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THE SUNFLOWER CROP IN MINNESOTA

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REGULATIONS AND SUGGESTIONS FOR THE USE OF CHEMICALS IN THIS BULLETIN ARE SUBJECT TO CHANGE. SOME PRODUCTS AND PROCEDURES MAY BECOME ILLEGAL OR OBSOLETE. NEW PRODUCTS AND PROCEDURES MAY BE APPROVED. THEREFORE, IT IS THE RESPONSIBILITY OF EACH USER OF AGRICULTURAL CHEMICALS TO FOLLOW DIRECTIONS ON THE MANUFACTURER'S LABEL AND TO BE FAMILIAR WITH CURRENT REGULATIONS.

R. G. Robinson is a professor, Department of Agronomy and Plant Genetics.

Use of commercial names does not imply endorsement nor does failure to mention a name imply criticism.

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THE SUNFLOWER CROP IN MINNESOTA

R. G. Robinson

INTRODUCTION

For many years, sunflowers in Minnesota fields and gardens have turned their heads and greeted the morning sun. During the twenties and thirties they were grown for silage in north central and northeastern Minnesota. But when early maturing corn hybrids pushed profitable corn production northward, sunflower acreage dwindled. Present day sunflower production is for three markets—birdfeed, human food, and oil.

Commercial birdfeed production began about 1952 and has continued as the major nonoil use of the crop.

Commercial production for human food started in the sixties. Previously, most of the seed for roasting and salting was obtained from California-grown Manchurian and Greystripe varieties. The introduction of dehulled sunflower seed as a nutmeat stimulated Minnesota production for the food market.

Oilseed production began in Canada in 1943 and in Minnesota in 1947. The attempt at oilseed production in the United States lasted only 2 years since enough soybeans became available to keep the oil extraction industry operating. Minnesota Agricultural Experiment Station trials at Rosemount in 1961 showed that some Russian varieties produced seed containing more than 40 percent oil. This research led to renewed interest in sunflowers as an oilseed crop, and commercial production started in 1966. In 1972 for the first time, oilseed production exceeded nonoilseed production.

Minnesota sunflower acreage has been increasing and reached 301,000 in 1972. Norman, Wilkin, Polk, Clay, and other west central and northwestern counties have had the largest acreage.

World production of sunflowers is also increasing. Since 1967, sunflowers have been second only to soybeans in world production of vegetable oils. Russia accounts for at least half of the world's production with 11 to 12 million acres annually. Argentina with about 3 million acres and Rumania with over 1.5 million acres are also major producers. The sunflower acreage of 850,000 in 1972 was an all-time high for the United States.

ADAPTATION AND MONETARY RETURN

Sunflowers are adapted to most of the climates and cultivated soils of the United States and Canada. Varieties of sufficiently early maturity for Minnesota are available, and good yields can be obtained on soils ranging in texture from sand to clay. When land values are considered a production cost, sunflowers have done well on sandy soils. Sunflowers have not been chlorotic on some high-lime soils where sensitive crops are often yellow.

A study conducted from Texas to Manitoba showed that sunflowers take longer to develop in the north than south. For example, eight varieties of varying maturities were planted May 14 at College Station, Texas (31° latitude); Stillwater, Oklahoma (36° latitude); Manhattan, Kansas (39° latitude); Lincoln, Nebraska (41° latitude); Presho, South Dakota (44° latitude); Rosemount (45° latitude); Fargo, North Dakota (47° latitude); Crookston (48° latitude); and Morden, Manitoba (49° latitude). Days from planting to bloom averaged 54, 58, 66, 67, 74, 76, 80, 84, and 90, respectively. On the average, sunflowers took 2 days longer per 70 miles northward to reach ray flower stage.

Oil from sunflowers grown in Minnesota contains more linoleic acid than oil from sunflowers grown in the central and southern United States. Thus, the northern crop has a quality advantage in markets requiring this type of oil.

Young plants are resistant to freezing and have survived temperatures in the low twenties. This resistance is gradually lost until by the six- to eight-leaf stage, temperatures slightly below freezing may injure the crop. Freezing at this stage may injure the terminal bud and result in branched plants of low yield. After heading but before pollination is completed, freezing causes sterile seed (empty hulls). Much of the 1965 crop was exposed to a mid-August freeze. Examination of heads indicated that sterile seeds were arranged in a doughnut-like circle, whereas the seed inside and outside the circle was normal. Evidently seed in a critical stage at the time of the freeze did not develop.

Sunflowers are drought tolerant except for the 3-week interval from heading to flower completion. This critical period usually occurs in late July and early August. Moisture stress at this time halts flower development and the lower leaves dry up. During the drought of 1964, sunflowers at the Rosemount Agricultural Experiment Station remained in a 10-percent ray flower stage from August 1 to September 1. But September rains revived the crop, and the field produced over 600 pounds per acre. Obviously, delays in maturity due to drought could be very damaging in the north where the growing season is short. In extremely droughty situations, some stalks break from 6 to 24 inches above the ground at heading time. This is a natural way of thinning the population.

Sunflowers should not be planted on fields infested with thistles, leafy spurge, or other perennial weeds that require spraying because most herbicides for perennial weed control also kill sunflowers.

Damage from sunflower head moth has been greater in southern than in northern Minnesota. The insect has also been worse in southwestern and west central than in eastern Minnesota. Commercial fields have neither been sprayed nor suffered severe loss.

Average yields of sunflowers like those of most other field crops, usually offer little or no profit above costs of production. Average Minnesota yields from 1968 through 1972 ranged from 863 to 1,086 pounds per acre and average price from $4.16 to $5.13 per 100 pounds. Some farmers consistently harvest 1,200 to 1,700 pounds and occasionally over 2,000 pounds per acre. Much of the crop is contracted in the spring for fall or winter delivery at the contract price. Table 1 is a guide for comparing gross returns of sunflowers with other crops. Where the other crops are adapted, sunflowers are a higher risk crop because of diseases, insects, and birds.

Costs of the basic field operations and tillage involved in growing and harvesting sunflowers do not greatly differ from those of small grain, flax, or soybeans. Sunflowers have usually had a lower seed cost per acre than the other crops in the table. In addition to seed and field operation costs, total direct cost of production per acre varies with usage of fertilizers, herbicides, insecticides, fungicides, artificial drying, and other inputs.

Table 1. Yields of sunflowers and other crops needed to give a gross income of $30-$90 per acre

	Crop and price received by grower*					
Gross income per acre	Sunflowers 4½¢/lb.	Soybeans $3.00/bu.	Corn $1.10/bu.	Oats 60¢/bu.	Barley $1.00/bu.	Flax $2.90/bu.
dollars	pounds per acre	.... bushels per acre				
30	667	10	27	50	30	10
40	889	13	36	67	40	14
50	1,111	17	45	83	50	17
60	1,333	20	55	100	60	21
70	1,556	23	64	117	70	24
80	1,778	27	73	133	80	28
90	2,000	30	82	150	90	31

* Comparisons can be made at lower or higher prices, respectively, by increasing or decreasing the yields shown in the table.

SEED QUALITY FACTORS

No legal test weight (pounds per bushel) has been established for sunflower seed, so the crop is sold by the pound. Nevertheless, test weight is an important quality factor within a variety or type because it is an indication of seed filling. Because of differing seed size and hull thickness among human food, birdfeed, and oilseed types, test weight is not a good measure of quality for comparing the three types. Within a type, it is an excellent measure of quality. For example, one company's contract on birdfeed and oilseed types offered 5 cents per 100 pounds seed as bonus or discount, respectively, for each pound of test weight above or below 26.

Seed size is important for nonoil human food sunflowers. Buyers usually pay a higher price if at least 40 percent of the seed is held on a 20/64 round hole screen. Occasionally a still higher price is paid if a certain percentage is held on a 22/64, 24/64, or 26/64 screen. These premium prices may encourage growers to use wider plant spacing to increase seed size. Test weight is often not considered when good seed of this type is bought on a size premium basis, but seedlots weighing less than 22 pounds per bushel may bring a lower price.

Oilseed sunflowers should contain at least 40 percent oil, and some buyers pay more for seed of 41 percent or higher oil.

Discounts for excess moisture often start at 12 percent.

SUNFLOWER SEED GRADE STANDARDS

There are no United States grading standards for sunflower seed. The following standards were developed by representatives of industry, the grain inspection services of Minnesota and North Dakota, and agricultural experiment station and extension service personnel:

"Sunflower seed shall be any grain which before the removal of dockage consists of 50% or more of tame sunflower seeds and not more than 10% of other grains for which standards have been established.

Class I — Edible and Birdfeed varieties.
Class II — Oilseed varieties.
Class III — Mixed Class. Seed that contains more than 2% of both Class I and Class II.

Dockage — Includes weed seeds, other grains, parts of stems, leaves, heads, chaff, hulls, straw, dirt, stones, and any other material which can be removed readily from sunflower seed by use of prescribed sieves, aspiration and hand pick. The quantity of dockage shall be calculated in terms of percentage based on total weight of sunflower seed including dockage."

	Minimum test weight per bushel			Maximum limits of			
	Class I		Class II		Damaged seed		
Grade	Large seed*	Small seed		Moisture	Total	Heat damaged	Dehulled seed
number	pounds			percent			
1	24	27	29	10	5	0.5	2
2	22	25	27	14**	8	1.0	3
3	20	24	25	14**	10	1.5	5

Sample Grade — shall include sunflower seed that does not come within the requirements of the Grades No. 1, No. 2, or No. 3 of Class I, Class II, or Class III; or which contains fire damaged sunflower seed; or which contains more than 14% moisture; or which is musty, or sour, or heating, or hot; or which has any commercially objectionable foreign odor; or which is otherwise of distinctly low quality; or which shows evidence of chemicals not approved.

* 30% or more held over 20/64 Round Hole Screen.
** Tough shall be sunflower seed in Grades No. 2 and No. 3 containing more than 12% but not more than 14% moisture.

VARIETIES AND MARKETS

Varieties and markets should be considered together, since choice of variety limits where the crop can be sold.

Human Food Market

This market usually pays the highest price. Large seed is desired. Seed passing over a 24/64 or 26/64 round hole screen is used for the roasted whole seed trade; medium large seed is dehulled and used for the nutmeat trade. Seed passing through a 20/64 screen and surplus large seed are sold for birdfeed.

Birdfeed Market

Medium-size, striped seed of high test weight is desired by most buyers, although lesser amounts of large and small seed are also used. Oilseed sunflowers are less popular because they are small, black with small hairs, and unattractive to some buyers. Purple seed such as that found in some imported mixed seed is undesirable because it stains feed trays. The large-seeded varieties used for the human food market sometimes cause packaging difficulty because some birdfeed packages marked for certain weight won't hold enough seed.

