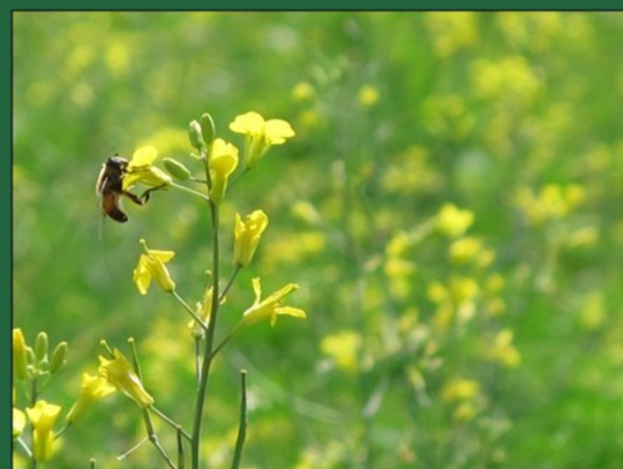
OILSEED PRODUCTION IN THE NORTHEAST

A Guide for Growers of Sunflower and Canola



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UNIVERSITY OF VERMONT EXTENSION

CULTIVATING HEALTHY COMMUNITIES

This manual has been developed by the University of Vermont Extension Northwest Crops & Soils Program and is intended to provide the best and most broadly applicable agronomic practice information at the time of its printing. Our aim in writing is for the bulk of this manual to be as useful as possible for as long a period of time as possible. Therefore, we have designed it to address practices that are unlikely to change, while avoiding making specific recommendations for varieties or equipment. More specific information is contained in annual trial reports published in the winter and early spring, available on the UVM Extension NWCS program website (www.uvm.edu/extension/cropsoil/oilseeds). This manual will remain available as a PDF on the website as well.

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The UNIVERSITY of VERMONT
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NORTHEAST SARE Sustainable Agriculture Research & Education

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OILSEED CROPS IN THE NORTHEAST

Over the past decade, farm diversification has gained momentum as more and more farmers in the Northeast have looked for ways to increase farm revenue, combat declines in soil health and fertility, and cut down on operational costs. In more recent years, as the cost of petroleum products such as diesel fuel and synthetic fertilizers has increased, farms have begun to search for ways to reduce fuel, feed, and fertilizer expenses. Oilseed crops have emerged as a welcome opportunity for many farms. Both the oil and seed meal, the two main products of the crop, have a wide variety of possible uses and markets. Sunflower and canola, two of the most common oilseed crops, can be easily incorporated into the local cropping systems, and produce added benefits such as enhanced soil health and increased biodiversity in the rotation.

Because sunflowers and canola in the United States are grown predominantly in the Great Plains, many of the technical resources are not applicable to agronomic conditions in the Northeast. Additionally, there are production constraints that farmers in the Northeast face that are relatively unknown in the more common oilseed-growing regions. The University of Vermont (UVM) Extension's Northwest Crops and Soils (NWCS) Program developed this manual to act as a collection of the best regional information for oilseed producers in the Northeast. For the past seven years, UVM Extension Agronomist Dr. Heather Darby and the NWCS Program have conducted a wide range of agronomic trials to develop locally-adapted information to aid producers in growing sunflower and canola. These trials represent a significant resource on agronomic issues such as variety selection, seeding rates, planting dates, fertility amendments, weed and pest management, and harvesting techniques.

SUNFLOWER

Helianthus annuus

1. GROWTH AND DEVELOPMENT

Germination and Emergence

Sunflower is a fast-growing annual plant of the Aster family (Asteraceae) with a vast number of relatives native to New England. Like other aster-family plants, each "flower," or head, is made up of hundreds of individual florets attached to the receptacle, each of which is its own fully functional flower (Figure 1-3, page 9). Each disk floret produces one seed, while ray flowers are usually sterile and only serve to attract pollinators.

Sunflowers germinate when the soil temperature is between 50°F and 55°F. In the Northeast, these conditions typically occur mid- to late-May, depending on elevation, soil type, soil moisture and other cropping practices.

Sunflowers are particularly sensitive to soil conditions during the first several hours after planting. Cold and wet soil at planting can delay and lower germination, which often increases susceptibility of the developing seed and shoot to fungal pathogens. Fungicide treated seed can improve germination levels in these conditions to some degree, though seed treatment is not a substitute for waiting for better planting conditions. Organic producers are at particular risk for severely depressed germination from cold and wet soils, particularly when high levels of crop residues keep soils cool and wet in the spring. Under normal conditions, emergence occurs 5-10 days after planting (Figure 1-1).

Growth Stages

The growth stages of sunflower are generally broken broadly into vegetative and reproductive stages, of which has further divisions that relate to specific developmental stages in sunflower. Table 1-1 (page 8) provides descriptions of each stage and also approximate growing degree day (GDD) units to reach each stage. Days to each stage are not given because of the extreme variability in growing season conditions in the Northeast. Being able to identify sunflower growth stages is important when attempting to identify diseases and pests, many of which affect the plant at only specific development stages. This system of staging is also important as it allows farms, scientists, and related industry to talk about sunflower development on a common basis.

Figure 1-1. Sunflower emergence, early June.

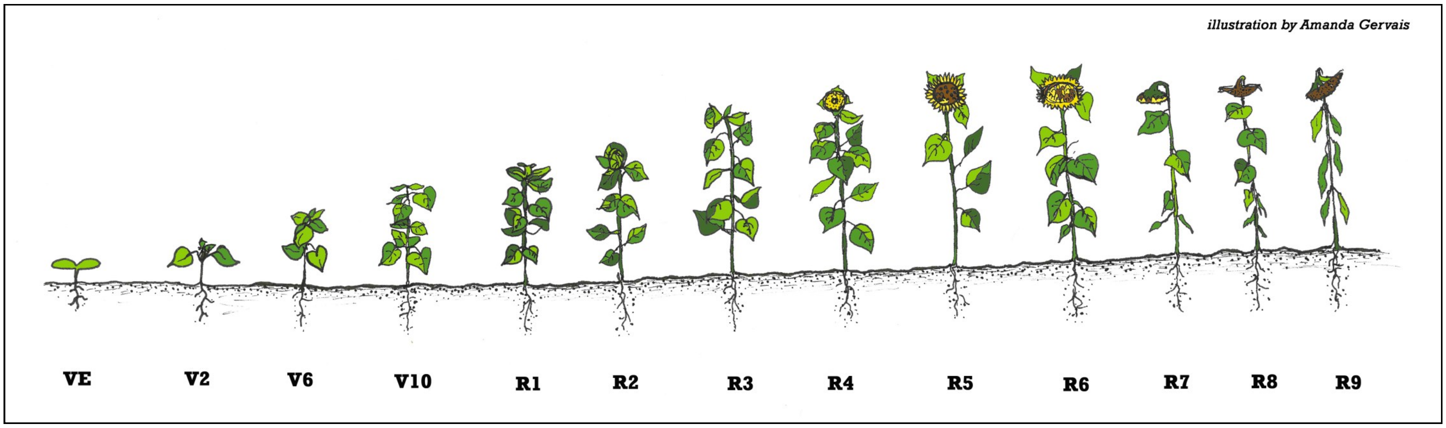

Figure 1-2. Growth stages of sunflower. R9 is physiological maturity.

The vegetative phase is denoted with a V, followed by the number of true leaves greater than 2" long – for example, V-4 describes when the plant has 4 true leaves, and V-10 when the plant has 10 true leaves. The reproductive phase is denoted with an R, followed by a number that represents stages of flower development and maturation. Significant milestones in this phase are R2 (immature bud formed), R5 (flowering), and R9 (physiological maturity) (Figure 1-2).

Pollination Requirements

Most varieties of commercially-available sunflowers are self-compatible, which means that flowers from one plant are capable of pollinating themselves and producing viable seed. Interestingly, some studies have shown that sunflowers that are outcrossed with other flowers by insect pollinators have higher yields and higher seed oil contents. In our region, there is generally a sufficient population of insect pollinators, except when insecticides are used. Many of the insect pests that present significant economic problems in our area appear at the same time that pollinators become important; spraying insecticides becomes problematic in those situations.

Table 1-1. Growth stages of sunflower (*Berglund, 2007*).

Development Stage	Description	GDD units
VE	Emergence, where only the cotyledons and/or true leaves less than 2 in. are showing	165
V-2, V-4, etc.	These vegetative stages are determined by counting the number of true leaves longer than 2 in., counting any leaves that have senesced	350-870
R-1	The terminal bud produces a floral bud; bracts are visible instead of true leaves	920
R-2	The floral bud begins to elongate, but remains within 1 inch from the topmost leaf; bracts are clearly distinguishable	1250
R-3	The floral bud continues to elongate, and is now more than 1 in. from the nearest leaf; bud remains tightly closed	1395
R-4	Bud begins to open, showing immature ray flowers	1490
R-5	Flowering; sub-stages are denoted by a decimal that represents the percentage of disk florets that have flowered (e.g. 5.1 is when 10% of florets have matured, 5.5 is when half of the florets have matured)	1545 (5.1) 1625 (5.5)
R-6	Flowering complete, all disk florets mature, ray flowers withering	1780
R-7	Upper stalk and back of head begin to yellow	2050
R-8	Back of head completely yellow, but bracts still green	2210
R-9	Back of head and bracts fully brown; this is physiological maturity	2470

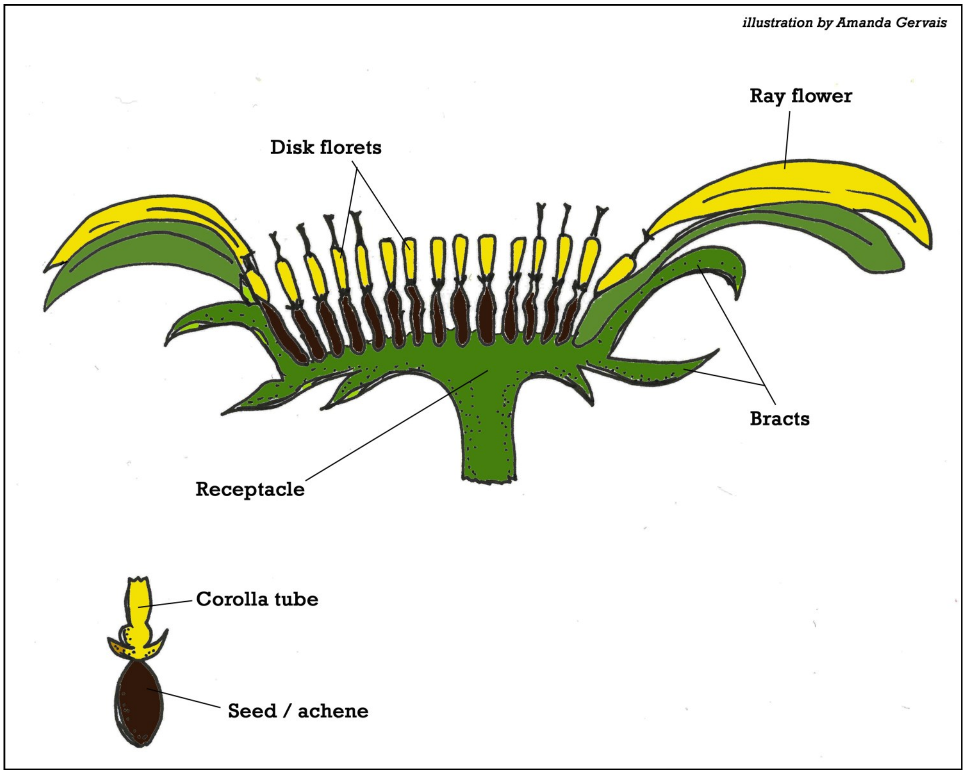

Figure 1-3. Anatomy of a sunflower head, showing selected plant parts.

Maturation and Senescence

Sunflower development is particularly dependent on accumulation of GDDs, which influences the rate of maturation of the seed. Full maturity of the seed requires about 2500 heat units, depending on the variety. In much of the Northeast, reaching 2500 heat units can be a challenge. Once the plant has reached physiological maturity it will require additional time to dry the seed and the head to a moisture content that will allow for combining. Therefore, choosing earlier to mid season varieties that dry down quickly is very important for the region. In UVM Extension trials, varieties listed between 88 and 97 days to maturity, have reached harvestable moistures and resulted in acceptable yields. Hence, early to full season varieties can be grown in the Northeast. However, selecting varieties that are considered "early" to "medium-early," may be the most likely to reach maturity from year to year. Of course, some areas in the Northeast have growing seasons that will support the production of full season varieties. In these cases, growing varieties that mature very early will most likely reduce yield potential.

When the seed reaches physiological maturity (Figure 1-4), the receptacle tissue in the head is generally still too wet to allow harvest with a combine. Dry down of the receptacle is dependent on weather conditions. Quickening drydown of the plant with desiccants such as glyphosate is a common practice in the Great Plains, and can help avoid crop losses to birds by getting the seed out of the field before the peak of the migratory bird season. Applying a desiccant can hasten sunflower harvest by 20 days.

Figure 1-4. Sunflower in reproductive stage, full flower.

2. CROP ESTABLISHMENT AND PRODUCTION

Like any other crop, establishing a good stand of sunflowers requires careful attention to a variety of production practices. This section provides guidelines for managing soil fertility, selecting varieties, preparing the seedbed and planting.

Soils and Fertility

Sunflowers perform well in a wide variety of soil types. However, they are best-suited for well-drained soils that have good water-holding capacity (i.e. high organic matter and good soil structure). They will tolerate heavy, wet soils, and light, excessively drained soils better than other crops, but yields will be lower compared to sunflowers grown under better soil conditions.

Sunflowers in the Northeast often require far less added soil fertility than sunflowers grown in the Plains. Vermont soils can have high levels of nitrogen (N), phosphorus (P), and potassium (K) native in the soil, as well as high levels of organic matter (>6-8%). This high fertility is most often associated with our long history of using manure as a primary source of fertility, Sunflowers are exceptional scavengers of soil nutrients because of their extremely long taproots. In deep soil, sunflowers are able to access nutrients from between three and four feet, far below the profile of corn and hay. Many nutrients in the lower soil profiles that are lost to other crops are still accessible to sunflowers. For the most accurate information on what nutrients are available to the plants, we recommend taking soil samples to a depth of two feet. In a UVM Extension trial, 30-45% of the N available to the plant was found in the lower half of the two-foot soil sample (Table 2-1).

Nutrient Application

To produce optimal yields of sunflowers, 100 to 150 lbs of N per acre are required. In the Great Plains, sunflowers generally require 5 lbs of N for every 100 lbs of desired seed yield (i.e. 2000 lbs of seed requires 100 lbs nitrogen). Because Vermont soils and agricultural practices differ from the U.S. plains region, required nitrogen rates will be highly variable. For example, UVM Extension sunflower trials have yielded approximately 2800 lbs per acre on average with application rates of 120 lbs N per acre or less, as opposed to the 145 lbs N the Midwest rule of thumb would suggest.

UVM Extension N fertilization rate trials (applied by topdressing at approximately R-1 stage) have found that seed and oil yield vary widely with N amendment rates between 0-120 lbs per acre (Figure 2-1, page 11). Adapting N applications to specific field management conditions is crucial to maximize yield and quality. Essentially, the amount of N fertilizer or other organic amendment will depend on your yield goal, soil type, and past years fertility practices. Taking a nitrate sample (pre sidedress nitrate test, PSNT) to a two foot depth will help guide actual N needs of the crop during the growing season.

Sunflowers also require relatively low levels of P and K. Standard soil tests will estimate available P and K in the soil. Recommendations will be provided by the testing laboratory. However, as a general recommendation, soils testing high to very high in P and K will require no additional input of these nutrients. If soil test levels are low to medium, 60 to 100 lbs of P or K per acre will be required to produce a sunflower crop.

Table 2-1. Nitrate-N availability in the top and second foot of a soil sample.

