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THE SUNFLOWER CROP

IN MINNESOTA

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

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INTRODUCTION

For many years, sunflowers in Minnesota fields and gardens have turned their heads and greeted the rising 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 since then birds have consumed over 80 percent of the crop.

Commercial production for human food started in the sixties. Prior to then, most of the seed for roasting and salting was obtained from Manchurian and Greystripe varieties grown in California. 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. Agricultural experiment station tests showing that high-oil Russian varieties could be grown here led to renewed interest in oilseed production starting in 1966.

AGRONOMIC ADAPTATION

Sunflowers are adapted to most of the climates and cultivated soils of the United States and Canada. The Sunflower Belt of North America includes the Red River Valley and adjacent counties. Because of the risk of sunflower moth damage, sunflowers generally should not be grown commercially south of a line between Minneapolis and the southeast corner of North Dakota. And sunflowers should not be planted on fields that need spraying for perennial weed control, since 2,4-D and MCPA kill sunflowers.

Sunflowers are very drought resistant 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 were in a 10-percent ray flower stage August 1 and still were in that stage 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.

Young plants are resistant to freezing and have survived temperatures in the twenties. However, temperatures below 30° F. 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.

With fertilizer, good yields can be obtained on soils ranging in texture from sand to clay. Field observations indicate that sunflowers may be a useful crop for growing on some high lime soils where susceptible crops often show extreme chlorosis.

Sunflowers take longer to develop in the north than in the south. For example, eight varieties of varying maturities were planted May 14 at Rosemount (45° latitude); Fargo, North Dakota (47° latitude); Crookston (48° latitude); and Morden, Manitoba (49° latitude). Days from planting to bloom averaged 76, 80, 84, and 90, respectively. This study was conducted from Texas to Manitoba. On the average, sunflowers took 2 days longer to reach ray flower stage per 70 miles northward.

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 may have a quality advantage in markets requiring this type of oil.

ECONOMIC ADAPTATION

In recent years, yields on reasonably well cared for fields have varied from 500 to 2,000 pounds per acre, and the price received by farmers has varied from 3 to 7 cents per pound. The average price has been 4½ cents per pound and the average yield 900 pounds. 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. However, sunflowers have a lower seed cost per acre than the other crops in the table.

Considering land value as a production cost, sunflowers have done well on the light soil in and east of the Red River Valley. Tests of sunflowers on sandy soil north of Minneapolis indicate that the crop has potential in the area north of where soybeans are well adapted.

Table 1. Yields of sunflowers and other crops needed to give a gross income of $30-$60 per acre

Gross income per acre	Crop and price received by grower				
	Sunflowers, 4½¢/lb.	Soybeans, 4½¢/lb. ($2.70/bu.)	Flax, $2.90/bu.	Oats, 60¢/bu.	Barley, $1.00/bu.
dollars	pounds per acre	bushels per acre			
30	667	11.1	10.3	50.0	30.0
40	889	14.8	13.8	66.7	40.0
50	1,111	18.5	17.2	83.3	50.0
60	1,333	22.2	20.7	100.0	60.0

QUALITY FACTORS AND MARKET GRADES

No legal weight per bushel has been established for sunflower seed, so the crop is sold by pounds. Nevertheless, bushel weight is an important grading factor within a variety or type, as it indicates whether or not the seed is well filled. Because of differing seed size and hull thickness among human food, birdfeed, and oilseed types, bushel 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 bushel weight above or below 26.

Buyers of Mingren and other large seed varieties often pay a premium of about 1 cent per pound for seed held on a 20/64 round hole screen. Sometimes the higher price is paid for seed held on a 24/64 screen. These premium prices may give growers incentive to use wider plant spacings to increase seed size. Usually bushel weight is not considered when good seed of this type is bought on a size premium basis.

There are no U.S. grading standards for sunflower seed. The Minnesota Grain Inspection Department uses market grades based on bushel weight, moisture content, and percentage of damaged seed. A revision of these standards with differing requirements for edible, birdfeed, and oilseed varieties is being considered.

Most seed is sold to local markets and is not officially graded.

VARIETIES AND MARKETS

Varietal recommendations are revised each year, and the data are published in University of Minnesota Agricultural Experiment Station Miscellaneous Report 24, *Varietal Trials of Farm Crops*. Relative performance of important sunflower varieties is shown in table 2.

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. Mingren is the largest seeded variety, followed by Commander and Mennonite. Seed held on 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 (figure 1).

Birdfeed Market

Arrowhead and surplus human food varieties are used for birdfeed. The medium-size, striped seed and high bushel weight of Arrowhead are popular with buyers. Peredovik and other high oil varieties are small,

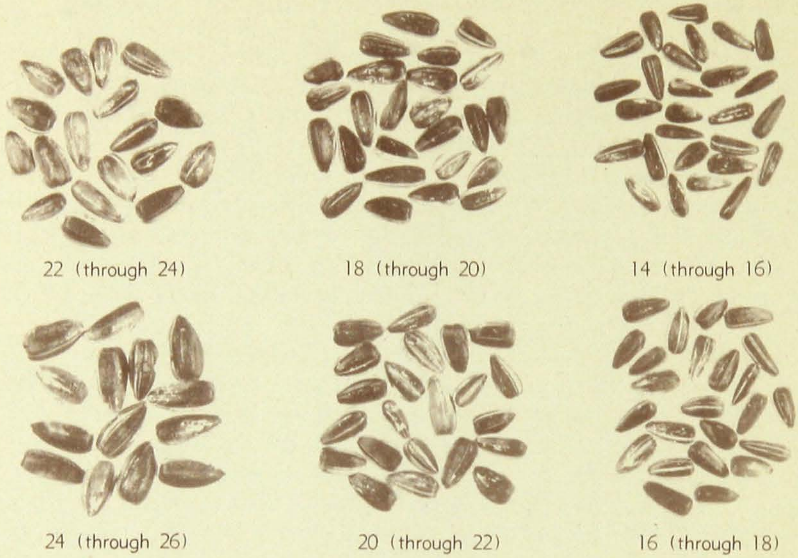


Figure 1. Screened seed sizes

black, and unattractive to some buyers. Low bushel weight varieties sometimes cause packaging difficulty because packages marked for a certain weight won't hold enough seed. Purple seed such as that found in imported mixed seed from Africa is undesirable because it stains feed trays.

