## CHAPTER 9

# Corn Production

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Corn and soybean continue to be the largest Minnesota crops for both organic and conventional growers. From 1995 to 2005, organic corn production nation-wide increased four-fold. The majority of the organic corn crop is used within the U.S. for organic livestock feed and food products. In 2009, corn was grown on roughly 7.7 million acres across Minnesota, and about 3 percent was organic. While conventional corn yields tend to be higher, net return from organic acres continues to be greater than net return from conventional acres (Table 9-1).

Major commercial types of corn in the United States include: dent corn, sweet corn, popcorn, and flint corn (Figure 9-2, Table 9-2). Specialty corn grown commercially in the United States includes waxy corn, high-amylose corn, high-oil corn, and high-lysine corn. Most of the corn grown is yellow dent used to feed livestock. Some

**Table 9-1. Net returns per acre of corn in Minnesota for organic and conventional producers, 2006-2008.** *Adapted from Minnesota Department of Agriculture, 2009, and FINBIN, 2009.*

| OPERATION | 2006 | 2007 | 2008 |
|---|---|---|---|
| Organic | $601 | $271 | $148 |
| Conventional | $153 | $165 | $127 |

DAVID L. HANSEN

**Figure 9-1.** *Corn field in Minnesota.*

STRAND MEMORIAL HERBARIUM.

**Figure 9-2.** *Dent corn (top) and flint corn (bottom).*

is food-grade quality, white or yellow dent corn with specific starch traits that can be used in cereals, tortillas, corn chips, and cornmeal. Another food grade corn that organic growers produce is blue corn, a flour type. The specific type of corn selected depends largely on the available markets and price premiums. Organic growers face several issues in corn production including variety selection, soil fertility, planting variables, weed management, and pest management.

**Table 9-2. Types of corn and their characteristics.**

**DENT :** 2/3 of starch is hard and 1/3 is soft. The dent is caused by shrinkage of soft starch in the crown as the kernel dries, while the surrounding hard starch shrinks less. Dent is thought to be a result of crossing flint with flour corn.

**SWEET:** Contains sugar instead of starch. Plants are leafy and tend to tiller. It is the only corn that is eaten fresh.

**FLINT :** Very hard kernels because the entire crown is hard starch. More pest resistant and stores well. Not commonly grown except where the growing season is too short for dent varieties.

**FLOUR :** Starch is soft and surrounded by thin layer of hard starch. It is easily ground into meal and used in tortilla chips.

**POP :** Closely related to flint, but has a higher amount of hard starch. Moisture in each starch grain expands with heating. Kernels are round or pointed.

## Variety selection

When selecting corn varieties, producers must follow the USDA National Organic Program guidelines that state, "…The producer must use organically grown seeds…except…non-organically produced, untreated seeds and planting stock may be used to produce an organic crop when an equivalent organically produced variety is not commercially available…"(§ 205.204). In other words, untreated, non-GMO seed produced conventionally is allowed when that variety is not otherwise available. While some producers do use conventionally produced hybrids, many others use organic seed. There are several companies producing organically certified corn seed (Table 9-3).

An important concern in using untreated, conventionally produced hybrids is obtaining seed that has not been contaminated with pollen from transgenic corn. GMO contamination of organic crops is especially a concern in corn because it naturally cross-pollinates.

**Table 9-3. Suppliers of organic corn seed.**
***Adapted from Midwest Organic and Sustainable Education Service.***

**Albert Lea Seedhouse** • PO Box 127 Albert Lea, MN 56007 • Phone: (800) 352-5247
www.alseed.com
*Alfalfa, clovers, corn, cover crops, small grains, and soybeans. They test for GMOs.*

**Prairie Hybrids Seeds** • 27445 Hurd Road Deer Grove, IL 61243 • Phone: (800) 368-0124
*Corn*

**Blue River Hybrids** • 27087 Timber Rd Kelley, IA 50134 • Phone: (800) 370-7979
www.blueriverorgseed.com
*Corn, soybeans, alfalfa, red clover, sudangrass*

**Great Harvest Organics** • 6803 E 276th St Atlanta, IN 46031 • Phone: (317) 984-6685
www.greatharvestorganics.com
*Alfalfa, corn, wheat and soybeans*

**Merit Seeds** • PO Box 205 Berlin, OH 44610 • Phone: (800) 553-4713
http://www.meritseed.com/
*Alfalfa, clover and corn*

**Reducing risk: variety selection. If not using seed that is certified organic, check with your certifier to make certain the seed is acceptable. Consider corn varieties bred under and for organic systems if available. Choosing food grade varieties will be riskier than feed grade because of more stringent market requirements. Do not grow specialty corn unless it is under contract.**

## Hybrid and open-pollinated corn

Corn is naturally an open-pollinated crop (Figure 9-4), with significant pollen movement up to one-third of a mile. Prior to the 1930s, most corn grown by producers was "open-pollinated." With open-pollinated corn, it was a bigger challenge for plant breeders to make improvements in yield, disease resistance, and adaptation because of the extreme mixing of genetic material and random expression of traits.

Today, most corn varieties that are grown are hybrids derived from selection of open pollinated cultivars. Development of hybrid corn is a two step procedure: 1) potential male and female parents are inbred for several generations to concentrate desirable traits; and 2) selected inbreds are crossed to produce a superior hybrid with greater yield potential and other desirable traits than either parent. Today most commercial corn is single cross hybrid seed.

Some organic producers prefer open-pollinated corn over hybrids. Advantages are that producers can save seed with open-pollinated types and possibly produce grain with higher oil and protein concentrations (Table 9-4). Some open-pollinated varieties may perform better under lower fertility conditions. However, yields of open-pollinated corn can be much lower compared to hybrids (Table 9-5).


**Figure 9-4.** ***Corn has a unique morphology with separate male (left) and female (right) reproductive parts on the same plant. This morphology leads to significant pollen movement and genetic mixing among corn plants.***

**Table 9-4. Comparison of open-pollinated and hybrid corn.**

| OPEN-POLLINATED CORN | HYBRID CORN |
|---|---|
| Diverse/variable | Uniform stands and quality |
| Lower lignin concentration so more digestible silage, but lower standability | High standability, higher lignin concentration |
| More leaves | Less leaf area, smaller ears, shorter stalks |
| More digestible stalks | Less digestible stalks |
| Lower yields, but can have higher protein and oil concentration | Can be planted at higher plant populations for greater yield |
| Does well under organic and lower input conditions | Often selected for under high fertility conditions |
| Seed can be saved/selected from each year | Seed cannot be saved |
| Touted for higher drought tolerance, adaptability, and nutritional quality | Very stable production with synthetic fertilizers and herbicides |

**Table 9-5. Open-pollinated (OP) corn variety trial in Iowa, 2001.** ***The yields of all varieties were significantly different. 'Greenfield' suffered the most lodging. The hybrid also had significantly lower protein levels. Adapted from Delate et al, 2002.***

| VARIETY | TYPE | YIELD (BU/ACRE) |
|---|---|---|
| Pioneer 34W67 | Hybrid | 108 |
| Greenfield | OP | 50 |
| BS11/BS10 | OP | 74 |
| BSSS/BSCB1 | OP | 86 |