Sample	Nitrate-N 1 ft depth (ppm)	Nitrate-N 2 ft depth (ppm)	Total Nitrate-N (ppm)	Nitrate-N 1 ft depth (%)	Nitrate-N 2 ft depth (%)
1	6.7	5.4	12.1	55.4	44.6
2	5.3	3.3	8.6	61.6	38.4
3	5.4	2.3	7.7	70.1	29.7
4	7.1	4.8	11.9	59.7	40.3

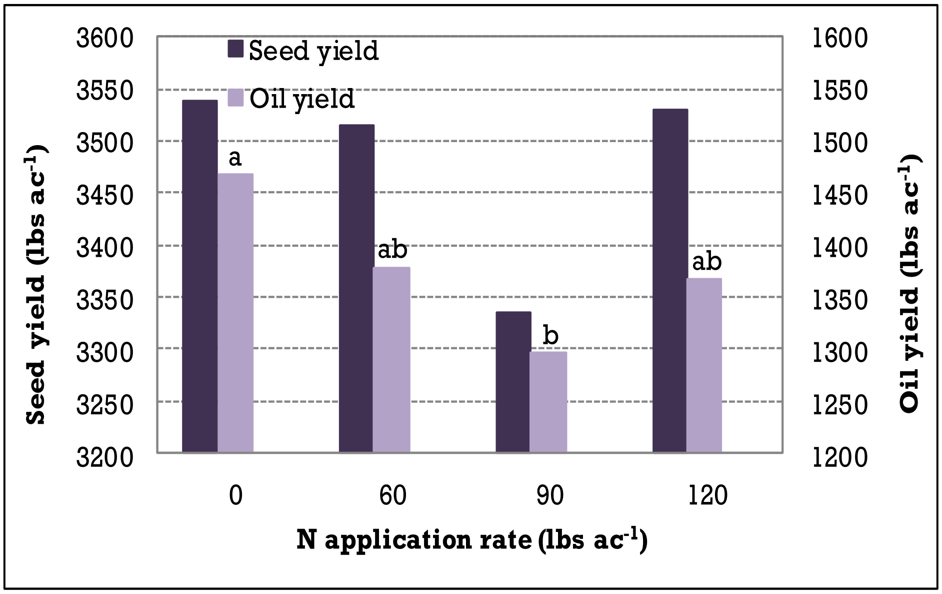

Figure 2-1. Effects of N application rates on yields, combined 2010-2012 UVM Extension data. ***Treatments that share a letter did not differ significantly from one another (p=0.10) in oil yield. Seed yields did not differ statistically by N application rate.***

Variety Selection

For our region, one of the most important decisions sunflower growers will make every year is variety selection. There are a number of varietal characteristics that must be considered to make the best choice, and the best variety for the situation often strikes a balance between yield potential, oil content, maturity, and resistance to disease and lodging. The following tips are meant to aid growers in selecting varieties.

Maturity

The most significant limiting factor for growing sunflowers in our region is the shortness of the growing season. On average, sunflowers require about 2,500 heat units (i.e. growing degree days) to reach physiological maturity. Once the crop is at physiological maturity it has a moisture content of approximately 36%. Additional time is required for the crop to reach an adequate moisture that allows for harvest with a combine. The time that it takes for the sunflower to dry down to adequate harvest moisture will partially depend on the variety as well as the climate. Vermont has a wide range of climatic conditions, though the unifying feature is that the growing season is much shorter than most other regions of the continental US, and the fall is typically wet. Some of the longest growing seasons in Vermont average between 3300 and 3400 GDDs for the entire growing season (May through October), while the shortest growing seasons finish at just over 2,500 GDDs (Table 2-2). For most of these regions, full season sunflowers would just reach physiological maturity before the end of the growing season, and harvest would be delayed until well after the frost. For areas in our region that support sunflower production, choose varieties that are listed as "Early" or "Medium," or that are listed between 88 and 96 days to maturity. "Full" season varieties can be grown in areas that have exceptionally long growing seasons. It is also important to select varieties that are reported to have excellent dry down.

Table 2-2. GDD accumulation for various locations in the Northeast, based on historical averages (NOAA, 1981-2010).

Weather Station Location	GDD Accumulation May - Oct.
Burlington, VT	3346
Montpelier, VT	3342
Rutland, VT	3093
Concord, NH	3340
Waterville, ME	3355
Worcester, MA	3352
Albany, NY	3607
Canton, PA	3165

Yield Potential

Seed yields in sunflower are determined by a large number of factors, the majority of which are environmental. However, plant genetics also can play a major role. Some varieties exhibit a greater yield potential than others, which is important to know when determining which variety to plant. In general, shorter season sunflowers have slightly less yield potential than longer season varieties, but this is not always the case. Seed company charts can be helpful in determining the yield potential, but are difficult to accurately compare between companies. UVM Extension conducts yearly variety trials that provide good insight into which varieties are appropriate for the climate and cropping systems common to the region (Figure 2-2, page 12).

Growing sunflowers will only prove to be profitable for growers if they can regularly

Find out more! Annual research reports available at: www.uvm.edu/extension/cropsoil/research

Figure 2-2. UVM Extension's Northwest Crops and Soils Team conducts variety trials to determine seed and oil yield potentials.

achieve their fullest yield potential; therefore, it is critical to pick a variety that has the highest yield potential within the limits of varieties that perform well in our climate.

Oil Content & Quality

Like yield potential, oil content of the seed is largely based on environmental factors, but genetic potential is also significant. For sunflower producers who grow for biofuel feedstock, oil content is as important as yield potential. In our region, oil yields tend to be slightly lower than published values, likely because of the higher water availability in our soils, which can decrease oil content of the seed. Even so, UVM Extension trials have regularly achieved oil content averages of approximately 33%, and often reaching 40%.

There are two kinds of oilseed sunflowers which produce oils with different proportions of linoleic and oleic fatty acids, and therefore have different market potentials. Traditional oilseed sunflowers tend to have high linoleic and low oleic fatty acid levels, which makes them a good multi-purpose seed. These seeds typically enter the birdseed market, but also can be used for biofuel production. High-oleic varieties, such as those with the NuSun® trait, contain a minimum of 55% oleic fatty acids, and are in high demand for the food industry for use as frying oil. These oils are also good for use as cold-pressed raw oil.

Seed Size and Quality

Seed quality, is important to assure uniform germination rates in sunflowers. Most seed companies report 90% as the maximum germination rate under ideal conditions, though the actual germination rate depends on environmental conditions at planting. Cold and wet soils at planting can severely limit germination, while ideal conditions can raise the germination rate by several percentage points. Soils near 50° F are required for germination of sunflower. Most seed is treated with fungicides to protect seed from seed and seedling pathogens. Organic sunflower seed is available and is untreated. Therefore, it is essential to make sure planting occurs when soil conditions are ideal. Over time, germination rates of stored seed will decline, so producers should conduct their own germination tests for any seed stored from previous seasons before planting to establish an accurate estimate of viability. This will help in calculating a seeding rate for the coming year, and ordering additional seed if necessary.

Growers should select sunflower varieties that:

- **Mature within the producer's growing season**
- **Dry-down quickly in the field**
- **Have a high potential seed yield**
- **Have a high potential oil content**
- **Have desirable pest resistance traits**

Figure 2-3. Seed size, shape and plumpness can vary.

Seed size is very important for producers to consider when ordering seed (Figure 2-3). Sunflower seeds are assigned sizes between 1 and 5, where 1 is the largest and 5 the smallest; for oilseed sunflowers, sizes 2, 3 and 4 are most common. It is extremely important for producers to note the seed size and calibrate planters to meet the seed size.

Disease Resistance

Many sunflower hybrids are bred for resistance to fungal diseases. The resistance in sunflowers was developed through traditional breeding techniques, and the traits have been obtained either from wild sunflower or natural mutations in hybrid sunflowers. Therefore, they are not genetically modified (GM) crops. Of the available disease resistance traits, the most significant for our area is resistance to downy mildew. Because of our high-humidity climate, sunflowers are more prone to fungal diseases here than in other regions. Sunflower varieties resistant to rust and Verticillium wilt are also available. The most common and economically problematic fungal disease for sunflowers in our region is *Sclerotinia*, for which there is not a resistant variety of sunflowers. Growers should periodically ask seed distributors about new fungal resistance traits.

Herbicide Tolerance

Like disease resistance, herbicide tolerances have been bred into sunflower hybrids using traditional techniques, and are available as non-GM traits in sunflowers. There are currently two herbicide tolerance traits available for sunflower hybrids (Clearfield and ExpressSun). Clearfield gives resistance to the herbicide Beyond (imazamox), which can control several problem weeds in our area, including redroot pigweed, lambsquarters and velvetleaf. The ExpressSun trait provides tolerance to Express herbicide (tribenuron methyl), which provides control of many broadleaf weeds, including lambsquarters and redroot pigweed. These hybrids tend to be much more expensive than conventional sunflower hybrids, and so producers should consider other methods of broadleaf weed control, such as well-planned rotations, secondary tillage and cover cropping.

Planting Practices

One of the most common production problems in sunflower fields across the country is planter error that leads to long skips or clusters in fields and subsequent increased weed pressure and yield losses (Figure 2-4). Many of these errors can be avoided with seedbed preparation and planter calibration. It is also crucial to consider the maturity of a sunflower variety and plan seeding dates accordingly for maximum yields.

Seedbed Prep & Seeding

Sunflower seeds should be planted 1.5-2" deep into a moist, even seedbed, once soil temperatures have reached 50° F. Like most crops, sunflowers benefit greatly from a well-prepared, even seedbed. Inattention to seedbed preparation will cause cascading problems throughout the season, beginning with uneven emergence, and ending with premature sunflower maturation and dry-down. Good seedbed preparation can reduce workload through the rest of the season and help ensure a good crop.

In the Plains, no-tillage sunflower production systems are common. In Vermont, some producers grow sunflowers in no-till fields with good success as well, but it is not suitable for all fields. Because sunflowers need fairly warm soils to ensure good germination, they are generally not a good candidate for no-till systems on soils that are poorly drained or have a propensity to remain cold late into the spring. However, there are plenty of good opportunities on more moderate and light soils for reduced tillage. Reduced tillage systems can improve soil quality and reduce crop production costs.

Figure 2-4. Dense sunflower population due to planting error.

In conventional tillage situations, field preparation is very similar to preparation for corn, which generally includes moldboard and/or chisel plowing, followed by secondary tillage to break up large clods and even out the seedbed. Incorporation of pre-plant herbicides can occur at this point as well.

UVM Extension trials have evaluated the performance of sunflowers in reduced tillage and no tillage systems and shown that they can yield as well as conventional tillage systems. One recurring issue in the Northeast in reduced tillage systems is that sunflowers are not particularly competitive against weeds early in their development. In reduced and no-till systems, care must be taken to reduce weed pressure early in the season, and in particular, to reduce pressure from any pre-existing cover crop with herbicides or other means.

Planting Dates

Because sunflowers are a fairly long-season crop, it is important to plant them as soon as the soil conditions permit. In Vermont, soil temperatures of 50°F typically occur in the second or third week of May; it is a good rule of thumb to have sunflowers planted before June 1. If a short-season hybrid is planted at this time, it will generally be ready for harvest by the first or second week of October. Planting can extend to the first week in June, but planting later than that point introduces a significant risk that sunflowers will not reach maturity before first frost. Immature plants that are killed by a frost will have reduced seed-set, test weight, oil content and oil quality.

It is very important to note the maturity of a sunflower variety, as provided by the seed company. Generally, early season planting allows the farmer to plant a longer season variety. Longer season varieties often yield higher due to their extended growth period. If the planting date is delayed, often farmers must change to a shorter season variety that will be able to mature during the allotted growing season. If a longer season variety is grown at later planting dates, it may not have enough time to properly mature and yield potential and quality will be compromised. For example, a longer-season variety like Syngenta's '7120' (95 days) will have higher oil yields when planted on the earliest planting date. Shorter season varieties like Croplan's '306' (88 days) will have higher oil yields at the latest planting date (Figure 2-5). We would expect that the shorter season variety may outperform a later season variety as the planting date becomes delayed. Likewise, we would expect a later season variety to outperform a shorter season variety at earlier planting dates.

Equipment Recommendations

Sunflowers should be planted with corn planters or air seeders. Though producers sometimes use traditional grain drills, the irregular shape and size of sunflower seeds generally causes problems with seed spacing, as they get stuck in the seed openings or in the seed tubes. This poor movement of the seed results in a high percentage of skips and doubles, resulting in competition between plants in some spots, as well as long skips where weeds can become established. This can also lead to extremely dense clusters of plants, which cannot compete for resources and will not grow well.

Seed meters that use a finger pickup system often have interchangeable finger pickup wheels, and sunflower-specific fingers can be purchased relatively inexpensively (Figure 2-6, page 15). Metering systems that employ a vacuum seed plate also have sunflower-

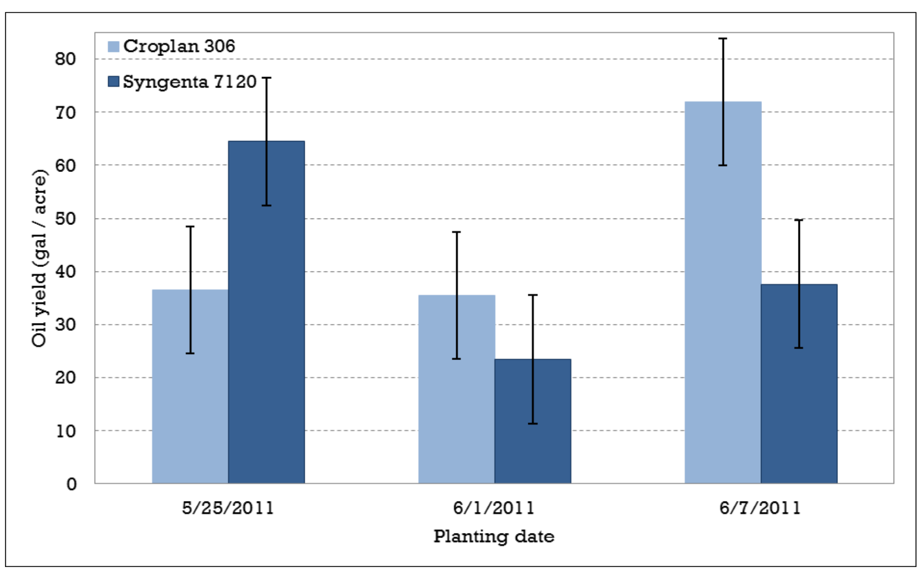

Figure 2-5. Effects of planting date on long and short season variety oil yields, 2011 data, UVM Extension.

specific plates (both flat plates and cell plates) that accommodate the unique shape of sunflower seeds. These basic adjustments provide huge improvements in seed spacing, which corresponds directly to increased yield.

Other small adjustments can be made to seeding systems within the meter that can greatly improve seed spacing. Doubles eliminators, or seed singulators, are common in vacuum planters, and can be adjusted to be more or less aggressive to accommodate seeds of different sizes. Doubles eliminators also exist in some finger pickup meters.

Replacing the seed tubes that deliver the seed from the meter to the ground can also provide improvements in seed spacing. The University of Nebraska has done numerous trials with various seed metering systems and seed delivery system adjustments to achieve ideal seed spacing (Smith, 2011). One additional finding from those trials is that a combination of talc and graphite greatly improved seed flow through the planter, resulting in better seed placement.

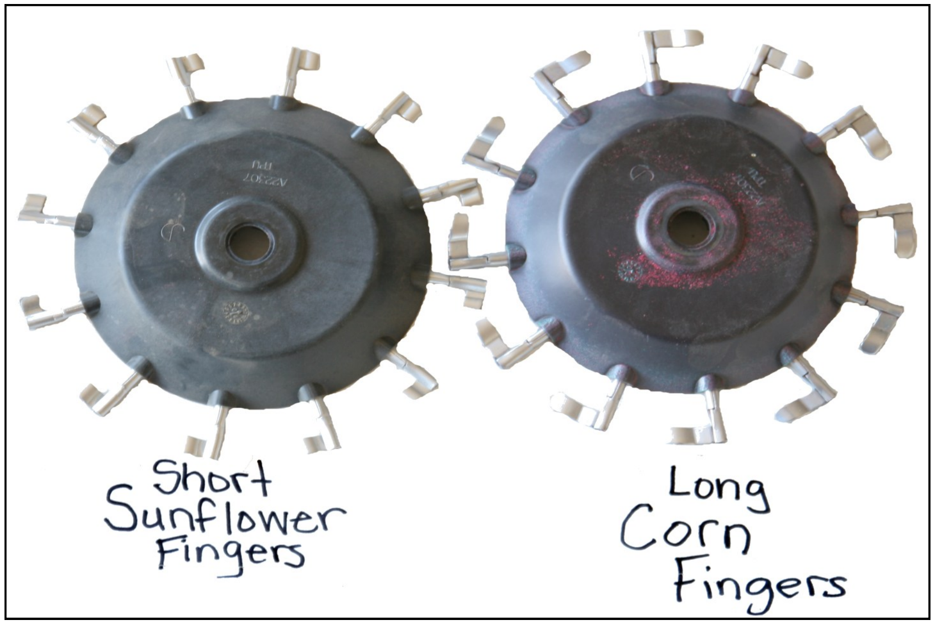

Figure 2-6. Finger pickups designed for sunflower (left) and corn (right).

Seeding Rates & Populations
Sunflower head size, height, and seed size are influenced by population density, which in turn causes a number of other responses in lodging rates and oil contents. With higher plant populations, head size, seed size and the number of seeds per head generally decrease. However, increased plant populations cause oil content to increase and plants to grow taller to compete for sunlight (Figure 2-7).

