Risk Management Guide for Organic Producers

EDITED BY KRISTINE M. MONCADA AND CRAIG C. SHEAFFER

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Risk Management Guide for Organic Producers

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DISCLAIMER

AVAILABILITY

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CHAPTER 1

Introduction

ABOUT THIS PUBLICATION

Organic agriculture is an ecologically-based management system with the primary objective of optimizing the health of soil, animals, and people. The term "organic" is defined by federal law so that any crop or livestock labeled or sold as "organic" must be produced according to the national regulations in the National Organic Program (NOP) rules. Most states in the Upper Midwest have seen an increase in the number of organic farms from 2000 to 2008 (Table 1-1), evidence that organic agriculture in our region is still growing. Even with the poor economy, sales of organic food products have been increasing, although at a slower pace than earlier in this decade (Minnesota Department of Agriculture, 2010).

Figure 1-1. ***Weeds are one of the biggest challenges for organic producers.***

Why is it important to address risk management in organic farming? We believe that organic agriculture intrinsically has greater risk than conventional agriculture because of the greater

Table 1-1. Number of certified farms in the Upper Midwest by state in 2000 and 2008. *Adapted from the USDA-ERS, 2010.*

	NUMBER OF CERTIFIED FARMS		
	2000	2008	% CHANGE
Illinois	95	162	+ 71
Indiana	73	180	+ 147
Iowa	332	677	+ 104
Michigan	143	256	+ 79
Minnesota	382	543	+ 42
North Dakota	170	152	- 11
South Dakota	91	103	+ 13
Wisconsin	432	1016	+ 135

An organic farmer from McLeod County says you can judge your overall level of risk in organic farming by gauging the following: 1) your management skill level, 2) your availability of labor resources, and 3) your equipment availability.

complexity in crop management issues such as fertility, weed control and pest control. Also, organic producers lack the many synthetic fertilizer and inputs for flexibility in management of risk. Consequently, there is a need for information directed to organic producers on managing risk. Risk is involved whenever producers make decisions where the outcome is uncertain. Decisions such as cropping sequence, variety selection, planting date, or planting rate are examples of decisions with elements of risk. Part of risk management is choosing to use resources to effectively achieve your objectives and to avoid loss, while still maximizing opportunities. There are many categories of risks affecting organic farmers. The types of risk include production, price, institutional, human, and financial. In this publication, we focus on production risks for crops that include cultural practices, variety selection, and management of pests and diseases.

A recent survey by the Minnesota Department of Agriculture identified the greatest production risks facing organic crop producers. Weed control is the leading concern, but numerous other factors including soil fertility contribute to the risks facing producers (Figure 1-2). As part of this project, we talked with organic farmers about important production topics and their concerns matched up closely with those of the survey.

Farmers recognize that decision making relies not only on hard facts, but also on experiences. Thus, the knowledge and practices of current organic farmers are among the most important aspects we included in this project, alongside University-based re-

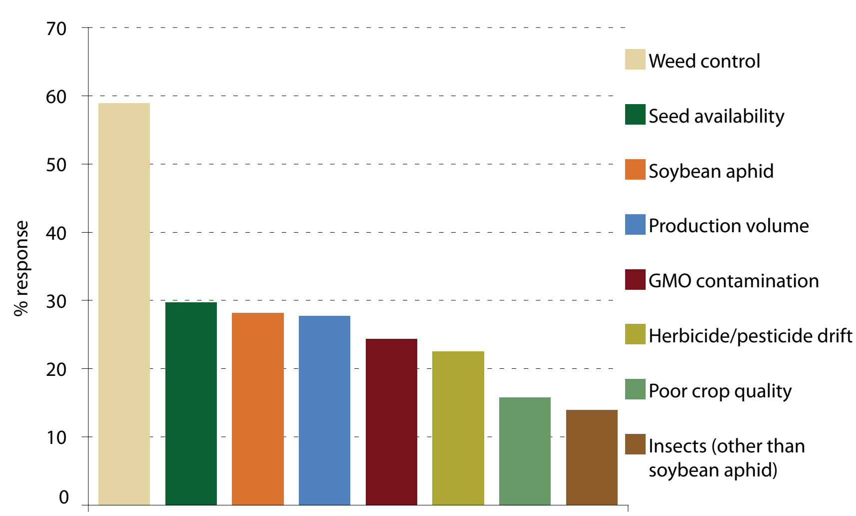

Figure 1-2. *Production challenges for Minnesota organic producers. Adapted from the Minnesota Department of Agriculture, 2008.*

search. This publication will help growers who are contemplating adopting organic production practices understand the risks that are associated with organic production and make choices that will minimize those risks. Additionally, this guide will also be beneficial to all organic producers, regardless of their level of experience.

HOW TO USE THIS PUBLICATION

This manual is intended as a guide for organic and transitioning producers in the Upper Midwest to lower risk in their operations. The fourteen chapters of this manual cover a wide range of production topics that are relevant to organic farmers. These include the importance of rotation, soil health and fertility, weeds, cover crops, and crop profiles. Each chapter can function as a stand-alone document if you are only interested in a certain topic, although the chapters were designed to be read consecutively.

At the end of each chapter are quizzes to gauge your risk in a given topic. Once you have answered all quiz questions and added up your score, your risk level in that area will be assessed with a "High", "Medium", or "Low" risk rating. Please realize that risk assessment does not predict failure or success; it provides the likelihood of an outcome. If your quiz results indicate high risk, use these results to examine your operation. It may be that there are areas in which you can improve, while still maintaining yield and preserving the ideals of organic agriculture.

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CHAPTER 2

Rotation

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CRAIG SHEAFFER

Crop rotation is the predetermined sequence of crops that one grows on a certain field (Figure 2-2). Typically, producers use cropping systems on their farms that include fields containing different rotations to provide a diversity of crops in any given year. The benefits of a well-planned rotation include lower disease and insect risk, improved soil structure and fertility, increased biological activity in soil, and better economic risk management. There are also other unknown rotation effects that can increase yield of subsequent crops.

Figure 2-1. *Alfalfa, soybean and corn.*

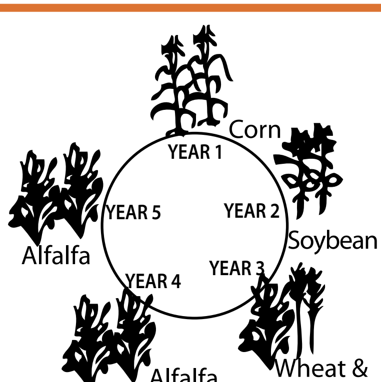


Figure 2-2. *A five-year crop rotation.*

Organic producers are required under the National Organic Program (NOP) rules to choose crop rotations that protect and improve the soil, and provide pest and nutrient management. Not only does one need to consider the factors above, but also that rotations need to be tailored to a specific site, as well as to an individual's skills and time management, equipment availability, and the economics and market for specific crops in an area.

Organic farmers are not able to use many of the strategies (such as those involving synthetic chemicals) available to conventional farmers. However, they still have one of the strongest management tools—rotation, which can address a variety of issues. A diverse rotation will lead to fewer insect, weed and disease problems and, with the inclusion of legumes and perennials, increase fertility and soil health. Rotation diversification is a key strategy to reduce both production and financial risk. This chapter addresses the benefits of how rotation can help with soil health, yield, weeds, pests, and economics, and what factors to consider in planning a rotation.

A farmer from McLeod County uses his rotation to manage issues with weeds. For example, he uses alfalfa to manage foxtail, small grains to manage broadleaf weeds, and sudangrass and sorghum to manage thistle. He has livestock which allow more flexibility in his operation.

Benefits of Rotations

ROTATION AND SOIL HEALTH

Longer rotations can improve soil health. Compare the difference in soil quality between two- and four-year rotations, managed organically or conventionally (Figure 2-3). The four-year organic rotation has the best soil structure.

Individual crops can have different effects on soil health. A perennial crop like alfalfa will benefit the soil structure more than corn or soybean in part because it is a perennial and is not tilled annually (Figure 2-4).

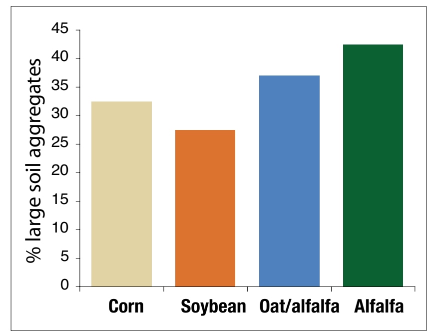


Figure 2-4. Crop effects on soil structure *in Lamberton, MN. In a four-year organic rotation, the soil structure was best after alfalfa. Adapted from Kuratomi et al, 2004.*

Increasing soil health through diverse rotations can lead to increased soil fertility and crop yield (Figures 2-5 & 2-6). Corn, which has high nitrogen needs, is an example of a crop that will have greater yields in diverse rotations.

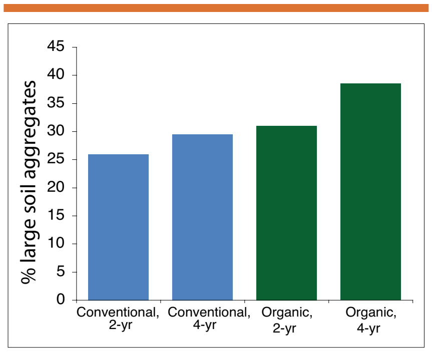


Figure 2-3. Soil aggregation, *a gauge of tilth and water infiltration, under different management systems and rotation lengths in Lamberton, MN. The 4-year rotation managed organically has better soil structure with the highest percentage of large soil aggregates. Adapted from Kuratomi et al, 2004.*

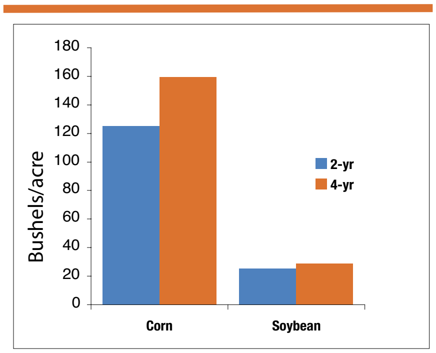


Figure 2-5. Corn and soybean yields *in organically managed 2- and 4- year rotations in Lamberton, MN. Corn and soybeans were grown either in a two-year rotation or in a four-year rotation including alfalfa. The yield of corn was significantly greater in the 4-year rotation. Adapted from Kuratomi et al, 2004.*

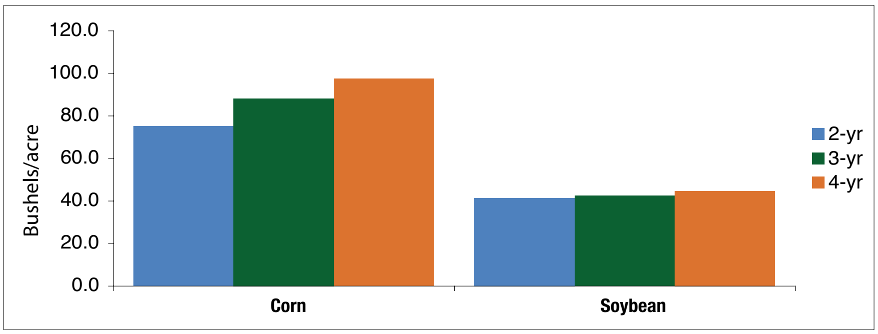


Figure 2-6. Corn and soybean yield *in 2-, 3-, and 4-year rotations in the mid-Atlantic region. The corn yields increase significantly as rotation length increases. Adapted from Cavigelli et al, 2008.*

A rotation can be managed to provide fertility. For instance, corn is a crop that depletes nutrients. On the other hand, legumes like alfalfa (Figure 2-7) contribute rather than deplete nitrogen. Legumes are often included in rotations because the nitrogen they fix is available to a subsequent crop. Producers need to consider overall fertility in planning their rotations. See Chapters 3 and 4 on soil and fertility for more information.

Reducing risk: soil health. Increase the length of your rotation. Include perennial legumes like alfalfa and red clover.

ROTATION AND WEEDS

Rotation will have an effect on the weeds in a system. Increasing the complexity of a rotation can reduce weeds because of the varying cultural practices used with different crops and differences in life cycles or grow habits.

Growing only warm season annual plants such as soybean and corn are a risk. Consider the reasons why. The planting dates for these crops are similar for the organic producer. Field prep and weed control operations may be performed at similar times. They are both planted similarly in rows. The outcome may be selection of weed species that are adapted to these similar conditions. Examples of weeds adapted to a corn and soybean system are foxtails or pigweeds (See Weed Chapters 5, 6, and 7 for more information).

Adding non-row crops like forages and small grains can be a tool to control weeds that thrive

Figure 2-7. *Alfalfa is one of the best crops for soil health.*

Table 2-1. Perennials and small grains and the weed species they may suppress

WEED SPECIES	WEED TYPE	SUPPRESSED BY:	
		Perennial forages	Small grains
Wild oats	Spring annual	✔	
Common lambsquarters	Summer annual	✔	✔
Common ragweed	Summer annual		✔
Giant ragweed	Summer annual	✔	✔
Eastern black nightshade	Summer annual	✔	✔
Foxtails	Summer annual	✔	
Pigweeds	Summer annual	✔	✔
Smartweeds	Summer annual	✔	✔
Velvetleaf	Summer annual	✔	✔
Wild proso millet	Summer annual	✔	
Horseweed	Winter or summer annual		✔
Canada thistle	Perennial	✔	
Hemp dogbane	Perennial	✔	✔

in row crops. Perennial forages and small grains can suppress many of the species that are problems in corn and soybean (Table 2-1). Because they are not row crops, they compete differently against weeds that are problems in corn and soybean. Alternately, perennial crops like hay can lead to selection for perennial weeds that might normally be controlled under a row crop. Alternating the different types of crops will reduce risk.