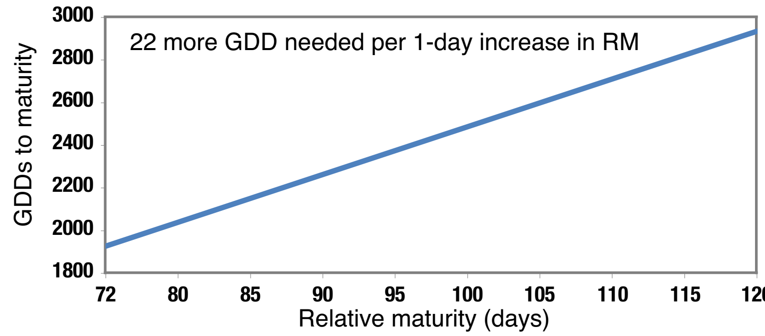


**Figure 9-5.** ***Relationship between growing degree days (GDDs) required for corn physiological maturity and relative maturity for 480 corn hybrids from four seed companies. Adapted from Coulter and Van Roekel, 2009.***

## SELECTION FACTORS

The first consideration in buying seed should be the seed company quality control standards for seed conditioning, since seed vigor is influenced by drying and handling. Verification that seed is not GMO-contaminated is also important.

The next choice should focus on variety selection. When selecting varieties, there are several important considerations listed below in order of importance. These include:

Maturity
Yield potential
Standability
Other traits

See Table 9-6 for steps in the process of selecting varieties.

### *Maturity appropriate for climate and planting date*

Corn varieties for grain should reach physiological maturity or "black layer" (maximum kernel dry weight) one to two weeks before the first killing frost in the fall. Corn maturity is specified using the relative maturity (RM) or growing degree day (GDD) rating system. Corn RM is expressed in terms of days, but this does not represent the typical number of days between emergence and physiological maturity. Instead, it is a relative indication of maturity when compared to a hybrid of known maturity. The RM rating system differs slightly among seed companies, but a general guideline is that a 95-day RM variety needs 2,350 to 2,400 GDDs from planting to maturity, with each one-day change in RM increasing or decreasing the variety's GDD requirement by about 22 GDDs (Figure 9-5). The GDD rating system is particularly useful because it allows one to compare a hybrid's GDD requirement with the number of GDDs that generally occur during the growing season for a given location and planting date (Table 9-7). Although the number of GDDs available for corn production decreases with delayed planting, research from Indiana showed that each one-day delay in planting after May 1 reduced a hybrid's GDD requirement by about 7 GDD (Nielsen and Thomison, 2003).

Days-to-maturity and GDD ratings, along with grain moisture data from performance trials, can be used to determine differences in corn maturity. Hybrids with a later maturity will not always

| **Table 9-6. Steps in the selection process:** |
|---|
| 1. Examine trials in zones nearest your farm. Sources may include the seed company trials, university performance trials or local on-farm trials. Some sources, such as university trials, will be more unbiased than others. |
| 2. Compare hybrids with similar maturities within a trial. |
| 3. Evaluate consistency of performance across zones and years. |
| 4. Compare performance in other unbiased trials. |
| 5. Consider hybrid performance for other traits, i.e. standability, dry-down rate, grain quality, etc. |
| 6. Producers will be taking a risk if basing their decision on one or two local test plots. |

## Table 9-7. Average growing degree day (GDD) accumulation (1971-2000) for various planting dates, along with median dates of critical fall temperatures (1948 to 2005) across Minnesota. *Adapted from Coulter and Van Roekel, 2009.*

| Location | Planting Date: April 20 | April 30 | May 10 | May 20 | May 30 | June 9 | Adjustment for 10 days of drying before 32°F | First fall frost: 32°F | 28°F |
|---|---|---|---|---|---|---|---|---|---|
| ***Southwest*** | GDD accumulation to first 32°F fall temperature[a] | | | | | | GDD[a] | Median date[b] | |
| Lamberton | 2,596 | 2,540 | 2,458 | 2,348 | 2,210 | 2,046 | 109 | Sep. 28 | Oct. 7 |
| Marshall | 2,703 | 2,647 | 2,565 | 2,456 | 2,320 | 2,158 | 97 | Oct. 4 | Oct. 14 |
| Pipestone | 2,460 | 2,408 | 2,332 | 2,230 | 2,104 | 1,954 | 115 | Sep. 24 | Oct. 3 |
| Redwood Falls | 2,797 | 2,734 | 2,643 | 2,525 | 2,378 | 2,206 | 109 | Oct. 2 | Oct. 9 |
| Worthington | 2,440 | 2,394 | 2,322 | 2,224 | 2,100 | 1,951 | 96 | Sep. 30[c] | Oct. 7[c] |
| ***South-Central*** | | | | | | | | | |
| Faribault | 2,484 | 2,434 | 2,361 | 2,263 | 2,138 | 1,987 | 103 | Sep. 29 | Oct. 12 |
| Mankato | 2,624 | 2,568 | 2,487 | 2,379 | 2,246 | 2,088 | 100 | Oct. 2[d] | Oct. 13[d] |
| Waseca | 2,547 | 2,494 | 2,415 | 2,308 | 2,175 | 2,018 | 105 | Sep 30 | Oct. 6 |
| Winnebago | 2,695 | 2,637 | 2,554 | 2,444 | 2,308 | 2,146 | 95 | Oct. 6 | Oct. 17 |
| ***Southeast*** | | | | | | | | | |
| Preston | 2,342 | 2,294 | 2,225 | 2,133 | 2,016 | 1,873 | 119 | Sep. 23 | Oct. 3 |
| Red Wing | 2,560 | 2,503 | 2,423 | 2,318 | 2,188 | 2,034 | 118 | Sep. 26[e] | Oct. 4[e] |
| Rochester | 2,378 | 2,329 | 2,258 | 2,163 | 2,045 | 1,904 | 94 | Oct. 1 | Oct. 12 |
| Winona | 2,690 | 2,633 | 2,553 | 2,447 | 2,315 | 2,158 | 91 | Oct. 7 | Oct. 20 |
| ***West-Central*** | | | | | | | | | |
| Alexandria | 2,316 | 2,271 | 2,202 | 2,109 | 1,995 | 1,860 | 83 | Oct. 1 | Oct. 12 |
| Canby | 2,713 | 2,656 | 2,573 | 2,465 | 2,329 | 2,169 | 105 | Oct. 1 | Oct. 10 |
| Fergus Falls | 2,328 | 2,282 | 2,211 | 2,117 | 1,999 | 1,861 | 92 | Sep. 28 | Oct. 8 |
| Montevideo | 2,559 | 2,506 | 2,409 | 2,326 | 2,196 | 2,042 | 102 | Sep. 30 | Oct. 7 |
| Morris | 2,474 | 2,422 | 2,345 | 2,241 | 2,114 | 1,964 | 96 | Sep. 29 | Oct. 6 |
| Wheaton | 2,531 | 2,481 | 2,407 | 2,308 | 2,184 | 2,034 | 91 | Oct. 1 | Oct. 10 |
| ***Central*** | | | | | | | | | |
| Collegeville | 2,660 | 2,601 | 2,516 | 2,405 | 2,271 | 2,116 | 94 | Oct. 5 | Oct. 18 |
| Hutchinson | 2,589 | 2,533 | 2,451 | 2,342 | 2,209 | 2,051 | 99 | Oct. 1 | Oct. 13 |
| Melrose | 2,415 | 2,368 | 2,296 | 2,197 | 2,074 | 1,926 | 106 | Sep. 25 | Oct. 5 |
| St. Cloud | 2,236 | 2,189 | 2,118 | 2,025 | 1,909 | 1,775 | 99 | Sep. 24 | Oct. 5 |
| Staples | 2,011 | 1,969 | 1,905 | 1,820 | 1,715 | 1,594 | 95 | Sep. 22[f] | Oct. 2[f] |
| Willmar | 2,525 | 2,472 | 2,395 | 2,291 | 2,162 | 2,009 | 89 | Oct. 3 | Oct. 15 |
| ***East-Central*** | | | | | | | | | |
| Aitkin | 1,904 | 1,869 | 1,812 | 1,735 | 1,639 | 1,525 | 82 | Sep. 24 | Sep. 30 |
| Forest Lake | 2,491 | 2,439 | 2,363 | 2,260 | 2,135 | 1,987 | 86 | Oct. 5 | Oct. 17 |
| Hinckley | 1,980 | 1,944 | 1,886 | 1,807 | 1,708 | 1,591 | 90 | Sep. 22 | Sep. 28 |
| Rosemount | 2,505 | 2,452 | 2,377 | 2,279 | 2,156 | 2,007 | 92 | Oct. 4[g] | Oct.14[g] |
| ***Northwest*** | | | | | | | | | |
| Crookston | 2,245 | 2,201 | 2,131 | 2,037 | 1,919 | 1,781 | 98 | Sep. 23 | Oct. 2 |
| Itasca | 1,805 | 1,777 | 1,728 | 1,657 | 1,566 | 1,456 | 81 | Sep. 20 | Sep. 26 |
| Moorhead | 2,365 | 2,316 | 2,242 | 2,142 | 2,020 | 1,876 | 103 | Sep.24[h] | Oct. 3[h] |
| Warroad | 1,935 | 1,906 | 1,855 | 1,782 | 1,686 | 1,568 | 77 | Sep. 23 | Sep. 30 |