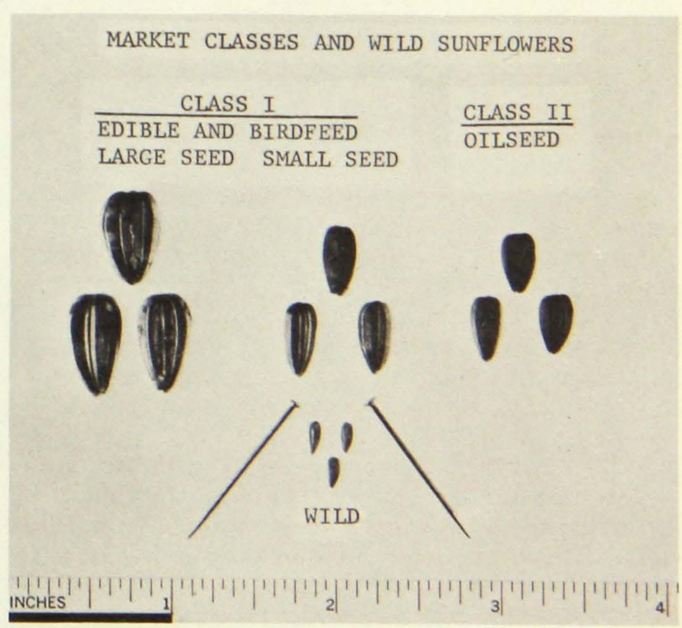

Figure 1. Market classes compared with wild sunflowers.

Oilseed Market

This market usually pays the lowest price, but it is the only market at the present time that can use increased production in Minnesota without reducing price. Price of oilseed sunflowers is greatly influenced by the price of exported Russian sunflower seed and oil and by the price of United States' soybean, cottonseed, and corn oils.

Mingren, Arrowhead, and Peredovik are high quality varieties representative of human food, birdfeed, and oilseed types, respectively (table 2).

Descriptions and trial data showing comparative performance of old and new sunflower varieties and hybrids are published annually in University of Minnesota Agricultural Experiment Station Miscellaneous Report 24, *Varietal Trials of Farm Crops.*

Table 2. Characteristics of sunflower varieties at Rosemount and Crookston, 1962-72*

Characteristic	Mingren	Arrow-head	Peredovik
Test weight, pounds per bushel	24	30	29
Large seed, percent	44	1	0
Weight per 100 seeds, grams	11	8	6
Oil, percent	28	31	44
Date 50 percent ray flowers, July	27	23	30
Height, inches	65	64	71

* Populations averaged 23,000 plants per acre.
Fieldwork at Crookston was supervised by Northwest Experiment Station agronomists—O. C. Soine in 1962; F. K. Johnson 1963-66; J. R. Lofgren 1967-70; L. J. Smith 1971-72.

SEED PRODUCTION AND HYBRID SUNFLOWERS

Sunflowers are cross-pollinated by insects. Cross-pollination by wind and self-pollination are relatively unimportant; however, some highly self-compatible hybrids are now available. Because bees carry pollen long distances, seed fields must be isolated. Fields for production of certified seed must be at least 80 rods from other sunflowers; foundation and registered classes require at least 160 rods' isolation. Even these distances are inadequate if apiaries are in the area and especially if apiaries lie between fields. Volunteer and wild sunflowers must not be allowed to bloom within the required isolation distance from the seed field.

Although isolation is needed for pure seed production, fields used for production of oilseed, birdfeed, or human food may be allowed to interpollinate. Canadian work indicates that the oil content of sunflower seed is affected by the plant on which it is produced and not by the pollinator plant.

One contractor reported that production cost of pure seed of nonhybrid varieties in 50-pound bags amounted to 22 cents per pound plus certification fees and inventory, carryover, and selling costs. Contractors have supplied certified seed to their growers at prices ranging from 30 to 60 cents per pound and sometimes furnish planter plates with the seed. Cost of hybrid seed production is not yet known, but it will be greater than that of nonhybrid varieties.

Each of the more than one thousand flowers on a large sunflower head has male and female organs. No inexpensive mechanical or chemical way has been found to remove or sterilize the male organs and thus permit use of the line as a female in hybrid seed production. However, hybrids can be produced by plant breeding.

Although sunflower hybrids have been available for 25 years, the method of seed production often failed to produce a high percentage of hybrids from large crossing fields. The release of genetic male sterile lines in 1968 made consistent hybrid seed production in large fields agronomically feasible, but the large amount of hand labor for roguing seed fields made costs too high. In countries with low labor costs, genetic male sterile lines have been used to grow seed for sale in the U.S.

Some supposedly hybrid seed may contain much nonhybrid seed. Seed labeling regulations of the United States Department of Agriculture (USDA) require that seed labeled hybrid must be at least 75 percent hybrid. Furthermore if the seedlot is less than 95 percent hybrid, the tag must give the exact percent hybrid or a range between 75 and 95 percent hybrid seeds. Unless the word "hybrid" appears on the tag, there is no assurance of receiving hybrid seed. Seedsmen can determine the percentage of hybrids during the winter by trial plantings in greenhouses or in Florida, Hawaii, or the Southern Hemisphere.

The discovery of cytoplasmic male sterile lines and fertility (pollen) restoring lines is expected to make hybrid seed production practical in the United States. The available sterile lines were developed from cytoplasmic male sterile material obtained from France in 1968. Cytoplasmic male sterile (cms) lines are called A lines and do not produce pollen. Each A line has an identical B line that does produce pollen. Thus, seed of an A line can be produced by growing it in rows in an isolated field with rows of its B line nearby to supply pollen (figure 2).

The A line will produce hybrid seed when pollinated by any other variety, but the plants grown from this hybrid seed will not produce pollen. Therefore, it was necessary to find a male parent whose hybrids with an A line would produce pollen. The first two pollen-restorer lines called R lines, RHA 265 and RHA 266, were released by the Texas Agricultural Experiment Station and United States Department of Agriculture in 1971.

Hybrid sunflower seed production is now being accomplished by alternating four to six rows of cms A line with two to four rows of R line. Only seed harvested from the A line is used for hybrid seed (figure 2). The

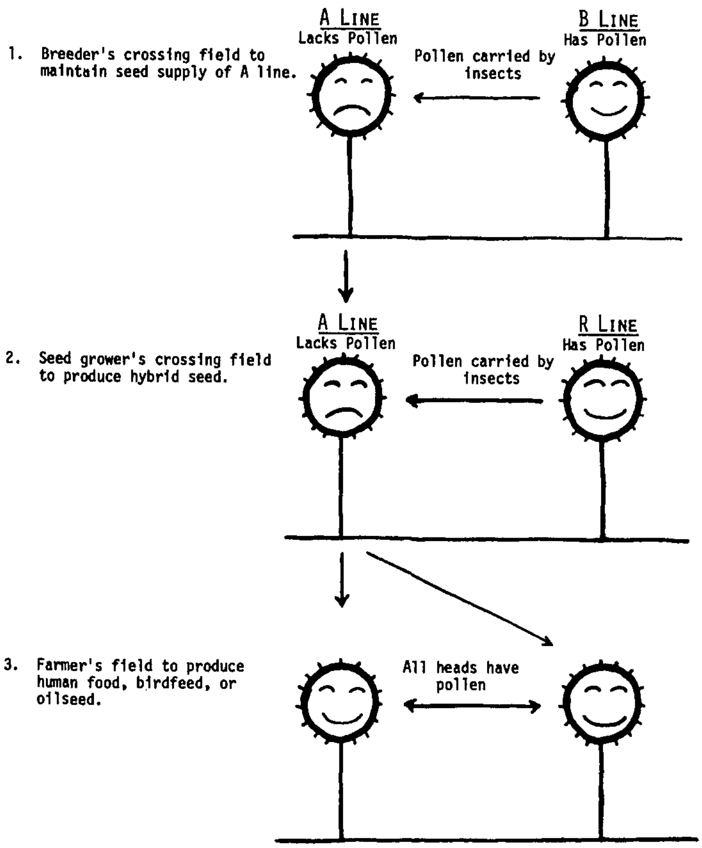

Figure 2. Cytoplasmic male sterile-restorer method of hybrid sunflower seed production.

R line rows are harvested to maintain seed supplies of the R line. In the future, hybrid seed production may be accomplished with R line rows much farther apart. From hives in a dozen R line rows at each side of the field and in the middle, bees might transfer enough R line pollen to pollinate an A line planted in the rest of a small field. However, this future procedure will require plentiful pollen production by the R line and sufficient nectar production by the A line to attract bees.

CROP SEQUENCE AND ROTATION

Three major considerations in determining crop sequence are control of volunteer sunflowers, control of diseases, and effect of sunflowers on the following crop.

Volunteer Sunflowers

Before and during sunflower harvest, many seeds fall to the ground. A small loss of 40 pounds per acre equals five to twelve times a normal rate of seeding. Enough of this seed survives the winter to create a weed problem unless the following crop can be sprayed. Trials at Rosemount showed that the following herbicides used *post-emergence* as recommended in various crops kill volunteer sunflowers: 2,4-D (at least 0.2 pound per acre), MCPA, 2,4-DB, MCPB, bromoxynil (Brominal, Buctril), dicamba (Banvel), bentazon (Basagran), chloroxuron (Tenoran, Norex), cyanazine (Bladex), or atrazine + oil (Aatrex + oil). Leaving a stand of volunteer sunflowers to produce a crop is not recommended, and in one instance, the practice resulted in severe rust losses to the crop in the next field, as well as total loss of the volunteer crop.

Seed dormancy is very short in cool temperatures and does not exceed 10 weeks at warm temperatures so sunflowers will not become a weed except through neglect. Nevertheless small amounts of seed, perhaps buried too deeply or trapped in dry clods the first year, germinate the second year after sunflowers. These stragglers should be pulled in crops that cannot be sprayed. Crop rotation cannot be highly effective in disease control unless all volunteer sunflowers are killed at an early stage of growth.

Disease Control

Crop rotation is the main method of reducing serious disease losses in susceptible varieties of sunflowers. Trials at Rosemount showed that after several years of continuous sunflowers, the *Verticillium* disease organism virtually destroyed the crop. Sunflowers in adjacent plots rotated with soybeans were not as seriously affected.