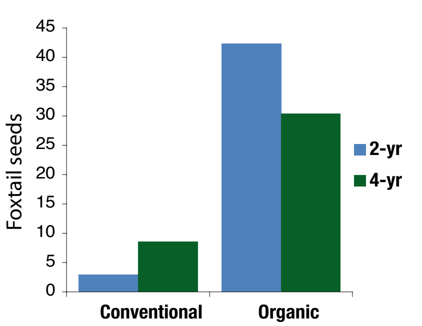


Figure 2-8. Rotation effects on foxtail *seed bank in Lamberton, MN. The four-year organic rotation has significantly fewer foxtail seeds compared to the two-year rotation. Adapted from Haar et al, 2008.*

Longer rotations in organic systems may have fewer seeds of some weeds in the seed bank (Figure 2-8). Crop sequence will also have an effect on the weed seed banks (Figure 2-9).

Reducing risk: weeds.

Increase the complexity of rotations by including crops with different life cycles and seasonal growth. Examine which weed species are an issue and plant a crop that may suppress that weed type.

ROTATION AND PESTS

One of the biggest benefits to a longer rotation is to break disease and insect pest cycles. Some pests overwinter in residue and soil and survive to harm the next crop if it is susceptible. Non-susceptible crops can cause the pest to die out without a host or move elsewhere. An example is European corn borer (Figure 2-10), which can be controlled by several years without corn in the rotation. Another example is soybean cyst nematode (Table 2-2). The pests that are affected by rotation and the number of years it takes to break pest cycles are shown in Table 2-3.

Not all pests will be affected by altering rotation. Good examples of this are soybean aphid, which overwinters on buckthorn, and soybean rust, which infects fields by traveling in each season via wind from warmer parts of the country.

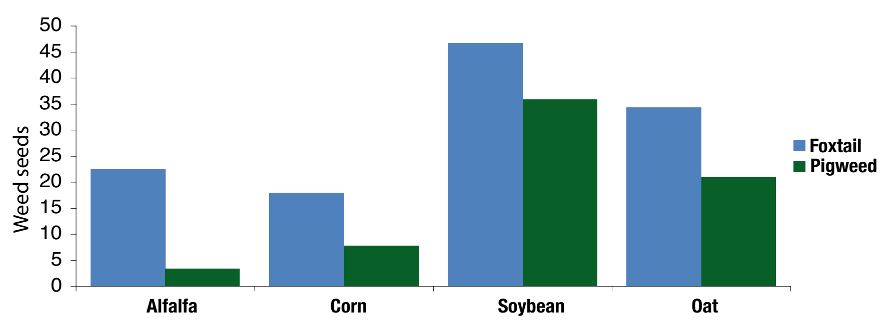


Figure 2-9. Crop sequence effects on weed *seed banks in Lamberton, MN. Fewer foxtail and pigweed seeds were found after alfalfa and corn compared to soybean and oat. Adapted from Haar et al, 2008.*

Table 2-2. Rotation and soybean cyst nematode on organic farms in Minnesota.

The shorter rotations had higher soybean cyst nematodes. Rotations with soybean every other year or every two years had SCN above the level at which crops are damaged.

ROTATION	SCN (eggs/100cc)
Soybean every other year	3657
Soybean every two years	1306
Soybean every three years	496
No soybean	0

Insects will be more difficult to control with rotations alone because insects are mobile. An additional factor is the predominance of that crop in an area. If a producer is surrounded by continuous corn grown by neighbors, rotation to control insects that plague corn will be less effective.

Planting later than conventional neighbors can sometimes assist in pest or disease management.

Reducing risk: pests. Be aware of surrounding farms when deciding on a rotation. Increase rotation length to disrupt pest cycles.

ROTATION ECONOMICS AND LOGISTICS

There are benefits to diverse rotations that are not related to production. Growing diverse crops in different fields can spread out the financial risk. If one of the crops is lost or suffers low yields due to disease, insects, or weather, there will still be other crops to produce income. However, one must be aware of what the markets are for different crops before selecting crops for rotations.

Growing diverse crops allows producers to spread out the work load. For example, 500 acres all grown with corn requires intense activity at specific times of the season. The time frames for planting, cultivating, and harvesting all the fields will occur simultaneously. Having fields with diverse crops like small grains, soybean, corn, and alfalfa will allow a producer to stretch the work out over the season.

Reducing risk: economics and logistics. Know the market potential for prospective crops. Realize time limitations for planting, cultivating, and harvesting crops that have similar schedules.

KEITH WELLER USDA-ARS

Figure 2-10. *European corn borer is an example of a pest that can be controlled with rotation.*

Table 2-3. Pests that are affected by rotation and the number of years it takes to break several different pest cycles.

CROP	PEST	ROTATION PERIOD
Soybean	Soybean cyst nematode	3-5 years
Soybean	Sclerotinia (white mold)	4-5 years
Soybean	Phytophthora	2-3 years
Soybean	Rhizoctonia	3 years
Corn	Corn root worm	1-2 years
Corn	Northern corn leaf spot	1-2 years
Corn	Gray leaf spot (corn)	2-3 years
Corn	Northern corn leaf blight	1-2 years
Corn	Corn ear mold	3-4 years
Corn	Scab	2-3 years
Corn	European corn borer	3 years
Small grains	Fusarium	1-2 years
Small grains	Septoria leaf glume blotch	2 years
Small grains	Bacterial leaf blight	2 years
Small grains	Common root rot	2 years
Small grains	Ergot	1 year
Small grains	Scab	2-3 years
Alfalfa	Verticillium wilt	2-3 years

Planning a rotation

There are two components of a good rotation to consider—diversity and sequence.

DIVERSITY

Increasing the length of a rotation will naturally mean more diversity in a rotation. The next question to answer is which crops to include that will promote diversity. For example, if choosing crops that have different root types (e.g. tap-rooted, fibrous-rooted, deep-rooted, shallow-rooted, etc.), instead of crops with only shallow roots, then the soil will benefit by having a better structure. Other examples would be alternating legumes with non-legumes, grasses with broadleaves or warm-season crops with cool-season crops (Figure 2-11).

Reducing risk: diversity. Vary species in rotation. Include species that have different characteristics.

SEQUENCE OF ROTATION

Along with the amount of diversity in a rotation, the order in which a certain crop occurs in a rotation can be critical. For example, it would be unusual to plant soybeans after three years of alfalfa. The prudent organic producer knows that it would be better to plant corn. Otherwise, the available nitrogen would not be utilized and there is the possibility of increased disease and insects due to following one legume with another. There can be different risks associated with planting one crop species after another (Table 2-4). Of course, while some combinations are generally preferable to others, it is also important to consider which issues are most important in a given operation.

Reducing risk: sequence. Vary species in rotation. Do not plant closely related species right after another.

Table 2-4. Risk levels of individual crop sequences.

Crop 1	*followed by* Crop 2	Disease	Weeds	Insect	Fertility	Moisture
Corn	Corn	NA	NA	NA	NA	NA
	Soybean	reduces risk	increases risk	reduces risk	reduces risk greatly	no effect or results varial
	Small grain	no effect or results varial	reduces risk	no effect or results varial	no effect or results varial	no effect or results varial
	Forage legume	reduces risk	reduces risk	no effect or results varial	reduces risk greatly	reduces risk
Soybean	Corn	reduces risk	increases risk	reduces risk	reduces risk	no effect or results varial
	Soybean	NA	NA	NA	NA	NA
	Small grain	reduces risk	reduces risk	reduces risk	reduces risk	no effect or results varial
	Forage legume	increases risk	reduces risk	increases risk	no effect or results varial	no effect or results varial
Small grain	Corn	no effect or results varial	no effect or results varial	no effect or results varial	no effect or results varial	reduces risk
	Soybean	reduces risk	reduces risk	reduces risk	reduces risk	no effect or results varial
	Small grain	increases risk greatly	increases risk	increases risk	no effect or results varial	no effect or results varial
	Forage legume	reduces risk	reduces risk	reduces risk	reduces risk	reduces risk
Forage legume	Corn	reduces risk	reduces risk greatly	reduces risk	reduces risk greatly	reduces risk greatly
	Soybean	increases risk	reduces risk	increases risk	no effect or results varial	reduces risk
	Small grain	reduces risk	reduces risk greatly	reduces risk	reduces risk	reduces risk
	Forage legume	increases risk greatly	increases risk	increases risk greatly	no effect or results varial	reduces risk

- = reduces risk greatly
- = reduces risk
- = no effect or results varial
- = increases risk
- = increases risk greatly

Figure 2-11. Examples of traits to vary to increase diversity in a rotation.

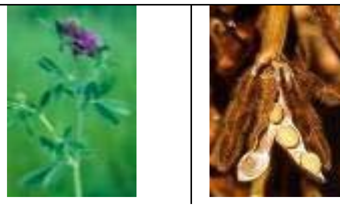
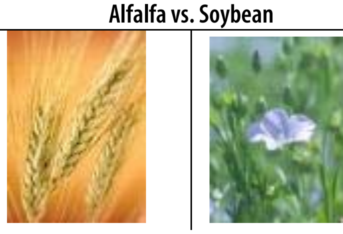
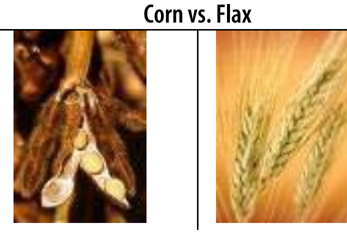
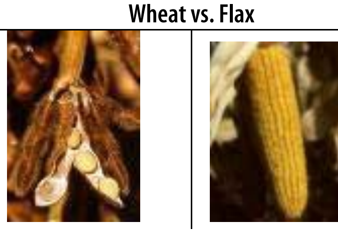
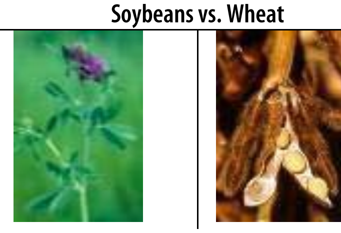
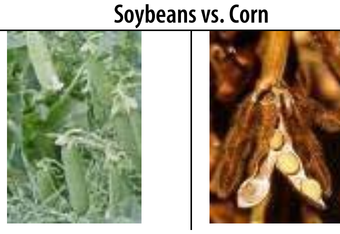
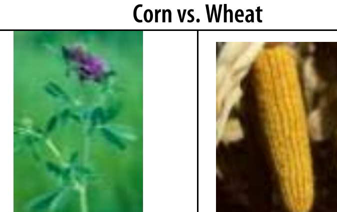
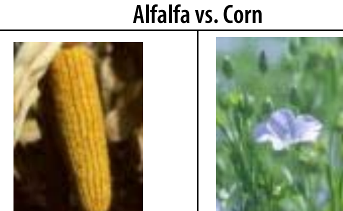
Trait to vary	Examples	Trait to vary	Examples
Nitrogen use: vary crops with high N needs with ones with low needs	 Corn vs. Red clover	**Species**: the more diversity in a rotation, the better	 Oats vs. Barley
Rooting depth: vary crops with deep roots with ones with shallow roots	 Alfalfa vs. Soybean	**Row spacing**: vary crops with different row widths	 Corn vs. Flax
Competitive: vary crops that compete well with ones that don't	 Wheat vs. Flax	**Planting dates**: vary crops with different planting dates	 Soybeans vs. Wheat
Legumes: vary legumes with non-legumes	 Soybeans vs. Corn	**Harvest dates**: vary crops with different harvest dates	 Alfalfa vs. Soybean
Season: vary cool season crops with warm season crops	 Field peas vs. Soybeans	**Crop height**: vary tall crops with short crops	 Corn vs. Wheat
Cultivars: vary cultivars to gain pest resistance and other benefits	 Cultivar 1 vs. Cultivar 2	**Life cycle**: vary annuals with perennials	 Alfalfa vs. Corn
Growth habit: vary crops with upright growth with low-growing crops	 Wheat vs. Red clover	**Adaptation to Mechanical Weed Control:** vary crops that tolerate mechanical weed control	 Corn vs. Flax

Figure 2-12. *Oats underseeded with alfalfa.*

Rotation examples for the Upper Midwest

To comply with NOP rules, the minimum number of crops and length rotations must be one of the following:

- Two crops, if one of the crops is a perennial that is grown longer than two years
- Two crops, if a cover crop is included
- Three crops, if two of the crops produce high residue (corn is high residue, while soybean is not)

Below are some rotations of organic farmers who grow row crops. They are listed in order of least to most risk. Generally, the longer the rotation, the less risky it is. Ways to reduce risk in each rotation are noted.