[a] Source: http://climate.umn.edu/cropddgen

[b] Source: http://climate.umn.edu/text/historical/frost.txt

[c] Worthington frost dates unavailable so Windom was used.

[d] Mankato frost dates unavailable so St. Peter was used.

[e] Red Wing frost dates unavailable so Zumbrota was used.

[f] Staples frost dates unavailable so Long Prairie was used.

[g] Rosemount frost dates unavailable so Farmington was used.

[h] Moorhead frost dates unavailable so Ada was used.

mature or dry down adequately before the first fall freeze, resulting in ears with tightly wrapped husks that do not dry down very well. In addition, insurance may not cover plantings with inappropriate maturities. Most organic producers plant later than conventional producers to reduce early-season weed densities, and thus should plant earlier-maturing varieties.

Producers should consider spreading hybrid maturity selections between early and mid-season hybrids to reduce the risks of damage from disease and environmental stress at different growth stages. This improves the odds of successful pollination and spreads out harvest time and workload. An example would be a 25-50-25 maturity balance, with 25, 50, and 25 percent of the acreage planted to early-season, mid-season, and mid- to full-season hybrids, respectively. Planting a full-season hybrid first, then following with planting early-season and mid-season hybrids allows the grower to take full advantage of the maturity ranges.

**Table 9-8. Corn variety trial websites in the Upper Midwest.**

| UNIVERSITY/WEBSITE | NOTES |
|---|---|
| Iowa State University<br>*http://extension.agron.iastate.edu/organicag/rr.html* | Dedicated trials to organic varieties |
| Ohio State University<br>*http://agcrops.osu.edu/corn/* | Dedicated trials to organic varieties |
| University of Wisconsin<br>*http://corn.agronomy.wisc.edu/HT/Default.aspx* | Dedicated trials to organic varieties |
| University of Illinois at Urbana-Champaign<br>*http://vt.cropsci.illinois.edu/corn.html* | Includes a few non-GMO hybrids |
| University of Minnesota Agricultural Experiment Station<br>*http://www.maes.umn.edu/vartrials/corn/index.asp* | At this time, usually only GMOs included |
| South Dakota State University<br>*http://plantsci.sdstate.edu/varietytrials/* | At this time, usually only GMOs included |
| North Dakota State University<br>*http://www.ag.ndsu.nodak.edu/plantsci/breeding/corn/index.htm* | At this time, usually only GMOs included |

### *Yield potential and performance consistency*

Yield potential is the most important selection trait when comparing hybrids of the same maturity. Hybrids that consistently produce high yields over multiple sites or years within a region should be targeted, since one cannot predict next year's growing conditions. When comparing yield results, it is critical to consider results from multiple locations, climates, and years. Trials with data that combine these factors and provide average yield data will be more useful than trials from a single location or year. When comparing one variety's performance across different trials, producers should take into consideration that trials may be managed differently with regard to plant population, soil fertility, weed control, and the type of planting and harvesting equipment used, and that these factors can cause variation in results among trials.

Unfortunately, information available to organic growers on corn varieties is less comprehensive than that available to conventional growers. Many universities in the Upper Midwest conduct yearly corn variety trials (Table 9-8). However, much of the information will not be applicable because of the prevalence of GMO corn entries, which are not allowed in organic agriculture. There are few large-scale variety trials that either include many non-GMO hybrids or are run under organic conditions. Organic producers may have to utilize trial information from neighboring states when local data is not available.

### *Standability*

High amounts of lodging will slow harvest and decrease yields. Lodging can be caused by insect damage to roots, high winds, or weak stalks caused by stalk rots. Stalk lodging can be enhanced by thin stalks resulting from high plant populations. Variety traits associated with improved lodging resistance and standability include resistance to stalk rots, genetic stalk strength, short plant height and ear placement, and strong rooting potential. Some variety trials will also include ratings for lodging.

### *Other traits*

There are other agronomic traits important to organic corn producers such as canopy closure, rapid early growth, disease resistance, dry-down, and grain quality. Many of these traits will be important relative to specific producers. For example, if a producer has their own drying facilities and are prepared to harvest at relatively high moisture levels (around 25 percent), then fast dry-down rates may be somewhat less important.