Small grains and corn are the best crops to separate sunflower crops in a rotation because these grain crops do not support disease-causing pathogens of sunflower. Most common nongrass crops and many weeds are troubled with the same diseases as sunflowers. For example the following two fungi cause important diseases of sunflowers and other plants:

Sclerotinia sclerotiorum attacks sunflowers, peas, field beans, soybeans, flax, rape, mustard, sugarbeets, potatoes, alfalfa, sweetclover, wild mustard, thistles, lambsquarters, and black nightshade. *Verticillium albo-atrum* attacks sunflowers, safflower, rape, sugarbeets, potatoes, alfalfa, red clover, and lambsquarters. However, these fungi include many races. The races that injure sunflowers may not injure all the other crops and vice versa. More research is needed to determine which crops are tolerant of the strains attacking sunflowers. Soybeans, flax, and sugarbeets have been grown in rotations with sunflowers without noticeable increase in diseases. Pathologists indicate that the same races of *Verticillium* attack both sunflowers and potatoes, and the same races of *Sclerotinia* attack sunflowers, mustard, rape, and field beans. Therefore, 3 or 4 years of crops resistant to these races should separate sunflowers, potatoes, field beans, mustard, or rape in a crop sequence.

Three or 4 years between sunflower crops are commonly suggested in the United States, but the practice followed on large state farms in Russia is about 8 years. A minimum time between sunflower crops should allow all sunflower stalk, root, and head residues to decompose. On well-drained soil, this takes 1 or 2 years, except in rare instances. This minimum time is enough to help control rust and other organisms that require sunflower residues for survival. Crop rotations of practical length can only be expected to reduce the amount of inoculum carryover, not eliminate it. If a disease becomes serious on a field, a longer time must elapse between sunflower or other susceptible crops. For example, the organism causing downy mildew has been reported to survive in soil for as long as 10 years. Experience on particular fields and availability of disease-tolerant sunflower varieties should be considered annually in adjusting crop rotations.

Effect on the Following Crop

Effect of sunflowers on the crop following them is an important consideration. Sunflowers are harvested later in the season than small grains, consequently less time is left for fall plowing. The stalks are easily broken up and incorporated into the soil. They usually amount to less than 2 tons of dry matter per acre compared with 4 tons of corn. Several years of research at Rosemount and Crookston and Portage la Prairie in Manitoba show that crops yield as much after sunflowers as after any of the common, nonleguminous field crops.

Research on chemical composition of sunflowers shows that even high yielding sunflowers cause less depletion of chemical elements than corn (tables 3, 4).

Table 3. Comparative chemical composition of mature sunflowers and corn at Rosemount, 1970-71

Chemical element	Sunflower seed	Corn grain	Sunflower stover	Corn stover + cobs
	percent			
Nitrogen	2.58	1.70	1.03	.68
Phosphorus	.39(.89*)	.37(.85*)	.08(.18*)	.06(.14*)
Potassium	.59(.71†)	.36(.43†)	1.51(1.81†)	.68(.82†)
Sulfur	.17	.13	.20	.10
Calcium	.11	<.01	1.10	.32
Magnesium	.23	.14	.58	.24
Sodium	<.02	<.02	.10	<.02
	parts per million			
Boron	14	1	34	5
Molybdenum	6	4	15	8
Zinc	48	26	34	36
Copper	13	1	4	3
Iron	33	26	152	143
Manganese	14	8	27	44
Strontium	3	<0.5	59	17
Aluminum	3	<1.5	189	131

* Figures in parentheses are for P_2O_5.
† Figures in parentheses are for K_2O.

Table 4. Comparative chemical content per acre of high yielding sunflowers and corn at Rosemount, 1970-71

Chemical element	Sunflower seed	Corn grain	Sunflower stover	Corn stover + cobs
	.... pounds per acre			
Nitrogen	83	115	51	59
Phosphorus	12(27*)	25(57*)	4(9*)	5(11*)
Potassium	19(23†)	24(29†)	74(89†)	58(70†)
Sulfur	5	9	10	9
Calcium	3	1	57	28
Magnesium	7	10	30	21
Sodium	<1	<1	5	1

None of the other elements listed in table 3 amounted to more than 1.5 pounds per acre

* Figures in parentheses are for P_2O_5.
† Figures in parentheses are for K_2O.

Both crops were given as nearly identical and optimum conditions as possible. Plant populations were 20,000 per acre. Soil was a fertile silt loam. Sunflower seed and stover yields were 3,243 and 5,080 pounds per acre, respectively. Corn grain and stover (+cob) yields were 6,775 and 8,773 pounds per acre, respectively.

Although the *concentration* of most chemical elements (table 3) is greater in sunflowers than in corn, the higher yield of corn offsets this, resulting in the lower *content per acre* for some of the elements (table 4). The stover is left in the field so the only elements removed from the soil are those contained in the sunflower seed.

Table 3 can also be used to calculate contents per acre for any desired yield level. Table 5 shows the chemical content per acre of a sunflower crop yielding 2,000 pounds of seed per acre. Sunflowers obtain oxygen, hydrogen, and carbon from air and water, but the other elements come from the soil.

Table 5. Chemical content per acre of sunflowers containing 10 percent moisture and yielding 2,000 pounds of seed, 3,200 pounds of stover, and 800 pounds of roots

Composition	Seed	Stover	Root
	..... pounds per acre		
Water	200	320	80
Oxygen	918	1,460	375
Hydrogen	114	181	46
Carbon	689	1,096	282
Nitrogen	48	31	3
Phosphorus	7(16*)	2(5*)	0.4(1*)
Potassium	11(13†)	45(54†)	4(5†)
Sulfur	3	6	0.4
Calcium	2	33	3
Magnesium	4	17	1
Boron, molybdenum, zinc, copper, sodium, iron, manganese	0.2	4	3
Nonessential minerals	4±	5±	2±

* P_2O_5.
† K_2O.

SEED PREPARATION FOR PLANTING

Seed passing once through a fanning mill often retains ergot-like, seed-sized bodies of *Sclerotinia* disease organism and parts of sunflower heads, stems, and leaf petioles. Such material carries disease organisms and should be removed by recleaning with a fanning mill or other seed cleaning machinery.

Ungraded seed varies greatly in size. Not only do large heads produce larger seed than small heads, but seed on individual heads varies from large on the outside to small in the middle. Therefore, seeds should be graded because most planters plant seed more evenly if it is uniform in size and shape. Several grades differing in size are obtained from a single seedlot, but crops grown from these grades do not differ in yield.

Fungicide seed treatment may help control some seedborne disease organisms and has increased stands obtained from a very few seedlots that became moldy in germination tests. Sunflower seed is tolerant of most treatment materials, but overdoses can cause injury. Injury symptoms are a short, thickened hypocotyl (figure 3) which may not elongate sufficiently for emergence. Most seed is not treated.

Captan (Orthocide) fungicide at 0.5 ounce and lindane insecticide at 1 to 2 ounces per 100 pounds of seed are approved by the United States Environmental Protection Agency. Lindane is for wireworm control.

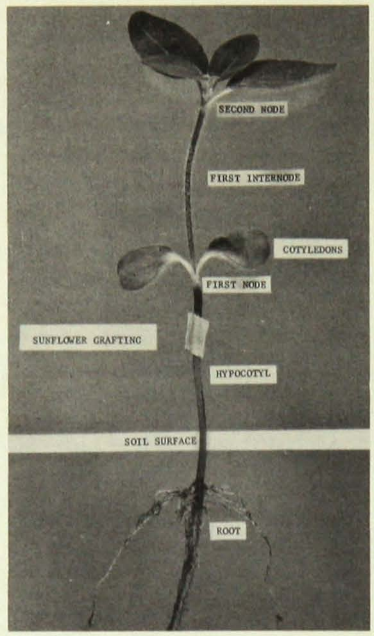

Figure 3. Parts of a sunflower seedling. Grafting studies have shown that the stem end controls plant characteristics. Roots of various varieties can be interchanged without affecting seed size, oil percentage, maturity, or number of leaves.

PLANTING TIME AND TEMPERATURE

A wide range of planting dates can be used for sunflowers, but highest yields were obtained from early May plantings in trials at Rosemount (table 6), Waseca, and Grand Rapids. June is too late for highest yields.

Temperature requirements for sunflower germination and growth lie between those of small grains and corn. Base temperatures used in growing degree-day or heat unit research for small grains, sunflowers, and corn are 40°, 45°, and 50°F., respectively. The minimum temperature reported for sunflower germination was 41°F. When volunteer sunflowers are evident in last year's fields, it is obvious that there have been sufficient growing degree-days to accomplish emergence.

Table 6. Average performance of three oilseed and three nonoilseed sunflower varieties at seven dates of planting, Rosemount, 1967-69

Date	Yield per acre	Test weight per bushel	Oil	Large seed	Weight of 100 seeds	Emergence after planting
	.... pounds		.. percent ..		grams	percent
April 24	1,524	28.5	35	45	7.3	83
May 3	1,757	28.0	35	47	7.0	88
May 12	1,652	27.5	35	50	6.9	89
May 21	1,520	27.2	34	50	6.9	89
May 31	1,340	26.9	32	49	6.8	85
June 17	1,045	27.1	32	37	6.3	81
June 28	832	24.7	30	40	5.7	83
LSD 5%*	125	.7	1	5	.3	3

* Least significant difference at the 5% level is a statistical measure of variability based on odds of 19 to 1 that data differing by the amount of the LSD were truly different.

PLANTING DEPTH

Sunflowers often take longer to emerge than grain crops because of the slow penetration of soil moisture through their thick hulls. The seedlings will emerge from depths of 3 inches or more, although table 7 shows a much greater percentage of emergence from the 1 inch depth. Days from planting to emergence were fewer with shallow planting.

Despite the advantages of the 1 inch depth, planting often must be deeper because of dry surface soil. Shallow planting on sandy soil may result in the soil drying before the seed absorbs water, thus delaying germination until rain.

Table 7. Effect of depth of planting in silt loam soil on sunflower emergence and time of flowering, Rosemount, 1965-66

Depth planted	Emergence of planted seed	Days from planting to: emergence	Days from planting to: first bloom
inches	percent		
1	97	15	69
3	68	19	73
5	42	23	76
7	5	—	—

ROW WIDTH AND PLANT POPULATION

Row Width

Sunflowers usually are planted with corn planters in rows 30 to 38 inches apart, with beet planters in rows 22 to 24 inches apart, or with grain drills with certain grain box holes covered to give rows of suitable width for cultivation. The holes of many drills can be covered with small cloth bags filled with soil.

