Phoma black stem disease.

When to treat: Significant yield losses and stalk breakage have not been demonstrated with this insect. Insecticide treatments are not considered necessary under most conditions.

Carrot Beetle

Ligyrus gibbosus (DeGeer). A moderate size (½ to ⅔ inch) and oblong-ovate, dark reddish-brown to black beetle (Photo 23). Pronotum with a low tubercle in the middle. Wing covers with longitudinal depressed furrows with punctures. Hind tibiae are expanded and truncate at apex.

When to treat: Generally this insect feeds on roots and there is no known insecticide control method.[1]

References

1. Pictures courtesy of Stan Pilcher, Area Extension Agent, Entomology, Colorado State University.

Cost-Return Prospects

A farmer's decision to produce either oilseed or confection sunflower should be based on the expected profitability of sunflower relative to competing crops. In any particular year, that decision will depend on the relative expected returns over variable costs for each of the cropping alternatives. In the long run, however, the selection of crop enterprises has to be based on returns over total costs (including machinery, land, and family labor). In the following dryland and irrigated crop budgets, all costs are accounted for except land, labor, and management. Table 8 shows average cost estimates for oil-type and confection sunflowers and other dryland crops in western Kansas and northeastern Colorado for the 1995 to 1997 period. The sensitivity of these dryland crop cost estimates to alternative yield outcomes is given in Table 9. Table 10 shows cost estimates for irrigated crops. Western Kansas irrigated cost estimates are based on 1999 projections. Northeastern Colorado irrigated cost estimates are taken from 1997 farm records. Break-even cost sensitivity to alternative irrigated crop yield levels are given in Table 11.

Production cost estimates for northeastern Colorado irrigated and dryland crop enterprises are taken, with permission, from Golden Plains Area Agricultural Handbooks. The northeast 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 in Tables 8 and 9. Center pivot irrigation systems are assumed for each of the irrigated crop budget estimates in Tables 10 and 11.

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 confection sunflower buyer-processors in the area. Specific information about sunflower grade requirements, oil content price premiums, confection seed size premiums and discounts, market supply-demand factors affecting 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 December 1997).

Table 8. Dryland Crop Production Costs Estimates for Northeastern Colorado[a] and Western Kansas[b]

	Oil-Type Sunflower	Oil-Type Sunflower	Confection Sunflower	Winter Wheat	Winter Wheat	Dryland Corn	Dryland Corn	Millet	Grain 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	9.5	13.5	40	44	75	66	17	65
Direct Costs									
Seed	$9.92	$11.66	$12.57	$9.93	$4.63	$18.60	$14.61	$4.44	$2.21
Fertilizer	7.92	19.38	7.92	13.23	11.74	17.20	16.23	9.12	14.38
Herbicide	11.50	18.22	19.68	15.22	8.20	28.63	21.70	13.41	15.33
Insecticide	12.46	7.12	25.11	0.00	0.00	0.75	3.44	0.00	10.30
Machinery Fuel & Lube	6.30	9.89	6.30	6.09	7.96	7.47	6.11	7.89	6.88
Machinery Repairs	8.62	7.85	12.63	10.92	5.71	14.40	5.71	5.89	12.40
Crop Insurance	5.75	16.50	8.04	5.36	9.79	6.22	4.75	3.00	5.40
Custom Spray/Hire	11.67	2.45	12.63	11.52	6.27	9.60	11.68	9.45	11.52
Drying Expense	0.00	0.00	0.00	0.00	0.00	7.50	0.00	0.00	6.50
Miscellaneous Expenses	5.00	0.00	5.00	5.00	0.00	5.00	5.00	0.00	5.00
Interest on ½ Variable Costs	3.86	4.35	4.94	3.87	3.03	5.76	4.76	2.64	4.50
Total Direct (Non-Labor) Costs	$82.99	$97.42	$114.81	$81.15	$57.32	$121.13	$93.99	$55.85	$94.43
Fixed Costs									
Crop Machinery Depreciation	12.39		12.39	12.34		12.22			12.42
Interest on Crop Machinery	12.86		12.86	12.82		12.69			12.89
Machinery Replacement		30.83			23.72		24.15	25.17	
Insurance on Machinery & Equip.	0.48	5.39	0.48	0.48	3.94	0.47	4.18	4.23	0.48
General Farm Overhead		10.00			10.00		10.00	10.00	
Total Fixed (Non-Land) Costs	$25.72	$46.22	$25.72	$25.63	$37.67	$25.38	$38.32	$39.40	$25.79
Total Costs Excluding Land and Labor	$108.71	$143.64	$140.53	$106.78	$94.99	$146.51	$132.32	$95.24	$120.22
Break-even $ to Cover All Costs Excluding Land & Labor	$7.25 per cwt	$15.12 per cwt	$10.41 per cwt	$2.67 per bu	$2.16 per bu	$1.95 per bu	$2.00 per bu	$5.57 per cwt	$1.85 per bu