**Reducing risk: selecting varieties. Choose more than one variety to spread risk. Consider planting different maturities to spread out the timing of field operations. Always choose the correct maturity for a location; the risk of loss will not be worth the slight potential for higher yields (in Minnesota, full-season hybrids have not consistently out-yielded mid-season hybrids). When trying a new variety, test it on a small area before committing to a whole field.**

## PRODUCER PROFILE

A producer from Pipestone Country relies on green manures like red clover, alfalfa and sweet clover for fertility. This field has had no other type of input since 1977 (Figure 9-6). He is pleased with his soil fertility and tilth with the green manure system. He says that his soil has greatly improved in the last 30 years. He moldboard plows his green manures in the fall because he has problems with green manures competing for moisture in the spring. He harrows twice in the spring before planting and uses inter-row cultivations for weed control. He plants corn hybrids with relative maturities in the mid-90s.

**Figure 9-6.** *Organic corn in Pipestone County on July 28, 2008. This field was planted on May 17th in 2008.*

## Soil fertility

Corn has a moderate to high requirement for essential nutrients, particularly nitrogen (N). Depending on the previous crop, residual soil N, inherent soil fertility, and economics, corn will need anywhere from 0 to 180 pounds N per acre. A good crop of soybean will provide about 40 pounds N per acre, but soybean alone in rotation will not supply all of the N needed by a following corn crop. To fulfill the remaining N requirements, corn growers will need to supplement with manure, compost, and/or green manure.

Livestock manures have the potential to provide many essential nutrients for corn, but their relatively low N concentration may lead to excessive phosphorus fertilization if they are the primary source of N for the crop and are applied at the rate needed to meet the crop's N requirement. Unfortunately, manure and compost are limited on many non-livestock farms. In addition to animal manures, sources of nitrogen include green manure crops and cover crops. Crop rotation including forage legumes, especially alfalfa, is key to supplying adequate N. Studies show that rotations where corn follows at least one year of alfalfa produce higher corn yields than the typical corn-soybean rotation. For example, at Waseca, MN, a single year of alfalfa improved the subsequent corn yield by 34 to 130 percent when compared to corn following corn, with the greatest rotation effect occurring when little or no N fertilizer was used (Table 9-9). This same study also found that a single year of soybean improved the subsequent corn yield by 16 to 40 percent when compared to corn following corn, and that this response was relatively consistent, regardless of the N fertilizer rate used. Cover crops or green manure crops differ in the nutrient content of their tissues and hence the amount of nutrients they provide to the subsequent crop. See Chapter 4 on soil fertility for more information.

**Table 9-10. Estimating plant population.** *For a given row width, count the number of plants in the corresponding length of row from the table and multiply by 1,000 to get plants per acre.*

| ROW SPACING | ROW LENGTH |
|---|---|
| 40″ | 13′ 1″ |
| 38″ | 13′ 9″ |
| 36″ | 13′ 6″ |
| 30″ | 17′ 5″ |
| 22″ | 23′ 9″ |
| 20″ | 26′ 2″ |
| 15″ | 34′ 10″ |

**Table 9-9. Corn grain yields as influenced by previous crop and N fertilizer rate at Waseca, Minnesota.**
*Alfalfa was incorporated in the fall. Adapted from Sheaffer et al, 1989.*

| N rate (lb N/acre) | CORN YIELD (BU/ACRE) BASED ON PREVIOUS CROP: Corn | Soybean | Wheat | Alfalfa, 3-cut | Alfalfa, 1-cut |
|---|---|---|---|---|---|
| 0 | 50 | 58 | 57 | 80 | 115 |
| 50 | 65 | 90 | 99 | 124 | 137 |
| 100 | 100 | 122 | 128 | 137 | 139 |
| 150 | 103 | 138 | 127 | 138 | 138 |
| 200 | 100 | 140 | 144 | 145 | 145 |

**Reducing risk: soil fertility. Conduct regular soil testing to confirm that corn nutrient requirements can be met. Use manure or compost to supply nutrients when necessary. Green manures and crop rotations are some of the best options for providing nitrogen to corn.**

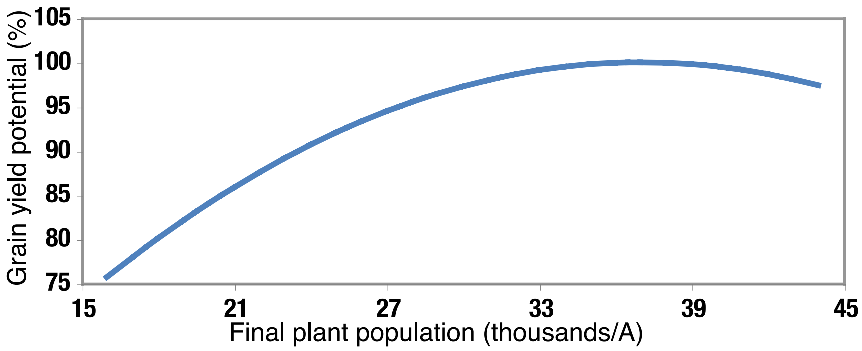


**Figure 9-7.** ***Potential grain yield as affected by plant population in Lamberton and Waseca, MN for conventional corn. When plant populations are around 36,000 plants/acre, yield is maximized. Adapted from Coulter, 2009b.***

# Planting

Successful planting sets the stage for the crop's utilization of resources.

## PLANT POPULATION

The seeding rate is the rate at which seed is planted while plant population is the number of plants that ultimately survive. Thus, seeding rates should be adjusted upward to account for losses in order to obtain the desired final plant population. The seeding rate for corn will depend on seed germination, planting date, soil conditions, the number and type of weed control operations, and pests present. The optimum final plant population is dependent on hybrid, moisture conditions, corn price, and seed cost. In general, plant populations are higher in high-yielding environments and lower in low-yielding environments. Research from Illinois suggests that optimum final plant populations change by 830 to 940 plants per acre with each 10 bushel per acre change in yield level (Nafziger, 2009).

Producers can estimate their plant populations by taking stand counts and using Table 9-10. A general guideline for organic corn growers is to target a final plant population between 28,000 to 32,000 plants per acre. For conventional producers in Minnesota, 32,000 to 34,000 plants per acre is optimum (Figure 9-7). However, there is evidence that organic producers may benefit from planting at higher rates (Table 9-11). Recent research in conventional systems from southern Minnesota indicates that the optimum final plant population is similar regardless of planting date

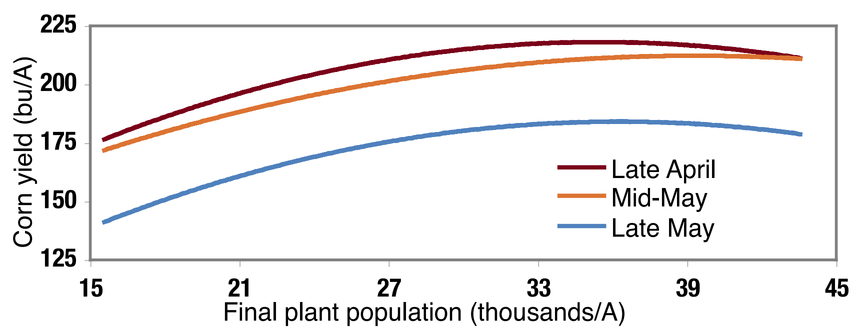


**Figure 9-8.** ***Response of conventional corn grain yield to final plant population by planting date at Lamberton and Waseca, MN in 2008 and 2009. Adapted from Coulter, 2009a.***

**Table 9-11. Organic corn yield by plant population in Wisconsin.** ***Highest yields were obtained with final plant populations over 30,000 plants per acre. Adapted from Holman, 2006.***

| | Yield (bu/acre) | | | |
|---|---|---|---|---|
| Population (plants/acre) | 2003 | 2004 | 2005 | Average |
| 18,000 | 81 | 79 | 79 | 80 |
| 24,000 | 86 | 91 | 94 | 90 |
| 30,000 | 92 | 95 | 102 | 96 |
| 36,000 | 101 | 102 | 112 | 105 |

(Figure 9-8). This is useful, since organic growers typically plant later than conventional growers for weed control purposes.