Sunflowers in rows 20 to 30 inches apart outyielded those planted in rows 36 to 40 inches apart by about 10 percent in trials at Crookston and Rosemount.

Large acreages in Canada are planted with a grain drill in rows 12 inches or less apart. Experimental sowings with a grain drill in noncultivated 6- and 12-inch rows for 3 years at Crookston, Rosemount, and in southwestern Minnesota and for 1 year in Anoka County usually resulted in weedy stands and low yields. In other experiments at Rosemount where herbicides were used and gave weed control, yields were high but sunflowers lodged severely when sown in 6- or 12-inch rows.

Plant Population

Since 1948, over 25 trials in Minnesota involving sunflower populations varying from 8,000 to over 100,000 plants per acre have shown that sunflowers yield well through a wide range of populations. Sunflowers adjust to thin populations by increasing head and seed size and to excessive population by decreasing head and seed size. Some varieties react to thin populations by undesirable branching. Under extremely dry conditions, the crop will reduce its population at heading time by stalk breakage 6 to 24 inches above the ground.

Despite these plant adjustments, adequate population is necessary to achieve maximum yield (table 8). The following number of plants per acre are a guide, and individual experience may indicate desirable changes:

sandy soils 15,000 to 20,000

silt loams with sandy subsoil 20,000 to 25,000

silt loams and clays in western Minnesota 15,000 to 30,000

silt loams and clays in eastern Minnesota 20,000 to 35,000

Table 8. Effect of plant population on sunflower yield and oil percentage at Waseca in 1971-72 and Morris in 1972

Sunflower plants per acre	Waseca	Morris
	... yield per acre, pounds ...	
15,000	2,752	1,806
20,000	3,189	1,909
25,000	3,366	2,046
30,000	3,638	1,770
35,000	4,223	1,757
LSD 5%	326	689
	.... oil in seed, percent	
15,000	38	40
20,000	38	42
25,000	39	43
30,000	39	43
35,000	41	42
LSD 5%	2	2

Fieldwork at Waseca was supervised by agronomist W. E. Lueschen and at Morris by agronomist D. D. Warnes.

Number of seeds planted should exceed the desired population by 10 percent on sand and 20 percent on fine textured soils based on seed of 100 percent germination (table 9).

Table 9. Guide to planting rate per acre based on seed weight and desired plant population

Weight per 100 seeds, grams	15.1	11.3	9.1	7.6	6.5	5.7	5.0	4.5	4.1
Number of seeds per pound	3,000	4,000	5,000	6,000	7,000	8,000	9,000	10,000	11,000
Population desired	Seed required per acre, pound*								
15,000	5.0	3.8	3.0	2.5	2.1	1.9	1.7	1.5	1.4
20,000	6.7	5.0	4.0	3.3	2.9	2.5	2.2	2.0	1.8
25,000	8.3	6.3	5.0	4.2	3.6	3.1	2.8	2.5	2.3
30,000	10.0	7.5	6.0	5.0	4.3	3.8	3.3	3.0	2.7
35,000	11.7	8.8	7.0	5.8	5.0	4.4	3.9	3.5	3.2

* Increase by 10 percent on sandy soils to 20 percent on other soils. Increase for less than 100 percent germination by: $\frac{\text{pounds per acre times 100}}{\text{percent germination}}$

Uneven stands are a major cause of yield reduction, and plant spacing in the best sunflower fields is usually less uniform than in most corn fields. Table 10 shows that a very small change in plant spacing at the higher populations or missing plants at any planted population will greatly change the final plant population.

Another problem is weak and diseased plants that don't utilize the space available. Nonhybrid varieties have a number of inbred or low yielding plants that provide competition to neighboring plants but contribute little to seed yield. It is expected that hybrids will reduce the weak plant problem.

Table 10. Plant spacings for various populations in rows 22, 30, and 38 inches apart

	Row width		
Plants per acre	22 inches	30 inches	38 inches
	..... plant spacing, inches		
15,000	19.0	13.9	11.0
20,000	14.3	10.5	8.3
25,000	11.4	8.4	6.6
30,000	9.5	7.0	5.5
35,000	8.1	6.0	4.7

Figure 4. Sunflowers planted with a grain drill in rows 6 inches apart.

Although varieties may differ in optimum population, these differences are not associated with oilseed and nonoilseed types. Nevertheless it may pay to plant nonoil human food varieties at a lower rate to qualify for a higher price per pound paid for large seed. A 5,000-plant reduction in population may not appreciably affect yield but will significantly increase seed size.

For oilseed production, the objective is to get maximum yield with no regard for seed size. Medium to high populations produce seed of higher oil percentage and bushel weight than low populations. High populations offer the advantage of small heads that remain more upright and dry faster than large heads. Although low populations have larger heads, they usually lodge less than high populations.

Arrangement of the population is achieved by choice of row width or by use of two- or three-plant hills instead of single plant spacing. Single plant spacing outyielded two-plant hills at both 13,000 and 26,000 plants per acre in 2 years' trials with two varieties at Rosemount.

CULTIVATION AND WEED CONTROL

Row cultivation is the major method of weed control. Cultivation should be done carefully, as sunflowers are easily damaged or broken. Hilling at the last cultivation covers small weeds in the row and reduces sunflower lodging. Sunflowers have a tap-root system (figure 5). On some soils, high winds partially uproot heavy-headed sunflowers when the soil is wet, and the stalks remain leaning or flat until harvest (figure 6). Hilling reduces this type of lodging (figures 7, 8). Heads were harvested by hand in the trials reported in table 11; the relative yield advantage from hilling would probably be greater with combine-harvest because of fewer lodged plants.

Table 11. Effect of type of cultivation on sunflower lodging and yield at Rosemount, 1969-71

Type of cultivation	Lodging	Yield per acre
	percent	pounds
None	29	1,420
Scraping less than 1 inch deep	25	1,574
Disk or shovel — not hilled	26	1,538
Disk or shovel — hilled	16	1,683
LSD 5%	5	157

Figure 5. Taproot of sunflowers has most branches near the soil surface.

Despite a good job of cultivation, weeds remaining in the row cause significant yield reduction (table 12). An average loss of 325 pounds per acre (20 percent) occurred in the 11 experiment station trials. Three methods of killing these weeds are flaming, pre- and postemergence harrowing, and herbicides. Tests for 3 years at Crookston indicated that effective weed control by flaming resulted in lower sunflower yields. Flaming is expensive and does not save cultivation expense because the area between the rows is cultivated at the time of flaming and the number of cultivations is often increased. Furthermore, weeds compete with sunflowers before flaming can be done.

Figure 6. Root lodging can be reduced by hilling-up. A more common type of lodging is stem breakage.

Figures 7-8. Sunflowers at the left were hilled at the last cultivation, those at the right were not.

Weeds frequently emerge before sunflowers and these can be killed by harrowing about 1 week after planting but before sunflowers germinate. After the sunflower seedlings have two or more leaves, such implements as the weeder, rotary hoe, spike tooth harrow, or coil spring harrow may be used to kill weeds.

Sunflower seedlings are strongly rooted, so small emerging weeds in the "white" stage can be uprooted and killed without injury to the larger sunflowers. Tractor speed and setting of the harrow or weighting of the rotary hoe to do the most damage to the weeds and the least to sunflowers can be accomplished on a "try and adjust" basis. Harrowing direction may be cross, diagonal, or with the rows. It may pay to harrow the field several different times if weed emergence warrants it.

Herbicides are available for preplanting, preemergence, and postemergence applications. Trifluralin (Treflan) at 0.5 to 1 pound per acre or EPTC (Eptam) at 3 pounds preplanting incorporated controls foxtails, barnyardgrass, redroot pigweed, and common lambquarters but does not control wild mustard, smartweed, velvetleaf, or cocklebur. EPTC sometimes controls wild oats and common ragweed. Incorporation should be accomplished within minutes after spraying to avoid loss of the herbicide, although incorporation of trifluralin can be delayed for a few hours if necessary. EPTC should be applied at planting time, but trifluralin can be applied either at planting time or up to several weeks before planting. One disking is enough to prevent herbicide loss, but a cross disking is needed before planting to give better distribution of the herbicide. The 0.5 pound per acre rate of trifluralin is for sandy soil, 1 pound is needed for silt loam and clay soils.

Chloramben (Amiben) at 3 pounds per acre preemergence is not quite as consistent in control of grass weeds but is usually better than the preplanting herbicides for control of nongrass weeds such as wild mustard, smartweed, and common ragweed. A preplanting application of trifluralin or EPTC followed by a preemergence application of chloramben often gives better

Table 12. Sunflower yields in pounds per acre obtained by cultivation alone and by cultivation plus hand pulling all weeds

Location and year		Cultivated	Cultivated and weedfree
Rosemount	1966	2,040	2,343
Rosemount	1967	1,291	1,681
Rosemount	1969	1,211	1,617
Rosemount	1969	749	1,304
Rosemount	1970	1,738	1,780
Rosemount	1971	1,772	1,639
Elk River	1967	589	735
Gonvick	1967	1,184	1,615
Crookston	1967	1,669	2,163
Crookston	1968	1,655	1,761
Crookston	1971	729	1,571
Average		1,330	1,655

Fieldwork at Crookston was supervised by agronomist O. C. Soine.

weed control than a single herbicide. The cost of chloramben treatment can be reduced by treating only the area over the row that can't be cultivated.

Barban (Carbyne) at 0.37 pound per acre kills wild oats in the 2-leaf stage but should not be applied later than 14 days after sunflower emergence.

There is no economical control for thistles and other perennial weeds in sunflowers.

Herbicide recommendations are revised each year and published in University of Minnesota Extension Folder 212, *Cultural and Chemical Weed Control in Field Crops.*

Broomrape, a parasitic weed with roots that attach to sunflower roots, is a major pest in Russia, but it has not been found on sunflowers in Minnesota. Resistant varieties have kept this weed under control in Russia, although new races have made resistance to the weed a continuing plant breeding problem.

FERTILIZER AND IRRIGATION

Sunflower yields are highest on fertile soils so fertilizer applications in the crop rotation that increase soil fertility are beneficial. About 100 pounds of nitrogen, 25 pounds of phosphate (P_2O_5), and 75 pounds of potash (K_2O) are required to produce a sunflower crop yielding 2,000 pounds of seed per acre and then recycle the crop residues into the soil organic matter. The nutrients in the seed are not returned to the field and must be replaced with fertilizer to keep soil fertility at a given level. Tables 3, 4, and 5 can be used to estimate chemical element removal by a sunflower crop.