FIVE-YEAR ROTATIONS

■ Corn-Soybean-Small Grain/Alfalfa-Alfalfa-Alfalfa

Considerations: Three years of alfalfa production will provide all the nitrogen to meet the fertilizer needs of a subsequent corn crop and provide weed control. Perennials like alfalfa will increase soil health. The soil will have continuous protection from erosion for three years. Rotations that are five years or longer in length with a diversity of crops are generally low risk from a production perspective. This rotation is often used by livestock producers and growers who market hay for organic dairy and livestock operations. A possible challenge to this system will be whether there is livestock to use the alfalfa hay.

Flexibility: Oat is the most traditional small grain companion crop for alfalfa (Figure 2-12). Wheat or barley could replace oats depending on markets. Likewise, field beans could substitute for soybean.

Risk level: This rotation is LOW risk.

■ Corn-Soybean-Corn-Small Grain/Alfalfa-Alfalfa

Considerations: Because corn is used twice in five years, there is one more year of a high value row crop when compared to the previous rotation. On the other hand, there is one less year of alfalfa, which leads to less nitrogen contribution and reduced weed control. The risk here is growing corn so soon after a previous corn crop which may lead to increased insect problems. Also there are three years of continuous row crops which can lead to more weeds adapted to row cropping.

Flexibility: Oat, wheat, or barley could be used as the small grain crop.

Risk level: This rotation is LOW risk.

FOUR-YEAR ROTATIONS

■ Corn-Soybean-Small Grain/ Alfalfa-Alfalfa.

Considerations: This is the four-year version of the first rotation above. One year less of alfalfa will mean less nitrogen for the next crop and less weed control. The soil will still have continuous coverage for two years. This can still be a good option with somewhat less N benefits and less weed control.
Flexibility: Oat, wheat, or barley could be used as the small grain crop.
Risk level: This rotation is LOW risk.

THREE-YEAR ROTATIONS

■ Corn-Soybean-Small grain/ Red clover

Considerations: This rotation is more common for producers who do not have livestock. The red clover can be clipped in the fall and then terminated in the spring. The red clover will provide some nitrogen to the corn. Because the red clover is kept growing over the winter, the soil will be protected from erosion one year out of three. One main disadvantage will be in reduced weed control. Fertility may be an issue. Soil amendments like compost and manure can supplement nutrients due to less green manure crops in the system.
Flexibility: Oat, wheat, or barley could be used as the small grain crop. Red clover can be terminated in fall instead of spring.
Risk level: This rotation is MODERATE risk.

A producer from Stevens County uses sunflowers as a substitute for soybean in her rotation during times of drought or aphid problems.

PRODUCER PROFILE

Here is how one experienced organic producer from Lac Qui Parle County handles his rotation. He grows barley, oats, wheat, flax, field peas, red clover, alfalfa, corn, soybean and some winter grains. His rotation is dependent on soil conditions. Weed issues also determine a specific rotation. He uses corn minimally due to nutrient and moisture needs. His rotation will range from a minimum of three years and up to six years. Fields with low weed pressure and high nutrients will have a rotation as little as three years (corn-soybean/small grains/red clover). However, his average rotation is four to five years long. An example of a longer rotation would be corn-soybean-small grain/alfalfa-alfalfa-alfalfa-alfalfa. For him, flax and field peas work in the place of small grains in his rotation. Every small grain (or flax or field peas) is seeded with a companion crop.

His success is due in part to his ability to be flexible in his rotation. Planning rotations is a mix of looking ahead as well as the ability to be flexible. He is always thinking two or three years ahead in his rotations. When he is out cultivating, he is considering weed issues he has that can be addressed with rotation. He considers the market and his time constraints before deciding how much flax to plant. He looks at nutrient levels before planting corn. In the winter, he examines the past 10 years of field histories before committing to the next season's crops. He has to be flexible with his rotation in years when he cannot get winter grains planted soon enough. The next year, he substitutes a spring grain like barley or field peas.

■ Corn-Soybean-Small grain

Considerations: Fertility may be an issue. Soil amendments like compost and manure will need to supplement nutrients due to no green manure crops in the system. Producers will see more benefits in this rotation by planting with an underseeded legume companion crop.
Flexibility: Oat, wheat, or barley could be used as the small grain crop.
Risk level: This rotation is MODERATE risk.

TWO-YEAR ROTATIONS

■ Corn –Soybean with cover crop(s)

Considerations: A two-year rotation must have three crops to be a technically acceptable rotation for organic farmers, but some certifiers may not allow this option. The cover crop will provide soil benefits, but can be risky to manage. There will be little protection from corn rootworm or soybean cyst nematode, not to mention many other diseases and insects. Weeds will be more prevalent in a two-year rotation. Advantages include growing high-value crops more frequently, and less need to diversify equipment. There may be nutrient issues because, although soybean is a legume, it contributes little nitrogen. Expect to utilize amendments like compost or manure.
Flexibility: Cover crop options in this scenario are rye, hairy vetch, red clover, oat, and others, that differ in how much, if any, nitrogen they provide.
Risk level: This rotation is HIGH risk.

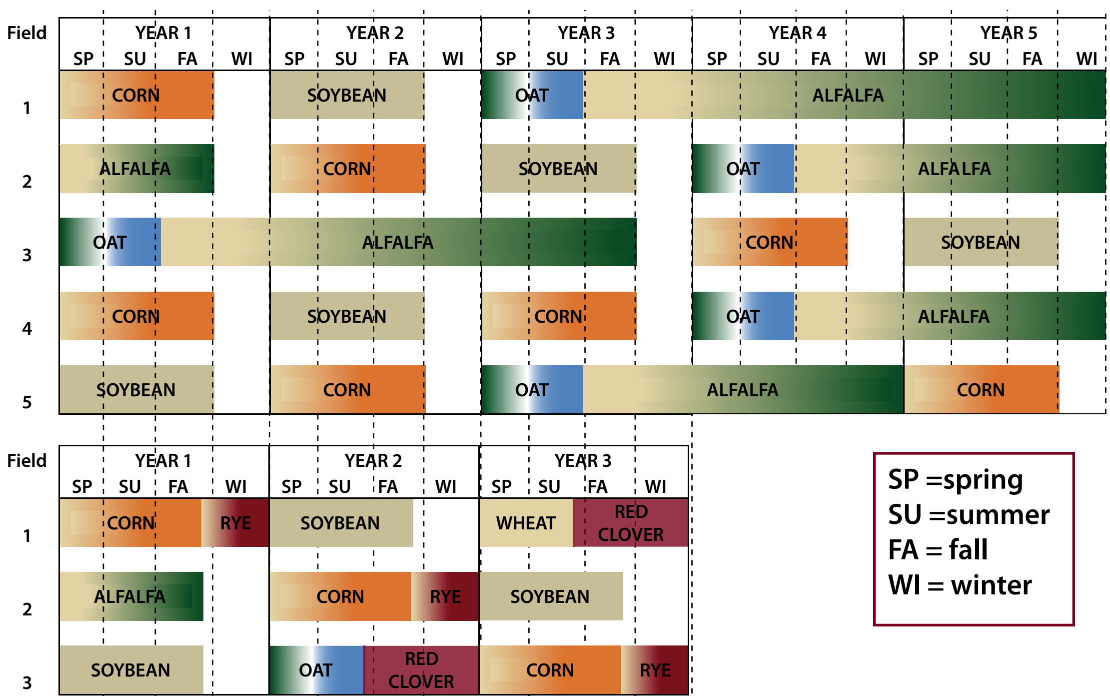


Figure 2-13. Multi-field rotations. *Here are two examples of farms, one with five fields and one with three fields. Notice how the different crops are spatially separate from field to field and not just temporally separate in a single field.*

WHOLE-FARM PLANNING

Rotations need to be managed at the whole-farm level, as well as for an individual field. In considering a rotation for a single field, the main consideration is separation through time (temporal separation). When considering an entire farm, there are multiple fields and separation through space (spatial separation) that must be regarded. For example, a producer who has a three-year rotation with corn, soybean, small grains and red clover would be unlikely to choose growing corn on every field in a given year. A better option would be to stagger rotations to have corn on one field, soybean on another, and small grains underseeded with red clover on yet another (Figure 2-13).

Consider the distance of a neighbor's fields in whole-farm rotation planning. Diseases and insects can be transmitted easily to an adjacent field if the same crop is grown the following year in an adjacent field. Note that while advance planning is always a good idea, flexibility to respond to new situations is helpful in considering a rotation.

Reducing risk: whole-farm planning. Develop long-term plans, but still maintain flexibility.

CONCLUSION

Rotation is an important management tool. In the following chapters, rotation will come up again as one of the best risk management techniques for the organic farmer. Take the following quiz to determine risks associated with rotation.

Crop Sequence Calculator

The Crop Sequence Calculator software provides information on crop production, economics, plant diseases, weeds, water use, and surface soil properties to aid producers in evaluating risks associated with various crop sequences. The crops included in the latest version (February 2008) are barley, buckwheat, canola, chickpea, corn, crambe, dry bean, field pea, flax, grain sorghum, lentil, proso millet, safflower, soybean, spring wheat, and sunflower. This software is recommended for the Northern Great Plains. Western Minnesota may be comparable. The Crop Sequence Calculator CD-ROM is available for free from the following link. http://www.ars.usda.gov/Main/docs.htm?docid=10791

Rotation Risk Management Quiz

	Points	Score
1. How many years is your rotation?		
2	0	
3	1	
4	3	
5	4	
6 or more	5	
2. How many different crops does your rotation include?		
3	0	
4	1	
5	3	
6	4	
7 or more	5	
3. How many legumes besides soybean does your rotation include?		
0	0	
1	1	
2	2	
3 or more	3	
4. Do you follow the same rotation or do you have flexibility to make changes when necessary?		
Yes, I follow the same rotation	0	
No, I am flexible	3	
5. How many years separate one corn crop from another?		
1	0	
2	1	
3 or more	2	
Not applicable	2	

	Points	Score
6. How many years separate one soybean crop from another?		
1	0	
2	1	
3 or more	2	
Not applicable	2	
7. How many years separate one small grain crop from another?		
1	0	
2	1	
3 or more	2	
Not applicable	2	
8. Does your rotation include a perennial?		
No	0	
Yes	3	
9. Do you use the same variety of a given crop or do you vary varieties?		
Use the same variety	0	
Change varieties	3	
10. When planning one field's rotation, do you also consider adjacent fields of your own or your neighbors?		
No	0	
Yes	3	
Add points from Questions 1 — 10:		
	TOTAL	

If you have:	Your risk is:
0 - 10	High
11 - 20	Moderate
21 - 31	Low

FOR MORE INFORMATION

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DAVID L. HANSEN

Figure 2-13. ***Soybean and corn fields.***

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CHAPTER 3

Soil Health

JOHN LAMB
SHERI HUERD
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Soil is a natural mix of weathered rock and organic matter that forms on the Earth's surface. It is the foundation for all crop production. It is biologically active and home to a wide range of living organisms including soil microbes, earthworms, and growing plant roots. Soil is composed of minerals, air, water, and organic matter that are important for healthy plant growth. The ability of soil to provide essential nutrients is called fertility. This chapter reviews some of the general properties of soil, soil conservation, and plant nutrient needs.

LYNN BETTS, NRCS

Figure 3-1. ***The topsoil contains most of the plant roots, organic matter and plant nutrients that are present in soil.***

Soil Profile

A soil profile consists of a number of horizontal layers, or horizons in a vertical arrangement down from the soil surface. The top layer is usually an A (mineral), or O (organic matter) horizon that overlays the A horizon (Figure 3-2). The A horizon, considered the topsoil, is the darkest, contains the most organic matter, is biologically active, and has the most available nutrients for plant growth (Figure 3-3). Most tillage operations affect the A horizon. Its depth will vary depending on the history of its formation and recent use. Most plant roots are in the top foot of soil; however, some crops like alfalfa have roots that penetrate to lower levels of the soil profile.

SOIL HORIZONS

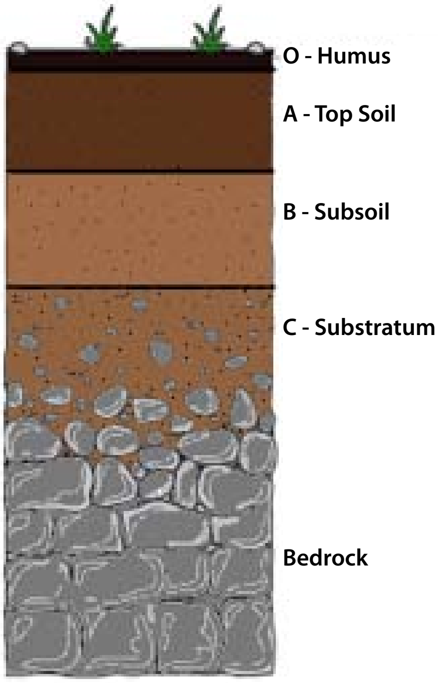


Figure 3-2. *Horizons of a soil profile.*

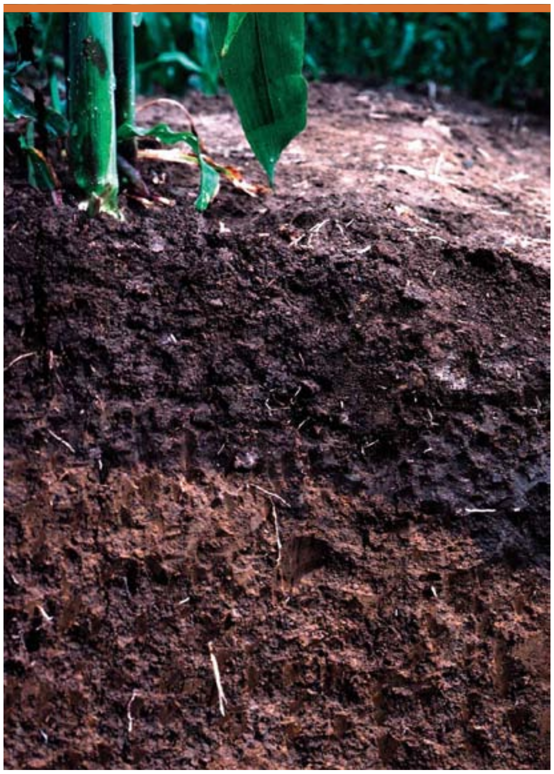

LYNN BETTS, NRCS

Figure 3-3. *Soil profile in central Iowa shows the dark color of the topsoil (A horizon).*

Soil organisms

Healthy soils contain numerous living organisms that affect soil structure and nutrient cycling. These microorganisms live in the rhizosphere, or root zone, the area of partnership between plant roots, soil, and soil organisms. There are three broad groups of below-ground organisms—microfauna, mesofauna, and macrofauna. Microfauna are a huge, microscopic class that includes protozoa and fungi (primary agents of organic matter decay; bind soil aggregates), actinomycetes (decomposers of organic matter; the 'smell' of soil), and bacteria (decomposition of organic and inorganic material, fixation of nitrogen). Mesofauna (nematodes and rotifers) help regulate microbial populations.