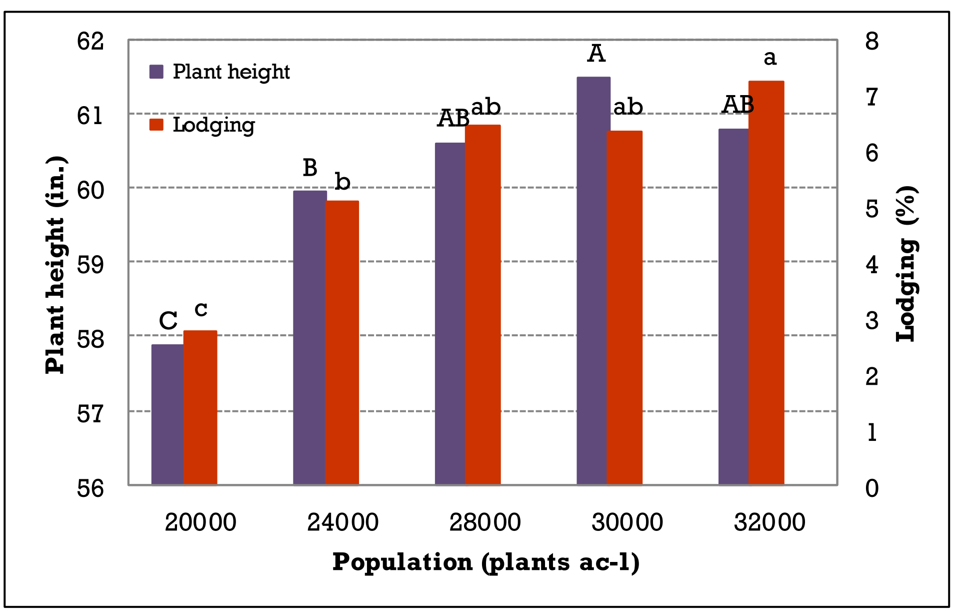

Figure 2-7. Effects of population on plant height and lodging, combined 2010-2012 UVM Extension data. ***Treatments that share a letter did not differ significantly from one another (p=0.10, compare capital letters for plant height and lower-case letters for lodging).***

Because of the plasticity of many of these plant stand characteristics, seed and oil yields are roughly equivalent over a wide range of seeding rates. However, changes in head size and seed size could have an effect on bird damage, insect predation, oil content, and perhaps most notably, drying rate, which in turn influences harvest date and seed drying time. As population increases, head width decreases, and drying time is shortened. At harvest time, moisture remains higher in sunflower stands with wider heads, or lower populations (Figure 2-8, page 16).

Harvest populations between 28,000 and 30,000 plants per acre have been shown to provide the greatest yields in re-

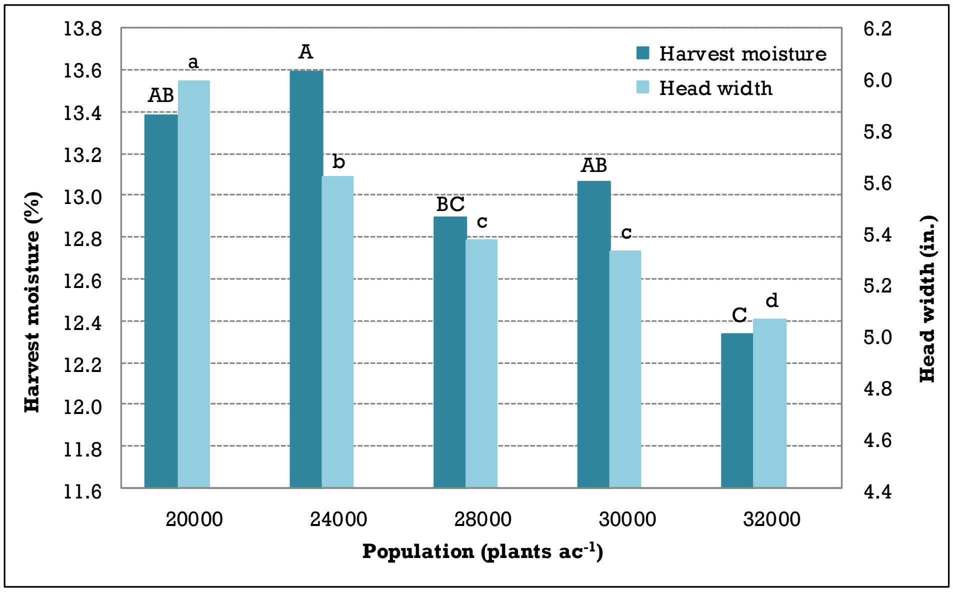

Figure 2-8. Effects of population on harvest moisture and head width, combined 2010-2012 UVM Extension data. ***Treatments that share a letter did not differ significantly from one another (p=0.10, compare capital letters for harvest moisture and lower-case letters for head width).***

cent UVM Extension trials. Additionally, populations between 28,000 and 30,000 plants per acre produce sunflower head sizes that are small enough to dry well, but large enough to encourage bending over to protect seeds from birds.

<u>*Row Spacing*</u>

The standard row spacing for sunflowers in our region is dictated by the available planting, cultivation and harvest equipment, most of which operates on 30-inch rows. Though planting in narrower rows confers some advantages such as reducing competition between individuals and reducing weed pressure by achieving more canopy closure, narrower rows can also lead to higher incidence of fungal pathogens due to higher humidity beneath the canopy. Thirty-inch rows relieve some of the pressure of fungal diseases by allowing more air circulation while still achieving adequate yields.

Where some flexibility exists and fungal diseases are less threatening, narrowing the rows while maintaining the total population would achieve a more even distribution of plants across the field and can result in higher yields.

RULE OF THUMB

In order to achieve a harvest population of 28,000 plants per acre, seeding rates must take into account the germination rate and any other expected reductions in plant population before harvest (loss from cultivation, disease, pests, etc). Gathering information like germination rate and taking note of the particular pest pressures and yield limiting factors in your fields will help you calculate an appropriate seeding rate. Producers can use the following equation to calculate the seeding rate (SR) needed to reach a desired harvest population (HP):

SR (seeds/acre) = HP (plants/acre) / [GR x (1-ASL)],

where GR is the germination rate (usually 90%) and ASL is the total Anticipated Stand Loss to cultivation, pests, and disease, both expressed as decimals (90% = 0.90, 15% = 0.15).

To achieve a stand of 28,000 plants given a germination rate of 90% and an anticipated loss of 5% from cultivation and 5% from Sclerotinia head rot...

Seeding Rate = 28,000/[0.90 x (1- 0.10)] = 34,567 seeds per acre.



3. PEST MANAGEMENT

Though sunflowers are a fairly new field crop to the Northeast, a variety of pests already exist and show signs of economic significance. Sunflower crops grown in research trials have shown susceptibility to weeds, insects, and diseases. Many of the significant pests that plague sunflower crops in the Plains do not occur in our region. However, those that do exist here can cause significant crop loss, and careful attention to management of sunflower crops is critical to keep these pests under control. This section provides identification guides for major pests and tools for their management.

The various strategies for pest management can be grouped into four categories: cultural, mechanical, chemical and biological. Several tools exist within each category, but not all options make economic or agronomic sense in every case. As a general rule of thumb, preventative pest management is far more effective and costs less than reactive pest management.

The most effective tool against pests of all kinds is a carefully planned rotation of sunflowers with grass and other broadleaf crops. Virtually every production guide in the U.S. recommends rotations that call for sunflowers to be planted in a field once every three to five years, and this is appropriate for the Northeast as well. Where levels of serious and destructive pests are high, periods of five to seven years are recommended between successive sunflower crops until pressure subsides. In the Plains, where sunflowers are grown on a much larger scale, pests are not generally mobile enough to move between fields. In Vermont, fields tend to be small, close together, and surrounded by hedgerows that can act as refuges for many pests. Therefore, insect and fungal pests are generally able to spread between fields, and it is important to provide enough space and time between successive sunflower crops that movement of those pests is limited.

In addition to good rotations, other agronomic practices can help reduce pest pressure. Row spacing and stand density have a strong influence over the microclimate conditions under the sunflower canopy. Where plants are dense and rows narrow, humidity near the soil surface can become very high, which provides better conditions for fungal infections. As rows widen and plant spacing increases, however, conditions become better for weeds that can compete with sunflower. Thirty-inch rows seem to be the best compromise for reducing fungal pressure but also keeping weeds at bay.

Planting and harvesting sunflowers earlier than normal can help avoid damage from certain pests such as banded sunflower moth and migratory birds, which only cause damage to the plant at certain times in the sunflower's development. By altering the time during the season when the sunflower reaches each stage, these sorts of pests can be avoided. However, because sunflowers require fairly warm soils to germinate, planting them earlier may not always be feasible. Harvesting earlier, when the combine can process the wet head, can lessen the damage from migratory birds, though the added cost of drying seed after harvesting must be considered.

Major Insect Pests

Currently, only a few insects are known to cause economic injury to sunflower crops in the Northeast. However, as sunflowers become more widespread additional insect pests are likely to cause damage to this crop. Several insects that have become significant pests in other regions are able to survive here, but have not yet been seen in our sunflower crops. Only banded sunflower moth has shown itself to cause serious crop injury thus far. However, sunflower midge is also present, and can cause yield problems on a field-by-field basis. There are several other common pests that do not cause crop injury, but should be identified and monitored.

Minor Insect Pests

Sunflower Maggot
Strauzia longipennis

Sunflower maggot fly is small (1/4–1/2") and yellow with brown striping on the wings that forms a distinct F-shape near the edge. The adults emerge from the soil in mid- to late-June and are highly active throughout the day. These small flies lay eggs on the stem of the flowers and the maggots hatch and then burrow their way into the stems, feeding on the pith at the center of the stem (Figure 3-4). Infestation rates are typically very high; in any given field, 60%-90% of plants will have 1-10 sunflower maggots in the stalk. However, because the pith is not responsible for any movement of nutrients up and down the stalk or for contributing to the strength of the stalk, the sunflower maggots cause the plant no real harm.

Figure 3-4. Sunflower maggot in stem pith.

Lygus bug
Lygus spp.

Lygus bugs, also called tarnished plant bugs, are very common in Vermont in virtually all vegetable and fruit crops (Figure 3-5, page 19). In sunflower they feed on developing flowers, which results in brown spots on the seed inside the husk. While this presents a significant problem for confection sunflower seeds, no yield loss in seed weight or oil has been observed even with heavy infestations of tarnished plant bug, and therefore there are

Banded Sunflower Moth
Cochylis hospes

Figure 3-1. Adult banded sunflower moth stuck on a trap.

Identification & Signs of Damage

The adult stage of this small moth can be identified by the dark brown stripe through the middle of the light beige-brown wings (Figure 3-1). The moths are typically 1/4" - 3/8" long as adults. Larvae are a creamy off-white, turning red and then green as they grow toward their pupal stage, and are around 0.5" by the time they emerge from the head. Banded sunflower moth damage results in empty seed hulls, where the larvae have eaten the contents and then exited through the hole at the top of the seed. Presence of the larvae is revealed by loose webbing over the top of the florets in the area where the larvae are eating seeds. The larvae leave the hulls intact and attached to the head, which may lead scouting efforts astray without careful attention to the condition of the seeds.

Life cycle

Banded sunflower moths overwinter in the soil as pupae, emerging from the ground in early to mid-July over the course of 3 to 4 weeks, laying eggs within a week of emergence. They favor field edges, especially where there are grassy and shrubby field margins. Adults are most active in the early morning and late afternoon, though they can occasionally be found on the plants' upper leaves during the middle of the day. Adults will typically lay eggs on the upper leaves and developing flower bud. As larvae hatch, they move to the interior of the bud, and begin feeding on developing florets, and eventually on seeds themselves as they grow (Figure 3-2). Their presence is difficult to detect until well into the reproductive phase (R 5.9-6.0), when larvae create loose white webbing over seeds that they have consumed. As the seeds begin to mature, larvae can be seen moving between seeds, and their exit holes can be seen in the top of the seed husk. Larvae emerge and drop to the soil to pupate sometime before the seeds reach physiological maturity.

Figure 3-2. Larvae will burrow into seed to feed.

Sunflower Midge
Contarinia schulzi

Identification & Signs of Damage
Sunflower midge is a small gnat-like insect (just over 1/16") that is difficult to spot in the field, with transparent wings and a tan, striped body. Maggots are very small as well (just under 1/8"), and are initially found along the edge of the sunflower head, between the bracts and the florets.

Sunflower midge maggots feed on tissue between the bracts and the head, slowly migrating into the center of the head as the florets mature. The initial result is dead tissue along the edges. As the maggots migrate into the head, their feeding causes the head to cup toward the center, and seeds will not develop properly (Figure 3-3). In severe infestations, the head will be almost completely closed, the receptacle enlarged, and there will be no seeds in the head. Damage from sunflower midge in Vermont is not widespread; most fields have only low levels of midge infestation. However, where sunflower midge does exist in high populations, significant percentages of the flowers (10-15%) can be cupped strongly enough to reduce seed development and complicate harvesting.

Figure 3-3. Sunflower midge damage.

Life Cycle
Sunflower midge, like banded sunflower moth, overwinters in the soil as pupae, and then emerge in June and July. The adults lay eggs along the bracts, and maggots migrate toward the center as the florets mature. The larval feeding results in necrotic tissue, which, in high midge populations, can lead to strong cupping of the head and poor seed development. As the maggots grow, they drop to the ground to pupate. Some of these will undergo a second generation in the fall, but there is no damage from these maggots, since there are no longer sunflowers in the ground to serve as hosts.

no established control measures in oilseed sunflower.

Management of Insect Pests

Cultural Controls
Banded sunflower moth is currently the most problematic insect pest in sunflower fields in Vermont. It is extremely widespread, and overwinters in our soils and field margins. The best management option is a good rotation where successive crops are located far enough from each other that the number of moths that can move between the fields is limited. Deep fall plowing after sunflower harvest has also been shown to reduce emergence of the adults by up to 80%, but that strategy can be costly in fuel and time, and is not practical for every field. Recent research suggests that delaying planting dates to early June may also reduce banded sunflower moth incidence and severity.

No regional methods have yet been developed for scouting for sunflower midge. Management options are limited, though rotation will help keep midge populations fairly low, since the adults are small enough to be limited in their mobility.

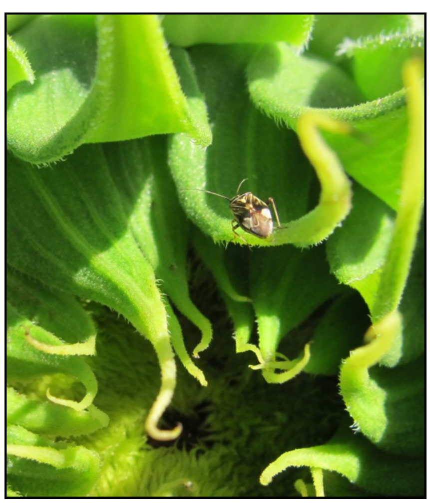

Figure 3-5. Lygus bug.

Chemical Controls
Applying insecticides is not a common practice in sunflowers in the Northeast. One of the main reasons for this is the lack of equipment in the area capable of spraying plants at the correct stage without damaging the crop. Most insect pests that cause serious damage reach critical life stages when the flower bud forms, or when the plant is just starting to flower, which generally means the plant is too tall and too delicate for commonly owned equipment in our area. The sunflow-

ers themselves are particularly sensitive at the growth stage in which the adult moths emerge, because the buds have begun to elongate, but still have not opened; they are therefore exposed and susceptible to damage that can reduce seed yield. Nevertheless, there is currently at least one insect pest that causes economic injury, and could warrant spraying insecticides (Table 3-1). Chemical management is limited to the adult stage, because the larvae are inside the head and seeds, and thus protected from insecticides.

Extreme care must be taken to avoid spraying insecticides during periods when pollinators are present, as many of these insecticides also kill pollinators such as honeybees. Because sunflowers are attractive to pollinators and many beneficial insect populations, pest management measures should take into consideration the resident insect populations in a field. There are many insecticides currently registered in Vermont for use in sunflowers, not all of which control important pests.

Biological Controls

Biological control of insect pests is not particularly common in sunflowers, and essentially non-existent as an active practice in Vermont and the Northeast. Keeping beneficial insects in sunflower fields can be extremely effective against insect pests; ladybeetles, lacewings, and hoverflies (syrphid flies) all have predatory stages, and feed on problematic insects.