a. Northeastern Colorado budget estimates represent 1997 CSU Enterprise Cost Estimates. Producers from the Golden Plains Counties in Northeastern Colorado were interviewed to collect primary data. Secondary data were acquired from Dalsted, Gutierrez, Nitchie, Sharp, and Tranel, Selected 1995 Crop Enterprise Budgets for Colorado, December 1996. Updates of this information can be obtained from Dennis Kaan, Ag & Bus. Mgmt. Economist, CSU Extension, Central Plains Research Station, Akron, CO 80720, phone: 970-345-0509.

b. Western Kansas budget projections were taken from 1998 to 1999 KSU Farm Management Guides. Budget updates can be obtained from Daniel O'Brien, Extension Ag Economist, K-State Research and Extension, Northwest Research and Extension Center, Colby, KS 67701, phone: 785-462-6281.

Table 9. Yield Sensitivity Analysis for Dryland Crop Break-even Cost (Excluding Land and Labor Cost)

	Oil-Type Sunflower	Oil-Type Sunflower	Confection Sunflower	Winter Wheat	Winter Wheat	Dryland Corn	Dryland Corn	Millet	Grain 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
Average Yield per Acre (100%)	15	9.5	13.5	40	44	75	66	17	65
Sensitivity to Yield Changes									
75% of Average Yields	$9.66	$20.16	$13.88	$3.56	$2.88	$2.60	$2.67	$7.42	$2.47
90% of Average Yields	8.05	16.80	11.57	2.97	2.40	2.17	2.22	6.19	2.05
100% of Average Yields	7.25	15.12	10.41	2.67	2.16	1.95	2.00	5.57	1.85
110% of Average Yields	6.59	13.75	9.46	2.43	1.96	1.78	1.82	5.06	1.68
125% of Average Yields	5.80	12.10	8.33	2.14	1.73	1.56	1.60	4.45	1.48

Table 10. Irrigated Crop Production Cost Estimates for Northeastern Colorado and Western Kansas[a]

	Oil-Type Sunflower	Confection Sunflower	Corn	Corn	Wheat	Wheat	Pinto Beans	Alfalfa	Alfalfa	Grain Sorghum	Soybeans
	KSU cwt/acre	KSU cwt/acre	KSU bu/acre	CSU bu/acre	KSU bu/acre	CSU bu/acre	CSU lb/acre	KSU ton/acre	CSU ton/acre	KSU bu/acre	KSU bu/acre
Yield per Acre	22	21	190	184	70	65	2920	5	6.18	110	50
Direct Costs											
Seed	$15.21	$19.36	$38.40	$32.76	$8.10	$9.02	$28.00	$8.55	$14.68	$8.80	$17.50
Fertilizer	22.80	22.80	45.90	63.14	19.35	22.94	33.15	16.20	46.29	27.3	10.80
Herbicide	11.54	11.54	36.85	18.39	4.92	0.00	20.52	20.64	14.90	21.15	28.87
Fungicides	0.00	0.00	0.00	0.00	0.00	0.00	28.23	0.00	0.00	0.00	0.00
Insecticide	13.25	26.49	43.98	27.55	0.00	0.00	4.39	12.76	9.50	10.54	0.00
Machinery Fuel & Lube	4.61	4.61	7.85	15.24	5.55	11.23	15.71	17.44	6.19	7.15	5.50
Machinery Repairs	14.10	14.10	25.00	19.08	14.16	12.06	12.62	50.13	11.51	19.49	16.54
Irrigation Energy	19.50	19.50	42.90	46.30	19.50	29.60	30.11	37.05	54.75	27.30	29.25
Irrigation Repair	3.00	3.00	6.60	10.00	3.00	10.00	10.00	5.70	10.00	4.20	4.50
Crop Insurance	5.10	6.17	6.26	24.17	4.75	4.30	9.65	0.00	0.00	3.73	6.71
Custom Spray/Hire	0.00	0.00	0.00	4.00	0.00	0.00	10.00	0.00	3.50	0.00	0.00
Drying Expense	0.00	0.00	19.00	0.00	0.00	0.00	0.00	0.00	0.00	11.00	0.00
Crop Consulting	5.75	5.75	6.50	0.00	5.25	0.00	0.00	6.50	0.00	6.25	6.25
Miscellaneous Expenses	8.00	8.00	8.00	3.50	8.00	2.45	2.45	8.00	9.50	8.00	8.00
Interest on ½ Variable Costs	6.14	7.07	14.36	18.14	4.63	5.21	14.37	9.15	15.84	7.75	6.70
Total Non-Labor Direct Costs	$129.00	$148.39	$301.60	$282.27	$97.21	$106.81	$219.20	$192.12	$196.66	$162.66	$140.62

Table 10. Irrigated Crop Production Cost Estimates for Northeastern Colorado and Western Kansas[a] con't.