Oilseed Market

Varieties of at least 40 percent oil are required (table 2).

SEED PRODUCTION AND HYBRID SUNFLOWERS

Important varieties now in production are open-pollinated. 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 not great enough 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 oilseed, birdfeed, or human food production 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.

Table 2. Average yields and other characteristics of sunflower varieties at Rosemount and Crookston, 1962-66

Variety	Years of trial*	Yield per acre (pounds)	Oil content (percent)†	Large seed (percent)‡	Weight per 100 seeds (grams)	Bushel weight (pounds)	Flowering date (July)	Plant height (inches)	Lodging§
Arrowhead	1962-66	1,653	30.2	1	8.0	29.8	22	63	3.0
Mingren	1962-66	1,639	28.3	36	11.0	24.6	26	63	3.5
Commander	1963-66	1,493	28.1	30	10.9	25.2	27	64	3.1
Peredovik	1962-66	1,355	43.8	0	6.3	28.6	29	69	3.9
Armavirec	1965-66	1,231	42.9	0	7.1	30.8	19	55	2.9
VNIIMK 89.31	1963-66	1,538	44.4	0	6.0	29.3	28	70	3.4
Smena	1964-66	1,428	46.4	0	6.2	29.7	28	64	3.5

* Data for varieties not grown in all years are adjusted to be comparable.

† Dry matter basis.

‡ Held on 20/64 round hole screen.

§ One erect, nine flat.

Each of the several hundred flowers on a sunflower head has male and female organs. No inexpensive 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. Hybrids are produced by using a line for female that produces little fertile, vigorous pollen and a line for male that is a good, vigorous pollen producer. This procedure has been only partially successful and often only half or less of the seed is hybrid. Since different seed lots of the same hybrid differ greatly in percentage of hybrids, the buyer should be informed of this percentage. Percentage of hybrids can be determined before planting time by testing seed lots in Florida or South America during the winter.

If cytoplasmic male sterile and restorer lines are developed by plant breeding, it may be possible to produce seed lots that are 100 percent hybrid at a low cost, as is now done with hybrid sorghum.

CROP ROTATION AND SEQUENCE

Perhaps the sunflower crop's reputation for severe soil depletion is based on its use as silage rather than as seed. A high yielding silage crop removes large quantities of mineral nutrients from the soil; potassium removal is particularly heavy. However, if only seed is removed from the field, mineral nutrient depletion is not high (table 3).

Soil test data from plots at Rosemount cropped continuously to sunflowers or soybeans indicate that the two crops do not differ appreciably in phosphorus and potassium removal (table 4). All of the potassium contents in the table are medium and the phosphorus contents over 20 are high. So, based on soil tests, there would be little difference in recom-

Table 3. Chemical composition of Mammoth Russian sunflowers*

Component	Seed	Stalk, leaves, and head	Total
		pounds per acre	
Dry matter	1,472.0	5,537.0	7,009.0
Nitrogen	37.3	37.4	74.7
Phosphorus	2.3	4.8	7.1
Potassium	12.5	80.3	92.8
Calcium	3.3	72.4	75.7
Magnesium	4.3	33.5	37.7
Sulfur	4.8	14.7	19.5
Iron	0.2	4.6	4.9
Sodium	0.6	4.4	5.0
Aluminum	0.4	7.2	7.6

* Data from Illinois Agricultural Experiment Station Bulletin 268. "The Sunflower as a Silage Crop." 1925.

mendations for phosphorus and potassium fertilization of crops following sunflowers or soybeans.

Continuous cropping and crop sequence trials from 1954 to 1959 at the Crookston Agricultural Experiment Station and from 1957 to 1962 at Rosemount do not indicate that crops following sunflowers yield poorly.

Cultivated Crops

The comparative effects of sunflowers, soybeans, and corn on the following crop are shown in table 5. At Crookston, crops following soybeans yielded more than crops following corn, and crops following corn yielded the same or slightly more than crops following sunflowers. Since

Table 4. Soil test data from Rosemount plots cropped continuously to sunflowers or soybeans, 1958-62

	1958		1962	
Nutrient	Sunflowers	Soybeans	Sunflowers	Soybeans
	...pounds per acre...			
Phosphorus	28	28	20	23
Potassium	160	170	100	120

Table 5. Effect of previous crop on yields of sunflowers, soybeans, and corn and on oil content of sunflowers and soybeans at Crookston, 1956-59, and at Rosemount, 1958-62

Crop sequence	Crookston	Rosemount
	.....yield, pounds per acre.....	
Sunflowers after sunflowers	964	788
Sunflowers after soybeans	1,158	1,002
Sunflowers after corn	979	....
Soybeans after sunflowers	1,163	1,726
Soybeans after soybeans	1,219	1,527
Soybeans after corn	1,197	....
Corn after sunflowers	2,867	....
Corn after soybeans	3,169	....
Corn after corn	3,043	....
	......oil content, percent......	
Sunflowers after sunflowers	32.1	28.0
Sunflowers after soybeans	35.0	29.9
Sunflowers after corn	32.0	...
Soybeans after sunflowers	...	17.4
Soybeans after soybeans	...	17.5

Figure 2. A comparison of sunflowers and soybeans at Rosemount.

no nitrogen fertilizer was used, the higher yields of crops after soybeans were perhaps due to residual nitrogen from the soybean crop. At Rosemount, a crop rotation of sunflowers-soybeans gave higher yields of sunflowers and soybeans than continuous sunflowers and soybeans (figure 2). Seed harvested from sunflowers after soybeans was consistently higher in oil than seed from sunflowers after sunflowers at both locations.

At Portage la Prairie, Manitoba, yields of crops following sunflowers, sugarbeets, corn, or soybeans gave no indication that sunflowers reduce the yield of the following year's crop.

Noncultivated Crops

Inclusion of a cultivated sunflower crop in small grain rotations is not harmful to crops following sunflowers. At Crookston, flax or oats following sunflowers yielded more than flax or oats after oats, flax, or oats-alfalfa green manure. In tests at Portage la Prairie, barley or wheat following sunflowers yielded more than barley or wheat after wheat, barley, or flax. However, sunflowers do remove soil moisture long after small grain crops are mature. So where late summer accumulation of soil moisture or early tillage for weed control is important, crops following sunflowers may yield less than crops following small grains.