Major Sunflower Diseases

Unlike most other sunflower growing regions, our climate is characterized by fairly wet growing seasons, especially in the spring and fall. This leads to high soil moistures throughout the summer, and consequently a large number of fungal diseases that can present problems for sunflower growers. The *Sclerotinia* group of fungal diseases is particularly devastating in all crops it infects, and sunflowers are no exception. Because of our humid climate, special attention needs to be paid to managing fungal diseases of all kinds, because they can also have serious effects on other crops in the cropping system.

Minor Sunflower Diseases

Verticillium

Verticillium is a common fungal disease in vegetables, and

Table 3-1. Insecticides currently registered for use in Vermont sunflowers, 2013. Check with your local Extension agent or State Agency of Agricutlure for up-to-date information on pesticide use.

Trade name	Active ingredient	EPA registration numbers	Controls: Banded Sunflower Moth	Controls: Sunflower Midge
Baythroid XL	beta-Cyfluthrin	264-840	Yes	Yes
Sevin 80S	Carbaryl	264-316	No	No
Chlorpyrifos 4E AG, Lorsban 4E, War-	Chlorpyrifos	66222-19, 62719-220, 34704-857, 62719-220-1381	Yes	No
Cobalt Advanced	Chlorpyrifos + lambda-Cyhalothrin	62719-615	Yes	No
Stallion	Chlorpyrifos + zeta-Cypermethrin	279-9545	Yes	No
Tombstone, Tomb-	Cyfluthrin	34704-912, 34704-978	Yes	Yes
Asana XL	Esfenvalerate	352-515	Yes	No
Declare	gamma-Cyhalothrin	67760-96	Yes	No
Lambda-Cy EC, Silencer, Grizzly Z, Nufarm Lambda-Cyhalothrin 1EC, Warrior with Zeon Technology, Warrior II with Zeon Technol-	lambda-Cyhalothrin	70506-121, 66222-104, 1381-211, 228-708, 100-1112, 100-1295	Yes	No
Cruiser 5FS	Thiamethoxam	100-941	No	No

a consistent problem in the Midwest, though it has not been positively identified in Vermont sunflowers to date. It is likely, however, that at some point Verticillium will become an issue in our region. Many of the same management concepts apply to controlling Verticillium. Rotation with non-susceptible crops is the best tool for managing disease problems.

Downy Mildew
While downy mildew can be a serious problem in sunflowers, especially in our wet climate, the advent and use of resistant hybrids has greatly diminished the potential that downy mildew can cause serious economic crop loss. Hybrids that contain this trait are labeled "Downy Mildew Resistant" or "DMR". New races of downy mildew are occurring regularly and often require fungicide treatment because resistant varieties have yet to be developed.

Sclerotinia Head Rot

Identification & Signs of Damage
In sunflower, *Sclerotinia* head rot is one of three forms of infection by the *Sclerotinia* fungus. This form develops late in the season, usually after physiological maturity is reached. Early signs of infection are given by sections of the back of the head that turn pink and soft while the face will have a fungal mass and swollen receptacle tissue pushing out between and engulfing the seeds. Eventually the sunflower receptacle tissue and seeds give way to the fungus, and the head is left a skeleton that contains only the sclerotia, the dormant fungal bodies of the *Sclerotinia* fungus (Figure 3-6).

Figure 3-6. Sclerotinia head rot. Note black sclerotia inside head.

Lifecycle
Sclerotinia overwinters as small black fruiting bodies called sclerotia that can lie dormant in the soil for as many as six years. They resemble small rocks or clods of soil. Each spring, some of the sclerotia in the soil germinate and release spores due to moisture or temperature cues, some release spores when the roots of host plants come in contact with them, and others continue to lie dormant. These spores float up to the sunflower canopy where they land on dead or decaying plant tissue (usually dead florets), and grow to infect the head. Rainy and humid conditions in the fall seem to be prime conditions for *Sclerotinia*; infection rates are higher in wet falls than in dry seasons. Once the head is fully infected, the resulting skeleton drops the fruiting bodies into the soil or they are scattered during harvest.

Management of Disease

Cultural Controls
Eliminating *Sclerotinia* from a heavily infested field can be very difficult, but a few basic principles will help keep new fields disease-free and fungal populations in old fields under control. The best tool for managing *Sclerotinia* is a well-planned rotation that employs crops that are not susceptible (i.e. grasses) and long periods between successive sunflower crops. For disease-free fields, sunflower should be planted no more than every 4 years in the same field, with other *Sclerotinia*-susceptible crops (essentially all broadleaf crops) making only rare appearances.

If fields are heavily infested with *Sclerotinia*, more grass crops should be used in place of broadleaf crops to allow more time for the sclerotia to be consumed in the soil, and time between sunflower crops should be increased to six years. Sclerotia can linger in soils and also be difficult to remove from harvested seeds (Figure 3-8, page 22).

Some preliminary research and anecdotal evidence suggests that spores can spread several hundred feet with enough concentration to infect new plants. As a result, yearly rotations should also ensure that successive sunflower crops are not located in adjacent fields.

Chemical Controls
Fungicides are common as seed treatments, but are usually not sprayed after the crop has emerged, though several fungicides are registered. The most common seed treatment is a combination of the following three fungicides: mefenoxam, azoxystrobin, and fludioxonil. Table 3-2 (page provides a list of registered fungicides for use in sunflow-

Sclerotinia Stalk and Base Rot

Identification & Signs of Damage

Sclerotinia stalk rot is fairly uncommon in our area, while base rot is nearly as common as head rot. The fungus is the same, and therefore the diseases are interchangeable and likely to change forms season-to-season and plant-to-plant. Stalk and base rots generally strike as the flowering stage is coming to a close, considerably earlier in the season than head rot. Both are characterized by tan lesions on the stem, dotted with small white fungal masses and, eventually, black sclerotia on the outside and inside of the stalk (Figure 3-7). Without walking through the field, stalk and base rots are hard to detect until they are advanced, because they generally can only be seen once the plant has died and the heads have browned.

Figure 3-7. Sclerotinia stalk rot, with telltale black sclerotia, white fungal bodies, and tan lesions.

Lifecycle

The lifecycle of stalk and base rot is the same as head rot, with the exception that sunflowers can contract *Sclerotinia* base rot through the roots. Additionally, base rot can travel from plant to plant through roots that are in contact with one another, infecting plants along the row.

Figure 3-8. Sclerotia bodies, seen above, are often similar in size and shape to sunflower, and can be difficult to remove during cleaning.

ers in Vermont. All of the fungicides listed control downy mildew, which is helpful if planting non-resistant varieties, but do not combat *Sclerotinia* diseases.

Table 3-2. Fungicides registered for use in Vermont sunflowers, 2013. Check with your local Extension agent or State Agency of Agriculture for up-to-date information on pesticide use.

Trade name	Active ingredient	EPA registration numbers	Controls: Downy	Controls: *Sclerotinia*
Dynasty, Quadris Flowable	Azoxystrobin	100-1159, 100-1098	Yes	No
Maxim 4FS	Fludioxonil	100-758	Yes	No
Apron XL	Mefenoxam	100-799	Yes	No
Fosphite	Phosphorus Salts	68573-2	Yes	No
Headline	Pyraclostrobin	7969-186	Yes	No

Biological Controls

The only actively applied biological agent for pest management is Contans®, a fungus that parasitizes the dormant fungal bodies of *Sclerotinia*. Though it is not as effective as well-planned rotations, Contans® is organic-certified and does reduce the number of sclerotia in the soil. Contans® does not fully eliminate them or prevent *Sclerotinia* infestations in the field, however, so it should not be used as a substitute for other management tools, but can be helpful where *Sclerotinia* is well-established.

Major Weed Pests

Broadleaves

Broadleaf weeds can be very difficult to control once the sunflower crop has emerged, because standard broadleaf herbicide options will target sunflowers as well as weeds. Fortunately, sunflowers are fairly hardy and respond favorably to mechanical cultivation, and once sunflowers begin to approach canopy closure (around V-8), they grow rapidly and easily outcompete weeds. The best conventional weed control strategies involve pre-plant herbicides followed by several cultivations to eliminate weeds. There are several particularly problematic weeds that share many physiological qualities with sunflower and therefore thrive in fields (Figure 3-9). Management of these weeds is treated collectively because of their similarity in growth habit.

Lambsquarters
This familiar weed is characterized by its alternate, triangular-shaped leaves, its pale green flowers that grow from junctions between the main stem and branches, the striped appearance of the main stem itself, and its tall, coarse growth habit (Figure 3-10). It is an annual weed that is quick to sprout on bare soil, and is therefore common in almost every broadleaf crop. It grows very quickly, and can reach heights of four feet or more by the end of the growing season. It produces thousands of seeds per year that are viable for long periods of time in the soil.

Redroot Pigweed
This weed is also commonplace in both broadleaf and grass crops, and is similar in appearance to lambsquarter. It is a member of the amaranth family, and like most of its relatives, it produces huge numbers of small seeds that sprout easily. It is a deep-rooted annual with a robust stem that survives cultivation well, especially if conditions are slightly wet (Figure 3-11).

CROP ROTATION IS KEY!

Reducing disease depends on careful field management. Possible four- and five-year rotations could look something like this:

Year	Crop	Susceptibility
1	Sunflower	High
2	Small Grain	None
3	Hay/Alfalfa	Moderate
4	Corn	None

Year	Crop	Susceptibility
1	Sunflower	High
2	Small Grain	None
3	Alfalfa	Moderate
4	Corn	None
5	Small Grain	None

Mustards
Unlike lambsquarters and redroot pigweed, mustards are not particularly coarse-stemmed, but they have an uncommon ability to redirect their growth and stand up after cultivation, unless conditions are perfect.

Figure 3-9. Serious weed pressure can decrease yields and make harvesting sunflowers very difficult.

Figure 3-10. Common lambsquarters, *Chenopodium album*.

Grasses
In conventional sunflower systems, grasses are not particularly problematic because there are many useful herbicide options. However, in organic systems perennial rhizomatous grasses such as quackgrass can cause real yield issues because they are not controlled well by cultivation. Tineweeding can be effective in sunflower fields to reduce grass weed pressure.

Figure 3-11. Redroot pigweed, *Amaranthus retroflexus*.

Management of Weeds

Mechanical Controls
Sunflowers can stand up well to a variety of types of mechanical cultivation. Producers in Vermont will often cultivate two or three times with relatively low crop loss. Cultivation

with a tineweeder can be a successful method for weed control in sunflowers, both pre- and post-emergence (Figure 3-12). Trials conducted in VT indicate that cultivation with a rear-mounted tineweeder at both 6 (pre emergence) and 12 (post emergence) days after planting can provide weed control similar in effectiveness to herbicide (Figure 3-13; Table 3-3, page 25). Timing of tineweeding is very important to achieve maximum weed control. The best time to tineweed is when the weeds are in the white thread stage and have yet to emerge. Once the weeds have emerged and become established removal with a tineweeder becomes more difficult. At this stage the tineweeding must become more aggressive and as a result can also lead to crop loss. Higher seeding rates should be used if mechanical cultivation is used for weed control in sunflowers. (Table 3-3, page 25).

Standard cultivation equipment such as row crop cultivators or spring-toothed harrows are highly successful at eliminating weeds between rows, but in-row weeds can remain problematic after using these implements. Generally, two cultivations before the sunflowers reach V-6 or V-8 is sufficient to eliminate weeds for the rest of the season. Often cover crops are seeded at the time of final cultivation. Seeding a cover crop at this stage will not interrupt sunflower growth. Canopy closure occurs around V-10, after which pressure from newly establishing weeds is nearly non-existent.

Tineweeding is extremely effective at eliminating weeds when they are just germinating, and row crop cultivators remove weeds between rows very efficiently. Because herbicide options to control broadleaf weeds after sunflower has been planted are limited, most producers rely heavily on cultivation after sunflower emergence. In organic systems, strong rotations and cover crops become equally important elements of the weed control strategy.

Figure 3-12. Rear-mounted tineweeder.

Chemical Controls

Because sunflower is a broadleaf crop, herbicide options for broadleaf weed control are limited, and are essentially restricted to pre-plant incorporated herbicides that have relatively short periods of activity in the soil. As mentioned earlier there are also herbicide tolerant varieties (Clearfield; ExpressSun) that can also be used to assist with postemergence broadleaf weed control. Herbicide options for annual and perennial grass weeds are fairly extensive (Table 3-4, page 25). However, care must be taken to ensure that these are registered for use in sunflowers and will not cause damage to the crop. Most of the herbi-

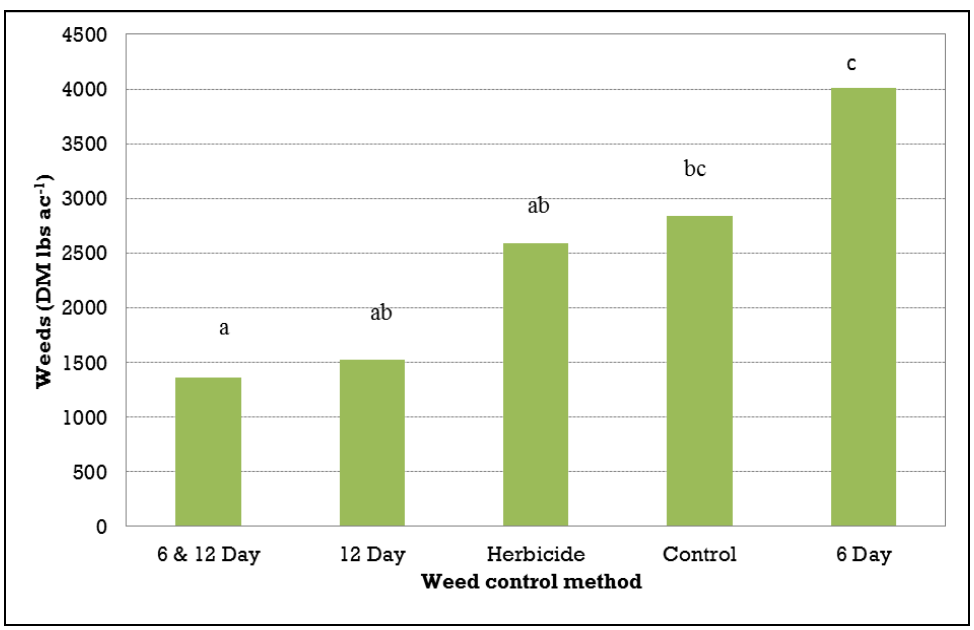

Figure 3-13. Effects of tineweeding and chemical controls on weed populations, 2010 data, UVM Extension.

Table 3-3. Effectiveness of tineweeding and its timing on population and yield (DAP = days after planting), 2011.

Weed Treatment	Harvest Population	Sunflower Yield		Weed Biomass
	(plants/acre)	(lbs/ ac)	(bu/ ac)	(lbs/ac)
Tineweeded 6 DAP	20,700	2,176	77.7	1,133
Tineweeded 12 DAP	20,400	2,108	75.3	1,218
Tineweeded 6 & 12 DAP	18,800	2,075	74.1	505
Control	21,900	2,170	77.5	1,821
Herbicide	22,900	2,482	88.6	594
Mean	20,990	2,200	78.6	1,050

cides that are registered for use in sunflowers should be applied pre-planting, and many have strict guidelines about incorporation. Always closely follow the directions found in the label and contact your local Extension agency or herbicide dealer for more information.

Sunflower Bird Pests

Birds are a highly problematic pest in all sunflower systems. They are mobile, they can eat huge amounts of seed, and they typically travel in large flocks that can collectively cause serious devastation (Figure 3-14, page 26). In Vermont, birds are especially de-

Table 3-4. Herbicides registered for use in sunflowers in Vermont, 2013. Check with your local Extension agent or State Agency of Ag for up-to-date information on pesticide use.