	Oil-Type Sunflower	Confection Sunflower	Corn	Corn	Wheat	Wheat	Pinto Beans	Alfalfa	Alfalfa	Grain Sorghum	Soybeans
	KSU cwt/acre	KSU cwt/acre	KSU bu/acre	CSU bu/acre	KSU bu/acre	CSU bu/acre	CSU lb/acre	KSU ton/acre	CSU ton/acre	KSU bu/acre	KSU bu/acre
Yield per Acre	22	21	190	184	70	65	2920	5	6.18	110	50
Fixed Costs											
Crop Machinery Depreciation	12.81	12.81	15.34		12.35			8.26		12.81	12.42
Crop Machinery Interest	13.30	13.30	15.93		12.83			8.57		13.30	12.89
Machinery Replacement				63.89		52.08	42.11		35.35		
Machinery Taxes & Insurance				11.27		8.95	7.21		6.17		
Irrig. Equip, Well Depreciation	62.96	62.96	62.96		62.96			62.96		62.96	62.96
Irrig. Equip & Well Interest	20.01	20.01	20.01		20.01			20.01		20.01	20.01
Insurance on Mach. & Equip.	1.49	1.49	1.59		1.48			1.32		1.49	1.48
Sprinkler Lease				50.00		50.00	50.00		50.00		
General Farm Overhead				10.00		10.00	10.00		10.00		
Total Non-Land Fixed Costs	$110.57	$110.57	$115.83	$125.16	$109.63	$111.03	$99.32	$101.12	$91.52	$110.57	$109.76
Total Costs (w/o Land, Labor)	$239.57	$258.96	$417.43	$407.43	$206.84	$217.84	$318.52	$293.24	$288.18	$273.23	$250.38
Break-even $ Covering All Non-Land & Labor Costs	$10.89 per cwt	$12.33 per cwt	$2.20 per bu	$2.21 per bu	$2.95 per bu	$3.35 per bu	$10.91 per cwt	$58.65 per ton	$46.63 per bu	$2.48 per bu	$5.01 per bu

[a] See footnotes a and b in Table 1 for sources of information for Northeastern Colorado and Western Kansas crop budgets.

Table 11. Yield Sensitivity Analysis for Irrigated Crop Break-even Cost (Excluding Land and Labor Costs)

	Oil-Type Sunflower	Confection Sunflower	Corn	Corn	Wheat	Wheat	Pinto Beans	Alfalfa	Alfalfa	Grain Sorghum	Soybeans
	KSU cwt/acre	KSU cwt/acre	KSU bu/acre	CSU bu/acre	KSU bu/acre	CSU bu/acre	CSU lb/acre	KSU ton/acre	CSU ton/acre	KSU bu/acre	KSU bu/acre
Yield per Acre	22	21	190	184	70	65	2920	5	6.18	110	50
Sensitivity to Yield Changes											
75% of Average Yields	$14.52	$16.44	$2.93	$2.95	$4.01	$4.47	$14.54	$78.20	$62.17	$3.31	$6.68
90% of Average Yields	12.10	13.70	2.44	2.46	3.34	3.72	12.12	65.16	51.81	2.76	5.56
100% of Average Yields	10.89	12.33	2.20	2.21	3.01	3.35	10.91	58.65	46.63	2.48	5.01
110% of Average Yields	9.90	11.21	2.00	2.01	2.74	3.05	9.92	53.32	42.39	2.26	4.55
125% of Average Yields	8.71	9.86	1.76	1.77	2.41	2.68	8.73	46.92	37.30	1.99	4.01

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 sunflower that serve as a reservoir for diseases and pathogen-carrying insects.