Agricultural soil can have a surprising number of microfauna and mesofauna (Table 3-1). Macrofauna (earthworms, insects) accelerate organic matter decomposition, mix organic matter and soil together, and aerate the soil by channeling and burrowing.

Some soil organisms such as insects (e.g. corn root worm) and plant disease pathogens (e.g. seed rotting fungi) can be harmful to crops, but some bacteria (rhizobia) and fungi (mycorrhizae) associated with roots are beneficial. Other bacteria and fungi are responsible for essential soil processes like plant residue degradation and nitrogen mineralization from organic matter. Earthworms are a positive indicator of soil quality and productivity. Reduced tillage systems have more earthworms than conventional tillage systems. Likewise, other beneficial organisms can be promoted through organic practices.

Table 3-1. Number of organisms in topsoil.

SOIL ORGANISM	Number per gram of soil (dry weight)
Bacteria	100,000,000 to 1,000,000,000
Actinomycetes	10,000,000 to 100,000,000
Fungi	100,000 to 1,000,000
Protozoa	10,000 to 100,000
Nematodes	10 to 100

Reducing risk: soil organisms. Earthworm and other beneficial soil organism populations can be increased by reduced tillage, increasing crop residues, and diverse crop rotations including perennial forages.

Soil Properties

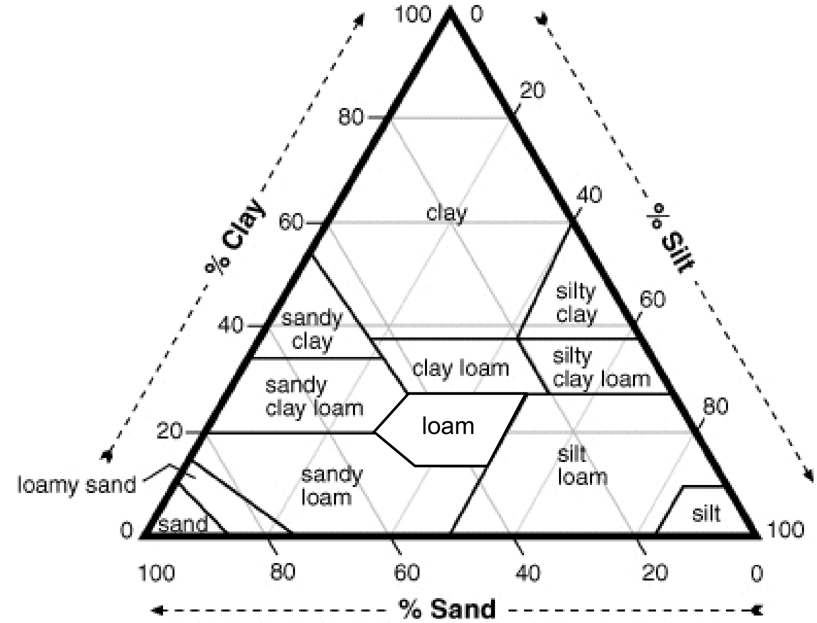
Soil has many physical and chemical properties. Some are changeable, while others are difficult or impossible to adjust. Texture, structure, drainage, and organic matter content are physical properties. Soil also has many chemical properties that affect plant growth, including cation exchange capacity and pH.

SOIL TEXTURE

Texture is determined by the proportion of sand, silt and clay. These fractions vary greatly in size (Table 3-2). Soil texture affects soil physical, chemical, and biological properties (Table 3-3).

Table 3-2. Soil particle sizes.

PARTICLE	DIAMETER
Sand	0.05-2 mm
Silt	0.002-0.05 mm
Clay	<0.002 mm



UNIVERSITY OF MINNESOTA EXTENSION.

Figure 3-4. *Soil textural triangle. The proportion of clay, silt, and sand particles determines soil texture.*

Water-holding capacity is an important soil property influenced by texture. Soil water fills small spaces around the soil particles. Sandy soils have a large pore space between particles and hold less water than clay soils. Clay soils have the greatest water content at field capacity. Plant available water is greatest in silt loam and silty clay loam soils. Although farmers cannot change soil texture, knowing soil texture can aid decisions regarding crop selection, use of landscape position/site aspect, manure man-

Table 3-3. The relative amounts of each soil particle influence soil properties.

PROPERTY	SAND	SILT	CLAY
Porosity	Low	Moderate	High
Infiltration rate	High	Moderate	Low
Good drainage	High	Moderate	Low
Aeration	High	Moderate	Low
CEC	Low	Moderate	High
Storing plant nutrients	Low	Moderate	High
Resistance to pH change	Low	Moderate	High
Organic matter level	Low	Moderate	High
Compactibility	Low	Moderate	High
Good root penetration	High	Moderate	Low
Ease of cultivation	High	Moderate	Low
Suitability for tillage after rain	High	Moderate	Low
Warm-up in spring	High	Moderate	Low
Susceptibility to wind erosion	Moderate	High	Low
Susceptibility to water erosion	Low	High	Low

agement, tillage equipment, and planting dates. Soil texture can be determined by feel (see http://soils.usda.gov/education/resources/lessons/texture/) or by a soil testing laboratory. Soil texture categories are described using the textural triangle and knowledge about the relative proportion of sand, silt, and clay (Figure 3-4).

Reducing risk: soil texture. Soil texture cannot be changed by management but texture should influence crop and soil management decisions.

SOIL DRAINAGE

Some soils are poorly drained because of their texture, the landscape position, and the height of the water table. Poorly drained soils tend to be cooler in the spring and they may limit plant root growth because of lack of aeration. Drainage is affected by soil texture. Sandy soils are well-drained and retain less moisture. Clay soils can be poorly drained and lack aeration, which negatively impacts plant growth. Subsurface tiling is a practice to enhance drainage and promote soil aeration. See regional publications such as *Planning an Agricultural Subsurface Drainage System* http://www.extension.umn.edu/distribution/cropsystems/components/07685.pdf .

Reducing risk: soil drainage. Ensure that drain tiles are properly installed to maximize their efficiency while protecting water resources. Soil tillage and crop management practices should take into account soil drainage.

SOIL STRUCTURE

Soil structure refers to the clustering of soil particles into larger masses called aggregates, which are held together by organic matter. These aggregates vary in size and provide a configuration for soil pores that allow air and water to occupy space. Soil structure is fragile and can be damaged by compaction, excessive tilling, tilling when the soil is too wet, and loss of organic matter. Soils that are primarily clay or that have been damaged by excessive compaction do not have good soil structure, are impermeable to water, and are hard to till. Soils compacted by excessive traffic and tillage do not allow for penetration of roots or movement of water. A soil with a good structure is well-aerated and has good 'tilth'. Tilth refers to soil having beneficial qualities related to crop growth. A soil with good tilth will have high organic matter, high aggregation, and low compaction (Figure 3-5).

A producer from Redwood County says that since going organic, his soil is easier to plow. Another producer, also from Redwood County, described how his son bought a new farm that was conventionally farmed. He thought something was wrong with it because he had to go one gear down on the tractor because the soil was of poor tilth.

Reducing risk: soil structure. Hard pans or compaction zones can develop in portions of the soil profile in some soils because of excessive tillage or harvest of wet soils. Although compaction does not occur on all soils, to reduce the risk of compaction it is best to avoid use of heavy machinery and tillage in wet soils.

SOIL ORGANIC MATTER

Soil organic matter is promoted by diverse rotations, crop residue, cover crops and conserva-

LYNN BETTS, NRCS.

Figure 3-5. *Three soil profiles. The dark-colored soil on the left has good tilth and is productive. The two soils on the right have been eroded.*

tion tillage. Organic matter is beneficial to agricultural soils because it enhances soil water holding capacity, water infiltration, fertility, and microbial activity.

Farming techniques that preserve and improve organic matter content promote long-term soil fertility and produce healthy crops. Organic matter is derived through the decomposition of plant residues, manures, and soil

Table 3-4. Ways to increase organic matter in cropping systems:

- ✔ Use grains and grasses as green manures
- ✔ Keep crop residue/stubble on fields
- ✔ Use grains, grasses, and perennial forages in crop rotation
- ✔ Minimize tillage
- ✔ Reduce bare soil
- ✔ Compost or manure additions
- ✔ Use cover crops
- ✔ Minimize soil erosion

organisms. Soil organic matter is a source of both macronutrients like nitrogen and phosphorus, as well as micronutrients including iron, copper, and zinc. Organic matter contains 95 percent of all soil N. Fertile soils contain 3-6 percent organic content, with a good goal around 4 percent. There are several ways to increase the level of organic matter in the soil (Table 3-4).

Humus, or stable organic matter, is a product in the decomposition process. Humus confers a dark color, aggregation, crumbly structure, and characteristic 'earthy' smell of soil. Decomposition of humus leads to release of plant nutrients. Thus, humus provides long-term nutrient reserves (Table 3-5). It also improves structure and increases cation-exchange capacity.

Table 3-5. Functions of humus:

- ✔ Supplies plant nutrients, especially N, P, and S
- ✔ Holds nutrients, thus reduces leaching
- ✔ Increases tilth of heavy soils
- ✔ Binds soil particles together, thus reduces soil erosion
- ✔ Improves porosity, increases air and water movement through soil
- ✔ Increases soil water-holding capacity
- ✔ Provides nutrients to soil micro-organisms

Reducing risk: soil organic matter. Add organic matter to soil through diverse rotations which includes perennial crops. Allow crop residue to remain on the soil surface. Utilize green manures and cover crops. Conservation tillage practices that leave greater than 30 percent residue on the soil surface will over time increase the soil organic faction. Moldboard tillage will result in the greater loss of soil organic matter compared to chisel plowing and conservation tillage.

CATION EXCHANGE CAPACITY

Cation exchange capacity (CEC) describes the amount of exchangeable cations (positively charged ions such as H+, K+,

Table 3-6. Cation exchange capacity values for different soil types

SOIL TYPE	CEC (MEQ/100G)
Sand	1 - 5
Fine sandy	5 - 10
Loam	5 - 15
Silty loam	15 - 25
Clay loam	30 - 35
Clay	> 35
Organic	50 - 100

Ca++, Mg++) a soil can hold. Chemically, CEC is the negative surface charge of small, crystalline clay particles and organic matter in the soil (Figure 3-6). CEC is used by some as a measure of the potential fertility of a soil (Table 3-6); however, the CEC capacity of most soils in the Midwest is adequate and not to be a factor limiting fertility.

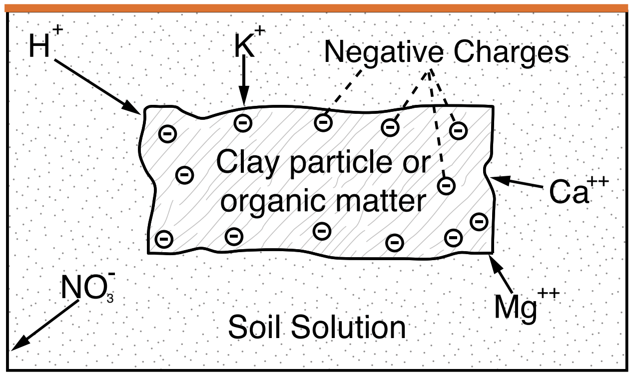


Figure 3-6. *Clay particles and organic matter in soil are negatively charged, so their surfaces attract positively charged ions such as K^+, Ca^{++}, and H^+. The negatively charged nitrate ion ($NO3^-$) is not attracted.*

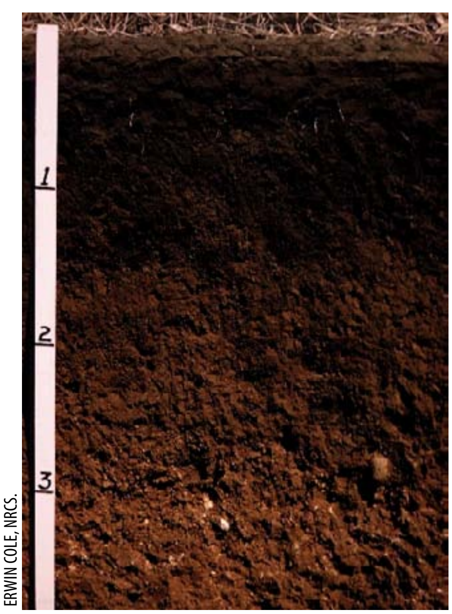
pH

Soil pH describes the concentration of hydrogen ions (H+) in a soil. The pH scale runs from 0 to 14. A pH of 7 is neutral, less than 7 is acidic, and greater than 7 is alkaline or basic. Soil pH is critical because plants vary in the required pH range for best growth and yields. Most important field crops grow best at a pH of 6–7. Additionally, pH influences the availability of nutrients to plants. A soil pH of below 5.5 or above 7.3 may limit phosphorus available to plants even though soil phosphorus levels are adequate. Low soil pH may cause toxic levels of available aluminum and manganese in the soil. Additionally, pH affects the growth of beneficial soil organisms that facilitate biological nitrogen fixation with legumes and of microbes mineralizing nitrogen from organic matter.