Tradename	Active Ingredient	EPA registration numbers	Sunflower Growth stage applied	Weed group control
Micro-Tech	Alachlor	524-344	Pre-plant, pre-emerge	Germinating annual grasses and broadleafs
Aim EC	Carfentrazone-ethyl	279-3241	Pre-plant	Newly established grass & broadleaf; non-selective
Clethodim	Clethodim	42750-72-72693	Any	Growing annual & perennial
Sonalan HFP	Ethalfluralin	62719-188	Pre-plant (spring or fall)	Germinating annual grasses & some broadleaves
Roundup Original MAX, Roundup PowerMAX, Roundup WeatherMAX,	Glyphosate (Potassium Salt)	524-445, 524-549, 524-537, 100-1121	Pre-plant, pre-emerge, pre-harvest desiccant	Established grass & broadleaf; non-selective
Duramax/Durango DMA	Glyphosate Diethylamine Salt	62719-556	Pre-plant, pre-emerge, pre-harvest desiccant	Established grass & broadleaf; non-selective
Durango, Glyphomax Plus, Honcho Plus, Glyphosate 41 Plus	Glyphosate Isopropylamine Salt	62719-517, 62719-322, 524-454, 42750-61-72693	Pre-plant, pre-emerge, pre-harvest desiccant	Established grass & broadleaf; non-selective
Beyond*	Imazamox Ammonium Salt*	241-379	Post-emergence	Broadleaf weeds*
Gramoxone, Helmquat 3SL	Paraquat Dichloride	100-1217, 74530-32	Pre-plant, pre-emerge, pre-harvest desiccant	Established grass & broadleaf; non-selective
Prowl H20, Prowl 3.3 EC	Pendimethalin	241-418, 241-337	Pre-plant (fall)	Germinating annual grasses & some broadleafs
Assure II	Quizalofop p-Ethyl	352-541	Any	Established annual & perennial grasses
Sharpen	Saflufenacil	7969-278	Pre-harvest desiccant	Established broadleafs
Poast	Sethoxydim	7969-58	Any	Annual grasses
Dual Magnum/ Medal EC	S-Metolachlor	100-816	Pre-plant, pre-emerge	Germinating annual grasses & some broadleaf
Spartan 4F	Sulfentrazone	279-3220	Pre-plant (fall or spring)	Small seeded broadleaf and sedges
Trust, Treflan TR-10, Dintec Treflan 4D	Trifluralin	1381-146, 62719-131, 68156-4	Pre-plant	Germinating annual grasses & some broadleafs

* Only for use in Clearfield sunflowers

Figure 3-14. Bird damage reduces yield drastically in Vermont sunflower crops.

structive because our small fields, typically bordered by hedgerows, provide the perfect food with nearby shelter from predators (Figure 3-15). On a field scale, physical protection such as netting is not generally feasible, and therefore deterrents are the best option. Cannons, squawk boxes, scarecrows, eye-spot balloons and shiny ribbons can be effective for short periods of time. However, birds will become accustomed to each of these tactics fairly quickly; they need to be moved regularly and used in combinations in order to stay unpredictable to the birds.

<u>*American Goldfinches*</u>

American goldfinches are common birds in our area in fields, hedgerows and at bird feeders. During the spring and summer, male goldfinches are bright yellow, except for their black foreheads and black wings with white markings. Females are slightly drabber in coloration, with an olive hue on their upper body. American goldfinches are late breeders, generally nesting in late June and early July. During this time, they feed on seeds almost exclusively, usually of plants in the sunflower family (e.g. thistles) and of alder, birch and elm trees. Though they are mostly year-round residents and do not migrate, concentrated flocks of immature and adult goldfinches form in late September and early October (once the breeding season is over) in search of food for winter fat reserves.

<u>*Red-winged Blackbirds*</u>

The glossy black color and bright red and yellow shoulder patches of male red-winged blackbirds are hard to mistake. They are arguably the most common bird in North America, and are also one of the most visible. They commonly sit on high perches in fields, on telephone wires, and anywhere else that they can be noticed easily. Red-winged blackbirds generally begin their fall migration in late October and November – in northern Vermont, migrations begin at the earlier end of that range, while in southern Vermont, flocks form around the first of November. Occasionally, large flocks (mostly of males) will form during the final two weeks of August, and move short distances south before beginning the bulk of their migration with the rest of the population. Males double fat reserves shortly before beginning migration.

Management of Birds

Because flocks of goldfinches and red-winged blackbirds are typically at their peak activity just as sunflower seeds reach maturity, but while the plants are still too wet for harvest, the birds can do significant damage. Taking the sunflowers out of the field before the birds become problematic is not practical, since combines generally cannot remove seed

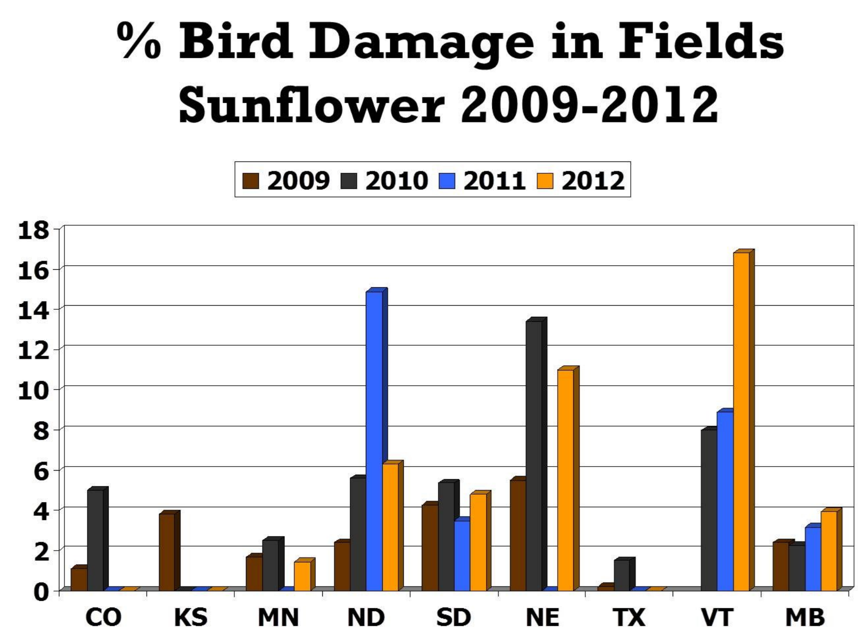

Figure 3-15. Average bird damage in Vermont, as compared to other sunflower-producing regions, 2009-2012 (*Kandel, 2012*).

from the sunflower head until it has dried down significantly. There are a few strategies to protect the crop from birds while the sunflowers dry down.

Cultural Controls

Scare tactics can be effective, but only with heavy management (Figure 3-16). Goldfinches and blackbirds are both highly intelligent, and become accustomed to scare tactics quickly. Scarecrows, eye-spot balloons and shiny ribbons need to be moved around the field on a daily or every other day basis. Cannons and squawk boxes need to go off at random intervals, and should also be moved around the field to different spots on a regular basis. While these tactics will not eliminate crop losses to birds, they can reduce losses by shortening the time birds feed in the field. Unfortunately, quantifying the gain from such devices is difficult.

A second strategy is to select varieties that have large and flat enough heads to fully bend over as the plant dries. It is much easier for birds to feed on sunflower heads that are still standing vertical, because they are able to perch easily and access the entire head. As the head becomes horizontal and parallel to the ground (face down) the birds only have access to the very edge of the head (Figure 3-17). This trait, though controlled genetically, is not currently selected for in varieties.

Some producers have also opted to deal with the amount of crop that a bird flock eats by planting additional acres of sunflowers. A bird flock of a certain size can only eat an amount proportionate to the size of the flock. An extra few acres, therefore, can accommodate that loss.

Lastly, preliminary evidence suggests that planting dates can be manipulated to avoid bird populations. Planting dates pushed into the first part of June tend to have less bird damage than sunflowers planted in mid-May. More research needs to be conducted to better understand the relationship between planting date and bird damage in sunflowers.

Figure 3-16. Some farmers deter birds with "scary eye" balloons suspended above fields; nets are only feasible on small plots.

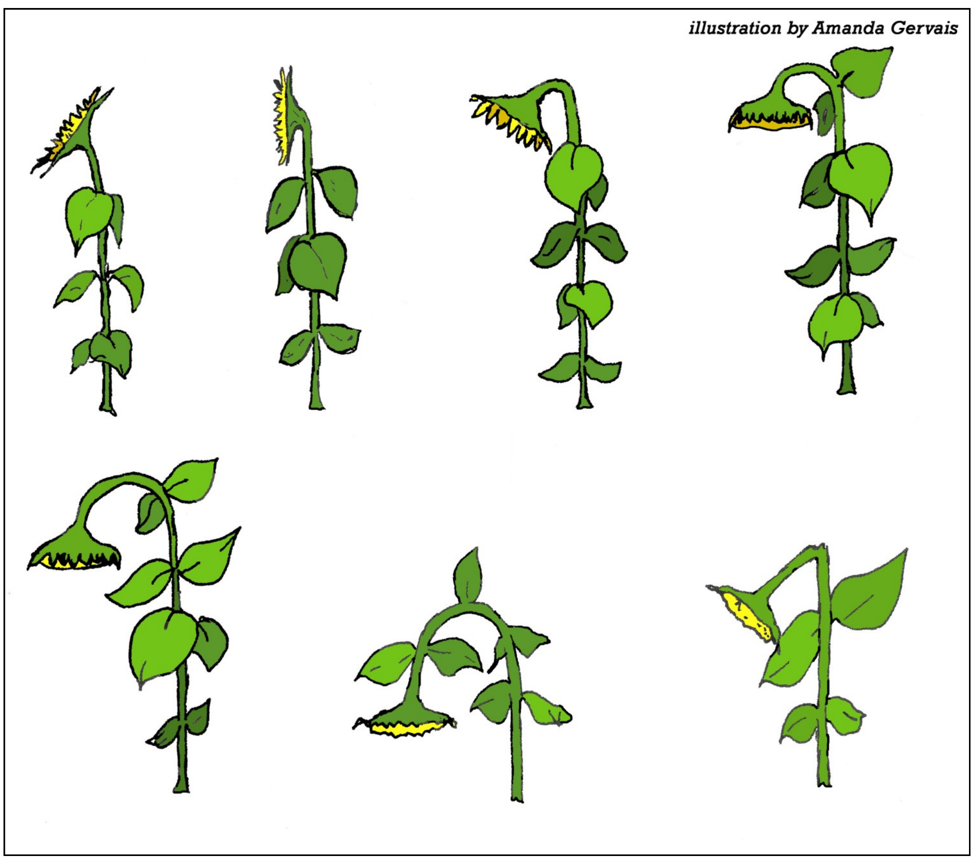

Figure 3-17. Head morphology can minimize bird damage. Large, drooping sunflower heads are more difficult for most birds to access.

4. HARVESTING PRACTICES

Timing the harvest correctly is essential not only to getting the most seed possible, but also to getting the highest quality seed and oil from the crop. Seed harvested before the head is dry will cause the wet tissue to clog up the combine, the seed will not thresh out of the head easily, and the trash will not separate well from the seed. Harvested too late, the seed will break in the combine, have poor oil content, and not yield as well. Adjusting and checking the performance of the combine is as critical as calibrating the planter – without carefully adjusted equipment, the losses from shattering and seed blowing out the back of the combine quickly eat into yields.

Plant Maturity & Seed Moisture Content

In general, sunflower seeds need to be somewhere below 20% moisture in order to harvest with a combine. The limiting factor is not the seed itself as much as it is the sunflower head. In order for the combine to be able to break apart the head and thresh the seed easily, the head needs to be dry enough that the receptacle tissue is not sticking to the seed anymore. To test this, flex the seed head; the seeds should appear somewhat loose, but not so loose that they fall out immediately. Waiting too long will lead to shattering during harvest and hence yield losses. Additionally, overly dry seed will often break and be dehulled in the combine, increasing the likelihood that it will blow out the back with the lighter trash (stems, chaff, weeds and other unwanted plant material).

Harvesting Equipment

Combines with row crop heads are often used to harvest sunflowers. Row crop headers work well, however, because the chains that hold onto the sunflower stalks can keep the plant moving toward the cutter bar and thresher. Grain heads do not work well because sunflowers plants stand much higher than grains and can fall over and be lost on the ground. However, modifications can be made to a grain heads to harvest sunflower. One major adaption are catch pans. Sunflower pans are produced by many combine manufacturers. Sunflower-catch pans, are designed to catch sunflower heads as they break from the stalk and fall between rows or to the sides. While this attachment can be quite expensive, the designs can be replicated fairly easily and inexpensively on the farm (Figure 4-1).

Figure 4-2. Modified combine in action, Alburgh, VT, 2012.

Because sunflower seeds are large, light, and fairly delicate compared to many other crops, cylinder and fan settings should be much lower than with most other crops, and concave settings should be more open. As seed moisture increases, concave settings should be closed slightly, and cylinder speeds increased. Review the equipment manual's recommended settings and make the adjustments at harvest, and continue to tweak and adjust as needed depending on the particular conditions of the crop (Figure 4-2).

Figure 4-1. Left: homemade sunflower pans for a Case 660 combine (design by Roger Rainville, Borderview Research Farm); right: corn silage harvest head modified for harvesting sunflowers.

5. SEED PROCESSING AND STORAGE

Seed Cleaning

Cleaning seed before storage is critical to maintaining the quality of the seed and oil over the long term. Trash in the combined seed is mostly made up of the wet, dead florets still attached to the seed and green weed seed and residue. This wet trash can cause the seed to heat as it begins to rot or ferment in storage. Heated seed decreases oil yield and oil quality. Trash is also a source of moisture that can contribute to condensation in the storage bin and lead again to rot and mold. In addition, trash in the seed at the time of pressing can cause unnecessary wear on the oilseed press. The sunflower harvest can also contain the small black fungal bodies of sclerotia, which are difficult to separate from seed due to similar shape and weight.

Post-harvest seed cleaning is often necessary, and usually requires running the collected seed through a rotary cleaner or fanning mill (Figure 5-1).

Figure 5-1. A stationary Clipper fanning mill can be used to clean the sunflower harvest.

Seed Drying

If the sunflower crop is harvested above 12% moisture, the seed must be dried to bring the moisture down to a point where it can be stored without unnecessary risk of spoilage and reduced oil content. Measure the percentage of moisture in the crop with a moisture meter. Grain bins with perforated drying floors intended for other small grain crops are suitable for sunflower – its large, oddly-shaped seed means that a floor designed for essentially any other small grain will work. The target moisture for seed storage is between 9% and 12% – the drier end of the range is better for seed stored into the winter, while the wetter end of the spectrum is adequate for shorter-term storage (on the order of weeks).

It is best to dry sunflowers with natural air powered by a blower, in a bin designed specifically for storage and drying. Sunflowers should never be dried with air heated by open flame or exposed heat coils, for risk of fire. Small fibrous hairs on the sunflower husk often rub off and can ignite in the heat

Table 5-1. Drying times for several seed moistures and airflow rates with 47°F air at 65% relative humidity, typical for the Northeast.

Initial Seed Moisture	Airflow Rate (cfm/bu)	Drying Time
17%	1.0	648 hours (27 days)
15%	1.0	480 hours (20 days)
	0.75	720 hours (30 days)
	0.5	960 hours (40 days)
13%	1.0	336 hours (14 days)
	0.75	504 hours (21 days)
	0.5	672 hours (28 days)

Figure 5-2. A screw-in auger is perfect for drying one-ton batches.

Don't risk a fire! Avoid open flame and exposed heating coils when drying sunflower seed!

source, and then travel back to the highly flammable seed.

The required drying time varies with initial seed moisture, air temperature and relative humidity, and the volume of air moving through the seed (Table 5-1, page 29).

Small dryers that can be placed in bulk bags with the seed can dry relatively small batches of seed (a ton or less). These auger-like aerators are often physically screwed into a one-ton tote bags of seed to aerate the batch (Figure 5-2). With these dryers (and with larger dryers), special care must be taken to not over-dry the seed before pressing. Seed below 6% moisture loses oil content very quickly and can plug up the press, requiring constant maintenance.

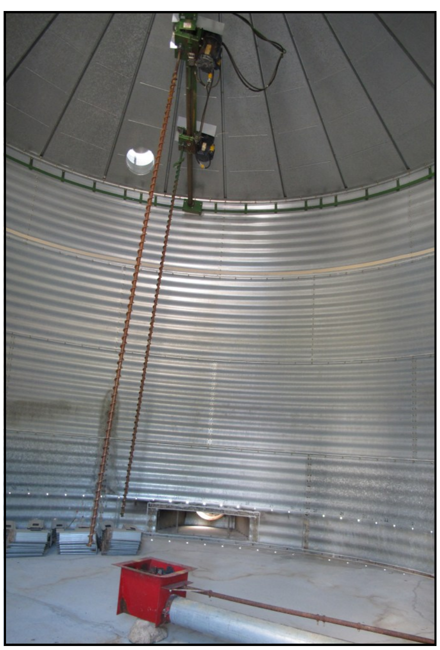

Figure 5-3. Grain bin interior. Check on seed regularly during long-term storage.

Seed Storage

Once the sunflower seed has gone into the grain bin for storage, producers should perform weekly checks for seed heating and for condensation on the bin walls and ceiling until the crop has cooled to below freezing (Figure 5-3). If any changes in humidity or temperature occur within the bin, the seed should be cooled with an aerator immediately until the bin has regained its normal condition. Once the bin and the seed have reached mid-winter temperatures, reducing checks to once per month is adequate.