Disease problems affecting sunflower can generally be divided into two types, nonparasitic and parasitic. Nonparasitic diseases would include problems such as hail injury, herbicide damage, nutritional deficiencies, and weather related problems. Parasitic diseases would 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 & Residue Management section in this book.) 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. Sunflower is 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 (Photo A1 and A2). 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 sunflower 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 sunflower, 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 B1). During periods of high humidity or dew, a white, cottony growth (fungal spores and mycelium) develops on the underside of the leaf (Photo B2). 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 B3). 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 sunflower, 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 C1). 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 C2). 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 non-host 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 D). 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 will also 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 E). *Phomopsis* causes more pith degradation than does *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 F1). 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 F2). 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 G1, G2, and G3). 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 frequently lodging 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 sunflower 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 confection 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 confection 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 H). 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 sunflower, controlling wild sunflower 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 sunflower 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 I1). A creamy white, blister-like pustule forms below this spot on the underside of the leaf (Photo I2). 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 sunflower. It occurs on sunflower 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 J1). 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 J2). On the head, the entire seed layer falls away leaving only a bleached, shredded skeleton interspersed with large sclerotia (Photo J3). 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 non-susceptible 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 non-host crops (wheat, corn, sorghum) to prevent buildup in infested fields. Sunflower 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 non-host 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 K1). 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 K2). 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

A1* Phenoxy herbicide injury to sunflower. W.E. Sackston, McGill University.
A2 Doug Jardine
B1–B2 Tom Gulya
B3* Downy mildew. M.L. Straley, Cargill Inc.
C1* Verticillium wilt leaf symptoms. R. R. Urs, Dahlgren & Co.
C2* Verticillium wilt stem symptoms. D. W. Zimmer, USDA–ARS.
D Doug Jardine
E Unknown
F1* Charcoal rot symptoms on stem. W. E. Sackston, McGill University.
F2* Charcoal rot—sclerotia and internal symptoms. J. S. Baumer, University of Minnesota.
G1* Alternaria Symptoms on head. G. N. Fick, Sigco Research
G2* Alternaria Symptoms on leaf. G. N. Fick, Sigco Research
G3* Alternaria Symptoms on stem. G. N. Fick, Sigco Research
H Red rust on sunflower leaf. Howard F. Schwartz, Colorado State University.
I1–I2 Doug Jardine
J1* Sclerotinia wilt (white mold). B. D. Nelson, North Dakota State University.
J3* Sclerotinia wilt in head. B.D. Nelson, North Dakota State University.
K1* Rhizopus head rot. M. L. Straley, Cargill Inc.
K2 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 sunflower although machine settings and adjustments will differ. Sunflower crop conditions can change very rapidly. Because of this producers should prepare early to harvest sunflower 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. In addition, natural factors contribute to crop loss before harvesting begins. For sunflower 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 sunflower? 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 High Plains: row crop, corn, and small grain platform head. All can be used to harvest sunflower, 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. Sunflower 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 sunflower 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 soybean planted in row spacings from 30 to 42 inches. It has been used successfully without modification to harvest sunflower. 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 sunflower. 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 sunflower 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 towards 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 utilize 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 type 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 sunflower.

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: Sunflower thresh relatively easy. 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 confection 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 to begin. 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, sunflower can be stored safely if proper management practices are followed. The most critical aspects of storing sunflower 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 sunflower.

Clean sunflower. Sunflower 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 sunflower.

Store at safe moisture content. Sunflower should be stored at 10 percent or less moisture if marketing within 6 months after harvest. Sunflower 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 sunflower 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 sunflower 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 sunflower is not necessary. In most bins, 2 to 3 days will be required to cool sunflower.

Check the seed. Sunflower should be sampled weekly the first 6 weeks after harvest or until seed temperatures are below 60 degrees Fahrenheit. Then sample the sunflower 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 sunflower 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 sunflower to market immediately as the problems will only increase.

Although some cooperators experience problems when storing sunflower, 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 sunflower can be dried and stored easily.

Drying

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

Temperatures in the plenum of a dryer should be 160 degrees Fahrenheit or less 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 confection sunflower in batch and bin dryers should be less than 140 degrees Fahrenheit and 110 degrees Fahrenheit, respectively. Plenum temperatures for oil sunflower are 180 degrees Fahrenheit in column dryers and 120 degrees Fahrenheit for bin dryers.

Operators should recognize the fire potential when drying sunflower. 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 also 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 also may be needed for sunflower with high oil content.

Crop Rotation and Residue Management

Crop Rotations

As with any other crop, sunflower responds to good management practices, including desirable placement within the rotation. While sunflower grows well on summer-fallowed land, their deep extensive 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 sunflower 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, Colorado, showed that available soil water at winter wheat and proso millet planting was significantly affected by the presence of sunflower in a crop rotation. A summary of USDA–ARS research at the Central Great Plains Research Station is given in the Water Requirements section of this publication.