Nitrogen is the only element that has usually increased yield in experiment station field trials. However, few trials were conducted on soils low in phosphorus or potassium. Trials in Manitoba and North Dakota on soils testing low in phosphorus showed significant increases from phosphate fertilizer. The relatively high potassium content of sunflowers (tables 3, 4) suggests that response to potash fertilizer would occur on soils testing low in this element.

Phosphate and Potash Rates

Phosphate (P_2O_5) rates of 40 or 20 pounds per acre, respectively, are suggested where soils test low (less than 10 pounds of available P per acre) or medium (11 to 20 pounds of available P per acre). Potash (K_2O) rates of 60 or 40 pounds per acre, respectively, are suggested where soils test low (less than 100 pounds of available K per acre) or medium (101 to 200 pounds of available K per acre). Yield increases from potassium may not occur when soils test in the upper medium range.

Nitrogen Rates

Nitrogen (N) recommendations range from 0 to 90 pounds per acre depending on previous crop, soil organic matter level, nitrate tests, and moisture supply.

Comparative response of sunflowers and corn to nitrogen is of interest because the large amount of research on corn fertilization might be applied to sunflowers. The trials reported in table 13 were conducted on fertile silt loam soils that tested high for both phosphorus and potassium. Ammonium nitrate at 200 pounds per acre was applied in three ways: (1) broadcast before disking and dragging for seedbed preparation, (2) applied 2 inches deep in a band midway between the rows when the crops were about 10 inches tall, and (3) broadcast in April and sidedressed in June. Neither corn nor sunflowers responded to the nitrogen treatments with significantly higher yields.

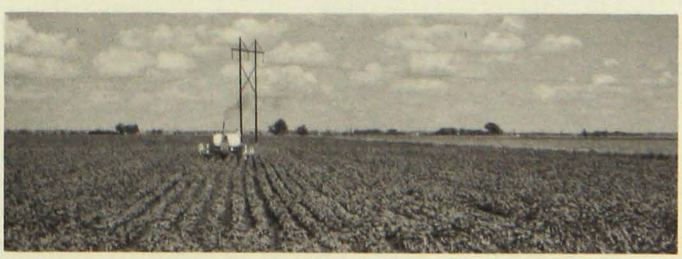

Figure 9. Sunflowers being sidedressed with anhydrous ammonia in the Red River Valley.

Table 13. Effect of nitrogen fertilizer on yields of sunflowers and corn on fertile silt loam soil at Rosemount, 1969-71

Treatment and date	Yields per acre, pounds	
	Sunflowers	Corn
None	2,052	5,680
Nitrogen broadcast preplanting in April	2,235	5,549
Nitrogen sidedressed postemergence in June	2,156	5,973
Nitrogen broadcast in April and sidedressed in June	2,106	6,013
LSD 5%	393	393

Yield differences due to treatment not statistically significant by F test.

On the other hand, large response to nitrogen occurred on sandy soils testing high in phosphorus and potassium (table 14). Without irrigation, nitrogen increased yields of sunflowers but failed to increase corn yields. During dry periods in June, sunflower leaves remained turgid in contrast to rolling of corn leaves, suggesting that sunflowers in the preheading stage are more drought tolerant than corn. In July at heading stage, sunflower leaves readily wilted in dry periods. The combination of irrigation and nitrogen greatly increased yields of both crops.

Table 14. Effect of nitrogen and irrigation on yields of sunflowers and corn on loamy coarse sand at Elk River, 1969-70

Treatment	Yields per acre, pounds	
	Sunflowers	Corn
None	506	1,578
Nitrogen	872*	1,253
Irrigation†	683	1,960
Nitrogen and irrigation	2,397*	6,126*

* Yields significantly lower or higher than untreated.
† 1969. Adjusted to be comparable with 1969-70 data.

The results of these trials indicate that sunflowers are responsive to nitrogen fertilizer on soils where the

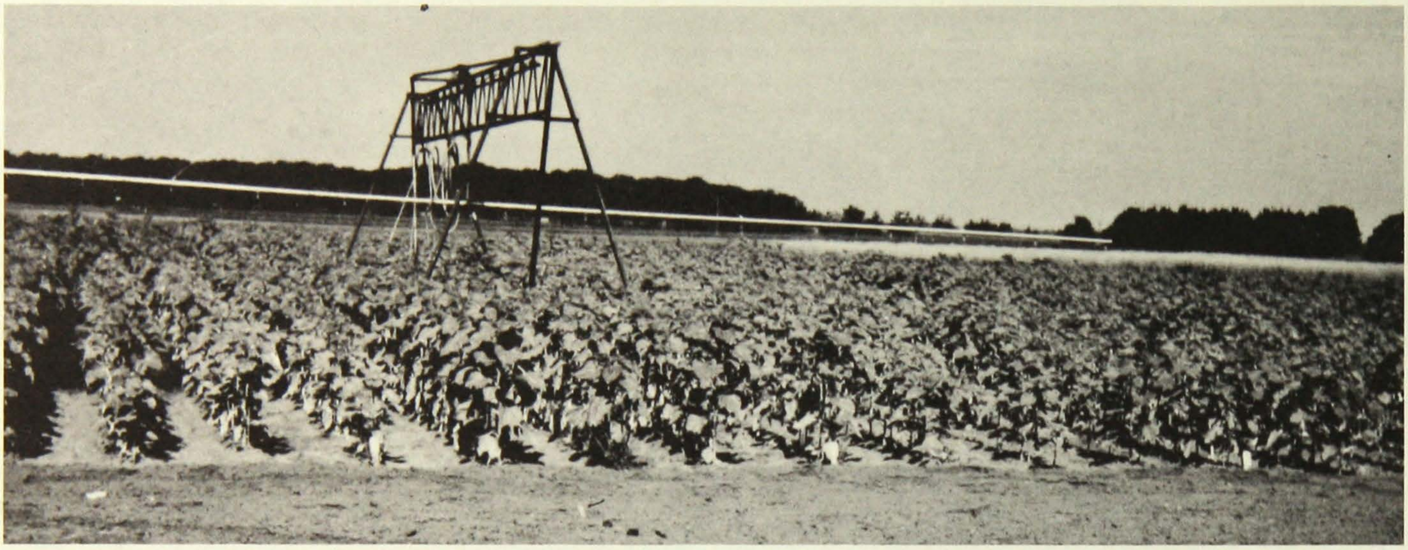

Figure 10. Portable plot irrigator developed by agricultural engineers sprinkles 20- x 50-foot sunflower plots. Boom is raised when sunflowers grow taller.

element is not available in adequate amounts. Sunflowers also respond to irrigation and may be a useful rotational crop for some irrigated farms.

In trials where fertilizer increased yields, it also increased head and seed size and usually caused earlier maturity. Nitrogen decreased oil percentage in the seed from unirrigated plots at Elk River, but nitrogen plus irrigation did not decrease oil percentage.

There is little danger of crop injury from broadcast applications of fertilizer, but band applications of medium to high amounts should not contact the seed.

Although research in Hungary indicated that foliar fertilization at flowering time greatly increased sunflower yield, this was not confirmed by Rosemount results. Applications were made at various stages of growth. Water-soluble 15-30-15 fertilizer including trace elements was used. A 6 percent solution (40 pounds in 80 gallons of water per acre) caused some leaf burn in 1969. A 3 percent solution (10 pounds in 40 gallons of water) did not cause any injury in 1970-72. In these trials on fertile silt loam soils, significant yield increases did not result from foliar applications at heading or flowering stages.

HARVESTING AND STORAGE

Sunflower headers for combines are made in factories and by local machine shops. The conventional combine reel is replaced with either a three-arm reel of 1 x 12 inch boards with or without a curved sheet metal shield in front (figure 11) or by a small diameter rotating drum or metal reel (figure 12). Some headers are used without a replacement for the reel (figure 13).

Metal pans 2.5 inches (1.5 to 3 inches) apart and 4.5 to 8 feet long extend in front of the cutterbar. Sunflower stems pass between the pans and are pushed toward the sickle by the reel or rotating drum. The heads are cut off and pass through the combine. Short pegs or strap iron on the reel or drum rotate over the spaces between pans and aid in dislodging clogged stalks and heads.

Pan widths vary from 9 to 39 inches depending on row widths (figure 12). Custom operators who harvest various row widths commonly use pans 9 inches wide (figure 11). Some farmers using 9-inch pans reported that in certain situations harvesting in a direction diagonal to the rows gave less loss than the usual practice of following the rows.

Usually there are only a few good combining days in October when the seed is dry enough for storage. Test runs should be made and moisture content of the seed determined before combining a field. Concave clearance should be open wide with cylinder speed about 300 r.p.m. for dry sunflowers. Indications of good adjustment are removal of seed without breaking heads, no dehulled seeds, and low dockage.

Sunflowers are mature long before they are dry enough for combining. The crop is mature when the backs of the heads turn yellow, but the fleshy heads take a long time to dry. Applications of several preharvest desiccants at Crookston did not speed up seed drying. These chemicals have not been approved for use on sunflowers.

Cutting and windrow-drying was tried experimentally at Rosemount. Five varieties were windrowed at maturity and 10 days later were combined from the windrow and from standing plots. Windrowed plots averaged 1,384 pounds per acre compared with 1,368 pounds per acre for standing plots. Seed averaged 15 percent moisture from windrowed plots and 18 percent moisture from standing plots. The greater speed of drying from windrowing is not enough to offset the windrower and combine pickup modifications needed for practical operation.

Many high moisture sunflowers were harvested in late August and early September 1972 in the Corn Belt. Green petiole (leaf stalk) stubs caused stalks to plug the 2.5 inch space between the pans. Pieces of green leaves moved with the seed, making it stick in the hopper and inner surfaces of the combine. Some Illinois growers reported that spraying the inside surfaces of the combine with silicone permitted combining seed up to 27 percent moisture, but tests to confirm this have not been made.

Early harvesting reduces shattering loss, but artificial seed drying is then necessary. Seed should be below 12 percent moisture for temporary storage and below 9.5 percent for longtime storage. Seed moisture of up to 15 percent is satisfactory for temporary storage in freezing weather, but spoilage is likely to start after a few days of warm weather.

Spoilage results from invasion by fungi, and their respiration causes heating. Research in the University of Minnesota Department of Plant Pathology showed the following moisture percentages of sunflowers and grains that are equal in resistance to invasion by storage fungi: oilseed sunflower 10% = nonoilseed sunflower 10.6% = corn or wheat 15%; oilseed sunflower 12.8% = nonoilseed sunflower 13.3% = corn or wheat 18.5%.

