Hybrid Selection and Production Practices

Hybrid Selection

(Jerry Miller)

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

NuSun Sunflower

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

Traditional Sunflower

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

Confection Sunflower

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

Criteria for Hybrid Selection

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

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

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

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

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

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

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

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

Semidwarf Sunflower

(Duane Berglund)

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

Sunflower Branching

(Duane Berglund)

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

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

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

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

Production Practices

Seed Quality

(Duane Berglund)

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

Soils

(David Franzen)

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

Soil Fertility

(David Franzen)

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

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

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

Fertilizer Recommendations

(David Franzen)

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

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

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

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

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

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

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

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

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

Fertilizer Application

(Dave Franzen)

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

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

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

Water Requirements for Sunflower

(Duane Berglund)

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

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

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

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

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

Soil Water Management for Dryland Sunflower

(Duane Berglund)

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

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

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

Irrigation Management

(Tom Scherer)

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

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

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

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

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

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

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

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

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

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

Tillage, Seedbed Preparation and Planting

(Roger Ashley and Don Tanaka)

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

Tillage and Seedbed Preparation

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

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

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

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

Conventional-till Production Systems

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

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

Minimum-till Production Systems

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

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

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

Air Drill Use

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

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

No-till Production Systems

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

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

No-till and One-pass Seeding

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

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

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

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

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

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

Planting Dates

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

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

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

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

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

Row Spacing and Plant Population

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

Desired seed spacing may be calculated using the following formula:

$$SS = (6,272,640/RS)/(PP/(GR \times SR))$$

Where:

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

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

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

Postharvest Tillage

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

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

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

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

Crop Rotation

(Greg Endres)

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Pollination

(Gary Brewer)

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

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

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

Table 11. Sunflower rotation examples for North Dakota.

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

*medium susceptibility to Sclerotinia.

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

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

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

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

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