Reducing risk: pH. Adjust pH as necessary (see pH adjustment in Chapter 4) Conduct regular soil testing. Be familiar with the pH requirements of your crops.

SOIL CLASSIFICATION

Soils throughout the United States are classified using a standard system. The classification is based on several factors including soil properties, geographical location, type of native vegetation, and topographical position. The system used to classify soils based on their properties is called Soil Taxonomy. The system is a collaborative effort of the U.S. Department of Agriculture and University faculty from throughout the United States. Soil classification is valuable because it describes the characteristics of individual soils, defines relationships between soils, and also describes properties related to specific uses.



ERWIN COLE, NRCS.

Figure 3-7. *Soil profile of Clarion soil, one of Minnesota's soil series.*

SOIL QUALITY

Soil quality and soil health are very general terms but generally describe a soil's potential for long-term productivity. Building healthy soils is a long-term process. Fortunately, organic soil management practices are designed to develop fertile soils with good tilth that will support crop health. According to National Organic Program regulations (205.203), organic producers must:

- ✔ Implement sustainable tillage and cultivation practices that improve or maintain the soil and minimize erosion.
- ✔ Manage fertility through rotations, cover crops, and organic amendments.
- ✔ Not contribute to soil, water, or crop contamination through use of amendments.

Organic farmers realize the importance of maintaining soil quality on their land and are proud of the soil improvements that their production methods generate. Most consider stewardship of the land critical to their vocation.

Reducing risk: soil quality. Follow NOP rules on soil management. Check with certifier about a soil management plan, particularly when using amendments.

WEB SOIL SURVEY

The Natural Resource Conservation Service has a valuable database program for producers called the Web Soil Survey. Producers can map the soils on their farms and learn about the suitability of the soil types. For example, Figure 3-8 shows research plots near the University of Minnesota's St. Paul campus. This area consists of primarily a Waukegan silt loam (411 and 411b). The report describes the soil and some of its attributes like parent material, drainage class, profile, and available water capacity. For more information, visit http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm

Figure 3-8. *Soil map of the research plots.*

Conservation tillage

Conservation tillage is any tillage practice that leaves the soil with greater than 30 percent ground cover after spring planting. Residue is especially important to have on the soil during early spring when the probability for soil erosion and nutrient runoff is high. Newly planted crops do not offer much protection until later in the season and in the spring the soil moisture is generally at capacity. Residue that remains on the soil during this time will reduce soil erosion. One drawback to conservation tillage is that the residue will result in slower soil warm-up in spring, which can delay planting. At the same time, residue can preserve soil moisture when it is lacking.

Reducing the intensity of tillage is another aspect of conservation tillage (Figure 3-9). Fewer tillage operations and/or less aggressive types of tillage can lead to better soil structure, increased moisture infiltration, less soil compaction, increased soil organic matter, and increased biological activity.

Ways to reduce risk in conservation tillage systems (adapted from DeJong-Hughes, 2008) include:

- ✔ Use harvesting equipment like chaff spreaders or choppers that evenly spread residue to prevent overly thick mounds of residue that hamper spring planting
- ✔ Add a residue manager to your planter
- ✔ Plant with a reduced tillage planter to increase plant populations

TIM MCCABE, NRCS

Figure 3-9. *Conservation tillage.*

PLANT FERTILITY NEEDS

Essential elements are those that are necessary for a plant to complete its growth cycle, whose functions cannot be replaced by other elements, and that are components of a molecule or an enzyme within the plant. Minerals in the soil provide many of the essential nutrients for plant growth. Based on their average concentrations in plant tissue, elements are classified as either macronutrients or micronutrients (Table 3-7).

MACRONUTRIENTS

Macronutrients include carbon, hydrogen, oxygen, nitrogen, phosphorous, potassium, calcium, magnesium, and sulfur. Plants obtain carbon, oxygen, and hydrogen from the air and the other nutrients from the soil.

Table 3-7. Macronutrients and micronutrient functions in plants. ***Other macronutrients include carbon, oxygen, and hydrogen, which plants obtain from the air.***

CATEGORY	ELEMENT	INVOLVED IN:
Primary macronutrients	Nitrogen	Proteins, nucleic acids, coenzymes, chlorophyll
	Phosphorus	ATP, nucleic acids, proteins, phospholipids
	Potassium	Enzyme activation, stomata movement, meristems
Secondary macronutrients	Sulfur	Amino acids, coenzymes
	Calcium	Movement of substances through cell membranes, enzymes
	Magnesium	Chlorophyll, enzymes
Micronutrients	Iron	Photosynthesis, oxygen transport
	Manganese	Enzymes
	Copper	Metabolism, photosynthesis
	Zinc	Auxin, enzymes
	Boron	Sugar movement, RNA and DNA synthesis
	Molybdenum	Nitrogen fixation, metabolism, chloroplasts
	Chlorine	Photosynthesis

R.L. CROISSANT, COLORADO STATE UNIVERSITY

Figure 3-10. ***Leaves from nitrogen-deficient corn.***

Nitrogen, phosphorus, and potassium are often added to soils through amendments.

Nitrogen

Nitrogen is the most common nutrient limiting growth and production of many crops especially grasses like corn and small grains. Its effect on vegetative (leaf and stem) growth are pronounced and later impact grain formation. Legumes like alfalfa and soybean that form a symbiotic relationship with soil *Rhizobia* have potential for conversion of atmospheric N to amino acid forms and therefore should not require nitrogen fertilizers (Table 3-8). Most of the N in the soil is in organic forms. Plants cannot use atmospheric N or organic N in the soil, but take up N mostly as nitrate (NO_3^-) or ammonium (NH_4^+). Nitrate or ammonium are supplied by mineralization of organic matter, manures, or fertilizers. Nitrogen is mobile in the plant and symptoms of nitrogen deficiency in grasses include yellowing of older leaves as N is translocated to the growing points (Figure 3-10). While most plants (except legumes) respond to N fertilization, excessive fertilization beyond crop needs can lead to nitrogen loss from the soil through leaching. In addition, excessive N fertilization can cause crop lodging.

Table 3-8. The amount of nitrogen fixed by various legume species. ***Adapted from Sheaffer et al., 2003.***

	NITROGEN FIXED PER YEAR
LEGUME	N FIXED (lbs/ac)
Alfalfa	70-200
Birdsfoot trefoil	44-150
Crownvetch	98
Cicer milkvetch	140
Crimson clover	57
Hairy vetch	99
Kura clover	17-158
Lentil	149-168
Red clover	60-200
Soybean	20-200
Sub clover	52-163
Sweetclover	120
White clover	115-180

Table 3-9. Possible nutrient deficiencies in Minnesota soils.
Adapted from Rehm et al, 1989, 1994, 1997 and 2002.

NUTRIENT	SOILS WITH POSSIBLE DEFICIENCY	LOCATION IN MINNESOTA	CROP WITH POSSIBLE DEFICIENCY
Calcium	Sandy, acid, or dry soils	Not an issue for most of MN	Various
Sulfur	Sandy soils	See Figure 3-12	Brassicas, others
Magnesium	Sandy, acidic or excess K soils	Central, east-central	Various
Zinc	Fine-textured or excess P soils	West	Corn, beans
Copper	Organic soils	North	Small grains
Boron	Low organic matter soils	See Figure 3-13	Alfalfa, clovers

Phosphorous

Phosphorous has many roles in crop growth. Phosphorous increases seed production, increases winter survival (especially of legumes), stimulates root growth, promotes early maturity of crops, and produces strong stalks. Symptoms of phosphorus deficiency include purplish leaves and stunted growth (Figure 3-11).

Potassium

Potassium is especially important for crops with extensive root systems (e.g. legumes, tomatoes, potatoes). It is needed for photosynthesis, fruit formation, winter hardiness, disease resistance, stalk strength, legume competitiveness, and increased microbial activity including nitrogen fixation. Symptoms of potassium deficiency in grasses include yellowing of leaf margins. Other crops like alfalfa display a white spotting on the leaves.

Sulfur, Calcium, and Magnesium

Sulfur, calcium, and magnesium are called secondary macronutrients because they are taken up in smaller quantities compared to nitrogen, phosphorus, and potassium.

R.L. CROISSANT, COLORADO STATE UNIVERSITY.

Figure 3-11. *The purplish leaves of phosphorus-deficient corn.*

Legumes require sulfur for nitrogen fixation and brassicas require sulfur for oil and protein formation. Sulfur deficiency symptoms include yellowing of leaves and light green foliage. Magnesium is part of chlorophyll and deficiency of this nutrient can lead to stunted growth. Calcium is contained in cell walls and deficiency will be seen in the new growth, which will fail to develop normally. Many soils in some areas have deficiencies in secondary macronutrients. For example, sulfur, calcium, and magnesium are generally not limiting in soils in Minnesota, except on sandy and/or acidic soils (Table 3-9 and Figure 3-12). The main sources for these nutrients are discussed in Chapter 4.

MICRONUTRIENTS

Micronutrients are needed in smaller quantities in plants than macronutrients and deficiencies are usually less widespread. These include iron, manganese, copper, zinc, boron, molybdenum, nickel, and chlorine.

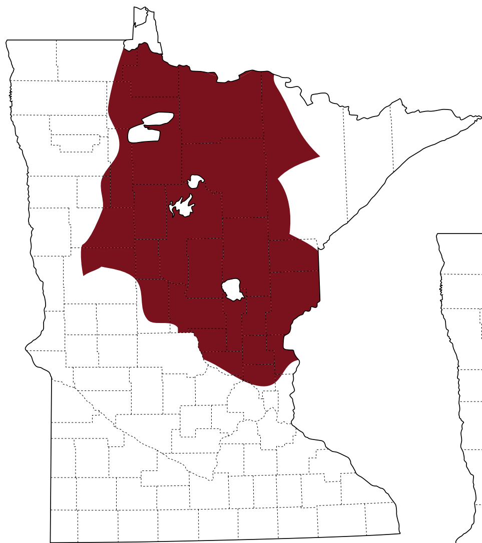


Figure 3-12. ***Possible sulfur-deficient soils (in red). Adapted from Rehm and Schmitt, 1989.***

Potential micronutrient deficiencies can be dependent on soils and environment. See Table 3-9 and Figure 3-13 for examples of micronutrient deficiences in Minnesota. Micronutrients can be added by compost, kelp, and other amendments on soils where deficiencies occur, but generally the use of manure and compost will supply adequate levels. Excessive use of micronutrients above those needed by plants can cause toxicities.

Reducing risk: macronutrients and micronutrients. Test soil annually at the same time each year. Macronutrient and micronutrient tests may not be necessary when farming a soil in a region where nutrient deficiencies do not normally occur.

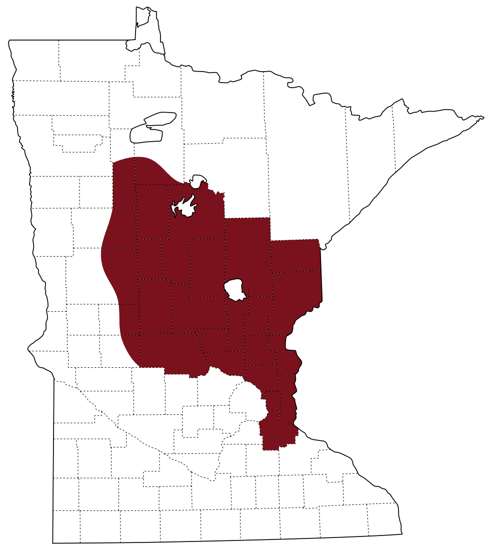


Figure 3-13. ***Possible boron-deficient soils (in red). Adapted from Rehm et al, 2002.***

Soil testing

Routine soil nutrient monitoring is a key to successful soil fertility management. Soil testing involves sampling the soil and analyzing the pH and nutrient content. Monitoring changes in soil nutrient status over time will allow evaluation of crop production and fertilization effects on crop yields. For manure and compost application, testing prevents over-application which can contaminate the environment and increase farmer fuel/labor costs.