Fallow

In parts of Canada, sunflowers are grown in widely spaced rows as a substitute for summer fallow. Row spacing varies from 8 to 16 feet, depending on the width of the machinery used for tilling fallow land. Average yields of 300 to 400 pounds per acre have been obtained in Alberta and Saskatchewan with no detrimental effect on the following wheat crop when the sunflowers were fertilized. And the soil moisture used by sunflowers was replenished to a depth of at least 3 feet by spring.

Planting rate should be four seeds per foot of row. In areas where a moldboard plow is not used and where trash is left on or near the surface, a hoe drill or lister planter will clear trash and shattered wheat seed from the row area and place the sunflower seed in moist soil. Normal fallow tillage will control weeds between rows. Wide-row sunflowers will control wind erosion and hold snow on fallow land.

Rotation For Pest Control

Rotations may reduce losses due to diseases, insects, and weeds. A 4-year or longer rotation is suggested.

Trials at Rosemount showed that after several years of continuous sunflowers the *Verticillium* disease organism virtually destroyed the crop. Because of *Verticillium*, potatoes and safflower probably should not be grown in rotation with sunflowers. Otherwise, sunflowers may be grown in rotation with any of the common field crops except possibly field beans if the *Sclerotinia* disease organism is a problem.

Wheat, oats, barley, flax, corn, millet, or fallow should follow sunflowers, since they can be safely sprayed with at least three-sixteenths pound of 2,4-D in amine formulation per acre to control volunteer sunflowers. Soybeans, field beans, field peas, mustard, rape, or crambe should not follow sunflowers because they also are susceptible to 2,4-D.

SEED TREATMENT

Seed treatment helps control some seedborne diseases and has increased stands obtained from a very few seed lots that appeared moldy in germination tests. Both organic mercurial and nonmercurial organic fungicides have been used at rates suggested for other crops with no injury to sunflowers. Recommended rates per bushel for other crops were used on sunflower "bushels" of 24 pounds. Even though sunflowers are quite resistant to most seed treatment chemicals, large overdoses of either mercurial or nonmercurial fungicides resulted in deformed seedlings that probably would not emerge.

Captan (Orthocide) at one-half ounce per 100 pounds of seed has been approved by the Pesticides Regulation Division, U. S. Department of Agriculture (USDA). Other fungicides do not yet have approval.

PLANTING TIME

Sunflowers grow well under a wide range of planting dates. A satisfactory time for most years is from May 1 to May 25 (table 6). June is too late for highest yields.

Table 6. Comparison of early and late planting dates for sunflowers at Rosemount, 1960-61

Dates	Yield per acre	
	1960	1961
	............pounds............	
May 3-4	1,610	2,332
May 29-June 1	1,194	1,987

Seasons and locations vary as to optimum planting date. A good guide is to observe a field where sunflowers were planted the previous year. When volunteer sunflowers are sprouting, it is time to plant.

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 data in table 7 show a much greater percentage of emergence from the 1 inch depth. As indicated in the table, 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.

RATES AND SPACINGS

Sunflowers usually are planted with corn planters in rows 36 to 40 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 most drills can be covered with small cloth bags filled with soil.

Trial data show a consistent advantage of 6-inch over wider plant spacings (table 8). Although row width is of less importance than plant spacing, rows narrower than 40 inches tend to give higher yields. In 1966 at Crookston, average yields from four varieties in 20-, 30-, and 40-inch row widths were 1,992; 1,987; and 1,865 pounds per acre, respectively. Two varieties gave highest yields in 20-inch rows, whereas the other two gave highest yields in 30-inch rows.

A comparison between single plant spacing and two-plant hills did not show any advantage for two-plant hills at either high or low plant population (table 9). However, two-plant hills may give more emergence through crusted soil than single plants.

For oilseed production, the objective is to get maximum yield with no regard for seed size. For human food and some birdfeed production,

Table 7. Effect of planting depth on emergence and maturity of Peredovik planted May 19, 1965, and Arrowhead and Mingren planted May 7, 1966, at Rosemount

Depth planted (inches)	Emergence of planted seed (percent)				Days from planting till emergence				Days from planting to first bloom		Days from planting to maturity	
	Arrow-head	Min-gren	Pere-dovik	Average	Arrow-head	Min-gren	Pere-dovik	Average	Arrow-head	Min-gren	Arrow-head	Min-gren
1	100	100	92	97	16	16	13	15	67	71	108	121
3	72	46	85	68	21	21	15	19	71	75	113	122
5	51	30	45	42	25	25	18	23	74	77	122	124
7	10	0	5	5	26	..	21	..	76	..	122	...

Table 8. Yields of seed from plants spaced 6, 12, and 18 inches apart in rows 40 inches apart at Rosemount, Morris, and Crookston

Plant spacing	Rosemount, 1955-56	Morris, 1948-50	Crookston, 1948-50
inches		....yield, pounds per acre....	
6	1,257	1,252	1,114
12	1,046	1,200	1,045
18	848	....	....

Table 9. Comparison of two-plant hills and single plant spacing with Arrowhead and Advance varieties in rows 40 inches apart at Rosemount, 1955-56

Plants per acre	Yield per acre: Two-plant hills	Yield per acre: Single plants	Weight/100 seeds: Two-plant hills	Weight/100 seeds: Single plants	Oil content: Two-plant hills	Oil content: Single plants	Bushel weight: Two-plant hills	Bushel weight: Single plants	Hull content: Two-plant hills	Hull content: Single plants
	......pounds.....		.......grams.....		......percent....		.......pounds......		.....percent.....	
13,068	950	1,047	7.6	7.6	27.6	27.4	25.3	25.2	41.5	41.8
26,136	1,233	1,257	6.6	6.4	29.6	29.4	25.3	25.5	40.3	40.1

Table 10. Effect of fertilizer, plant spacing, and row width on seed weight of Arrowhead and Advance varieties at Rosemount, 1955-56, and Arrowhead, Mingren, Peredovik, and Armavirec varieties at Crookston, 1966

			Crookston—four varieties				Crookston—Mingren			
	Rosemount—two varieties		Row spacing, inches				Row spacing, inches			
Plant spacing	No fertilizer	Fertilizer*	40	30	20	Average	40	30	20	Average
inches	................weight, grams per 100 seeds...............						......large seed, percent†.....			
6	6.2	6.5	7.9	7.4	6.3	7.2	39	32	18	30
12	7.2	7.9	8.6	7.9	6.9	7.8	58	29	28	38
18	8.2	8.6	8.7	8.3	7.5	8.2	61	48	25	45
Average for row widths at Crookston, 1966			8.4	7.8	6.9		53	36	24	

* 124, 72, and 36 pounds N, P_2O_5, and K_2O, respectively.