Experience with crops of higher bushel weight such as corn may result in overdrying sunflower seed because equal *volumes* of sunflowers and corn at the same moisture *percentage* differ greatly in moisture *content*. One bushel of corn at 20 percent moisture contains about 11 pounds of water while 1 bushel of sunflowers at 20 percent moisture contains only about 4.5 to 6.5 pounds of water. In addition to the moisture in the seeds, the excess moisture in the air between seeds must also be removed when drying.

An oily fuzz rubs off sunflower hulls as the seed is moved. This fuzz floats in the air and ignites if contacted by flame. Overdried, hot sunflower seed may ignite if exposed to burning fuzz, so drying facilities should be planned and operated with concern for fire prevention. Long air tunnels or other devices at the air inlet to insure that trash-free air enters the drier and removal of trash that may collect in the plenum chamber will help prevent fires.

Canadian research indicates that the merchant and saw-toothed grain beetles and the red and confused flour beetles attack sunflower seed in storage. But the rusty grain beetle, a serious insect of stored grains, could not live on sunflowers. None of these insects will thrive unless there are dehulled, broken, or crushed seeds in the bin.

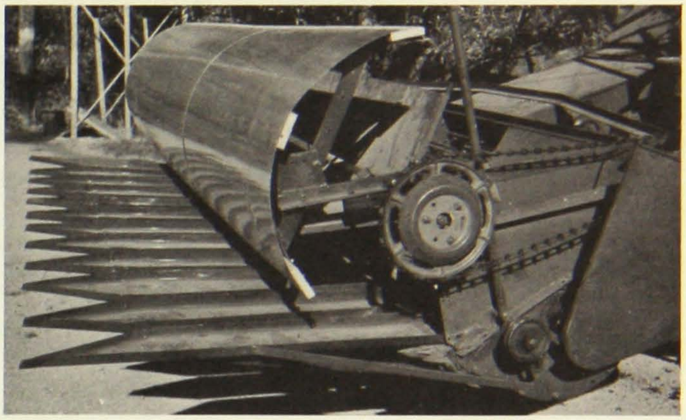

Figure 11. The curved sheet metal shield pushes the plants forward. The stems pass between the metal pans that are bolted to the cutterbar, and the heads are cut off by the sickle.

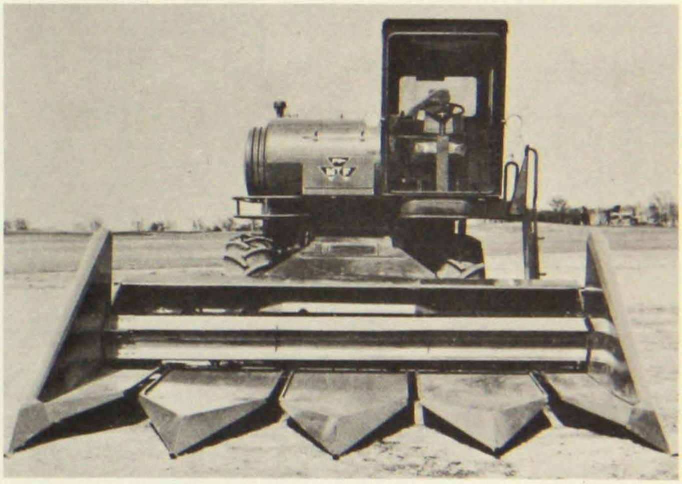

Figure 12. Sunflower header with a small diameter reel above the pans to pull the heads into the combine auger.

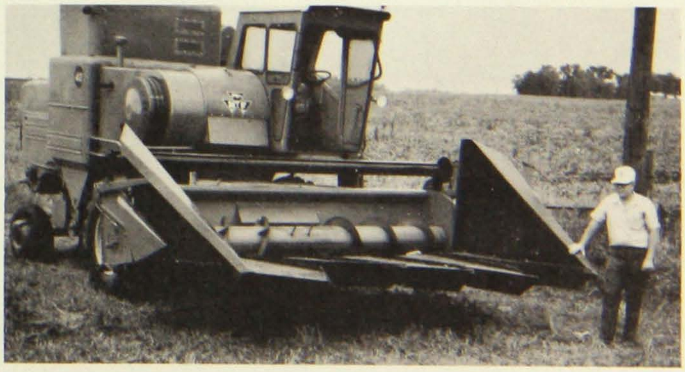

Figure 13. Sunflower headers are sometimes used without a special reel in front of the auger.

Figure 14. A combine with a corn head attachment can be used if acreage is too small to warrant purchase of a sunflower header. Shattering seed will be lost because there are no pans to catch it.

DISEASES

The most serious diseases are caused by fungi and include *Verticillium* wilt (leaf mottle), downy mildew, rust, and *Sclerotinia* stem and head rots. Varieties or hybrids tolerant of the first three diseases are listed in Minnesota Agricultural Experiment Station Miscellaneous Report 24, *Varietal Trials of Farm Crops.*

Crop rotation, tolerant varieties, early control of volunteer and wild sunflowers, and use of clean seed help reduce losses. Plowing or incorporation of sunflower crop residues into the soil in the fall or early spring helps reduce the spread of inoculum to other fields.

Sunflower diseases, causes, and symptoms are shown in table 15.

Table 15. Sunflower diseases, causes, and symptoms

Disease and causal organism	Symptoms and special characteristics
Leaf mottle (Verticillium albo-atrum)	Symptoms often appear before heading. Dead areas along the leaf veins. Dead areas bordered by light yellow-green margins (figure 15). Some severely infected plants may die before flowering. Occasionally leaf symptoms don't appear, but cross section of stem may reveal decayed vascular bundles.
Downy mildew (Plasmopara halstedii)	**Systemic infection.** Dwarfed plants sometimes only 1 foot high (figure 16). Leaves often show contrasting discoloration of yellow green and green. Cottony fungus sometimes on underside of leaves in early morning or after rain. Some plants grow to full height but have erect "bird platform" heads and much sterile seed (no meats). Disease most severe where much rain occurs immediately before or after emergence. **Local infection.** Soil-borne or seed-borne spores of the fungus cause blackening and sometimes swelling at the base of the stem. These plants are more likely to lodge and suffer from drought than healthy plants. Wind-borne spores from systemically infected plants may infect young leaves of healthy plants and under some conditions systemic symptoms may develop.
Powdery mildew (Erisiphe cichoracearum)	Cottony fungus on green leaves late in the summer. Has not caused perceptible loss.
Rust (Puccinia helianthi)	Rust colored pustules on the leaves, later as black specks on the stems (figure 17).
Stem and head rots (Sclerotinia sclerotiorum)	Wilts soon after flowering (figure 18). If no wilting, symptom is a light tan band around the stem normally at soil level (figure 19). Gray-black bodies called sclerotia variable in size but often as large as sunflower seed in rotted heads or stems. Black seed from infected heads lacks shine of healthy seed, and striped seed looks like stripes were partly scraped off. Meats discolored.

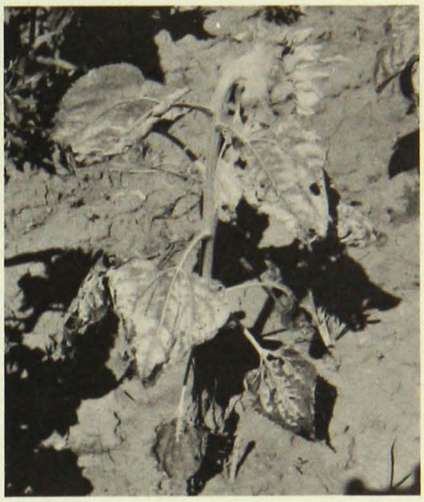

Figure 15. Leaf mottle — the leaf at the lower right shows mottling.

Figure 16. Downy mildew — dwarfing and a bird platform head are evident. Stem at the left is on a normal-size plant.

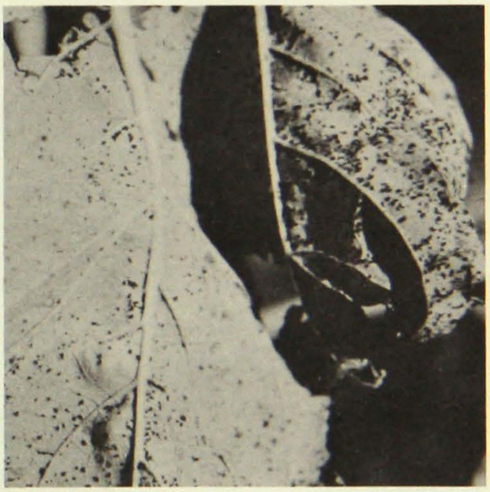

Figure 17. Rust on sunflower leaf.

Figure 18. Stem rot caused wilting of the plant on the man's right.

Figure 19. Stem rot — dead bands at the base of the upright and lodged stalks.

Head rot (Rhizopus arrhizus)	Soft rot starting with brown areas on back of head. Research in Israel indicates wounding of head necessary for infection, and birds may spread this fungus and also **Sclerotinia** when they grasp heads with their talons.
Head rot (Botrytis cinerea)	Affects heads near maturation time. Seed symptoms similar to those caused by **Sclerotinia.**
Bacterial head rots (bacteria)	Occur where water collects on backs of bent-over heads.
Leaf spot (Septoria helianthi)	Dead blotches appear on lower leaves before heading and may spread to upper leaves under favorable conditions for the fungus. Larger than rust pustules. Has not caused appreciable loss.
Premature ripening (Unknown)	Stems break at nodes about 3 weeks before maturity. Worse in fields ready for harvest before frost.
Charcoal rot (Macrophomina phaseoli)	Prematurely ripe plants. Pepper-like specks in stem pith. Most severe under dry, hot conditions.
Black stem (Unknown)	Large chocolate colored blotches on stems of plants approaching maturity. Some caused by **Phoma** sp. but major causal agent unknown.
Aster yellows (mycoplasma spread by leafhoppers)	Small leaves replace normal floral parts in the head (figure 20). Ray flowers sometimes green instead of yellow. Sometimes no head symptoms but black, slimy rot on the stalk below the head.

Figure 20. Aster yellows — small leaves growing in the head face.

Figure 21. The strap-leaf condition of the upper plant resembles 2,4-D injury, but its cause is unknown.

INSECTS

Sunflowers attract bees and other insects that feed on the heads, leaves, and stalks.

Bees and Pollination

Bees are beneficial because they carry pollen from plant to plant. Most sunflower varieties will not produce high yields unless insects are present to transfer pollen. All sunflowers produce some sterile seed (no meats), but large amounts suggest a lack of pollinating insects if the plants were healthy and growing conditions were good. To have enough pollen-carrying insects, some growers keep hives of bees in sunflower fields at pollination time. In addition to the honey obtained, the beekeeper is usually paid for each hive placed in the field.