CANOLA

Brassica napus , brassica rapa, brassica juncea

6. GROWTH AND DEVELOPMENT

Germination Requirements

Canola, or oilseed rape (*Brassica napus*), is a tap-rooted member of the mustard family and like its relatives, is fast growing and competes favorably with other plants. In addition to the Argentine variety that is the most common (*Brassica napus*), some agricultural varieties of Polish canola (*Brassica rapa* syn. *campestris*) exist, as well as an Argentine canola-quality mustard (*Brassica juncea*), though both are rarely commercially available in the US. However, research is underway in Canada to develop Polish canola varieties that yield as well as Argentine canola and provide other agronomic benefits. Argentine canola has been bred as both winter and summer annuals, both of which have shown some success here in Vermont. All canola varieties are very cold tolerant, and germinate well in soil temperatures as low as 38°F. This allows spring crops to be planted in mid- to late-April. Winter canola crops should be planted early enough to allow significant vegetative and root growth to reduce winterkill; for Northwestern Vermont, mid-August is usually sufficient.

Growth Stages

Growth stages of canola are divided into six major stages (0-5), all of which can be divided further for more specificity (denoted with a second digit). Though only the major stages will be discussed in detail, Table 6-1 (page 32) details all of the subdivisions of the growing stages.

Growth stage 0 occurs between germination and emergence. In our area, emergence generally occurs within 7 days in warm conditions, but can take as long as 14 days in cooler conditions. As the cotyledons unfold (stage 1), and true leaves unfold (stage 2), the plant begins to form a rosette of true leaves. The taproot begins to elongate at this point as well. For winter canola, the development of a strong rosette in the fall is important, since the plant will go dormant once the soil freezes. The next spring, plants will resume growth and develop new leaves from the crown of the plant. Energy stored in the overwintering root will be used to jump start early spring growth. Once the rosette is well-established, a flower cluster develops at the top of the main stem, which then begins to elongate.

The plant bolts as the flower develops, and by the time the plant nears its maximum height, the flower buds at the bottom of the flower cluster begin to open (Figure 6-1, page 32). As flowering progresses to the top of the cluster, flowers at the bottom drop away and the seed pods elongate. Once flowering has completed for the whole plant, the pods at the bottom have usually begun to visibly fill with seed (stage 5), which change from green to yellow to brown as they mature. Oftentimes, stages 4 and 5 occur simultaneously, so that some seeds may be mature while others are still green.

Table 6-1. Canola growth stages in detail (*Canola Council of Canada, 2011*).

Growth Stage		Description
0	Pre-emergence / Germination	The seed absorbs water and germinates, breaking the soil surface 4-10 days after planting
1	Seedling	The cotyledons unfold, but no true leaves develop
2.1	Rosette	The first true leaf expands
2.2	Rosette	The second true leaf expands
2.3, etc.	Rosette	More true leaves expand, without the stem elongating significantly. The rosette stage typically lasts through 8-10 leaves forming before stem elongation begins
3.1	Bolting	A flower cluster is visible in the center of the rosette
3.2	Bolting	The stem begins to elongate (bolt), as more of the flower cluster becomes visible
3.3	Bolting	The lower buds of the flower cluster become yellow
4.1	Flowering	Flowers at the bottom of the cluster open
4.2	Flowering	Most flowers open; bottom pods begin to elongate, with no indication of seed fill
4.3	Flowering	All flowers are open; the bottom pods begin to fill with seed
4.4	Flowering	All flowering completes; seeds in the bottom pods begin to enlarge
5.1	Ripening	Seeds in lower pods full size, translucent
5.2	Ripening	Seeds in lower pods mostly green
5.3	Ripening	Seeds in lower pods green-brown or green-yellow
5.4	Ripening	Seeds in lower pods yellow and brown
5.5	Ripening	Seeds in lower pods fully brown, plant mostly dead

Pollination

All Argentine canola varieties are highly self-compatible and require no pollinator activity to achieve high yields. However, honeybees are strongly attracted to canola, and will contribute to pollination (Figure 6-2), page 33). Polish varieties (*B. rapa*) are not self-compatible, and require pollinators to carry pollen from plant to plant. If Polish varieties become more common in the US, it will be important to understand the different pollination requirements and effects on the crop.

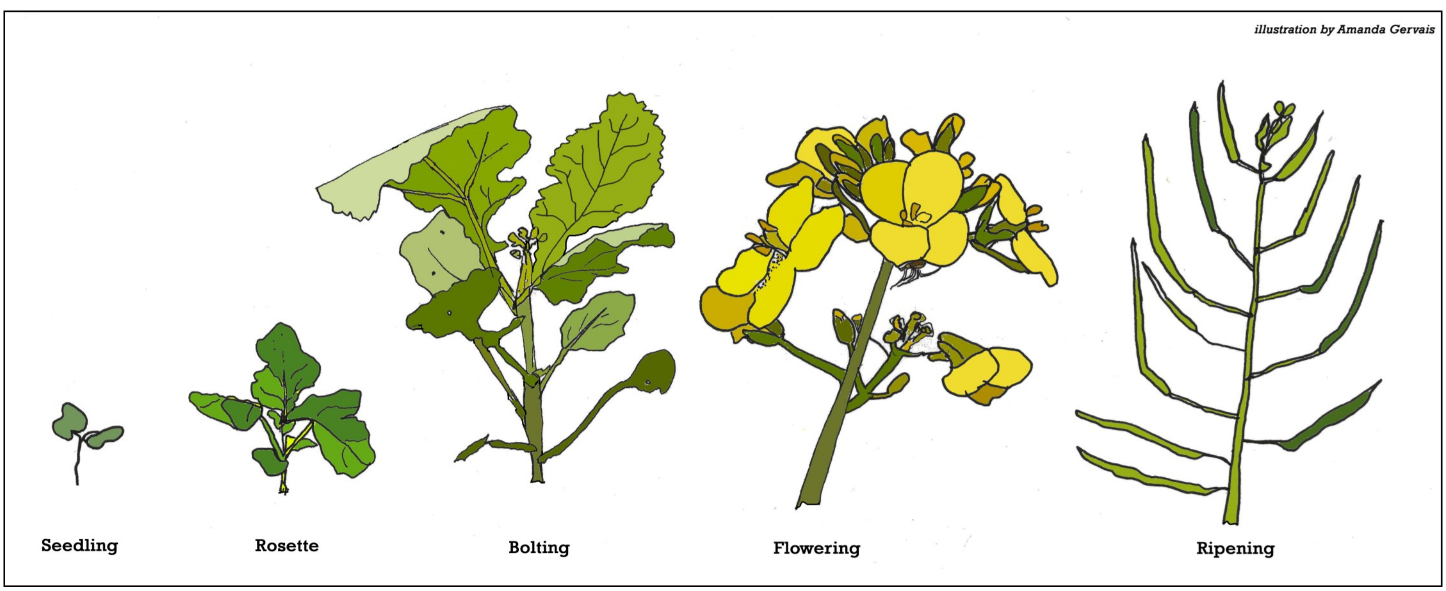

Figure 6-1. Canola growth stages.

Figure 6-2. Pollinators are attracted to canola's bright yellow flowers.

Maturation and Senescence

After all of the seeds in the pods have turned brown, the plant begins to die and dry down (Figure 6-3). As the plant tissue dries, the pods become highly susceptible to shattering, which can cause the pods to split and result in seed loss. Timing harvest to capture the maximum number of mature seeds while avoiding losses to shattering requires regular scouting in the field to determine when the crop is ready.

Figure 6-3. Seed pods fill and begin to ripen in spring canola.

7. CROP ESTABLISHMENT & PRODUCTION

The process of establishing a good stand of canola requires careful attention to seed bed preparation, planting date, and fertility and pest management. This section describes best production practices for canola in the Northeast.

Soils and Fertility

Canola does well in a wide variety of soil conditions, though it excels in loamy soils with good internal drainage and a pH in the 6.0-7.0 range. Yield losses begin to occur in soils with pH 5.5 and lower; symptoms of low pH include cupped leaves early in the development of true leaves. Canola does not perform well in soils that are saturated, especially when they do not drain quickly. Hardpan soil layers that reduce subsurface drainage or surface compaction that holds water on top of the soil can easily drown canola plants. Emergence can be significantly reduced if heavy rains cause soil crusting after planting; canola seedlings are particularly ineffective at breaking through hard soil crusts. In excessively drained, dry soils, drought stress can be problematic, as canola is also intolerant of water stress.

<u>Nutrient Application</u>
Canola has nutrient requirements that are similar to most small grains, with the exception that canola requires much more sulfur (Table 7-1, page 34). These data provide estimates of whole plant and seed crop nutrient uptake requirements. Nutrients contained in the seed are removed from the field, while the remaining nutrients are generally returned to the field.

Nitrogen should be applied pre-planting due to the high sensitivity of canola seed to salt and ammonia injury. N availability of 90-125 pounds per acre will allow a yield potential in the range of 2000-3000 lbs per acre, assuming other field conditions are favorable and production practices are done properly.

For spring canola, field specific N recommendations are given by multiplying the yield goal (lbs/ac) by 0.05, then subtracting the available nitrate N and the previous crop credit. An example follows:

For a yield goal of 2000 lbs per acre on a field following hay, with 15 lbs per acre of available N from the soil:

2000 x 0.05 - 15 (soil N) - 40 (hay credit) = 45 lbs N per acre to be applied

Care should be taken to not over-apply nitrogen, as canola is very prone to lodging as a result of over-fertilization. Applying the correct amount (i.e. addressing only the crop need) of nitrogen is more critical in winter canola than in spring canola because both too much and too little N will inhibit winter survival; too little N does not allow enough vegetative growth before winter, and too much encourages leggy plants that are more sensitive

Table 7-1. Nutrient uptake values for whole plant and for seed crop (*Canola Council of Canada, 2011*).

	Whole plant uptake (lbs/ac)	Removal in seed (lbs/ac)
Nitrogen (N)	93.0	55.0
Phosphorus (P)	14.0	10.0
Potassium (K)	76.0	14.0
Sulfur (S)	23.0	7.0
Boron (B)	0.16	0.04

to frost damage. Fall nitrate tests are important for correctly addressing winter canola N demand. A general rule of thumb calls for one-third of the total N needed for the crop to be applied in the fall before planting winter canola, with the remainder to follow in the spring.

Phosphorus and K recommendations should be determined through a standard soil test. Canola is an excellent scavenger of P and generally 20 to 30 lbs per acre applied as starter fertilizer can meet the needs of the crop. If soil test P levels are low additional P fertilizer may be required. Potassium fertilizers can also be added to the starter but special care must be taken to make sure N + K rates do not exceed an approximate 10 lbs per acre. Canola seed is especially susceptible to fertilizer salts and hence, high levels of N and K fertilizers can cause detriment to the emerging seeding.

The major difference between small grains and canola nutrient demand is in sulfur requirements. Canola has a much higher sulfur demand than most other crops, and significant yield boosts can occur from sulfur additions. Soils with test values lower than 10 ppm sulfur should receive additional sulfur in the form of either ammonium sulfate or degradable elemental sulfur at rates of 20 – 40 lbs per acre.

Variety Selection

Similar to other oilseeds, most canola is grown in the Great Plains and central Canada. Varieties that perform well there do not necessarily perform well in the Northeast. Even within Vermont, different amounts of snowfall and dates of spring thaw from year to year will produce significant differences in how varieties perform (Figure 7-1). The guidelines below are meant to aid growers in selecting varieties, but growers' own experience should be followed over these guidelines.

Maturity

The first major element of selecting canola varieties for production is to choose varieties that can perform within the length of the growing season. Canola's rapid maturation makes it an ideal oilseed candidate for colder regions of Vermont where fall-seeded small grains or cover crops follow the canola crop.

Though winter canola varieties are not generally rated for maturity, it is important to choose varieties that perform well in the fall and that have good winter hardiness. Most seed companies rate winter hardiness as part of the evaluation of the variety. For the most current evaluations of variety performance in Vermont, contact UVM Extension.

In spring canola variety trials in Vermont, most varieties were fairly consistent in their time requirement for development. Generally, 1100-1500 GDD units are required to reach maturity, but because the plant dries down quickly, harvest can occur very soon afterward.

Yield Potential

Most canola varieties (both

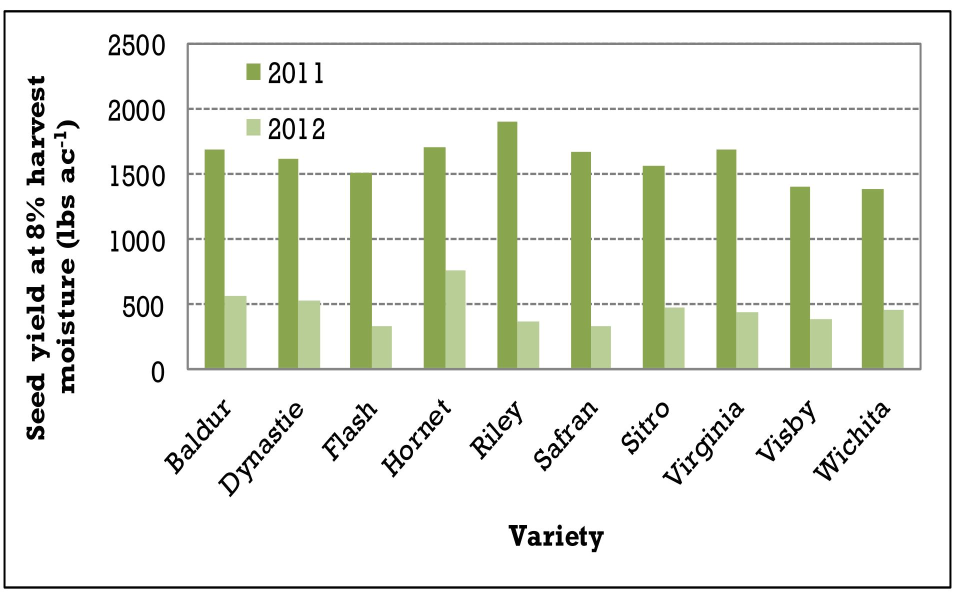

Figure 7-1. Seed yields from selected winter canola varieties, 2011-2012 data, UVM Extension.

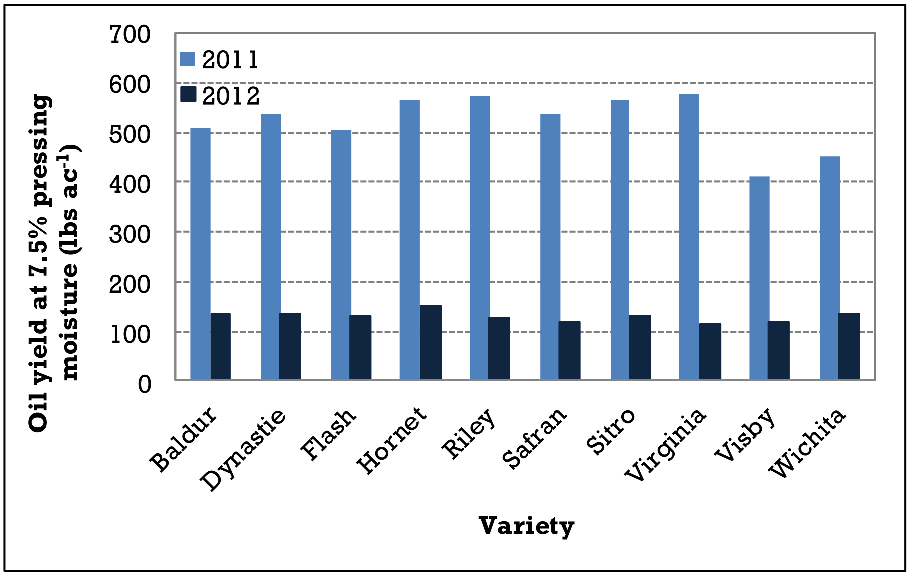

Figure 7-2. Oil yields from selected winter canola varieties, 2011-2012 data, UVM Extension.

winter and spring) have slightly higher yield potential as compared with other oilseeds such as sunflowers. Yields in Vermont have been variable in the past, but range between 1300 and 3000 lbs per acre, with a mean of about 1900 lbs per acre depending on nitrogen fertilization, seeding rates and pest damage. Some varieties have occasionally yielded as much as 4000 lbs per acre, and while such high yields are rare and difficult to achieve, they reflect what yields are possible under ideal conditions. Winter canola has yielded slightly better in our region, primarily due to lack of disease and pest pressure.

Oil Content & Quality

In general, oil contents of 40%-42% are expected and often reported for most canola varieties across the country, though canola oil contents in UVM Extension trials typically average 30-35%. However, several factors control oil content during and after the growing season, including variety, soil moisture, soil N availability, and seed moisture at pressing. High rates of N application reduce oil content in the seed, though the likely increases in seed yield may outweigh the reduction of oil content. Seed moisture below 6% can reduce oil content as well; pressing over-dried seed has resulted in oil contents as low as 20% in UVM Extension pressing trials. There is a great deal of variability in oil yield from varietal differences in oil content, as well as year-to-year differences (Figure 7-2).