† Held on 20/64 round hole screen.

a premium for large seed encourages the use of minimum seed for a balance between good yield and large seed. Fertilizer, wide rows, and wide plant spacings encourage the development of large seeds (table 10). On the other hand, high populations offer the advantage of smaller heads that remain more upright and dry faster than large ones.

Tables 11 and 12 show the relationships between row width, plant spacing, plant population, and planting rate. The populations suggested in table 12 are a beginning guide; experience on specific soils may indicate desirable changes. The population suggested for Mingren is lower than for the others in order to give a desirable balance between seed size and yield. Fieldmen from contracting companies often recommend a population that may give the optimum combination of seed size and yield in a particular area.

In contrast to the precision stands obtained by corn growers, sunflower stands have been uneven. Improved planters and improved seed grading by some seedsmen are partially alleviating this problem. Unless uniform stands can be obtained, it is necessary to use excess seed.

Experimental sowings with a grain drill in noncultivated 6- and 12-inch rows usually resulted in weedy stands and low yields. These experiments were performed at Crookston, Rosemount, and in south-

Table 11. Plants per acre for plants spaced 6, 12, 18, and 24 inches apart in rows 22, 30, and 40 inches apart

	Row width		
Plant spacing	22 inches	30 inches	40 inches
inches		plants per acre	
6	47,520	34,848	26,136
12	23,760	17,424	13,068
18	15,840	11,616	8,712
24	11,880	8,712	6,534

Table 12. Guide to planting rate per acre based on seeds per pound and suggested populations

Variety	Weight per 100 seeds (grams)*	Number of seeds per pound*	Plant population	Seed per acre (pounds)	Recommended seed per acre (pounds)†
Peredovik	6.3	7,200	23,000	3.2	4.0
Arrowhead	8.0	5,670	26,000	4.6	5.8
Mingren	11.0	4,124	20,000	4.8	6.0

* Based on average seed weights. Pounds of seed per acre should be increased for heavy seed and decreased for light seed.

† Based on seed of over 90 percent germination on a good seedbed with allowance for 20 percent seed mortality.

western Minnesota for 3 years and in Anoka County for 1 year. Where herbicides were used and gave weed control, sunflowers lodged when sown in 6- or 12-inch rows at twice the population used in rows 40 inches apart. Present herbicides usually do not give all-season weed control without cultivation.

WEED CONTROL

Sunflowers are often a weedy crop. They compete well with weeds but do not develop ground cover quickly enough to prevent weeds from establishing. Since weeds frequently emerge before sunflowers, many weeds can be killed by spike tooth harrowing about 1 week after planting but before sunflowers germinate. After the sunflowers emerge, 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. 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. It may pay to harrow the field several different times if weed emergence warrants it.

Row crop cultivation to kill weeds between the rows is the major method of weed control. Cultivation should be done carefully, as sunflowers can be easily damaged or broken. Tests with flame cultivation for 3 years at Crookston indicated that effective weed control in the row 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 often is increased. Furthermore, weeds afford considerable competition to the crop before flaming can be done.

EPTC (Eptam 6-E) at 3 pounds per acre applied before planting and incorporated into the soil has given excellent control of many grass and broad-leaved annual weeds. However, disking or other incorporation must be accomplished within minutes after spraying to avoid loss of the herbicide. Spraying the plowed ground followed immediately by seedbed preparation of cross disking twice at right angles, spike tooth harrowing once, and planting has given good weed control and no sunflower injury. EPTC has not been effective on wild mustard or smartweed and only occasionally effective on wild oats.

EPTC often is applied broadcast from a boom mounted on the front of a disk. For band application, rotary tiller or disk attachments in front of the planter and behind the spray nozzle are used to incorporate EPTC 3 inches deep. Experimental preemergence application of EPTC followed by disking resulted in seed movement that later hindered cultivation.

Sunflowers are tolerant to certain other effective preplanting, preemergence, and postemergence herbicides that do not have label approval from the USDA Pesticides Regulation Division (figure 3). Herbicide recommendations are revised each year and published in University of

Figure 3. In this herbicide trial at Rosemount, the herbicide applied to the plot in the foreground left a few grass weeds, the one applied in the middle killed all weeds, and the check plot at the top remained a grassy sod.

Minnesota Agricultural 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.

FERTILIZERS

Sunflower yields are highest on fertile soils, so good fertilizer practices throughout the crop rotation are important. Trials at Crookston and Rosemount show that sunflowers may respond to commercial fertilizer in earlier flowering, earlier maturity, and increased yield and seed weight (table 13). These trials were on soils of medium to high phosphorus and medium to very high potassium content. Neither bushel weight nor oil content of the seed from these trials indicated any response to the fertilizer.

Growers should have their soil tested to learn the relative need for phosphorus and potassium. Sunflowers are more likely to respond to potassium than are small grains. Nitrogen at 25 pounds per acre has delayed emergence, so it should be placed away from seed to avoid injury.

In the Red River Valley, suggested rates per acre are 10 to 40 pounds nitrogen and 20 to 40 pounds phosphate (P_2O_5). East of the Valley,

Table 13. Effect of fertilizer on yield and seed weight

Plant nutrients			Yield per acre			Weight per 100 seeds	
			Crookston		Rosemount	Crookston	Rosemount
			1947-48	1966 (two trials)	1954-56	1966	1954-56
N	P_2O_5	K_2O	pounds			grams	
0	0	0	1,282	1,397	1,037	5.6	6.9
20	0	0	....	1,465	....	6.4	..
40	0	0	....	1,621	....	6.3	..
0	40	0	1,700	1,515	....	5.9	..
0	80	0	....	1,450	....	6.2	..
0	0	20	....	1,550	....	6.0	..
0	0	40	....	1,288	....	5.8	..
20	40	0	1,602	1,582	....	5.9	..
40	80	0	....	1,690	....	6.6	..
0	40	20	....	1,505	....	6.2	..
0	40	40	1,759	....	....	..	..
0	80	40	....	1,412	....	5.7	..
20	40	20	....	1,527	....	6.5	..
20	40	40	1,579	....	....	..	..
40	80	40	....	1,664	....	6.6	..
124	72	36	....	....	1,245	..	7.5

where soils are often higher in phosphorus and lower in potassium than Valley soils, rates per acre of 10 to 40 pounds nitrogen, 10 to 40 pounds phosphate, and 0 to 40 pounds potash (K_2O) are suggested. On soils of low fertility, greater than normal rates may be needed in the crop rotation to increase soil fertility to a satisfactory level.