Harmful Insects

Sunflowers are attacked by many common leaf and stem feeding insects that attack other crops. These include grasshoppers, cutworms, wireworms, sugarbeet webworms, and woolybear and painted lady (thistle)

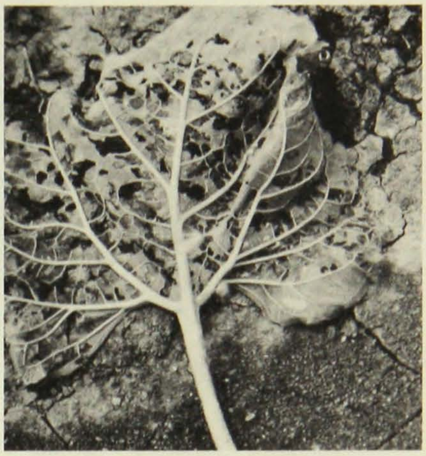

Figure 22. Salt marsh caterpillars have eaten much of the foliage around the veins of the leaf.

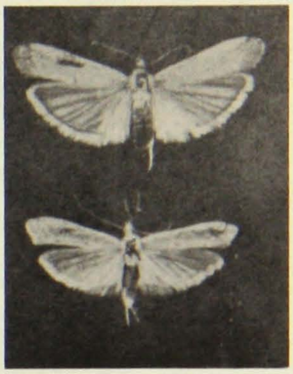

Figure 24. Sunflower head moth adults. The female (top) has a wingspread of 1 inch. The male (bottom) is smaller.

caterpillars (figure 22). The ragweed plant bug has seriously damaged sunflowers in the two- to eight-leaf stage. The leaf scratches are insignificant, but the ragweed plant bugs carry a toxin which retards and distorts sunflower growth. Springtails are pinhead-size, round, gray, fast hopping insects which leave chewing marks on sunflower cotyledons shortly after emergence. Aphids are often numerous on sunflower leaves after flowering, but ladybird beetles or other natural controls usually destroy them.

Headfeeding insects common to other crops include northern, western, and southern corn rootworm beetles, which become numerous on the faces of sunflower heads and eat pollen but usually cause little injury. Grasshoppers and blister beetles often feed on the yellow ray flowers of the head. Lygus and alfalfa plant bugs are sucking insects commonly found feeding in sunflower heads. Fireflys are also frequently found on the heads. The picnic beetle, which is about 0.4 inch long with yellow spots on its back, feeds on heads after they have been damaged by head moth larvae.

Insects specific to sunflowers that feed on the heads include the larvae of three moths: (1) *Sunflower head moth (Homoeosoma electellum)* for many years made commercial sunflower production impractical in many states south of Minnesota. The insect is most commonly found in west central and southern Minnesota but only infrequently caused severe losses (figures 23 and 24).

Figure 23. Sunflower head moth larva enlarged six times. The dark bands running the length of the body distinguish it from larvae of the banded sunflower moth.

The moth lays eggs in the head at flowering time. The eggs hatch larvae in about 1 week. The larvae feed on floral parts and tunnel through the seeds. Most Minnesota fields have not needed spraying, but it is difficult to determine whether spraying is needed before damage occurs. Growers should examine the first heads in their fields for matted, cobwebby faces and for larvae on the faces and in the heads. When attacked early, the heads curl up like a closed fist. Approved insecticides that might reduce losses from heavy infestations are available.

Some varieties or plants within varieties have a black "armor" layer in the hulls, which is found by chemical treatment or less certainly by scraping off the surface cells with a knife. This layer has not prevented larval feeding in the United States, but California research indicates it may reduce damage and could lead to development of resistant varieties.

(2) *Banded sunflower moth (Phalonia hospes)* is found in northern but not in central or southern Minnesota. It has brown areas in the middle of its wings, which have a spread of 0.5 inch. Eggs laid on the heads hatch in about 1 week. The larvae are not dark striped and are smaller than sunflower head moth larvae. A larva makes a small hole at the top of a seed, eats the meat before moving to another seed, and tends to feed on the small seeds in the center of the head. It is much less damaging than the sunflower head moth. Approved insecticides are available.

(3) *Olethreutid moth (Suleima sp.)* is dark gray and about 0.5 inch long. It lays eggs on sunflower plants in early June. The 0.5 to 1 inch larvae feed in the young stem and often eat or partially eat the head before it emerges. The damage is seen at heading time as headless plants or damaged heads (figure 25). Large holes in the stem often near a leaf petiole and surrounded by black frass are a notable symptom (figure 26).

Sunflower midge (Contarinia schulzi) adult is a 0.1 inch gnat and the larva is 0.1 inch long and cream colored. The adults lay eggs in the head when the heads are about 1 inch in diameter. Brown spots at the base of individual florets in a head may indicate presence of larvae. Damage may appear as absence of ray flowers, cone shaped heads, cupping of heads, rotten centers with

Figure 25. Olethreutid moth larvae caused the head damage at the 5 and 10 o'clock positions.

Figure 26. Olethreutid moth larva caused the hole in the stem. Much black frass is present until rain washes it away.

Figure 27. Sunflower weevil was responsible for the dangling head.

a rim of seeds around the outside of the heads. Insecticide spray when the heads were 2 inches in diameter reduced damage in one trial at Hendrum but recommendations have not been made.

Sunflower weevil (Rhynchites aeneus) has a curved snout and is black and about ¼ inch long. It causes head drop by feeding just below the head (figure 27).

Sunflower beetle (Zygospila exclamationis) adult is about ¼ inch long with yellow stripes running lengthwise on each of its wing covers. The humpbacked yellow larva eats large holes in the leaves in May, June, and July. Sunflowers can stand much defoliation, so spraying is rarely needed.

Sunflower maggot (Strauzia longipennis) adult is a yellow fly with dark markings on its wings. It is slightly smaller than a housefly. The eggs, which are laid in the stem, hatch into maggots in about 1 week. Tunnels made by maggots are visible if the stalk is split.

Insect Control

Some destructive insects overwinter in sunflower crop residues and near the soil surface. Deep plowing in the fall or early spring reduces emergence of some of these insects.

The only insecticides approved for use on a sunflower crop are endosulfan (Thiodan) and methyl parathion. The maximum limit is three applications of not more than 1 pound each. Application of methyl parathion should not be within 30 days of harvest. If insecticides are needed, application method and timing should avoid killing bees that are needed for pollination. The list of approved insecticides is revised each year and published in Minnesota Agricultural Extension Bulletin 263, *Insecticides and Their Uses in Minnesota.*

BIRDS

Birds are a major pest of sunflowers. The crop suffers relatively more birdfeeding loss than other field crops.

Blackbirds, goldfinches, doves, grosbeaks, sparrows, and other birds eat tremendous amounts of seed on some fields. Other fields may not be bothered. Goldfinches start feeding about 1 week after sunflowers bloom and show a preference for small, thin-hulled seed. Birds that feed in the fall when feed is less plentiful readily eat all types.

Experience at experiment stations indicates that the birdfeeding problem may increase after sunflowers have been grown for a few years. The birds become more numerous and are harder to frighten.

Scaring devices should be put in operation at or before the first sign of damage. Once a flock becomes used to feeding in a field, most scaring devices are not effective. Scarecrows, fright owls, and aluminum strips that glisten in the sun and rustle in the wind help in small plots. Slow burning fuse ropes strung with firecrackers are illegal.

Carbide exploders make a loud noise at regular intervals. The noise is created by the ignition of acetylene gas from a welder's tank or from the reaction between water and calcium carbide. Results with the exploder (figure 28) were unsatisfactory due to high costs and the inability to keep the machine operating. Other models are reported to be satisfactory. Permission from the Minnesota Department of Natural Resources and County Boards of Supervisors is required to operate these devices.

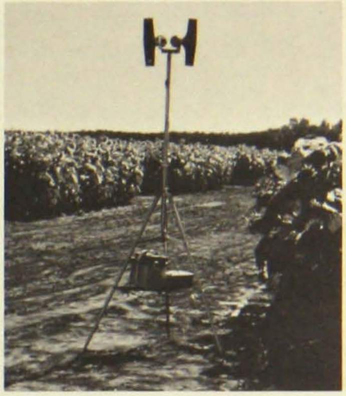

Figure 29. A two-speaker bird frightening device.

Figure 28. A welder's tank supplies acetylene gas for this bird frightener. The gas is ignited by a glow plug powered by a storage battery. The explosions, which come at 45-second or longer intervals, are several times louder than a shotgun.

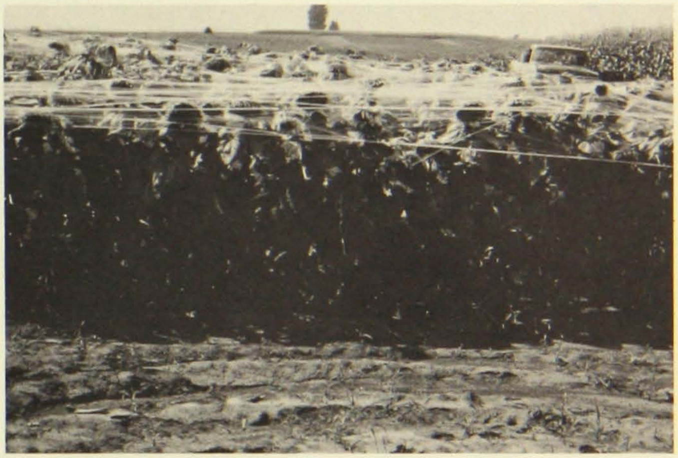

Figure 30. Lightweight webbing to prevent birdfeeding.

A new approach to bird control is the use of certain noises which interfere with the bird's hearing and interpretation of sounds. It is claimed that this method will give about 90 percent control because birds will not remain where the environment confuses them. The equipment (figure 29) is powered by a 12 volt storage battery and required much less maintenance than other noise-making devices needed for protection of large acreages. But it did not control birds the first year of trial at Rosemount. More knowledge as to noise timing, frequency, and volume may produce better future results.

Other than bagging individual heads, a webbing of acrylic fibers manufactured in Switzerland has been the most successful method of preventing birdfeeding on small plots (figure 30).