Disease Resistance

Disease resistances bred into canola have been helpful to growers in lowering the pressure from significant diseases such as Blackleg, which can be devastating to a canola crop. Choosing varieties that have some resistance to common fungal diseases can improve yields, especially here in the Northeast where fungal diseases are common. Canola varieties are often rated on their resistance to Blackleg as compared to a "check variety" that is highly susceptible to the disease (Table 7-2).

Herbicide Tolerance

Like disease resistance, herbicide tolerant varieties can be useful tools for farmers. Varieties that are resistant to Roundup (glyphosate) and Liberty (glufosinate) herbicides have been developed through genetic engineering technology. Clearfield canola varieties were developed through traditional breeding (i.e. non-GMO) and offers resistance to the herbicide Beyond (imazamox). Some Clearfield canola growers have reported that seed losses at harvest can introduce a heavy weed population that is difficult to control later in the rotation with other Clearfield crops (e.g. Clearfield canola volunteers are difficult to control in Clearfield sunflowers).

Hybrid vs. Open-Pollinated

Many varieties of canola are hybrids, but there are also a large number of open-pollinated (OP) varieties, and

Table 7-2. Blackleg resistance ratings, with incidence ranges.

	Rating Code	Incidence of Infection*
Highly Susceptible	HS	90%-100%
Susceptible	S	70%-89%
Moderately Susceptible	MS	50%-69%
Moderately Resistant	MR	30%-49%
Resistant	R	0%-29%

* As compared to Westar, a highly susceptible variety

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growers should take into account this difference when ordering seed. Hybrid seeds are the product of two distantly-related parent lines which create offspring that are typically very robust and produce high yields. When these hybrids reproduce, however, they do not produce similar offspring – instead the next generation often has many stems or branches, produces few flowers, and is generally not as vigorous. Therefore, growers cannot save seed from hybrid crops (e.g. corn, soy, sunflower) for the next year's planting.

In open-pollinated varieties, closely related parental lines are crossed to produce offspring similar to the parental lines. Though open-pollinated varieties often yield slightly lower than hybrid varieties, this has not been consistently true for UVM Extension trials. In less than ideal conditions, open-pollinated varieties can sometimes yield better than hybrids because of their ability to tolerate a wider variety of conditions. The fact that open-pollinated varieties produce plants similar to the adults allows farmers to save seed from year to year, which can virtually eliminate seed costs. Over the long term, open-pollinated crops have the ability to adapt to the microclimate of the farm as natural outcrossing between individual canola plants in the field occurs.

It is important to remember that varieties with specialty traits often require the grower to sign a trait agreement.

Figure 7-3. Canola row with emerging seedlings.

Planting Practices

Canola can produce similar yields across a variety of plant populations by adapting the number of flowers, pods and seeds per pod. However, ensuring a good, even stand of canola is also important for reducing lodging and for controlling weed pressure and disease (Figure 7-3).

Seedbed Preparation & Seeding Methods

Because of canola's small seed size, it requires a fairly shallow planting depth with good soil to seed contact, which in turn requires a smooth and level seedbed. Because of this need, canola has not traditionally worked well in reduced-tillage situations, especially no-till, where residue and an uneven soil surface generally leads to uneven emergence. Canola benefits most from an even seedbed that has been lightly packed, though this must be balanced with the need to leave the soil structure coarse enough to prevent surface crusting.

To plant canola, grain drills should be set to plant at a depth of 0.5—1.0", which helps to provide even emergence. Planting as deep as 1.5" is only suitable for large-seeded varieties, which usually include hybrid varieties; otherwise, emergence will be poor and weed pressure high. Trials conducted in northwestern Vermont showed that the highest yields result from seeding rates between 6 and 9 pounds per acre, though no significant yield increase occurs from seeding rates higher than 6 pounds per acre. Therefore, to save seed costs, lower rates should be used. In addition to higher cost of planting at higher rates, lodging and disease transmission are more likely and can be more rapid, leading eventually to reduced yield (Figure 7-4, page 37).

Data from field trials in northwestern Vermont have also shown that row spacing from 6 to 18" produce similar yields. Individual canola plants respond to differences in plant density by adjusting the amount of branching and the number of flowers per branch. Depending on the planting and harvesting equipment available, UVM Extension recommends planting in 6-inch rows to help control weed pressure and promote even plant spacing across the field. Wider rows may be used especially if white mold issues are prevalent. Wider rows may help with more airflow in the field.

Seeding Dates

Spring canola should be planted as early as the fields can support tillage and planting equipment. Because germination occurs once soils have reached 38° F, canola could be planted as early as mid-April, but often early May is more feasible. Planting spring canola early also allows an earlier harvest, which is helpful to producers because it spreads out workload and equipment availability in the fall, and allows for the establishment of a cover crop or a winter cereal grain. Because heat and humidity during the flowering period can be detrimental for pollination and seed set, spring canola should be planted no later than mid-May.

Winter canola should be planted early enough in the fall that it can establish a strong rosette before the first killing frost, when it will become dormant. Usually, this requires that it be planted before September (Figure 7-5). In UVM Extension's winter canola planting date trials, only plots planted before September 1 were harvestable.

Figure 7-5. Winter canola planted on varying dates (left to right: 15-Aug, 23-Aug, 29-Aug, and 6-Sep). Photographed 24-Sep 2012.

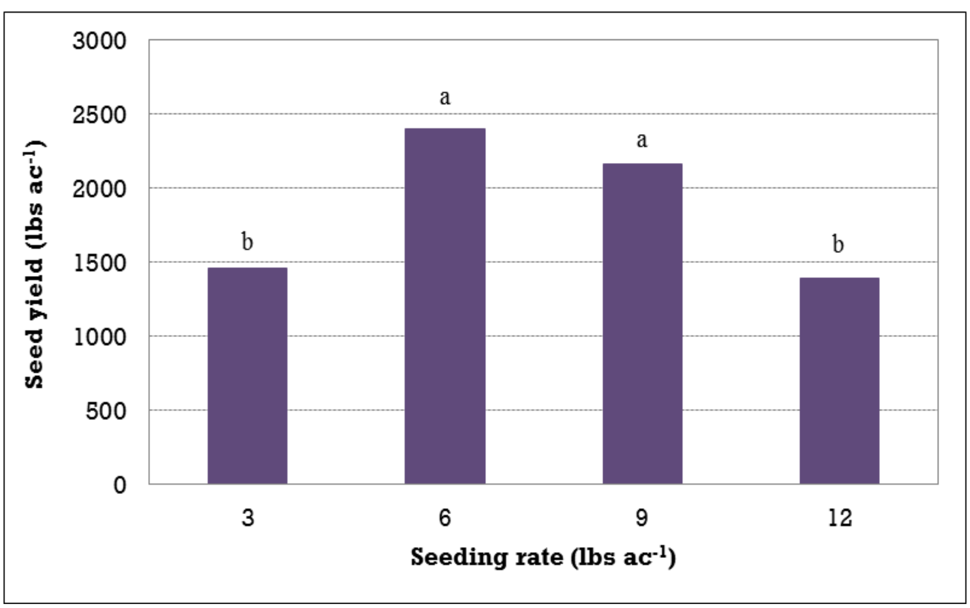

Figure 7-4. Effect of seeding rate on spring canola seed yields, 2008 data, UVM Extension.

8. PEST MANAGEMENT

Though oilseed canola crops are fairly new to the region, other *Brassica* crops are very well established and the pests that are problematic for those are also problematic for canola. In particular, several weeds and fungal diseases warrant careful management, and there are a large number of insects that could be challenging to control depending on the other crops in the rotation. Birds have become the most severe pest for our trials, consistently causing the greatest harvest loss.

There are benefits and costs associated with each pest management strategy, and growers must decide for each situation which tool presents the best chance of eliminating or reducing a particular pest problem at the lowest cost. In most cases, preventative control measures are cheaper and more effective, but require more planning, typically in the form of rotation cycles and timing field practices correctly.

Flea Beetles
Phyllotreta cruciferae, Phyllotreta striolata

<u>Identification & Signs of Damage</u>
Flea beetles are small beetles that get their name from the fast hops that they take when disturbed, similar to fleas. They are common pests in spring and winter canola, feeding heavily on early leaf tissue, which is when they cause the most damage (Figure 8-1). Damaged seedlings can be set back significantly in their development and are often noticeably lacey or holey in appearance. Winter canola is less susceptible than spring canola to flea beetle damage because the plants grow out of their most susceptible stage prior to beetle emergence.

Figure 8-1. Flea beetle on canola seedlings.

<u>Lifecycle</u>
Flea beetles overwinter as adults in the leaf litter and dead grasses of hedgerows between fields. They emerge in early May when temperatures average about 50°F, feeding on young emerging plant tissue, including crops. Females lay eggs in the soil, which hatch in a week or two. The larvae continue to feed on plant tissue until fully grown. They then pupate in the soil for 11 to 13 days before emerging as the new generation of adults.

Table 8-1. Insecticides registered for use on canola crops in Vermont, 2013. Check with your local Extension agent or State Agency of Agriculture for up-to-date information on pesticide use.

Common trade name	Active ingredient	EPA registration numbers	Labeled for use against:	
			Flea beetles	Lepidopteran larvae*
Brigade 2EC, Brigade WSB	Bifenthrin Ammonium Sulfate	279-3313, 279-3108	Yes	AM, CW, WW, L, OL
Hero, Hero EW	Bifenthrin zeta-Cypermethrin	279-3315, 279-3329	Yes	AW, CW, OL
Warrior with Zeon Technology, Warrior II with Zeon Technology	lambda-Cyhalothrin	100-1112, 100-1295	Yes	AW, CW, L, OL
Cruiser 5FS	Thiamethoxam	100-941	Yes	WW
Mustang MAX EC, Steed	zeta-Cypermethrin	279-3327, 279-3380	Yes	AW, CW, L, OL

* Lepidopteran larvae includes: armyworms (AW), cutworms (CW), wireworms (WW) loopers (L), & other caterpillars (OL)

Figure 8-2. Blackleg infection on spring canola leaf.

Major Insect Pests

There is only one main insect pest in canola production in the northeast, and has contributed to complete crop failure in some seasons. Flea beetles have been detrimental to canola growers, and fields should be scouted regularly for the insect.

Management of Insects

Cultural Controls
Early planting of canola may help reduce flea beetle damage in spring canola. Early planting will allow canola plants to develop past the seedling stage prior to flea beetle emergence in mid to late May. Larger plants may withstand flea beetle damage and allow the plant to continue developing without insecticidal sprays. Delaying the planting date of canola crops until after the overwintering beetles have emerged is also a strategy, though such a delay could push harvest back into September, causing more of an issue with birds. Planting a "trap crop" around the field edge has been effective for smaller areas, or where the trap is more desirable than the protected crop.

Chemical Controls
In Vermont, applying insecticides is not common after the plants are established, if at all. However, several insects, including flea beetles, can cause serious damage to young plants. There are several conventional insecticides that are registered for flea beetle control in canola (Table 8-1). Organic insecticides are also available. Each state has different regulations and requirements regarding pesticides, so it is best to contact your University Extension service or pesticide dealer to find out more.

Canola Disease Pests

Though the climate in Vermont is ideal for fungal pathogens, especially in crops that are seeded in narrow rows and have dense vegetation like canola, fungal diseases in canola crops do not appear to be as extensive and well-established as they are in sunflower. However, rather than viewing this lack of disease as breathing room, it should be viewed as an opportunity to maintain good cropping practices that will keep disease away.

Blackleg

Identification & Signs of Damage
Blackleg is characterized by tan or brown lesions that develop first on the leaves and then develop on the stems as similar lesions ringed in black tissue (Figure 8-2). Small black fruiting bodies eventually appear on the exterior of the dead tissue. Stem infections are most common during the rosette stage and early bolting stages of canola's development, and occur typically just below a leaf attachment. Stem lesions eventually girdle the stem and then can cause collapse and often lodging.

Lifecycle
The Blackleg fungus overwinters on plant residue infected the previous growing season. During the following spring, the fungus produces fruiting bodies that discharge spores, infecting the next season's crop. However, these fruiting bodies release their maximum number of spores in the second year, and will continue to release spores until the plant residue has been fully degraded by the fungus.

Once environmental conditions reach an optimum for Blackleg infection (wet plant tissue, between 60° and 75°F), the spores begin to infect the plant tissue. Any previous damage to the plant tissue aids in the infection, as these breaks in the plant tissue act as entry sites for the fungus. The infected plant tissue becomes residue that remains in the field, and supplies new spores for the next generation cycle.

Sclerotinia (White) Molds

<u>Identification & Signs of Damage</u>

In canola, *Sclerotinia* infects the stems as a stem rot. The disease develops late in the season, usually after flowering has ended. Early signs of infection are brown lesions on the stem that eventually give way to white mold with black sclerotia (small fruiting bodies) as the plant dries down. Stem infections often cause the plant to die, sometimes prematurely, and to eventually lodge. In heavily infested fields, lodging can occur in large patches as falling plants put more pressure on already weak stems.

<u>Lifecycle</u>

Sclerotinia overwinters as sclerotia that can lie dormant in the soil for as many as six years. They resemble small rocks or clods of soil and camouflage very well. Each spring, some of the sclerotia in the soil release spores due to moisture or temperature cues, some release spores when the roots of host plants come in contact with them, and others continue to lie dormant. These spores float up to the canopy where they land on dead or decaying plant tissue (usually dead flower petals), and grow to infect the stem tissue (Figure 8-3). Rainy and humid conditions in the fall seem to be prime conditions for *Sclerotinia*, because infection rates are higher in wet falls than in dry seasons. Once the plant is fully infected, the sclerotia cause the stem to collapse, dropping the fruiting bodies into the soil; otherwise they are scattered during harvest.

Figure 8-3. Sclerotinia causes deformed growth.

Management of Disease

<u>Cultural Controls</u>

Choosing disease-resistant hybrids is one way to mitigate the incidence of disease in canola crops. For example, due to the development of Blackleg-resistant hybrid varieties, the incidence of this disease is fairly low in Vermont. Reports of severe infestations are essentially non-existent in canola. However, even for varieties that have a rating of "Resistant," there can still be low levels of infestation that take away yield potential. Therefore, even with the use of resistant hybrids, it is still important to practice good rotations.

Like most other crops, the most effective tool for combating pest issues while maintaining soil health and crop yield is a well-planned rotation that utilizes alternating broadleaves and grasses and longer periods of fallow or mixed-species hay. Rotations are especially important for canola because of its susceptibility to both *Sclerotinia* and Blackleg, two fungal diseases that are capable of high levels of crop damage. *Sclerotinia*, also discussed in the sunflower section of this manual, is a wide-ranging fungal disease that infects over 350 species of host plants, both cultivated and wild. Blackleg is similar, though the number of host plants is far smaller. However, the lifecycles of both diseases have periods of dormancy in fruiting bodies that can last up to four years (Blackleg) and up to six years (*Sclerotinia*). Because canola is slightly less susceptible to *Sclerotinia* than sunflower and Blackleg populations are not well established in most fields yet, successive canola crops should be planted no more than every 3 years in any field, with non-susceptible crops in the intervening time.

Table 8-2. Registered fungicides for use in Vermont for canola, 2013. Check with your local Extension agent or State Agency of Ag for up-to-date information on pesticide use.

Common trade name	Active ingredient	EPA registration numbers	Controls:		
			Black Leg	*Sclerotinia*	*Alternaria Blight*
Dynasty, Quadris	Azoxystrobin	100-1159, 100-1098	Yes (seed-borne)	No	Yes
Endura	Boscalid	7969-197	No	Yes	No
Fosphite	Phosphorus Salts	68573-2	No	No	No

Sclerotinia is well established in Vermont, though canola appears to be slightly less susceptible than other crops, most likely because it is generally harvested around the same time the conditions are becoming wetter and more conducive to *Sclerotinia* infections. Eliminating the disease from a heavily infested field can be very difficult, but sticking to good rotations that only reintroduce canola into a field every third year will help keep new fields disease-free and fungal populations in old fields under control.

Wider row spacing can reduce pressure from fungal diseases by promoting airflow around the base of the plant, but also encourages more weeds to sprout. Spacing rows from 6 to 9" seems to provide a good balance of weed control and airflow to reduce fungal pressure.

Chemical Controls
The use of fungicide-treated seeds is widespread and successful for preventing fungal diseases in the seedling stage, though many of the more serious fungal pathogens emerge later in the lifecycle of the plant. Most canola seed is treated with a combination of fungicides that target downy mildew, seedling dampening, and other diseases that plague seedlings. Most fungicides approved for use in canola in Vermont are best used as part of a regular spray program, which makes them very expensive to use, and probably not worth the cost. Table 8-2 provides a list of registered fungicides that can be used in Vermont for canola crops.