HARVESTING AND STORAGE

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 drying. These chemicals have not been approved for use on sunflowers.

Early harvesting (before heads are completely dry) reduces shattering loss. However, artificial seed drying is then necessary. Seed of some varieties has a fuzzy covering that rubs off as the seed is moved. This oily dust is flammable, so fire prevention rules should be observed.

Moisture content of seed should be below 12 percent for temporary storage and below 9½ percent for longtime storage. Moisture contents of up to 15 percent are satisfactory for temporary storage in freezing weather, but spoilage is likely to start after a few days of warm weather.

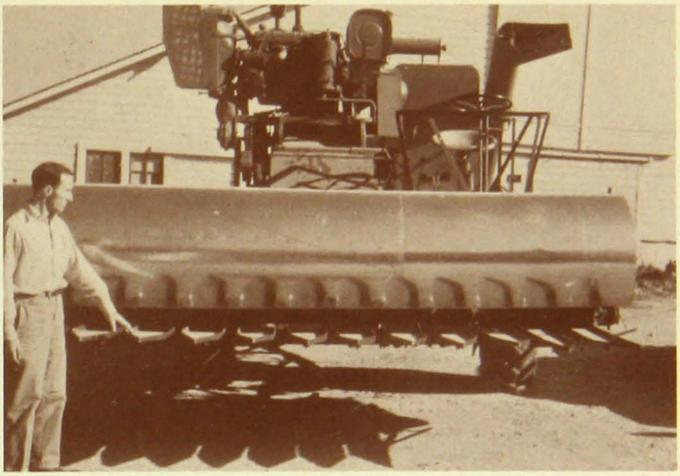


Figure 4. Front view of combine attachment.

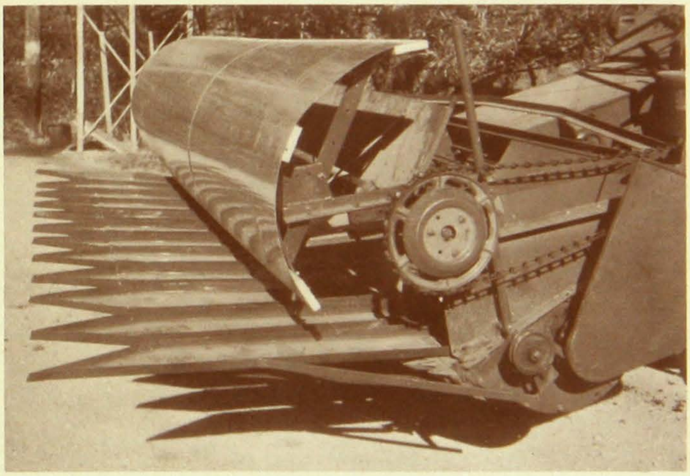


Figure 5. Side view of combine attachment.

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 and cylinder speed have to be adjusted to keep head breakage and seed dehulling at a minimum.

Sunflower harvesting attachments for combines are not standard equipment—they are made in local machine shops on special order for specific combines. An attachment for a large combine costs over $400. The curved sheet metal shield on the attachment shown in figures 4 and 5 pushes the plants forward. The stems pass between the long metal pans that are bolted to the cutterbar. The conventional combine reel is replaced with a three-arm reel of 1- by 12-inch boards. This reel operates behind the shield and pushes heads toward the cutterbar. The heads are cut off, thrown into the feeding auger, and pass through the combine.

Figure 6. Corn-combine harvesting foundation seed (Arrowhead).

A combine with a corn head attachment can do a fair job of harvesting sunflowers. However, shattering seed will be lost since there are no gathering pans to catch it (figure 6). Nevertheless, a grower with access to this equipment can try it on sunflowers before investing in special machinery or modifying combine reels.

The diagram on the opposite page shows the basic design of most attachments. It is taken from Canada Department of Agriculture Publication 1019, *Sunflower Seed Production.* This diagram is not drawn to scale; measurements are given in inches.

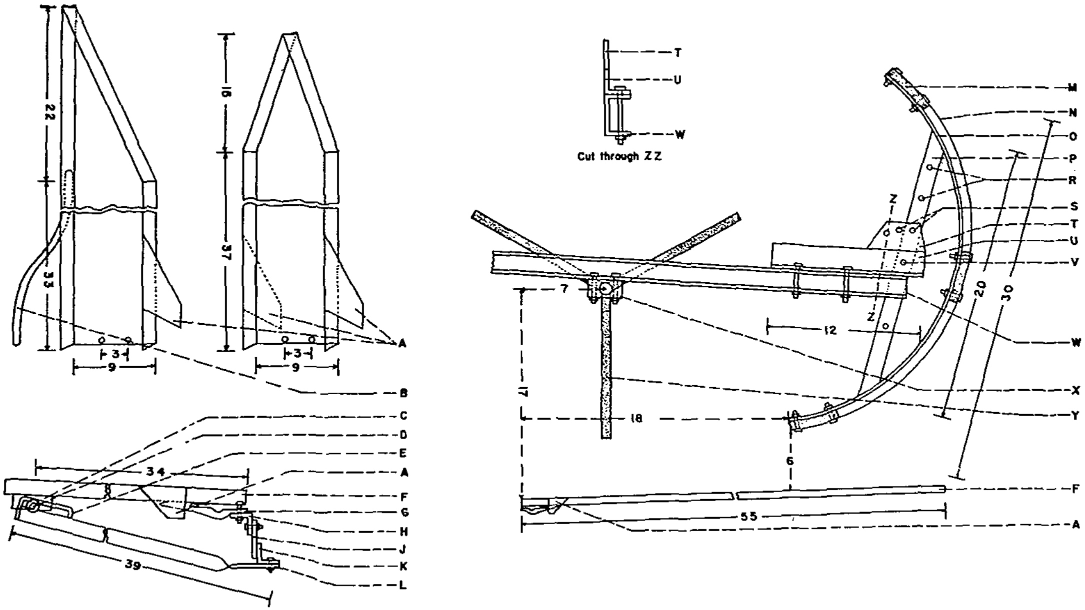
Except for the end ones, the pans in the diagram are 52 inches long, 9 inches wide, and spaced 12 inches center to center. This arrangement leaves a 3-inch space for stalks to pass between the pans. A few machines have pans up to 6 feet long, 15 inches wide, and 2½ inches apart. Some growers report that a ¾-inch overhanging lip around the top edge of the pans helps prevent shattered seed from bouncing out.