WHEN TO TEST AND HOW OFTEN

Soils can be sampled for pH, P, K, and micronutrients at any time during the year. Samples for nitrogen analysis should be taken when temperatures are below 50° F, usually in mid-to-late October in Minnesota. Fall also gives enough time to prepare for spring by making changes in management by applying amendments or making rotation changes. Consistency of timing soil sampling from year to year is important for noting trends; for example, spring samples may have higher nutrient values compared to fall.

For routine soil testing, farmers should develop a plan so that the whole farm gets soil tested over a three-to-five-year period.

TAKING SAMPLES

Taking a representative soil sample is a critical first step in soil testing. Directions for taking a sample may be different depending on the nutrient tested. For example, nutrient concentrations can vary with soil depth so instructions may vary for which depth to sample for different nutrients.

Each soil sample should be a composite of 15 to 30 subsample cores taken from different spots on a field in order to represent the entire field. Sampling should be avoided at field edges (especially near gravel roads), eroded areas, and low spots. If a part of the field varies significantly in soil properties from the rest of the field, it should be sampled separately. If the site to be tested is uniform, one sample can be taken for up to 20 acres. Otherwise, for non-uniform sites, one sample can represent 5 acres.

In taking the sample in the field, the soil surface residue should be scraped off, so as not to include crop residue or unincorporated manure. Sampling should be done in a zigzag pattern. Sample to a 6 to 8 inch depth for pH, P, K, and organic matter and sample to a two-foot depth for nitrate. The cores should be thoroughly mixed in a clean container. If wet soil is sampled, it needs to be dried before mixing and sending to the lab. Provide the quantity of soil that the soil laboratory requests or as much is needed to fill the sample bag or box. Producers should completely fill out the soil sample information sheet as specified by the laboratory. Sending samples to the same lab each year also provides consistent results that show changes in soil nutrient status in the same field from year to year.

Conventional soil testing for organic producers

Some organic producers may question the relevance of using soil tests geared to conventional systems because fertilizer recommendations do not directly translate to organic systems. Some have said that in their experience, yields did not suffer as predicted due to lack of nutrients that soil tests may indicate. Soil testing lab recommendations are focused on the fertilizers used in conventional systems rather than slow release organic compounds, so simple substitutions for organic systems are not available. Organic systems are more complex and producers primarily obtain nutrients released from decomposition of soil organic matter, manures, and crop residue. However, conventional soil testing and the resulting recommendations based on variable yield goals is based on years of research and still has considerable value in developing a soil fertility program.(Table 3-10).

Alternative soil laboratories that follow various soil philosophies exist; visit ATTRA's website for information http://attra.ncat.org/attra-pub/soil-lab.html.

Table 3-10. Benefits of conventional soil testing.
Adapted from Phillips, 2009.

- Develops baseline figures to evaluate trends; results will be relative
- pH and organic matter, included in standard soil testing, are important factors for organic producers, regardless of the laboratory source
- Helps avoid nutrient loading due to manure and compost
- Required by some certifiers
- Conventional laboratories often have a long history of operation and can provide consistent results
- Conventional testing is just one tool of several organic producers can use to monitor soil health
- Local laboratories will have results adapted to regional soils
- University laboratories have reasonable prices

INTERPRETING RESULTS

A basic soil test will provide information on soil texture, organic matter, pH, buffer index, phosphorus, potassium and nitrate. Most soil tests will give a range for the nutrients, such as low, medium, and high, to give an indication of relative amounts of nutrients in the soil. When a nutrient is in the low range, it means that added inputs of that nutrient will likely show a strong growth response in the next crop planted. A conventional soil laboratory will provide fertilizer recommendations based on the next crop to be grown and yield goals. Table 3-11 shows actions organic producers can take based on basic soil test results.

Reducing risk: soil testing. **Follow soil laboratory instructions for taking representative samples to the proper depth. Use the recommendations based on the testing results to make input decisions.**

TIM MCCABE, NRCS

Figure 3-14. *Soil sampling in spring.*

Table 3-11. Actions for organic producers to take based on basic soil test results.

SOIL TEST	RESULT	ACTION: SHORT TERM	ACTION: LONG TERM
Soil texture	Various	Texture will not be changeable; choose adapted crops	Texture will not be changeable
Organic matter	Low	Building organic matter is a long term process	Manage soil to promote organic matter retention and to increase organic matter by following practices as outlined in Table 3-4
	High	None	Maintain current soil management practices
pH, buffer index	Low	Verify that next crop to be planted is suitable for existing pH; follow laboratory lime recommendations using NOP-approved amendments	Monitor pH and plan for future lime additions as needed
	High	Verify that next crop to be planted is suitable for existing pH	Monitor pH
Phosphorus	Low	Add compost, manure or NOP-approved amendment (See Tables 4-16 & 4-17.)	Monitor phosphorus levels
	High	If overly high, consider not using compost and manure which can lead to phosphorus loading; if other nutrients are deficient, use amendments without P	Monitor phosphorus levels and ensure that there are not too many additions of phosphorus; include green manures in rotation; minimize soil erosion to reduce leaching
Potassium	Low	If low, add compost, manure or NOP-approved amendment (See Tables 4-16 & 4-17.)	Monitor potassium levels
Nitrate	Low	If low, add compost, manure or NOP-approved amendment (See Tables 4-16 & 4-17.)	Monitor nitrogen levels; add green manures to rotation

PRODUCER PROFILE

An organic producer from Lac Qui Parle discusses how he uses soil testing in his fertility management. He says the part of the analysis he pays most attention to are the nitrogen, phosphorus, potassium, pH and organic matter results. When he has questions on other details (like cation exchange capacity), he asks a soil consultant. For his farm, he pays particular attention to phosphorus, which can have high content but low availability in his fields. As far as nitrogen is concerned, he simply expects that it will need to be supplied and uses green manures and animal manures as a regular part of his system. He will consult data on nitrogen credits and availability over the longer term for these amendments. As an established organic grower, he finds that he uses soil testing as an indication that his system is working appropriately and will adjust things only when necessary.

Conclusion

This chapter provides an overview of soil health, which can be a complex topic. See the next chapter on Soil Fertility for more information. Take the following quiz to determine your risk on soil health.

Plant analysis

Plant analysis determines the levels of specific elements present in plant tissue. It includes results for nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, iron, manganese, copper, zinc, and boron.

Reasons producers use this test:

1. When there is suspected nutrient deficiencies

2. To verify effectiveness of current nutrient management practices

The levels of nutrients will vary depending on crop and maturity (Table 3-12). While plant analysis can tell much about current fertility, producers should use tissue analysis in conjunction with soil testing.

Table 3-12. Nutrient sufficiency levels for various crops. *Adapted from Rehm, 2006 and others.*

		N	P	K	S	Ca	Mg	B	Cu	Fe	Mn	Zn
	Growth stage			%					ppm			
Corn	Silking	2.7 to 3.5	0.2 to 0.4	1.7 to 2.5	0.1 to 0.3	0.4 to 1.0	0.2 to 0.4	4 to 15	3 to 15	50 to 200	20 to 250	50 to 150
Soybean	Early to mid-bloom	4.26 to 5.50	0.26 to 0.50	1.71 to 2.50	0.25 to 0.60	0.36 to 2.00	0.26 to 1.00	21 to 55	10 to 30	51 to 350	21 to 100	20 to 50
Small grains	Prior to heading	2.20 to 3.50	0.30 to 0.50	1.80 to 3.00	0.20 to 0.30	0.25 to 0.45	0.20 to 0.40	8 to 20	6 to 15	35 to 120	30 to 60	20 to 50
Alfalfa	At bud (top 6")	2.50 to 4.00	0.25 to 0.45	2.25 to 3.40	0.25 to 0.50	0.70 to 2.50	0.25 to 0.70	25 to 60	3 to 30	30 to 250	20 to 100	20 to 60

Quiz: Soil Quality

	Points	Score
1. Have you developed a long-term plan to manage soil quality?		
Yes	5	
No	0	
2. Do you know if your soil has high levels of macrofauna (earthworms and/or insects)?		
Yes	1	
No	0	
3. Do you know what your soil texture is?		
Yes	3	
No	0	
4. Do you adapt your management practices to account for soil texture?		
Yes	3	
No	0	
I wouldn't know how	0	
5. Do you know what your soil drainage is?		
Yes	2	
No	0	
6. Do you adapt your management practices to account for soil drainage?		
Yes	2	
No	0	
I wouldn't know how	0	
7. How many tillage operations do you perform in a given field per year?		
1 or less	5	
2	4	
3 or more	0	
8. Do you till when the soil is wet?		
Yes, sometimes unavoidable	0	
No, avoid at all costs	4	
9. Do you consider your soil well-drained?		
Yes	3	
No	0	
10. Do you consider your soil to have good tilth?		
Yes, definitely	5	
Somewhat good tilth/is improving	3	
No	0	
I don't know	0	

	Points	Score
11. Do you monitor soil organic matter?		
Yes	5	
No	0	
12. What is your soil organic matter content?		
Less than 2%	0	
2 - 3 %	2	
3 - 4%	4	
Greater than 4%	6	
I don't know	0	
13. Do your management practices maintain or increase your soil's organic matter?		
Yes	3	
No	0	
I don't know	0	
14. Which of the following practices do you use? Choose as many practices as apply. Add 1 point for each choice.		
Green manures	1	
Cover crops	1	
Diverse rotations	1	
Perennials crops	1	
Manure application	1	
Compost application	1	
Conservation tillage	1	
Leaving crop residue on field	1	
15. Do you know what your soils are classified as?		
Yes	3	
No	0	
Not sure	0	
16. Do you know and follow the NOP rules on soil management?		
Yes	7	
No	0	
Not sure	0	
	TOTAL	

If your score is:	Your risk is:
0-16	High
17 - 46	Moderate
47 - 65	Low

FOR MORE INFORMATION

Web Soil Survey, NRCS-USDA. http://websoilsurvey.nrcs.usda.gov/app/

Soil management: National Organic Program regulations. ATTRA. http://attra.ncat.org/attra-pub/PDF/organic_soil.pdf

Sustainable soil management: Soil systems guide. ATTRA. http://attra.ncat.org/attra-pub/PDF/soilmgmt.pdf

Soil quality: Improving how your soil works. NRCS-USDA. http://soils.usda.gov/sqi/

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University of Minnesota Extension. Conservation tillage. http://www.extension.umn.edu/topics.html?topic=4&subtopic=15

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CHAPTER 4

Soil Fertility

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CRAIG SHEAFFER
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Organic farmers have different approaches to supplying crop needs compared to conventional farmers who provide fertility by numerous synthetic fertilizers, (Table 4-1). However, even among organic producers, there can be different philosophies when it comes to supplying nutrients. Some believe it is important to keep fertility on-farm and avoid any external outputs. These producers gain nutrients for their crops from longer, diverse rotations with green manures and cover crops, and perhaps manure from their livestock. Other producers supplement organic practices with external amendments purchased from outside sources. Both viewpoints are valid and are based on a similar principle – to provide good nutrition for crops and develop healthy soils without environmental degradation.

PHOTO COURTESY OF JOHN DEERE

Figure 4-1. *Manure spreader.*

Compost manure, animal manures, and green manures are examples of commonly used organic fertilizers for short and long-term fertility management. Other soil amendments can be mineral-based such as rock powders and lime, or organically-based such as fish emulsions and kelp (Table 4-2). Mineral fertilizers and some of the organic-based amendments are slow-acting and require long-range planning. Once soil fertility and nutrient cycling have been established in organic rotations, some producers find that mineral amendments are rarely necessary. Instead, fertility is managed by conserving nutrients, using green manures and composts, by leaving stubble in the field, and keeping hay on the farm.

Adjusting pH

Soil pH affects nutrient availability (Figure 4-2). Even if nutrients are present, they may not be available for plant uptake. Overly acidic or alkaline soils need to be adjusted to proper levels for crops to grow adequately. With the exception of alfalfa, which requires a pH of 6.5 or more, most crops do well with a pH of 6.0. When soil is overly acidic, lime is applied to increase the pH of soil.

Liming is the practice of adding crushed limestone (calcium carbonate) to raise the pH and reduce the acidity of a soil. In organic systems, only natural sources like mined products are allowed to adjust pH. There are two main types of lime—calcitic lime (also called calcite) and dolomitic lime (also called dolomite). Both types not only correct soil pH, but also supply calcium (Ca^{++}) for plant nutrition. Soils in Minnesota generally have adequate calcium so the use of lime for the sole purpose of supplying calcium is not recommended. Dolomitic limestone also contains magnesium (Mg^{++}) in addition to calcium carbonate. Calcium hydroxide and calcium oxide are synthetic liming products and are not allowed in organic systems.

Prior to liming, a soil test is needed to assess both the pH and buffer pH to apply the correct source of lime, if any. Soil samples should be taken from a six- to eight-inch depth. Lime application rates will be dependent

Table 4-2. NOP allowed soil amendments (other than compost and manures).
Deficiencies must be documented with soil/tissue testing prior to amendments.

ALLOWED AMENDMENTS
Aquatic plant extracts (other than hydrolyzed)
Elemental sulfur
Humic acids (naturally occurring)
Magnesium sulfate
Soluble boron
Sulfates, carbonates, oxides, or silicates of zinc, copper, iron, manganese, molybdenum, selenium, and cobalt.
Liquid fish products
Lime (naturally occurring)

Table 4-1. Organic versus conventional fertilizers.
Adapted from Cogger, 2000.