**Reducing risk: seeding rate. Keep track of seeding rates, final stands, and yields for every field. When considering a higher plant population, try varying seeding rates by 10 percent above your normal seeding rate in test strips before making a change over the entire farm.**

## PLANTING DATE

Organic farmers in Minnesota generally plant their corn up to two weeks later than conventional growers within the same region. The benefits of later planting dates are many, including better mechanical weed control, warmer soils that facilitate quicker and more uniform corn emergence (Figure 9-9), fewer seedling diseases, and lower risk for GMO contamination from neighboring conventional fields due to differences in the time of pollination.

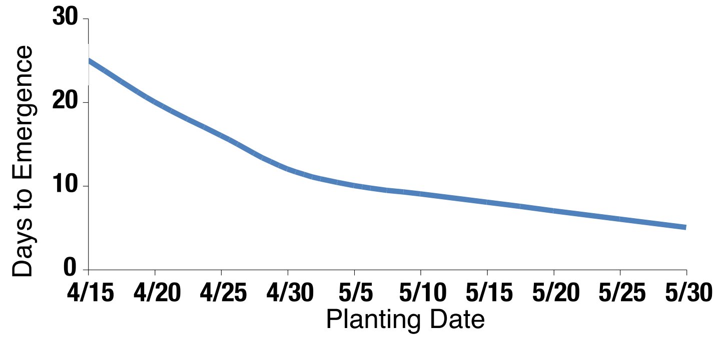


**Figure 9-9.** *Days to emergence will vary by planting date. When planted on April 15th, seed takes 25 days to emerge, while planting on May 10th (a typical corn planting date for Minnesota organic farmers) seed takes 9 days to emerge. Good weather conditions can sometimes make up for some lost time of delayed planting. Adapted from Hicks, 2004.*

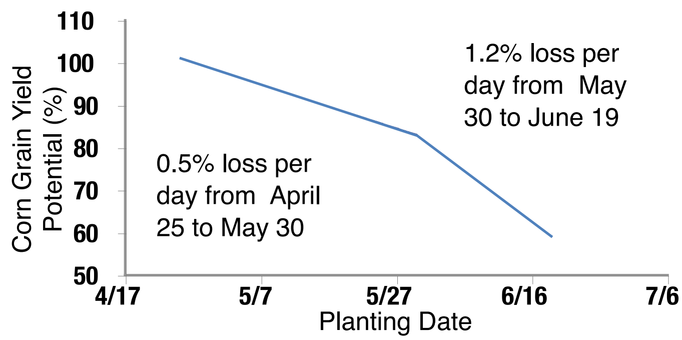


**Figure 9-10.** *Potential yield loss at later planting dates. Adapted from Hicks et al, 1999.*

Drawbacks of late planting include reduced yield (Figure 9-10), a smaller selection of early-maturing varieties than mid- or full-season varieties, and a later harvest date that may result in wetter grain and a narrow window of time available for planting a winter cover crop or conducting fall tillage. Producers must decide how to balance the tradeoffs when choosing when to plant. See Table 9-12 for the latest recommended planting dates.

**Table 9-12. Latest recommended planting dates for corn.** *Adapted from Hicks et al., 1999.*

| DATE | LOCATION | TYPE |
|---|---|---|
| June 5th | central and northern MN | grain |
| June 15th | southern MN | grain |
| June 25th | southern MN | silage |

**Reducing risk: planting date. Unless weeds are especially problematic, producers should plant as early as possible. Choose earlier maturities when planting later.**

**A producer in Faribault County plants corn around May 12 to May 15. The red clover regrowth in the spring is also an indicator of time to plant. The latest he will plant corn is May 29 and he does notice lower yields when using this late date.**

**Table 9-13. Rotary Hoeing Tips for Corn.**
*Adapted from Endres, 2007.*

| |
|---|
| Hoe when weeds are small |
| Most effective on weeds that have germinated, but not emerged, and when conducted 3 to 7 days after planting |
| Drier soils are better |
| Warm, windy, rain-free weather after hoeing is best |
| Don't hoe corn at spike to one-leaf stage |
| Increase planting rates five to ten percent for attrition losses |

### PLANTING DEPTH

An optimal planting depth for corn is 1.75 to 2 inches. Planting at a depth of 2.5 inches will help to ensure adequate moisture if soil conditions are very dry. When excessive soil moisture is present, producers can plant as shallow as 1.5 inches, but that increases risk. Planting shallow increases the risk for poor establishment of the nodal roots that develop between the seed and soil surface during the early vegetative stages. This is particularly true if the upper surface of the soil dries out or if corn is planted into fluffy soil that settles after heavy rains, resulting in seed placement that is shallower than originally desired.

**Reducing risk: planting depth. A planting depth of 1.75 to 2 inches is typically ideal, but can be adjusted slightly depending on soil moisture level. Plant seed into moisture.**

## Weed management

Weed management is important for optimizing organic corn yield. Weeds compete with corn for water, light, and nutrients, particularly nitrogen. Corn is not a strong competitor with weeds, especially perennials such as Canada thistle. A few of the nitrogen-loving weeds that are problematic for corn production

### Seed coatings

Seed coatings can protect seed from soil-borne pathogens and allow for earlier planting dates. Most often, organic seed is not protected by a seed coating because the conventional seed coat technology uses synthetic materials not allowed under organic regulations. Some organic seed coatings are available on the market, including Agricoat Natural II, Blue River Hybrids NII, and ProfitCoat seed coatings. Some seed coatings are formulated with microorganisms and nutrients. Under certain conditions, corn yield can be increased by using these organic seed coating (Figure 9-11). For producers who use a later corn planting date when soils are usually warmer and drier, coated seed may not be worth the additional price.