At Colby, Kansas, research suggests that a winter wheat-corn-sunflower-grain sorghum-fallow rotation is worth considering. Corn has shown more year-to-year yield variation than either sunflower 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, sunflower has shown the potential to extract water that is positionally unavailable to either corn or grain sorghum, which favors sunflower after corn.

Grain sorghum required 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 follow sunflower 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. At present, tillage is still necessary to incorporate preplant herbicides for optimum weed control in sunflower.

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

Sunflower is susceptible to triazine, Aatrex, and sulfonylurea (Ally, Amber, Peak), herbicide residues in the soil. Oat, wheat, proso, barley, and soybean all exhibit greater tolerance to these herbicides than do sunflower. Therefore, sunflower should not be planted where carryover may be a problem. Rotations may be as long 36 months. The weed control section in this publication contains a more thorough discussion of this topic.

Sunflower disease, insect, and weed pests are also 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. Rotations of at least 4-year spacings between sunflower crops, two of which must be cereals, are recommended to help prevent and control these diseases. The sunflower is also a host for diseases found in other crops. Verticillium wilt is found in potato, safflower, and sunflower. White mold is a disease found in dry edible beans, flax, rapeseed, soybean, mustard, sugarbeet, and sunflower. No more than one of these crops should be grown in the same rotation cycle in fields infested with these diseases. Refer to the Disease section in this handbook for a more thorough discussion.

Rotations help reduce populations of insects that overwinter in the soil or sunflower residue. Insects that migrate into an area from other geographic regions, or from fields planted to sunflower the previous year that are in close proximity to current season fields, are not effectively controlled by crop rotation. If possible, avoid planting sunflower 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 also minimize the potential for insect populations. This is discussed further in the Insects section of this handbook.

Suggested sunflower rotations for the High Plains include:

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

It may be desirable from a pest management and soil water storage stand point to alternate the winter wheat-sunflower-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 with the commencement of tillage. Research conducted for 3 years by the University of Nebraska at Sidney, Nebraska 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 12). 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. Other practical solutions to incorporating sunflower into High Plains cropping systems include strip cropping, following sunflower with a shallow-rooted summer crop such as proso millet, or interseeding legumes into the sunflower canopy.

Table 12. Sunflower residue weights and ground cover at five sampling times between sunflower harvest and winter wheat seeding the following year at Sidney, NE from 1993 through 1995.

Sampling time*	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

* 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 13. 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, Colorado.

	Initially at sunflower harvest		A year later at wheat planting time	
Fallow system	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

Research conducted at the USDA–ARS, Central Great Plains Research Station, Akron, Colorado, indicated an advantage in surface residue amounts when sunflower 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 (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 13). 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, Kansas, 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, Kansas, were 5,812 pounds per acre for corn, 5,350 pounds per acre for grain sorghum, and 3,823 pounds per acre for sunflower. 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 sunflower 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 four year period and increased oilseed yield an average of 327 pounds per acre.

Insect Pest Identification and Control Photos *(Continued)*

(see pages 13 through 16 for descriptions)

Photo 17.

Photo 18.

Photo 19.

Photo 20.

Photo 21.

Photo 22.

Photo 23.

Disease Photos

(see pages 21 through 24 for descriptions)

Photo A1.

Photo A2.

Photo B1.

Photo B2.

Photo B3.

Photo C1.

Photo C2.

Photo D.

Disease Photos *(Continued)*

(see pages 21 through 24 for descriptions)

Photo E.

Photo F1.

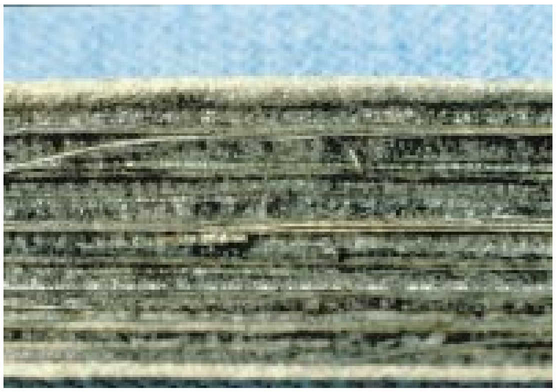

Photo F2.

Photo G1.

Photo G2.

Photo G3.

Photo H.

Photo I1.

Disease Photos *(Continued)*

(see pages 21 through 24 for descriptions)

Photo I2.

Photo J1.

Photo J2.

Photo J3.

Photo K1.

Photo K2.

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