Large curved sheet metal dividers could replace the dividing rod (B) on the end pan, resulting in a smoother looking machine that may do a better job of row separation.

PESTS

Sunflowers are a vigorous crop that can withstand unfavorable conditions relatively well. The major weakness of the crop is the present lack of control for certain diseases and insects. Crop rotation does help reduce losses from some of these pests. It is essential to control volunteer sunflowers in fields and waste places to get any benefit from crop rotation, because volunteer plants provide breeding and feeding places for disease organisms and insects.

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



KEY TO LETTERS IN DIAGRAM

A—guard clip, 6 inches long, 4½ inches deep

B—dividing rod of ½-inch iron

C—piece of 1- by ⅛-inch angle iron, 3 inches long, welded to F

D—front support bolt and washer

E—¼-inch iron rod welded to L to permit adjustment of pan height

F—pan

G—guard

H—original angle iron carrying guard

J—short plate of 2- by ¼-inch strap iron welded to K and bolted to H

K—new piece of 1½- by ¼-inch angle iron full width of combine

L—1- by ¼-inch strap iron brace for supporting pan

M—1- by 4-inch board full width of combine

N—28-gage sheet metal shield

O—1- by ¼-inch strap iron, 36 inches long, shaped to an arc 30 inches across

P—1- by ¼-inch angle iron, 20 inches long, welded to O

R—holes 3 inches apart, permitting adjustment of shield height

S—holes in an arc, which, with pivot hole V, permit adjustment of shield slope

T—small ¼-inch iron plate, welded to U

U—1½- by ¼-inch angle iron, 12 inches long

V—pivot hole, which, with S, permits adjustment of shield slope

W—channel iron support for original reel

X—reel boxing

Y—reel arm of 1- by 12-inch board

Figure 7. Leaf mottle—The leaf at the lower right shows typical leaf mottling caused by Verticillium.

Figure 8. Downy mildew—Dwarfing, short internodes, and bird platform head are evident. Stem at left is on a normal-size plant.

DISEASES

Crop rotation, tolerant varieties, and seed treatment help reduce losses. The most serious diseases are caused by fungi and include leaf mottle, downy mildew, rust, and stem rot.

Leaf mottle (caused by *Verticillium*). Symptoms often appear before heading. The leaves have dead areas along the veins. These areas are bordered by light yellow-green areas (figure 7). Occasionally leaf symptoms do not appear, but a cross section of the stem may reveal decayed vascular bundles. Seed treatment and a 4-year or longer crop rotation help keep leaf mottle in check. *Verticillium* has a wide host range, but host plants in small grain fields can be eliminated with 2,4-D.

Downy mildew. The most obvious symptom is dwarfed plants, which sometimes are only 1 foot high (figure 8). A cottony fungus is sometimes evident on the undersides of leaves. Some plants resist the dwarfing effect and grow to full height. They have very erect, "bird platform" heads, and the seed is usually sterile (no meats). Rarely does the disease affect more than 5 percent of the plants in a field. A crop rotation of at least 3 years and seed treatment help keep losses down. Serious losses occurred in 1966 on a few fields that had been in sunflowers in 1964 or 1965.

Rust. Rust colored specks similar to the rust on small grain appear on the leaves. Rust is present in most fields but has not caused major losses in the United States. Admiral and Advent hybrids are resistant. A light infestation on volunteer sunflowers, which often are earlier than the planted crop, can spread and cause severe rust infection in commercial

Figure 9. Stem rot—The wilt of the plant on the man's right was caused by Sclerotinia.

fields. A crop rotation of at least 3 years and control of volunteer sunflowers are suggested for control.

Stem rot (caused by *Sclerotinia*). An alarming symptom is a sudden wilting of the plant shortly after flowering (figure 9). When wilting does not occur, the disease can be identified by a light tan band several inches wide around the stem at soil level. The stem may be green above this band, but its moisture supply has been cut off (figure 10). Stem rot has been found in a small percentage of fields and usually has not destroyed more than 5 percent of the plants. The wide range of hosts for this fungus may reduce the effectiveness of crop rotation, but spraying small grain fields with 2,4-D will help eliminate host plants.

Powdery mildew. The cottony growth of this fungus can be seen easily on the green leaves. It often appears on a late crop that is still leafy in September.

Aster yellows. Either the entire head or a pie-shaped sector of it appears abnormal. The ray flowers often are green instead of yellow

Figure 10. Stem rot—The dead band at ground level around plant stems at left was caused by Sclerotinia. Plant at right is healthy.

Figure 11. The strap-leaf condition of the diseased plant resembles 2,4-D injury, but the cause of the condition is unknown.

and small leaves replace the normal floral parts in the head. Sometimes these head symptoms are not evident, but a black slimy rot occurs on the stalk just below the head. The virus that causes this disease is spread by leafhoppers. Although the disease is common, it usually does not appear on more than a few plants in a field. Plants dwarfed by downy mildew often show the head symptoms of aster yellows.

Septoria leaf spot. Dead blotches occur on the leaves, usually before heading. Positive identification of the fungus is made by finding the long, clear, segmented spores under a microscope. The disease occurs in many fields but has not caused appreciable damage.

Bacterial head rots. These rots often occur where water collects on the backs of bent-over heads. When these heads dry and are struck by the combine they break and shatter seed.

Dark areas on the stem and backs of heads. Though the appearance of these areas is a common and serious disease symptom, the cause and control of the condition are unknown.

INSECTS

Sunflowers attract bees and many other insects that feed on the heads, leaves, and stalks. Many of these insects, although very noticeable, do not appreciably injure the crop. Aphids are very numerous on sunflower leaves after flowering, but ladybird beetles and other natural controls usually destroy them before the crop is seriously damaged.

The sunflower moth *(Homoeosoma)* has made commercial sunflower production impractical in most of the United States. At times, commercial production has been attempted in the Corn Belt and in the South, but it has failed to continue. California is the only state that has continued production in spite of moth problems; its crop is sprayed for moth control.