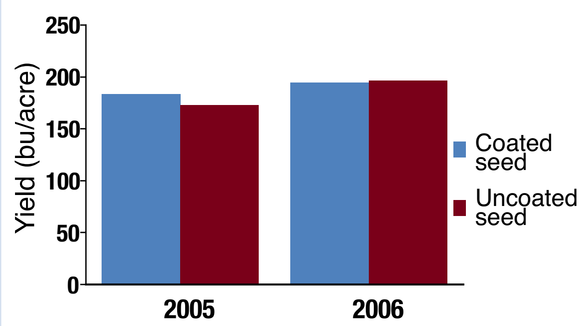


**Figure 9-11.** *Corn yields of organic coated (Agricoat Natural II) and uncoated seed of the same variety in 2005 and 2006. In 2005, a cooler season, the seed coat treatment had a significantly higher yield, while in 2006, which was warmer, there were no significant yield differences. Delate et al., 2006.*

**A producer from Lac Qui Parle County finds that a May 10 planting date for corn is too early. There tends to be a cold snap at that time and the soil temperatures are not consistently greater than 50° F. He wants emergence to occur within 10 days so the seedlings are vigorous so he plants on May 20.**

include lambsquarters, pigweed, and quackgrass. Tactics to manage weeds organically can be divided into cultural and mechanical control.

### Cultural weed control

Two effective techniques for weed management are delayed planting and crop rotation. Delayed planting allows the first flush of weeds to be killed with tillage prior to planting, and will balance yield gains from improved weed control against yield losses from later planting. Diversifying crop rotations to include non-row crops is another tactic for weed control. See Chapter 2 on crop rotations for more information.

**Table 9-14. Post-emergence operations by corn growth stage.** *Adapted from Canadian Growers Guide, 2001.*

| CORN HEIGHT | IMPLEMENT |
|---|---|
| 2-6 inches | rotary hoe |
| 4-6 inches | inter-row cultivation |
| 12-18 inches | inter-row cultivation |
| 2-leaf stage | flame weeder, above |
| > 2-leaf stage | flame weeder, side |

### Mechanical weed control

Timing of weed control operations is critical. Pre-plant weed control strategies can include false seedbed and stale seedbed. The false seedbed approach involves preparing a seedbed to enhance weed germination, followed by tillage to destroy the weed seedlings and prepare a new seedbed with less weed emergence than the original seedbed. A stale seedbed approach is similar to a false seedbed approach, except that weed seedlings are killed with very shallow tillage to avoid bringing new weeds seeds up to the soil surface where they have a better chance of germinating.

**Table 9-15. Corn yield under different weed management in Waseca, MN.** *Rotary hoeing occurred 9 and 13 days post-planting. Cultivations occurred 3 and 5 weeks after planting. Rotary hoeing in combination with cultivation was most effective. Adapted from Gunsolus, 1990.*

| WEED CONTROL TREATMENT | YIELD (BU/ACRE) |
|---|---|
| No weed control | 43 |
| 1 cultivation | 103 |
| 2 cultivations | 105 |
| 2 rotary hoeings | 91 |
| 2 rotary hoeings, 1 cultivation | 139 |
| 2 rotary hoeings, 2 cultivations | 149 |
| 2 rotary hoeings, 2 cultivations + herbicide | 168 |

Rotary hoe and harrows are commonly used by organic producers in the Upper Midwest for

## PRODUCER PROFILE

**An organic producer from Faribault County, MN uses diverse mechanical weed control operations in his corn. Seven to ten days prior to planting corn, he makes one pass with a field cultivator. He makes another immediately prior to planting. He then scouts three to four days after planting. Depending on weed germination, he may perform a pre-emergence operation by harrowing when the corn is 1/4 inch below the soil surface. He uses an aggressive type of harrow appropriate for his soil. He would not recommend aggressive harrowing on lighter soils such as a sandy loam. Once the corn has emerged, he will rotary hoe depending on weed pressure. He finds this usually does not hurt corn much. Row cultivations are done depending on weed pressure and are done at the white-root stage. If there are few weeds, he will skip this step and use a flame weeder instead.**

pre-emergence operations (Table 9-13). These mechanical methods work best if the soil is dry. Various implements can be used for post-emergence operations depending on the growth stage of the corn crop (Table 9-14). Rotary hoeing and the first inter-row cultivation are most important to reduce losses to weeds (Table 9-15). Rotary hoeing is most productive three to seven days after planting, but can also be used when corn is two to six inches tall. Inter-row cultivation is most effective on weeds three to five weeks after planting. Corn will generally need to be mechanically cultivated two to three times in the growing season. Mechanical control is necessary during the first six weeks after planting, but weeds that emerge after 6 weeks will not cause yield reduction.

See the Weed Management and Weed Biology chapters for more materials on weed management.

**Reducing risk: weed management. A diversified approach to weed control that includes crop rotation and timely tillage will be most effective.**

# Pest Management

The major insect pests of corn in the Upper Midwest are the European corn borer (ECB), corn rootworm, and seed corn maggot (SCM). Crop rotation and selecting resistant varieties are the first lines of defense in organic pest management.

## EUROPEAN CORN BORER

*Ostrinia nubilalis*

KEITH WELLER, USDA-ARS

**Figure 9-12.** *European corn borer.*

***Identification:*** ECB are 3/4 to 1 inch long, gray to creamy white, with a black head and a body with dark spots. Adults are straw-colored moths with roughly a 1-inch wingspan. Females lay eggs on the underside of corn leaves near the mid-bit; egg masses are about 3/16th-inch long.

***Life cycle:*** ECB overwinter as mature larvae, living in old stalks, weeds, or vegetable stems. Spring development begins when temperatures are above 50° F. Larvae pupate in May and moths appear in June. Cool weather or drought may cause a delay in development, while a warm spring will cause an early start. Moths spend evenings laying eggs in corn fields, especially when temperatures are high and humidity is low. Initial feeding occurs in the corn whorl, and as the plant grows, this feeding resembles shot holes in the leaves.

***Crop damage:*** Major injury to field corn by tunneling in the stalk and ear shank, which impairs the translocation of water and nutrients and causes ears to drop.

**Reducing risk: European corn borer. Late plantings are usually more resistant to ECB. Conserve grassland and wooded areas to attract natural enemies. Deep moldboard plowing can bury and destroy residue in which ECB overwinters. Stalk shredding or use of stalks for silage can also be used to prevent overwintering. However, ECB can migrate from neighboring fields. Use tolerant varieties. Crop rotation and disking are less effective control measures.**

## CORN ROOTWORM:

*Diabrotica spp.*

USDA-ARS.

**Figure 9-13.** ***Corn rootworm.***

Corn rootworms that are major pests in the US include western corn rootworm (WCR) (*Diabrotica virgifera vigifera*), northern corn rootworm (NCR) (*D. barberi*) and southern corn rootworm (SCR) (*D. undecimpuncata*). Both northern and western rootworms are pests on corn in MN.

***Identification:*** NCR adult beetles are pale green without stripes or spots. WCR adult beetles are larger, with three black stripes running down its yellow wing covers. Male WCR have black wing covers without stripes on a yellow background. SCR is yellow to green with black spots on wing covers. Larvae for all species are legless, slender, white with a tan head, and about 7mm long.