ORGANIC FERTILIZERS	CONVENTIONAL FERTILIZERS
Naturally occurring with minimal processing	Manufactured or extracted with substantial processing
Nutrients are usually slow release	Nutrients are usually immediately available
Nutrients occur in low concentrations	Nutrients occur in high concentratrations
Nutrients can be long-lasting	Nutrients are not long-lasting
Examples include manure, rock phosphates, and fish meal	Examples include ammonium sulfate, processed urea, and potassium chloride
Usually not more than one plication per season	May require multiple applications approximately within a single season
Nutrients that are slow release will have less potential to cause environmental damage	Nutrients have more potential to cause environmental damage

Table 4-3. Approximate amounts of lime needed to raise pH to 6.0. *The SMP buffer pH is a quick procedure used by laboratories to determine how much lime to apply in soils with pHs less than 6.0. Refer to Figure 4-3 for map with Areas I and II. Adapted from Rehm et al., 2002.*

SMP buffer pH	Lime (tons/acre) Area I	Lime (tons/acre) Area II
6.8	2.0	0
6.7	2.0	0
6.6	2.0	0
6.5	2.5	0
6.4	3.0	2.0
6.3	3.5	2.0
6.2	4.0	2.0
6.1	4.5	2.0
6.0	5.0	2.5
5.9	5.5	2.5
5.8	6.0	3.0
5.7	6.5	3.0
5.6	7.0	3.5

on recommendations in the soil test results, the quality of the lime (Effective Neutralizing Power, ENP), and the desired final pH (Table 4-3). Lime is not required in many soils (e.g., Western Minnesota) when the pH is 6.1 or higher because of the non-acidic subsoils (Figure 4-3).

Reducing risk: adjusting pH. For pH, take soil samples at six- to eight-inch depths. See Chapter 3 for more information. Follow liming recommendations and evenly apply. Verify liming materials and methods with certifier.

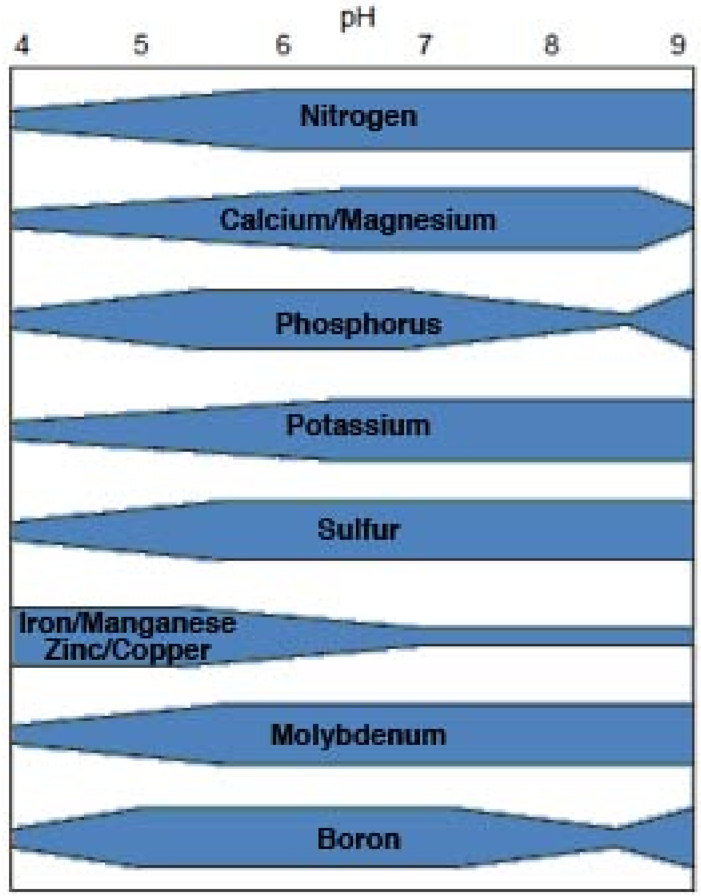

Figure 4-2. *Ranges of pH and nutrient availability. The wider the bar, the more that nutrient is available. Adapted from University of Minnesota Extension.*

Ca:Mg ratios

Some organic producers prefer calcitic limestone because they believe that dolomitic limestone is harmful to the soil because the magnesium in dolomitic limestone affects Ca:Mg ratios. However, considerable research has shown that insuring that the overall amounts of calcium and magnesium are sufficiently available is more important than ratios. In other words, it has not been possible to predict crop yields based on the Ca:Mg ratio. Therefore, both calcite and dolomitc limestone products should be acceptable and effective liming agents. In any case, producers should also consider that calcitic lime tends to be more expensive. Dolomitic lime can be slower acting and can supply magnesium, which can be deficient in Minnesota (see Table 3-9 from Chapter 3).

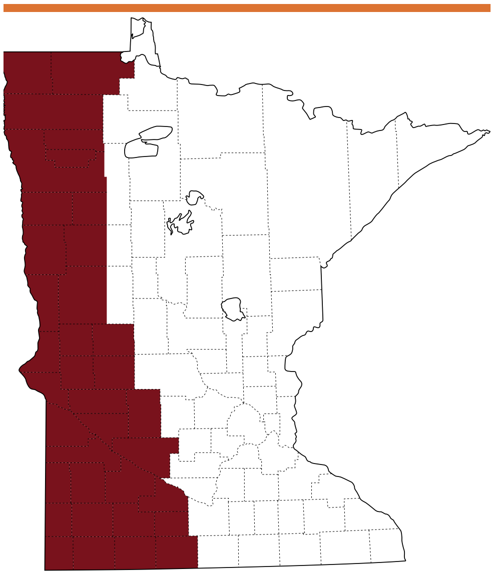

Figure 4-3. ***Lime is not recommended when pH is 6.1 or above in the western part of the state (in red). Adapted from Rehm et al, 2002.***

Figure 4-4. ***Alfalfa green manure.***

Green manures

A green manure is a crop that is incorporated into the soil to add organic matter, nitrogen or other nutrients. Green manures can be legumes that fix nitrogen or non-legumes that scavenge nutrients. In organic systems, legumes are often used as green manures to add nitrogen. Green manures can have dual functions; in addition to providing fertility, they also function as winter cover crops and forages. Legumes used as green manures can provide a significant source of nitrogen for the next crop;

Gypsum

Gypsum ($CaSO_4$-$2H_2O$) is a naturally occurring soft mineral obtained from mining of sedimentary deposits. Gypsum is widely used in a number of building materials including plaster and wallboard for construction. Gypsum is also marketed to organic producers as a fertilizer and as a soil building agent. However, in the Upper Midwest, its value is limited. Gypsum is a good example of why producers need to understand the properties of soil amendments before purchase and application.

When applied to the soil, gypsum dissolves slowly into Ca^{++} and SO_4^{--} ions and both can be taken up and used in nutrition of plants. But, a response to Ca fertilization is unlikely in most Minnesota soils, because most soils have adequate levels of Ca. However, gypsum can be a valuable sulfur fertilizer on soils with a sandy texture. When, applied as a fertilizer, gypsum dissolves slowly so an immediate response should not be expected.

Although gypsum contains both calcium and sulfur, gypsum has no effect on soil pH. This is related to soil chemistry and the Ca^{++} and SO_4^{--} ions that are formed when gypsum is applied to the soil. Soil pH is changed from addition of $CaCO_3$ (lime) and S (elemental S), and neither Ca^{++} and SO_4^{--} ion affects pH.

Gypsum is effectively used in the western United States to condition and enhance structure of soils containing high amounts of sodium. Fortunately, few of these soils are found in the Upper Midwest. In addition, the diversified crop rotations practiced by organic farmers are effective at maintaining soil structure.

Table 4-4. The amount of nitrogen (nitrogen credit) available to subsequent crops in the first and second year after. *Adapted from Rehm, et al., 2008.*

	NITROGEN CREDIT (LBS/ACRE)	
PREVIOUS CROP	1st year	2nd year
Harvested alfalfa		
- 4 or more plants/ft_2	150	75
- 2-3 plants/ft_2	100	50
- 1 or less plants/ft_2	40	0
Red clover	75	35

Figure 4-6. *Sorghum-sudangrass can provide soil organic matter and can smother weeds.*

this is referred to as a nitrogen credit (Table 4-4). However, unlike grasses, legumes do not make considerable lasting contributions to soil organic matter. Thus, legumes and grasses/cereals mixes create a good compromise and are often grown together to increase nutrient availability and soil organic matter. Green manures can be one of the most sustainable ways to provide nitrogen and other nutrients. As opposed to manure or compost, they do not cause phosphorous loading and there is reduced leaching of nitrogen because nutrients are released slowly.

SPECIES SELECTION

Selection of green manures requires knowledge of the crop rotation. Typically, organic producers who use legume green manures follow them with a crop like corn because of its high fertility needs. Other considerations are ease of incorporation, weediness in the following crop, timing of incorporation, and possible allelopathic effects. Alfalfa, red clover, and hairy vetch are common legume green manures used by organic producers in the Midwest. Alfalfa is a long-lived perennial, red clover a short-lived perennial and hairy vetch is a winter annual. For more information on growing these crops, see the Winter Cover Crops chapter and Forages chapter.

In addition to legumes, grasses such as winter rye and sorghum-sudangrass are used for plowdown to add soil organic matter (Figure 4-6). These grasses can accumulate soil nitrogen and release it when they are incorporated. In low nitrogen soils, incorporation of a large amount of grass biomass into the soil can cause a temporary tie-up of nitrogen until the microorganisms break the herbage down.

Is your green manure fixing nitrogen?

To determine if a green manure crop is fixing nitrogen, take the following steps:

- ✔ Dig up a legume plant that is over 1 month old but not flowering
- ✔ Remove soil from roots
- ✔ Look for nodules, which will look like round or elongate whitish growths on the roots (Figure 4-5)
- ✔ Break open some of the nodules. Actively-fixing nodules appear pink or red.

DAVID L. HANSEN

Figure 4-5. *Red clover root with pinkish, elongate nodules.*

Table 4-5. Factors that determine the amount of legume nitrogen available to the next crop.

FACTOR	EFFECT ON NITROGEN CREDIT
Stand condition (e.g. presence of weeds, density of stand)	Stand density is an important determinant. See Tables 4-2 & 4-3. Weeds will significantly reduce credit.
Stand age	Two or three year old stands of alfalfa will provide more N than first year alfalfa. See Table 4-6.
Stand height/herbage yield	If alfalfa height is taller than 8 inches, the nitrogen credit can be 40lb/ac greater than if the height is less than 8 inches. See Table 4-4.
Harvest management and number and/or removal of cuttings	Forage that has been cut once or not at all will usually provide a higher N contribution in the fall for use the following spring. See Figure 4-2. Removal of herbage will reduce nitrogen contribution.
Incorporation	Herbage left on the soil surface will provide less N (because some has been lost to the atmosphere) than if it had been incorporated.
Time of termination: spring vs. fall	Legume crops that are terminated in the spring before planting rather than the fall will provide more nitrogen in the year of incorporation though some nitrogen may be available to a crop in the 2nd year. The hazards to spring alfalfa termination are possible moisture shortages as well as potentially less accommodating seed beds.
Soil type	Nitrogen credits will be lower on sandy soils compared to medium or heavy textured soils. See Table 4-4.
Soil moisture	Determines when the nitrogen is available. Herbage will break down faster in moist soils.
Soil temperature	Determines when the nitrogen is available. Herbage will break down faster at higher temperatures.
Legume species	Nitrogen fixation rates vary by species.

PRODUCER PROFILE

Red clover seeded with a spring small grain can be used as a late fall plowdown to provide nutrients for subsequent crops. An organic producer from Clay County plants his small grains with underseeded red clover. After small grain harvest, he plows down the red clover in the fall (usually in October). The red clover green manure is the only nitrogen source he uses; no manure or soil amendments have been used for the past eight years. His organic inspector says his fields are the least weedy he has seen.

NITROGEN CREDITS

The amount of nitrogen that is provided by a legume green manure is influenced by many factors (Table 4-5). Legumes vary in nitrogen fixation and also the amount of nitrogen rich herbage they produce. Alfalfa generally will provide twice as much nitrogen as red clover. Soybean, though a legume, has a low credit (about 30 pounds/acre) as most of the fixed nitrogen is removed at harvest. Important management factors include stand density, harvest management, and timing of incorporation (Figure 4-7 and Tables 4-6). Environmental factors affecting nitrogen production and utilization include soil temperature and soil moisture.

In addition to the amount of nitrogen available from green manures, the timing of the release of nutrients is a critical component. Once legumes are worked into the soil, about half of their nitrogen is released in one month. Unfortunately, this may occur before the primary crop needs it most and the nitrogen can be lost (Figure 4-8).

Reducing risk: green manures. Choose a species adapted to your area and cropping system. Plant an appropriate crop to be grown after the green manure like corn or another grass to utilize nitrogen. To protect soil and minimize carbon loss, use the least intensive tillage method (i.e. chisel plowing vs. moldboard) that is still effective to terminate green manures.

PRODUCER PROFILE

A producer from Waseca County regularly grows red clover as part of his rotation. He uses it as a green manure for a subsequent corn crop. In the fall, he partially controls the red clover with chisel plowing and does another operation in the spring to complete the termination. He finds it difficult to control unless he does a fall operation. If conditions do not permit fall chisel plowing, in the spring he will use a spike tooth digger rather than a shovel digger, which causes compaction on his soil.