Minnesota sunflowers are not and should not be sprayed until the USDA Pesticides Regulation Division approves effective insecticides. Insecticides that are exempt from this regulation, such as rotenone, pyrethrum, and ryania, are effective only a very short time. This insect has not caused serious loss in northern Minnesota though it is extremely damaging in southern Minnesota every few years (figures 12 and 13).

The moth lays eggs on the head at flowering time. The eggs hatch into larvae in about 1 week. The larvae feed on the floral parts and tunnel through the seeds. When attacked early, sunflower heads curl up like a closed fist. The matted, cobwebby appearance of the face of the heads makes identification easy. The "armor layer" in the hull of Peredovik and some Arrowhead plants does not provide moth resistance in the United States even though it gives resistance to a similar moth in Russia.

The **banded sunflower moth** *(Phalonia)* has been found in northern Minnesota but not in the central or southern part of the state. The moth has brown areas in the middle of its wings, which have a spread of one-half inch. Eggs laid on the heads hatch in about 1 week. The larvae are not dark striped and are smaller than sunflower moth larvae. A larva

Figure 12. Sunflower moth larva enlarged six times. Note the dark bands running the length of the body.

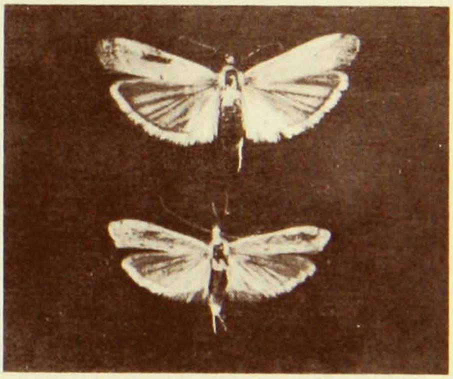


Figure 13. Sunflower moth adults. The female (top) has a wingspread of 1 inch. The male (bottom) is smaller.

makes a small hole at the top of a seed and eats the meat before moving to another seed.

Some of the following insects are not common and none of them has done serious damage to large fields.

The **sunflower maggot** adult is a yellow fly with dark markings on its wings. It is slightly smaller than a house fly. The eggs, which are laid in the stalk, hatch into maggots in about 1 week. The maggots feed in the pith of the stalk until fall. Tunnels made by maggots are visible if the stalk is split.

The **sunflower beetle** is the size and shape of a small Colorado potato beetle. The yellow stripes running lengthwise on each of its wing covers look like exclamation points. The eggs are laid on the undersides of leaves and hatch in about 1 week. The larvae feed on the leaves, especially those around the developing sunflower head. The damage appears as holes in the upper leaves. If adults are numerous, they can eat considerable amounts of young plant foliage.

Wooly bear and **painted lady (thistle) caterpillars** usually are found feeding on leaves in late summer and fall (figure 14).

Head drop is caused by a small fly that attacks plants during the early bud stage. The heads drop off before maturity.

Northern and **western corn rootworm beetles** and, to a lesser extent, **southern corn rootworm beetles** are extremely numerous on the faces of sunflower heads in late summer in corn growing areas.

Blister beetles and **grasshoppers** often feed on the yellow ray flowers of the head and on the leaves.

Lygus bugs and **alfalfa plant bugs** *(Adelphocoris)* are sucking insects found feeding in sunflower heads.

Striped beetles about one-fourth inch long found feeding on the heads of a seed increase field near Fosston, Minnesota, have been identified as one of the *Chrysomelid* or **leaf beetles.**

The **picnic beetle** often feeds on heads after they have been damaged by the sunflower moth. This black beetle is about three-eighths inch long and has yellow spots on its back.

The **ragweed plant bug** has been found feeding on sunflower leaves in June.

Springtails are pinhead-size, round, gray, fast-hopping insects that leave chewing marks on sunflower cotyledons shortly after emergence.

BIRDS

Blackbirds, goldfinches, and other birds eat tremendous amounts of seed on some fields; they may not bother others. Goldfinches start feeding about 1 week after sunflowers bloom and continue for about 1 month. Goldfinches show a decided preference for small, thin-hulled sunflower varieties. Birds that feed in the fall when feed is less plentiful eat all

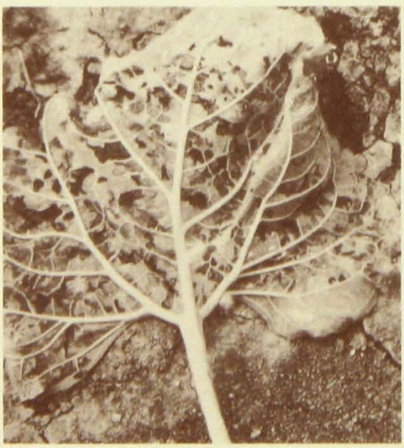
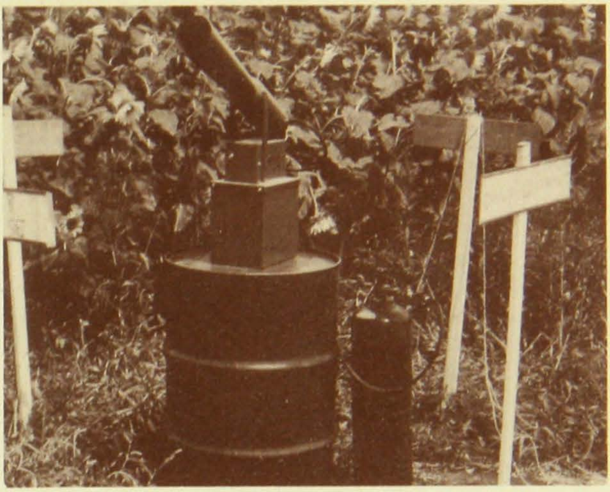


Figure 14. These salt marsh caterpillars have eaten much of the foliage around the veins of the leaf.

Figure 15. 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.



types. Blackbirds are the most common fall feeders. Sparrows tend to do the most damage to the parts of fields near buildings.

The birdfeeding problem may increase after sunflowers have been grown in an area for a few years. At Rosemount, goldfinches were a rare bird in open fields until sunflower production was begun. After 10 years of production, head bags and frightening devices must be used to protect experimental material from goldfinch flocks.