***Life cycle:*** Adult beetles feed in the field where they emerge. In the fall, adults migrate to late-planted corn fields to continue feeding and lay eggs in the soil. Eggs overwinter in the soil, and spring larvae look similar for all species. Larvae feed and pupate in the soil. Larvae will die if corn roots are not available when eggs hatch, though a new variant of this insect lays eggs that remain in the soil for two years prior to hatching, thus allowing this pest to overcome the corn-soybean rotation. In the central Corn Belt, another variant of this insect has adapted to the corn-soybean rotation by laying its eggs in soybean rather than corn. WCR and NCR have one generation per year in MN. SCR is unable to overwinter in Minnesota.

***Crop damage:*** Feeding on corn roots, which reduces water and nutrient uptake and increases the potential for root lodging. Adult beetles can also clip silks at pollination.

**Reducing risk: corn rootworm. Longer crop rotations with greater crop diversity will reduce infestations.**

**Some organic producers in Waseca County use later corn planting dates in order to have fewer issues with corn rootworm.**

## SEED CORN MAGGOT:

*Delia platura*

ERIC C. BURKNESS. UNIVERSITY OF MINNESOTA.

**Figure 9-14.** ***Seed corn maggot on bean seedling.***

SCM are an occasional pest of corn, especially in the spring to new seedlings. Damage is amplified if germination is slowed by wet, cold conditions.

***Identification:*** maggots are yellowish-white, 1/4 inch long, legless with wedge-shaped heads, and are found in seeds or feeding on cotyledons emerging from seeds. Pupae are brown, oval, 1/5 inch long. Adults are similar to small houseflies and dark gray. Large swarms can be seen in the spring, flying over freshly plowed fields.

LYNN BETTS, USDA-NRCS.

**Figure 9-15.** ***Physical barriers, such as this windbreak in Iowa, can reduce pollen drift from GMOs.***

***Life cycle:*** SCM overwinter as pupae in the soil and emerge in early spring as adult flies. Flies mate and lay eggs in soil with abundant decaying organic matter. Their lifecycle takes about three weeks, and three generations in Minnesota are common. The first generation causes the most crop damage.

***Crop damage:*** burrowing into and destroying newly planted seed; feeding on germinated seedlings.

**Reducing risk: seed corn maggot. Greatest damage potential from this pest is in cool wet springs. Prevention is the key strategy. If concerned, avoid cover crop plow down or animal manure application in spring before corn planting. Choose quality seed. Delay planting in cold wet springs and wet areas.**

## Preventing GMO contamination

Contamination from genetically modified organisms (GMOs) can occur at almost any step of the corn production process. Besides being one of the most prevalent crops on the landscape in the Upper Midwest, corn is one of the most likely crops to be genetically modified in conventional production. Because corn is highly out-crossing, preventing GMO contamination is extremely critical for organic growers. GMO contamination is a serious issue and can cause a crop to be rejected by the buyer or the crop to lose the organic premium. Federal crop insurance will not reimburse for GMO contamination.

**Although she would prefer to plant corn in early May, a producer from Stevens County plants later to avoid GMO cross-pollination from neighbors. Her corn is tested for GMOs.**

GMO contamination can occur from impure seed, mixing of seed, pollen drift, volunteer plants, equipment contamination, and hauling vehicles. Preventing contamination begins before the crop is even planted (Table 9-15). The first step is to verify that the seed you buy is non-GMO. The second step is to isolate crops physically with barriers or distance, or temporally with delayed planting and crop rotation to counter planting schedules of neighboring fields with GMO crops. 150 feet may be enough to separate GMO and non-GMO corn from significant pollen drift. Producers should keep samples of seed, harvested crop, and delivered crop until the buyer is certain that it falls below required tolerance levels. Good sanitation practices will need to be performed with all equipment, storage facilities, and transportation units. There is a quiz at the end of this chapter to assess your risk for GMO contamination.

**Table 9-16. Preventing GMO Contamination.**
***Adapted from Riddle, 2008.***

| |
|---|
| Verify non-GMO seed from supplier |
| Establish good communication with your neighbors |
| Know your neighbors—are they planting GMO corn? Which fields? |
| Be a good neighbor—post your fields as organic |
| Set up physical barriers by isolating fields with wind breaks or by distance |
| Coordinate planting with conventional neighbors to offset pollen drift |
| Keep harvesting/hauling vehicles clean |
| Keep equipment, storage facilities, and transportation units clean |
| Keep good records |
| Save samples of seed, harvested crop, and delivered crop |
| If on contract, know buyer specification for GMO tolerance |

**Reducing risk: GMO contamination. Be alert to conventional corn grown in neighboring fields and consider how they may affect your crop. Take proper actions at every step in the growing process to prevent contamination. Know what your buyers' specifications are for GMO tolerance levels.**

# Harvesting

Corn reaches physiological maturity at about 60 days after pollination. Physiological maturity coincides with the development of the black layer at the base of the kernel and disappearance of the milk line.

Prior to harvest, producers should monitor stalk strength, which can be checked by pinching the lower stalk at the first internode above the brace roots, or by pushing plants about 10 inches from vertical at ear level. Plants with weak stalks will collapse when pinched, or fail to bounce back when pushed. Fields with a high percentage of weakened stalks should be a priority in harvesting because of risk for lodging.

Combine adjustment is another important consideration before harvest. Producers who experience high levels of volunteer

JOHN DEERE

**Figure 9-16.** *Corn harvest.*

corn plants in subsequent crops should make combine calibration a priority. Field losses due to poorly adjusted equipment negatively affect yield in the crop harvested as well as the yield in the next crop because of volunteers.

At physiological maturity, corn grain moisture averages about 32 percent. Harvest of field corn usually begins when grain moisture is around 25 percent or less. Harvested grain is dried to 15 percent moisture for short-term storage and 13 percent for long-term storage. Field drying is the least expensive approach to reducing grain moisture levels (Table 9-17). However, delaying harvest to allow for more field drying could 1) increase pre-harvest losses due to lodging and dropped ears, 2) increase weather risk due to less calendar time for harvest, and 3) decrease time after harvest for other field operations such as manure application, tillage, or planting cover crops.

**Table 9-17. Field drying rates for corn in Minnesota.**
*Adapted from Coulter, 2008.*

| DATE | % MOISTURE LOSS/DAY |
|---|---|
| September 15 - 25 | 0.75 to 1 |
| Sept. 26 - Oct. 5 | 0.5 to 0.75 |
| October 6 -15 | 0.25 to 0.5 |
| October 16 - 31 | 0 to 0.33 |
| November | minimal |

Corn can be dried in several ways to attain the acceptable storage moisture concentration of 15 percent. To reduce moisture of the grain, it must be dried to prevent spoilage. Natural air drying can be successful in Minnesota as it works best under cool (40 to 60º F) and dry (55 to 75 percent relative humidity) conditions. Since average fall temperature and humidity are often in these ranges in the Upper Midwest, natural-air drying usually works quite well. Other methods include low-temperature bin drying, high-temperature bin drying, where air is heated to high temperatures for faster drying; and layer-drying, where grain is dried in layers rather than filling the whole bin. Temperature during drying must be kept below 110º F so that germination is not affected. Once dry, aerate to maintain temperatures of 50° F or less so grain does not mold. See Table 9-18 for tips on corn grain storage.