Chemicals are another method of bird control, but *none is approved for use on sunflowers in Minnesota.*

SUNFLOWER USES

Whole Seed For Food

The seed can be dehulled with fingernails or teeth and eaten raw. Nutritional toxins found in many other raw, unprocessed seeds have not been found in sunflower seeds. If a toasted flavor is desired, the whole seed is heated for 15 minutes in a 300°F. oven or heated and stirred in a frying pan. If salting is desired, the whole seed is soaked overnight in a salt brine (2 tablespoons salt to 1 cup of water), boiled for a few minutes and then dried with heat. The overnight soaking may be omitted if the seed is boiled in brine for at least 20 minutes. The salted whole seed can also be fried in edible oil for a different flavored product.

Dehulled Seed For Food

Dehulling is done commercially in oat, cottonseed, or sunflower dehullers. The seed enters the top of the machine, drops onto a revolving plate, and is flung against the machine's outer wall. The impact dehulls the seed, and the mixed hulls and meats are separated on grain cleaning machinery. The clean, dehulled seed is scanned by electric eye machines that remove discolored kernels.

Noncommercial dehulling of dry seed can be done using high cylinder speeds in a thresher. An effective method with several quarts or more of nonoilseed varieties, like Mingren, is to pour the seed through a small hammer mill with the screen removed, but this method did not work as well with the oilseed variety, Peredovik. A method for very small samples is to use a blast of compressed air to violently churn the seeds for several minutes in a closed container fitted with a wire-mesh, air outlet. Hulls and meats can be separated by screening them in the wind or floating off the hulls in water.

Commercially dehulled seeds are either roasted in sunflower or other vegetable oil or dry roasted and salted. Dehulled seeds are used for nutmeats and in candy, salads, cereals, and bakery goods. Ground dehulled seeds are used in home and commercial food products.

Seed For Birdfeed and Other Recreation Feeding

This use provides pleasure and recreation for thousands of people. Cardinals, grosbeaks, wild canaries, chickadees, nuthatches, and bluejays are among the birds attracted by sunflower seed. Wild bird feeding is the major use, but caged birds consume a considerable amount. Hamsters, squirrels, and other pets also consume large amounts of sunflower seed.

Oil and By-products

About 40 pounds of oil are obtained from 100 pounds of mature, dry (10 percent moisture) oilseed sunflower. By-products vary depending on whether the seed was dehulled before oil extraction. If dehulled, about 41 pounds of meal (39 percent protein, 12 percent fiber) and about 15 pounds of hulls are obtained. If not dehulled, about 55 pounds of high fiber (23 percent) meal of slightly under 30 percent protein is obtained.

Oil is extracted by crushing and pressing the seed or dehulled meats until about two-thirds of the oil is removed. Most of the remaining oil is then removed with hexane or some other solvent. The solvent is removed with steam and used again.

Oil For Food

Sunflower oil is pale yellow, but it usually is refined to the color of water. It is of good nutritional quality for cooking and salad oil uses. The oil is unusually good for frying food, for popping corn, and for other culinary processes where a liquid oil with a high smoke point is desired.

Some medical research indicates that vegetable oils of high linoleic acid content help decrease blood cholesterol, which in turn reduces the incidence of certain heart and circulatory problems. Sunflower oil from the northern states and Canada is unusually high in this desirable component (table 16).

High linoleic acid content is associated with cool temperatures during seed development. Analyses of seed produced in Minnesota compared with seed from Texas, Arizona, Nebraska, Kansas, and California revealed that oil from Minnesota seed had a much higher linoleic acid content than seedoil from the other states. Therefore, Minnesota sunflowers are more likely to compete with safflower for the premium market requiring high linoleic acid oil than are sunflowers from the central and southern United States. However, it may be possible to plant sunflowers in the southern states in July. If so, the seed from July plantings would ripen in the cool fall months and might be of high linoleic acid content.

The absence of linolenic acid in sunflower oil is desirable since this acid, a constituent of certain other vegetable oils, liberates decomposition products with undesirable tastes and odors when the oil is stored (table 16).

Sunflower oil has become the world's second most important vegetable oil because it has an unusual combination of high nutritional and keeping qualities and low production cost.

Oil For Industrial and Agricultural Products

The relatively low iodine number of sunflower oil indicates that it is of undesirable quality for a drying oil (table 16). Nevertheless, sunflower oil can be combined with driers and used in paints and varnishes. The absence of linolenic acid in sunflower oil results in paints that remain white after drying, in contrast to some other oil-base paints which yellow after they dry. Sunflower oil may be used in the manufacture of caulking compounds, putty, and plastics.

A potential use for sunflower oil is to replace petroleum oil in pesticide (herbicide, insecticide, fungicide) sprays (table 17). Sunflower oil is effective, safe, and is a renewable product from crop production rather than an irreplaceable fossil fuel like petroleum oil.

Meal and Flour

The meal remaining after oil extraction is most commonly used as a protein supplement for livestock feeds. Livestock feed grades made from dehulled meats have 38 to 46 percent protein and 8 to 12 percent fiber. The fiber comes from hulls that are not removed during processing and compares with a soybean meal fiber percentage of 3 to 7. The high fiber (23 percent), medium protein (30 percent) sunflower meal made from undehulled seed is a satisfactory protein supplement for cattle. Sunflower meal is low in lysine amino acid so care

Table 16. Approximate oil content of seed and iodine number and fatty acid composition of oils*

Crop	Seed oil	Iodine	Polyunsaturates Linoleic	Polyunsaturates Linolenic	Monounsaturates Oleic or erucic	Saturates
	percent	number	percent			
Sunflower†	40	130	68	0	20	12
Safflower	38	145	75	0	17	8
Corn	4	120	55	1	31	13
Soybean	20	135	50	7	28	15
Flax	40	180	16	50	23	11
Butter	—	—	4	1	31	64

* Figures are taken from commercial labels and published data. To simplify the table, a single figure has been quoted where actually a wide range occurs.

† Oilseed varieties grown in Minnesota, North Dakota, and Canada. With hulls removed, seed would be over 55 percent oil.

Table 17. Comparison of sunflower and petroleum oils as adjuvants to postemergence atrazine herbicide sprays on grain sorghum at Lamberton, 1968-71

Treatment and rate per acre	Weed control grass	Weed control nongrass	Grain sorghum yield per acre
	percent		pounds
Untreated	53	92	3,030
Atrazine, 2 pounds	77	100	3,959
Atrazine, 1.5 pounds + petroleum oil*, 1 quart	85	100	3,858
Atrazine, 1.5 pounds + sunflower oil*, 1 quart	90	100	4,110
LSD 5%	21	5	398

* 5% emulsifier added.

Fieldwork at Lamberton was supervised by Southwest Experiment Station superintendent, W. W. Nelson.

must be taken in formulating nonruminant rations to provide enough lysine. Sunflower meal is unusually high in thiamin and niacin. Nutritional toxins such as the goitrogenic substances found in protein meals from some other plant sources have not been found in sunflower meal.

The meal can be further refined into white flour of about 53 percent protein for human food.

Hulls

Disposal of sunflower hulls at a profit is a major problem. Analyses of the hulls vary depending on the type of sunflower and processing efficiency. Pelleted hulls of about 3 percent oil and 3 to 4 percent protein are used to replace part of the alfalfa hay purchased by large cattle feeders in the western states. The pelleted hulls can be used in sheep rations, according to research at Morris. Poultry litter is a major use of unpelleted hulls.

The hulls can be pressed into 7.5 pound logs for fuel. University of Minnesota Department of Forest Products research indicates that the hulls are a possible raw material for particle board in combination with aspen.

Stalks and Heads

These crop residues present no problem in preparing land for the next crop and there may be uses for these waste materials. Stalk yields are too low and nutrient concentrations too high for sunflower stalks to be an economic source of paper pulp. However, the possibility of disease and insect control benefits offsetting the loss to the soil of the stalk nutrients has not been investigated. The strength and light weight of chopped and ground stalks have aroused interest in their use as acoustical ceiling tile and as a core material for doors and partitions.

The receptacle of the sunflower head is extremely high in pectin that could be extracted easily. But pectin now is obtained from citrus fruit culls and processing wastes so there is no shortage.

When sunflowers are harvested in Russia, the threshed heads are caught in a combine attachment. These heads are ensiled or mixed with straw and ground and then used for cattle feed. Little is known in this country about the safety or value of this feed.

THE SUNFLOWER HEAD

A sunflower head contains hundreds of flowers (figures 31 through 34). The flowers around the rim are ray flowers; each has a long yellow petal. The other flowers on the head are called disk flowers and do not have long petals. One seed develops from each flower. Ripening proceeds from the rim of the head to the center. The head platform to which the seeds are attached is called the receptacle.

The sunflower head can be found at the tip of the stem in young plants (figure 35). The head and leaves face east in the morning and west in the evening. This movement is called phototropism. After the ray flowers are fully developed, phototropic movement ceases and most heads remain facing the east.

Figure 31. This head is still pollinating. The small sunken area in the middle has not yet started to pollinate.

Figure 32. This head has shed its ray flower petals, but the floral parts of the disk flowers will remain for a few days.

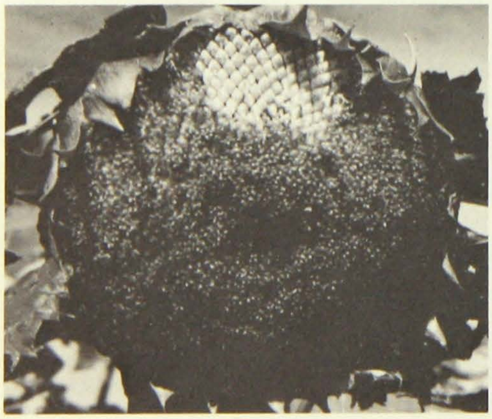

Figure 33. The upper part of this head shows disk flower parts removed and the seed exposed.

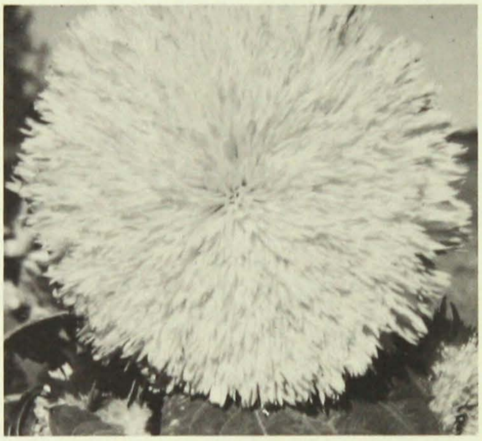

Figure 34. Some ornamental sunflower heads have all ray-type flowers.

Figure 35. A small head can be found at the tip of the stem in young plants at this stage of growth.