Scaring devices should be put into operation at 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 shown in figure 15 were unsatisfactory due to high costs and the inability to keep the machine operating. Other models may be satisfactory. Permission from the Minnesota Conservation Department and County Boards of Supervisors is required to operate these devices.

A new approach to bird control is the use of the chemical Avitrol. It is available only through licensed operators, who provide the material and apply it. Birds that eat the baited grain send out distress signals or act in such a way that other birds evacuate the area. The custom charge for several broadcast applications of the bait was $5 per acre in 1966. The writers do not have enough information to comment on the effectiveness of the practice.

SUNFLOWER USES

Seed For Food

Sunflower seed may be dehulled and eaten without processing; dehulled, roasted in oil, and salted; or salted in the shell.

Commercial salting in the shell is done with pressure or by steaming the seed and then plunging it into a brine solution. This process breaks the inner layer of the shell and allows the brine to enter. A home recipe for salting sunflowers in the shell calls for 1 tablespoon of salt to 1 pint of water. The seed is immersed in the boiling brine, soaked until the meats are damp, and then dried.

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 outer wall of the machine. 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. Hulls and meats can be separated by screening them in the wind or floating off the hulls in water. Dehulled seeds are roasted in vegetable oil, then removed and salted to taste. Dehulled seeds are used for nutmeats and in candy, salads, and bakery goods.

Seed For Birdfeed And Other Recreational Feeding

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

Oil

From 100 pounds of mature, dry, oilseed sunflower, a recovery of 40 pounds of oil, 35 pounds of high protein meal, and 20 to 25 pounds of hulls is expected. After the hulls have been removed, oil is extracted by crushing and pressing the meats so that 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 foods, popping corn, and for other culinary processes where a liquid oil with a high smoke point is desired.

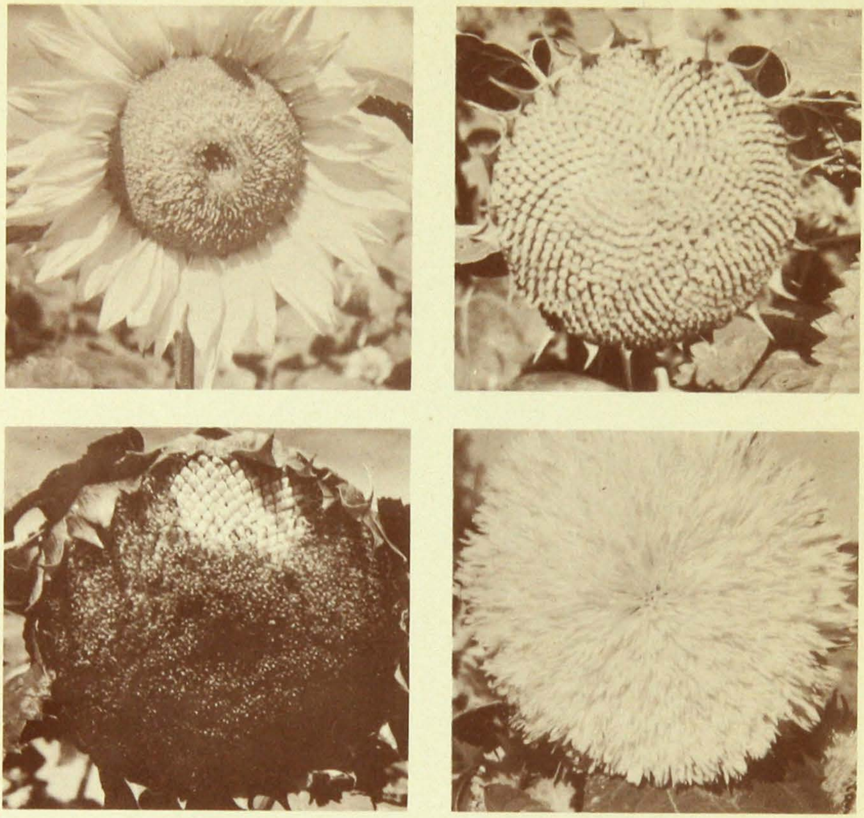
Considerable medical research indicates that vegetable oils of high linoleic acid content help decrease blood cholesterol, which in turn reduces the incidence of certain heart and circulatory problems. Sunflower oil from the northern states and Canada is unusually high in this desirable component (table 14).

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

Table 14. Approximate oil content of seed and iodine number and fatty acid composition of oils*

Crop	Seed oil	Iodine number	Polyunsaturates		Monounsaturates	Saturates
			Linoleic	Linolenic	Oleic or erucic	
	percent		percent			
Sunflower†	40	130	68	0	20	12
Safflower	37	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 oil content would be about 60 percent.



A sunflower head contains hundreds of flowers. 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.

Figure 16 (above left). This head is still pollinating. The small sunken area in the middle has not yet started to pollinate.

Figure 17 (above right). This head has shed its ray flower petals, but the floral parts of the disk flowers will remain a few days.

Figure 18 (bottom left). The upper part of this head shows disk flower parts removed and the seed exposed.

Figure 19 (bottom right). Some ornamental sunflower heads have all ray-type flowers.

that oil from Minnesota seed had a much higher linoleic acid content than seed from the other states. Therefore, sunflowers from Minnesota 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.

Oil For Industrial Products

The relatively low iodine number of sunflower oil indicates that it is of undesirable quality for a drying oil (table 14). 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 also may be used in the manufacture of caulking compounds, putty, and plastics.

Meal And Flour

The meal remaining after oil extraction is a high protein supplement for livestock. Livestock feed grades contain 40 to 46 percent protein and 10 to 12 percent fiber. The fiber consists of the small percentage of hulls that are not removed during processing and compares with a soybean meal fiber content of 5 to 7 percent. Sunflower meal is unusually high in thiamin and niacin and exceeds other common oilseed meals in carotene and calcium.

Tests in the University of Illinois Home Economics Department indicate that sunflower meal has potential as a supplement to wheat flour.

Hulls

Disposing of sunflower hulls at a profit is a major problem. A Canadian company presses them into 7½-pound logs for fuel. Most of the hulls recovered in Minnesota to date have been used for poultry litter. Use of hulls for fuel in oil extraction plants and in pelleted livestock feed is being considered by industry.

Stalks And Heads

These crop residues present no problem in preparing the land for the next crop. Even so, uses for these waste materials are being considered. Stalk yields per acre are too low for sunflower stalks to be considered an economic source of pulp.

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 and there is no shortage of it.

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.