Biological Controls
Contans®, an organic-certified biological agent (fungus) that attacks the dormant bodies of *Sclerotinia* in the soil, is also a highly effective means of reducing *Sclerotinia* build-up in the soil. Contans® has been reported to be very effective at reducing incidence of *Sclerotinia* white molds to near zero within two years, though it is not a substitute for well-planned rotations.

Canola Weed Pests

Fortunately for growers, canola is highly competitive with weeds, often smothering out even the toughest competition. However, broadleaf weeds can be very difficult to control between canola emergence and canopy closure, because standard broadleaf herbicide options typically make a point of targeting the mustard family. Fortunately, canola is fairly hardy and responds very favorably to tineweeding—once it is well established. Early planting will help the canola establish and grow rapidly prior to the germination of most annual broad leaves. The best conventional weed control strategies involve pre-plant herbicides. Organic strategies rely on good rotations that reduce weed pressure in the early spring.

There are two particularly problematic broadleaf weeds that share many physiological qualities with canola and therefore thrive in fields of that crop. Management of these weeds is treated collectively because of their similarity in growth habit.

Lambsquarters
This familiar weed is characterized by its alternate, triangular-shaped leaves, its pale green flowers that grow from junctions between the main stem and branches, the striped ap-

Figure 8-4. Common lambsquarters.

pearance of the main stem itself, and its tall, coarse growth habit (Figure 8-4, page 41). It is an annual weed that is quick to sprout on bare soil, and is therefore common in almost any broadleaf crop. It grows very quickly, topping out at 4' or more by the end of the growing season. It produces thousands of seeds per year that are viable for long periods of time in the soil.

<u>Redroot Pigweed</u>
This weed is commonplace in both broadleaf and grass crops, and is similar in appearance to lambsquarters (Figure 8-5). It is a member of the amaranth family, and like most of its relatives, it produces huge numbers of small seeds that sprout easily. It is a deep-rooting annual with a robust stem that survives cultivation, especially if conditions are slightly wet. It is best to hit this plant early, before the roots have had time to establish.

Figure 8-5. Redroot pigweed.

<u>Grasses</u>
In conventional canola systems, grasses are not particularly problematic because there are so many useful herbicide options. However, in organic systems perennial rhizomatous grasses such as quackgrass can cause serious yield declines because they are not controlled well by cultivation, and can easily smother young canola plants.

Management of Weeds

<u>Cultural Controls</u>
Managing row spacing is also an important tool in controlling weeds and other pests. Canola is highly successful in competition with weeds once it reaches the rosette and bolting stages. However, it is not a successful competitor in earlier stages – narrower rows provide a more even plant density across the field, which establishes a good canopy more quickly, but also creates more shade at ground level. While this even shade is beneficial for weed control, it also creates humid conditions at the soil surface, encouraging the establishment of soil-borne diseases such as *Sclerotinia* and Blackleg. Spacing rows from 6-9" seems to provide a good balance of weed control and airflow to reduce fungal pressure.

<u>Mechanical Controls</u>

Tineweeding is extremely effective at eliminating weeds when they are just germinating, and row crop cultivators are very effective at removing weeds between rows. Because herbicide options to control broadleaf weeds after canola has been planted are limited, producers may want to rely on cultivation after emergence of the crop. In organic systems, strong rotations and cover crops become equally important elements of the weed control strategy.

Because canola is planted in narrow rows, standard row cultivation equipment cannot be used to cultivate between rows. However, there are narrow-row cultivators, such as those made by the Schmotzer company from Germany, which make cultivating in these situations possible.

In addition, tineweeding once the crop is established can be somewhat effective in controlling weeds. Tineweeding just after planting can be risky as the shallow planting depth of the seed can easily be disturbed by the tines on the implement. This can lead to seeds being carried to the surface of the ground and result in poor and spotty germination.

<u>Chemical Controls</u>
Canola is a broad leaf crop and hence most herbicides available to control weeds in this crop are targeted towards grasses (Table 8-3, page 43). Several varieties of herbicide resistant canola plants have made chemical control of weed pests much easier. The Clearfield trait, which confers resistance to Beyond (imazamox), is the only herbicide resistance trait that is non-GM. Roundup Ready and Liberty Link canola varieties do exist and provide another means to weed control.

Canola Bird Pests

Birds are a highly problematic pest in all oilseed systems. They are mobile, can eat huge amounts of seed, and typically travel in large flocks that collectively can cause serious devastation. In Vermont, birds are especially destructive because our small fields, typically bordered by hedgerows, provide the perfect food with nearby shelter from predators.

Table 8-3. Herbicides registered for use in canola in Vermont, 2013. Check with your local Extension agent or State Agency of Agriculture for up-to-date information on pesticide use.

Common trade name	Active ingredient	EPA registration numbers	Canola growth stage	Weed group control
Aim EC	Carfentrazone-ethyl	279-3241	Pre-plant	Newly established grass and
Clethodim	Clethodim	42750-72-72693	Any	Growing annual and perennial
Stinger	Clopyralid Mo-	62719-73	Post-	Some broadleaf weeds, including
Reglone	Diquat Bibromide	100-1061	Pre-plant, pre-emergence, pre-harvest desiccant	Established grass and broadleaf; non-selective
Sonalan HFP	Ethalfluralin	62719-188	Pre-plant	Germinating annual grasses and
Traxion/ Touchdown Total, Roundup Original MAX, Roundup PowerMAX, Roundup WeatherMAX	Glyphosate (Potassium Salt)	100-1169, 524-445, 524-549, 524-537	Pre-plant, pre-emergence, pre-harvest desiccant	Established grass and broadleaf; non-selective
Duramax/ Durango DMA	Glyphosate Diethylamine Salt	62719-556	Pre-plant, pre-emergence, pre-harvest desiccant	Established grass and broadleaf; non-selective
Durango/ Glyphomax XRT, Glyphomax Plus, Honcho, Honcho Plus, Glyphosate 41 Plus, Helosate Plus	Glyphosate Isopropylamine Salt	62719-517, 62719-322, 524-445, 524-454, 42750-61-72693, 74530-4	Pre-plant, pre-emergence, pre-harvest desiccant	Established grass and broadleaf; non-selective
Beyond*	Imazamox Ammonium Salt*	241-379	Post-emergence	Broadleaf weeds*
Assure II	Quizalofop p-Ethyl	352-541	Any	Established annual and perennial
Poast	Sethoxydim	7969-58	Any	Annual grasses
Trust, Treflan TR-10, Dintec Treflan 4D	Trifluralin	1381-146, 62719-131, 68156 -4	Pre-plant	Germinating annual grasses and some broadleafs

* Only for use in Clearfield canola

American goldfinches are common birds in our area in fields, hedgerows and at bird feeders. During the spring and summer, male goldfinches are bright yellow, except for their black foreheads and black wings with white markings. Females are more muted in their coloration, with olive hues on the upper parts of their bodies.

American goldfinches are late breeders, generally nesting in late June and early July. During this time, they feed on seeds almost exclusively, usually of plants in the sunflower family (e.g. thistles), but are not hesitant to eat canola. They commonly perch in the flower cluster as the bottom pods are ripening (well before harvest time), and make small slits in the pod through which they eat the seeds. Because canola stems are not strong enough to support them well, they often knock plants over, causing shattering of the pods that they do not eat. Though they are mostly year-round residents and do not migrate, concentrated flocks of immature and

Figure 8-6. Bird damage in well-formed canola seedpods.

adult goldfinches form in late September and early October – once the breeding season is over – in search of food for winter fat reserves.

Growers in the Northeast have also reported detrimental flocks of red-winged blackbirds, mourning doves, sparrows, and other seed-loving birds (Figure 8-6).

Management of Birds

<u>Cultural Controls</u>
Adjusting planting and harvest dates can reduce pressure from particular pests by offsetting the lifecycle of the plant so that it is out of sync with the lifecycle (or infestation cycle) of a pest. For example, planting canola early may allow it to be harvested before the annual fall bird migration, thus reducing the amount of the crop that is eaten by birds. Harvesting canola crops earlier is possible, especially if desiccants or swathing are used to terminate the crop earlier than a direct cut combine harvest.

On a field scale, physical protection such as netting is often not feasible, and can be insufficient if not perfectly impenetrable (Figure 8-7). Therefore, deterrents may be the best option. Air cannons, squawk boxes, scarecrows, eye-spot balloons, and shiny ribbons can be effective for short periods of time. However, birds will become accustomed to each of these tactics fairly quickly, and so they need to be moved regularly and used in combinations in order to stay unpredictable to the birds.

Figure 8-7. A sparrow (foreground) and a finch (background) perch on canola netting, feeding on accessible seedpods.

9. HARVESTING PRACTICES

Knowing when to harvest canola can be one of the biggest challenges to growing this crop. It has a notoriously small harvesting window to maximize yield and quality – harvest too early and not all of the seed may be mature, which causes heating and sweating in the bin, while a late harvest leads to shattering and heavy crop loss. This section provides some tips on when and how to harvest to maximize yield and oil quality.

Plant Maturity & Moisture Content

Canola is ready to harvest when the seed reaches an average of 8-10% moisture (several measurements are needed because seeds from the bottom of the canola plant will be more mature than those at the top). Once the canola is this dry, however, the plant itself is so dry that the pods typically shatter on contact, and direct combining (also called direct cutting) can result in large crop losses. Harvesting earlier to avoid losses from shattering may mean that not all of the seed is mature, and canola seeds will not mature further once they're harvested, leading to lower oil content.

Harvest can occur either by the more conventional direct cutting, or by swathing and letting the seed finish maturing in a windrow and then combining once the seed is fully mature. Each method has its advantages and disadvantages, and producers should determine which will work best in their current production system. Direct combining is appropriate if the seed is mature enough (~10% moisture). In other regions, swathing can reduce losses from early frosts. However, in the Northeast, due to the likelihood that rain could damage the crop while it is in the windrow, swathing is not a common practice. Direct cutting is far more common, despite the fact that harvesting process losses can be high. Penn State University reports that seed losses during harvest can be as high as 35-40% of yield (Karsten, 2012).

Harvesting Equipment

Canola is harvested in a very similar fashion to a small cereal grain, using a grain head with a reel to pull in the plant (Figure 9-1). By harvest time, canola plants are often intertwined and sometimes pushed over, so it is important to set the cutter bar at an appropriate height to get all of the pods while reducing the quantity of stem material that gets processed. Getting out of the combine to check that the crop is

Figure 9-1. Harvesting winter canola with a small combine.

Direct Combining	Swathing followed by Combining
Shorter harvest window – can only occur below 15% seed moisture, but typically above 8%	Wider harvest window – can occur anytime after seed reaches 30% seed moisture
Harvest losses from shattering can range 10%-50% if harvest is late	Little to no field losses from shattering
Weed seeds mature and are harvested along with the canola – especially detrimental for OP varieties that get saved and planted again	Incorporates fewer weed seeds
Crop is safer from bad weather events other than high wind	Crop can be damaged by a heavy rain between swathing and harvest
Best yields and oil content if the crop is allowed to mature while standing in the field (assuming no shattering at harvest)	Swathed canola crops have lower yield and oil content than direct cut
Less equipment need (time and special attachments)	Requires more tractor time, and special swathing and pickup attachments
More effective for tall crops with intertwined stems	Less effective for tall, tight crops – higher danger of bunching and twisting the windrow

getting pulled in well is important to ensuring high yields, especially where the standability of the crop varies from field to field or within a field.

If swathing the crop, a swather is important to make good windrows that lay nicely on the stubble. To reduce the amount of soil and to also reduce loss during combining, keep the stubble between 5 and 7" so that the windrow stays off the ground. This height also lowers the likelihood of disease spreading through the crop during the dry down period. If combining large acreages of swathed canola, a windrow pickup head is helpful to get the crop into the head nicely and to avoid losses below the combine.

Combine settings should reflect the fact that canola threshes very easily – excessive grinding of the stems is not necessary and could increase the seed moisture. The concave settings should be opened to 3/4" in the front and between 1/8" and 1/4" in the rear. Keep the clearances as high as possible without losing full pods. The cylinder speeds should be fairly slow, because canola seed can crack easily. Fan speeds can be set similarly to other small grains, but it is better in general to separate the seed from the chaff by shaking it through the screens rather than blowing the chaff out.

One common source of harvest loss for many producers is seed running out of holes in the combine. It is important to seal any obvious holes before harvest with caulking or duct tape. Once there is seed in the bin it can be helpful to get out and look for other places that seed is running out of the bin. Canola's small size and smooth, round shape enables it to flow freely, often finding holes that are not obvious or even possible to see without the help of the seed.

10. SEED PROCESSING & STORAGE

Seed Cleaning

Clean seed is critical for long term storage, especially for small-seeded crops like canola. The small size allows the seeds to pack tightly, restricting airflow and encouraging fermentation of wet trash in the seed. The first step to clean seed is to select the correct screens for the combine. If the seed is not clean enough after one pass through the combine, passing it through a high volume seed cleaner can remove the necessary amount of trash (Figure 10-1). If trash comprises more than about 3% of the harvested seed bulk, problems such as hot spots, mold, and insect activity can erupt in the storage bin.

Seed Drying

Some modifications to normal grain dryers may be required to accommodate canola because of its small size. A secured layer of burlap or muslin over a standard larger-grain floor can provide a simple, low-cost alternative to buying a canola-specific seed-drying floor, though the edges of the bin can still present leakage issues if the fabric isn't secured well. Canola-specific floors for grain bins are not too expensive and are easy to install—they are generally available in long and wide sections so that they can be cut to fit effectively in the bin. Similar to other grains, concrete flooring in storage or drying bins is not recommended, because seed on the bottom will absorb moisture, and eventually mold and spoil. Additionally, like the combine, any holes or seams in the seed bin will leak seed, and should be sealed before the seed is put into the bin if possible.

Drying canola to long-term storage moisture is best done with unheated air (less than 15° F above ambient), since excessive heating reduces protein quality and leads to sharp declines in oil quality. Small dry-

Figure 10-1. A fanning mill like this could be set up indoors or outdoors.

ers that can be placed in bulk bags with the seed are also adequate for drying relatively small batches of seed (a ton or less). These auger-like aerators are often physically screwed into a one-ton tote of seed to aerate the batch (Figure 5-2, page 30). If heating is necessary, keeping temperatures below 110°F will help avoid over-drying, which would greatly reduce oil content. Airflow rates of 0.75 – 1.0 cfm/bu are the most cost-effective settings because of the relatively high airflow resistance that canola provides due to its small size.

Long-Term Storage

Once the seed has reached 8% moisture, it is ready for long-term storage. During the first month of storage, canola often undergoes a "sweating" period, which is exacerbated at high moisture contents and high temperatures. During warm days, moisture will accumulate at the center of the seed, close to the floor, as warm, moist air cools and falls through the seed, releasing moisture as it settles. On cool days moisture will accumulate at the peak of the storage bin, as the airflow patterns reverse. It is critical to look for moisture to determine whether aeration is necessary. Maintaining good aeration and frequent monitoring is critical to ensuring high seed quality. Dried seed can be stored in a multitude of containers, but should be monitored and/or moved often (Figure 10-2).

Figure 10-2. One-ton totes, or bulk bags, as shown here at Borderview Research Farm, are often used to transport and store seed.

ADDITIONAL RESOURCES

Berglund, D., editor. 2007. Sunflower production. North Dakota State University Extension Service, Fargo, ND.

Canola Council of Canada. 2011. Canola growers manual [Online]. Available at http://www.canolacouncil.org/crop-production/canola-grower%27s-manual-contents/ (verified 22 Jan. 2013).

Kandel, H. 2013. 2012 National Sunflower Association Survey. 2013 National Sunflower Association Research Forum, Fargo, ND. 9-10 Jan. 2013. National Sunflower Association.

Karsten, H. 2012. Penn State University. Canola research update 2011. 2012 Annual Oilseed Producers Meeting, White River Jct, VT. 26 Mar. 2012. University of Vermont Extension.

National Sunflower Association. 2012. Growers [Online]. Available at http://www.sunflowernsa.com/growers/ (verified 22 Jan. 2013).

Smith, J. 2011. Sunflower planter recommendations [PDF online]. Available at http://panhandle.unl.edu/c/document_library/get_file?uuid=417f49d4-6495-4d0d-ab5e-1a826071b8b7&groupId=131817&.pdf (verified 22 Jan. 2013).

The Greenbook Group. 2012. Chemical database solution [Online]. Available at http://www.greenbook.net/ (verified 22 Jan. 2013).

Vermont Agency of Agriculture. 2013. Pesticide programs: product registration. Available at https://usaplants.vermont.gov/ProductRegFSA/BrandSearch.aspx (verified 22 Jan. 2013).

Research and crop updates are always available at the University of Vermont Extension's Northwest Crops and Soils Program website!

www.uvm.edu/extension/cropsoil/oilseeds

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