**Reducing risk: harvesting. Scout corn fields for stalk strength and plan harvest accordingly. Make proper adjustments to combine before harvest and monitor harvest losses during harvesting operations. Corn grain should be dried to the correct moisture for storage.**

**Table 9-18. Tips for corn grain storage.**
*Adapted from Wilcke and Wyatt, 2002.*

| |
|---|
| Remove chaff, weed seeds and broken kernels |
| Handle grain gently to prevent damage |
| Store at 15% moisture for up to six months |
| Store at 13% moisture for longer than six months |
| Keep grain temperature less than 50° F; for winter storage, keep at 20-30° F. |
| Aerate stored grain |
| Monitor stored grain often |

# Conclusion

Take the following quiz to determine your ability to minimize risk in organic corn production.

# Corn Risk Management Quiz

| | Points | Score |
|---|---|---|
| **1. What type of seed do you usually use when growing corn?** | | |
| Conventional, untreated | 3 | |
| Organic | 4 | |
| Open-pollinated | 1 | |
| Saved seed | 1 | |
| **2. What type of corn do you usually grow?** | | |
| Feed grade | 4 | |
| Food grade | 1 | |
| Specialty | 1 | |
| **3. Which of the following do you use to choose a new corn variety? Score 2 points for each answer.** | | |
| University trials in my state | 2 | |
| University trials in other states | 2 | |
| Seed companies | 2 | |
| Local on-farm trials | 2 | |
| Recommendations from other producers | 2 | |
| **4. Do you select seed using maturity and yield potential as the primary deterimining factors?** | | |
| Yes | 3 | |
| No | 0 | |
| **5. Do you check with your certifier before using new seed types or seed treatments?** | | |
| Yes, always | 3 | |
| Yes, usually | 1 | |
| No | 0 | |
| **6. Do you have good working relationships with your neighbors?** | | |
| Yes | 3 | |
| No | 0 | |
| **7. Which of the following do you generally use to provide nitrogen to corn?** | | |
| Manure | 3 | |
| Compost | 3 | |
| Green manure | 3 | |
| Crop rotation | 3 | |
| Other amendment | 2 | |
| None of the above | 0 | |
| **8. Do you consider weather and field conditions prior to planting so seed will come up quickly?** | | |
| Yes | 1 | |
| No | 0 | |

| | Points | Score |
|---|---|---|
| **9. How long is your crop rotation?** | | |
| 2 years | 0 | |
| 3 years | 3 | |
| 4 years | 4 | |
| 5 or more years | 6 | |
| **10. What seeding rate (seed/acre) do you use for a corn hybrid?** | | |
| Less than 26,000 | 0 | |
| 26,000 to 28,000 | 1 | |
| 28,001 to 30,000 | 3 | |
| 30,001 to 32,000 | 4 | |
| More than 32,000 | 5 | |
| **11. What is your target plant population for a corn hybrid?** | | |
| Less than 26,000 | 1 | |
| 26,000 to 28,000 | 2 | |
| 28,001 to 30,000 | 4 | |
| More than 30,000 | 5 | |
| Do not have a target | 0 | |
| **12. What is your typical planting date?** | | |
| At the same time as conventional producers in my area | 1 | |
| One week later than conventional | 2 | |
| Two weeks later than conventional | 4 | |
| More than two weeks later than conventional | 2 | |
| **13. How deep should corn be planted under ideal soil conditions?** | | |
| 1 to 1.25 inches | 0 | |
| 1.25 to 1.5 inches | 0 | |
| 1.75 to 2 inches | 4 | |
| 2.25 to 2.50 inches | 0 | |
| **14. Do you vary maturities and varieties to spread risk?** | | |
| Yes | 3 | |
| No | 0 | |
| **15. Can you identify insect pests that attack corn?** | | |
| Yes | 3 | |
| No | 0 | |

| | Points | Score |
|---|---|---|
| **16. Effective control measures for corn rootworm include:** | | |
| Crop rotation | 4 | |
| Delayed planting | 4 | |
| Moldboard plowing | 0 | |
| Stalk chopping | 0 | |
| **17. How many different tools (i.e. equipment types) do you have for weed control?** | | |
| 1 | 0 | |
| 2 | 3 | |
| 3 | 4 | |
| 4 or more | 5 | |
| **18. How many weed control operations do you typically perform during the corn growing season?** | | |
| 1 to 2 | 1 | |
| 3 | 3 | |
| 4 | 5 | |
| 5 or more | 2 | |
| **19. Do you monitor fields for corn stalk strength before harvest?** | | |
| Yes, always | 3 | |
| Yes, usually | 2 | |
| No | 0 | |
| **20. Do you monitor stored grain regularly?** | | |
| Yes, always | 3 | |
| Yes, usually | 2 | |
| No | 0 | |
| | TOTAL | |

| If your score is: | Your risk is: |
|---|---|
| 52 or above | Low |
| 20 to 51 | Moderate |
| 9 to 19 | High |

# GMO Contamination Risk Management Quiz

| | | Points | Score |
|---|---|---|---|
| **1. Do you verify that your corn seed is non-GMO contaminated with seed test results from suppliers?** | | | |
| | Yes | 1 | |
| | No | 0 | |
| **2. Which of the following methods do you use to protect your organic fields from GMO drift? Score one point for each method.** | | | |
| | Distance | 1 | |
| | Windbreaks | 1 | |
| | Buffer rows | 1 | |
| | Rotation | 1 | |
| | Delayed planting | 1 | |
| **3. Do you communicate with your neighbors regarding your operations?** | | | |
| | Yes | 1 | |
| | No | 0 | |
| **4. Do you clean equipment thoroughly, particularly when using rented or borrowed equipment?** | | | |
| | Yes | 1 | |
| | No | 0 | |
| **5. Do you inspect and clean units prior to storage?** | | | |
| | Yes | 1 | |
| | No | 0 | |
| **6. Do you ensure that GMO-crops are segregated during storage from non-GMO crops?** | | | |
| | Yes | 1 | |
| | No | 0 | |
| | Not applicable | 1 | |
| **7. Do you replant saved seeds?** | | | |
| | Yes | 0 | |
| | No | 1 | |
| **8. Do you keep samples of seed, harvested crop, and delivered crop until buyer is certain of quality?** | | | |
| | Yes | 1 | |
| | No | 0 | |
| | Not applicable | 1 | |
| **9. Do you know what your buyer's tolerance for GMO contamination levels is?** | | | |
| | Yes | 1 | |
| | No | 0 | |
| | Not applicable | 1 | |
| | | TOTAL | |

| If your score is: | Your risk is: |
|---|---|
| 13 to 9 | Low |
| 8 to 5 | Moderate |
| 4 or less | High |

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