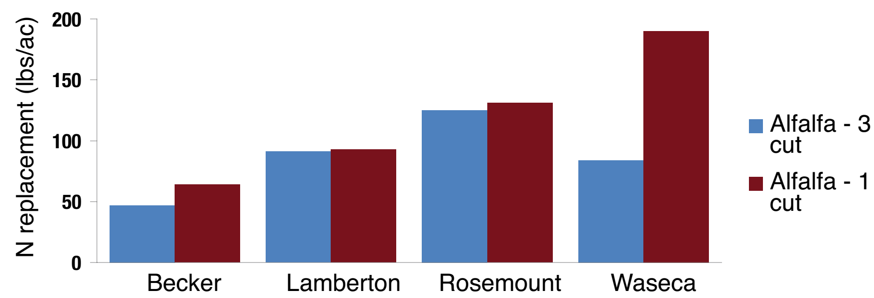

Figure 4-7. *N replacement values in lbs/acre for alfalfa that has been cut once or three times at four sites in Minnesota. Sheaffer, et al., 1989.*

Table 4-6. Nitrogen credits (pounds/acre) from alfalfa with varying stand heights and densities on different soils.
Adapted from Undersander, 2005.

	AMOUNT OF REGROWTH INCORPORATED			
Stand density (plants/ft^2)	CLAY/LOAM SOILS > 8″	CLAY/LOAM SOILS <8″	SANDY SOILS > 8″	SANDY SOILS <8″
> 4	190	150	140	100
1.5 to 4	160	120	110	70
< 1.5	130	60	80	40

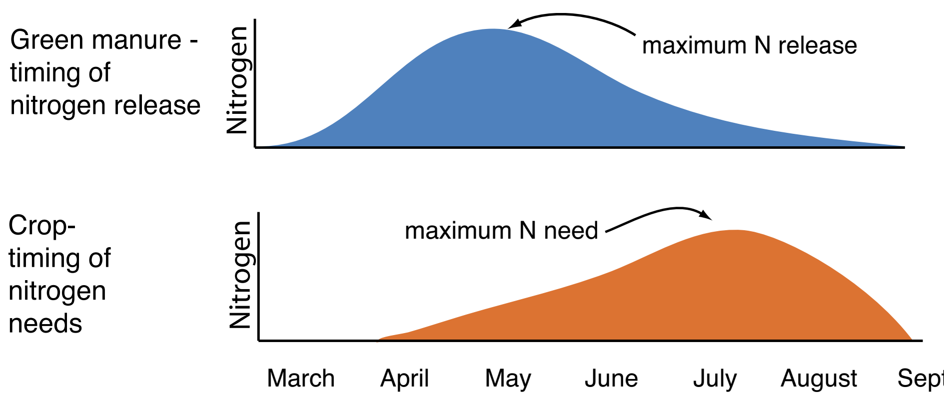

Figure 4-8. *Nitrogen rate of release from green manures relative to crop needs. The majority of nitrogen is released by June, while the crop needs are highest in July.*

Manure

NCRS, TIM MCCABE

Figure 4-10. ***Liquid hog manure being spread on a field.***

Manure is a valuable resource on an organic farm. Its application can serve as a source of organic matter and plant nutrients. Livestock are inefficient in extracting nutrients from feed and some of the nutrients in feed are excreted into the manure. Most common manures in the Midwest are beef, dairy, hog, chicken, and turkey. Properly managed manure can add plant nutrients and improve soil quality. Raw manure is high in nutrients, especially readily available N. Nitrogen is the main nutrient considered in application rate, but P and K should be monitored over time as they quickly build up in soil. Timing of application is also important, as raw manure is best applied to row crops in the spring prior to planting. Fall application could cause leaching and risk of runoff,

A producer from Chippewa County plows his alfalfa in the second year. He finds he has to use moldboard plowing to control alfalfa.

Terminating green manure crops

Terminating a perennial green manure crop in preparation for another crop can be a source of risk. If the green manure is only partially controlled, it will compete with the next crop. There are two things to consider: when to terminate and how to terminate.

The time to terminate will be largely dependent on soil and climate conditions. For instance, if soil moisture and anticipated spring weather conditions do not allow the type of tillage needed for complete control of the legume, fall tillage is a common practice. However, fall termination can expose the soil to erosion. Red clover is more easily terminated than alfalfa. Some organic farmers are able to control red clover with chisel plowing. Many organic producers who use alfalfa have few options other than moldboard plowing for termination (Figure 4-9).

Figure 4-9. ***Close-up of a moldboard plow.***

To terminate red clover, a producer from Lac Qui Parle suggests minimal straight point chisel tillage in the fall with more aggressive field cultivator seedbed preparation tillage in the spring as late as is possible depending on the subsequent corn crop.

but in some cases can be necessary to comply with NOP rules on manure application to certain crops. According to NOP rules, manure cannot be applied when the ground is frozen.

Manure from conventional operations is allowed under NOP rules, but the type of manure allowed may vary by certifier. Some will not allow conventional manure, some will allow conventional manure with restrictions, and some will allow conventional manure only if it has been composted. It is very important to verify the manure source and test the manure prior to use. Certifiers will also monitor levels of manure application, which should not be applied at excessive levels, which potentially lead to pollution problems of waterways and air quality. See Table 4-7 for NOP rules on manure and compost application.

MANURE TESTING

Animal manures vary widely in nutrient content and availability, depending on the animal source (Table 4-8). Since the nutrient content is so variable, testing is recommended. The Minnesota Department of Agriculture has a list of certified manure testing laboratories at http://www2.mda.state.mn.us/webapp/lis/manurelabs.jsp. Taking representative samples is critical for characterizing the manure nutrient content. Samples should be taken prior to application for the best estimate of nutrients. Mixing the manure before sampling will increase the chances of getting a more representative sample. A composite of at least 10 subsamples is best. Manure testing may be required to adhere to European or Canadian organic rules. Some manure from conventional operations, especially poultry litter, may be contaminated by heavy metals.

Table 4-7.

NOP MANURE & COMPOST RULES

1. No raw manure unless it is incorporated more than 120 days prior to harvest for crops for human consumption whose edible portion is in direct contact with the soil.

2. No raw manure unless it is incorporated more than 90 days prior to harvest for crops whose edible portion does not contact soil.

3. Compost can be applied at any time if produced according to requirements.

Table 4-8. Nutrient content of manures in the Midwest.

These values are estimates only. Adapted from Blanchet and Schmitt, 2007.

		LIQUID			SOLID		
		N	P	K	N	P	K
Livestock		lbs/1000 gallons			lbs/ton		
Swine	Farrowing	15	12	11	14	6	4
	Nursery	25	19	22	13	8	4
	Gestation	25	25	24	9	7	5
	Finishing	58	44	40	16	9	5
Dairy	Cows	31	15	19	10	3	6
	Heifers	32	14	28	10	3	7
Beef	Cows	20	16	24	7	4	7
	Finishing	29	18	26	11	7	11
Poultry	Broilers	63	40	29	46	53	36
	Layers	57	52	33	34	51	26
	Tom Turkeys	53	40	29	40	50	30
	Hen Turkeys	60	38	32	40	50	30

MANURE NUTRIENT AVAILABILITY

Manure nutrients vary in their availability to crops. Some nutrients are lost to the atmosphere and to leaching due to the application process (Table 4-9), while some nutrients are only available over the long-term. After manure testing to determine initial content, it will be helpful to consult with Table 4-9 that tells how application method and timing will affect availability. The amount of nutrients available post-application from manure will vary due to initial content, application method, and timing of application (Table 4-10).

Table 4-9. Percent nitrogen lost from original content based on application method, time of incorporation, and species.
Adapted from Blanchet and Schmitt, 2007.

	BROADCAST			INJECTION	
	No incorporation	Incorporated within 1-4 days	Incorporated within 12 hours	Sweep	Knife
Beef	40	20	5	5	10
Dairy	40	20	10	5	10
Swine	50	30	10	5	15
Poultry	30	20	5	NA	NA

The nitrogen in manures is in two forms: the organic form, which releases slowly; and the inorganic form (ammonium and nitrate), which are immediately available. Generally, the inorganic nitrogen will be depleted in the year of application, while a portion of the organic nitrogen is available over two to three years. Different types of manure have different proportions of the two types of nitrogen, which will be indicated on the manure analysis. Manure with a higher proportion of ammonium, like poultry manure, should be incorporated into the soil so that the nitrogen is not lost to the atmosphere. Timely incorporation also protects water sources from nutrient runoff.

Table 4-10. Percent nitrogen available over time based on application method, time of incorporation, and livestock.
Adapted from Blanchet and Schmitt, 2007.

		BROADCAST			INJECTION	
		No incorporation	Incorporated within 1-4 days	Incorporated within 12 hours	Sweep	Knife
Beef	Year 1	25	45	60	60	50
	Year 2	25	25	25	25	25
	Year 3	10	10	10	10	15
Dairy	Year 1	20	40	55	55	50
	Year 2	25	25	25	25	25
	Year 3	15	15	10	15	15
Swine	Year 1	35	55	75	80	70
	Year 2	15	15	15	15	15
	Year 3	0	0	0	0	0
Poultry	Year 1	45	55	70	NA	NA
	Year 2	25	25	25	NA	NA
	Year 3	0	0	0	NA	NA

Reducing risk: manure.

Check with your certifier about appropriate sources. Have manure tested for nutrient content prior to application. For maximum manure N use, apply manure before heavy-feeding crops like corn. Follow NOP rules on manure use and application. Apply manure two weeks to one month ahead of planting to synchronize nutrients to crop needs and to avoid problems with pests such as corn root worm and seed corn maggot. Be aware of potential environmental consequences of manure application such as excess phosphorus accumulation in the soil and loss of nutrients from during spreading.

Compost

Composting is the controlled decomposition of manure, crop residue, bedding, or other organic matter by microorganisms in the presence of oxygen. The goal of composting is to produce a nutrient stable product. There are numerous advantages to composting as compared to using raw manure that offset the storage and handling required to make the finished product. (Table 4-11). These include a high return of nutrients to the field; improvement of soil biological, physical, and chemical properties; slow and steady release of nutrients; easier handling; reduced weed seeds/insect larvae/pathogens; decreased crop disease/pest issues; and reduced odor.

Compost quality depends on the source materials of organic matter, the conditions under which the compost is made, and the maturity when the compost is supplied (Table 4-12).


KEN HAMMOND, ARS

Figure 4-11. ***Turning windrows is a necessary part of efficient composting.***

COMPOST APPLICATION

Mature compost is low in phytotoxins (chemicals harmful to plants) and is safe for application to any crop/growth stage. Compost alone may not be able to supply all the N for some crops. Incorporation of compost

Table 4-11. Advantages and disadvantages of compost as compared to manure.

ADVANTAGES
Slow release of nutrients
Spreads easier than manure
Fewer weed seeds
Less potential for runoff
Less pathogens
Fewer odors
Fewer NOP restrictions on time of application
DISADVANTAGES
More expensive than manure
May be more difficult to obtain
Lower nutrient content
Additional time and labor to produce own compost
Potential nutrient leaching during compost process

Heat-processed manure products

Heat-processed or dehydrated manure is another fertilizer source. Recently the NOP changed the rules for application of this product. Previously, the rules for applying heat-processed manure to organic fields were the same as for raw manure. Now this product can be applied without manure restrictions, similar to compost. However, heat-processed manure must reach a temperature of 165° F briefly or 150° F for at least one hour. In addition, it must be dried to a maximum moisture level of 12 percent. To verify these conditions, bacterial counts of no more than 1,000 fecal coliform per gram or three *Salmonella* per four grams should be found in the final product. Heat-processed manure will have nutrients available more quickly compared to compost, though there is greater potential for leaching.

Table 4-12. Compost nutrient content.
Adapted from Rosen and Bierman, 2005.

COMPOST	DRY MATTER	AVAILABLE N	TOTAL N	P_2O_5	K_2O
	%	------------------- lb/ton --------------------			
Poultry	45	1	17	39	23
Dairy	45	<1	12	12	26
Mixed (poultry, dairy, swine)	43	<1	11	11	10

Table 4-13. Estimated compost nutrient availability over time.
Adapted from Rosen and Bierman, 2005.

	% N availability		
Compost type	1st year	2nd year	3rd year
Poultry	30	10	10
Dairy	14	10	10

is recommended for organic N to be broken down by microorganisms. As with manure, testing compost is important and there can be great variability in nutrient content Compost nutrient N, P_2O_5, and K_2O content is usually in the range of 1-1-1 to 2-1-2. For composted dairy manure, 5 to 20% of N is available the first year (Table 4-13).

MAKING COMPOST

Making good compost depends on a good C:N balance of the starting material (Table 4-14). Usually animal bedding such as straw mixed with raw manure is an excellent base. The combined values of C:N ratios of the total starting materials must be in the range of 25:1 to 40:1. Finished compost will be half of these ratios. To produce compost approved for organic production, materials must be maintained at certain temperatures for defined time periods (Table 4-15). Other factors that are important in making compost are the correct levels of moisture and aeration. Proper conditions during composting are particularly important, as this will minimize odors. The three primary techniques for producing compost include static piles, windrows and in-vessel. See the "For More Information" section at the end of this chapter for resources on composting.

Some organic producers use semi-composted manure due to the difficulty in following the NOP composting rules. The benefits of using semi-composted manure can be similar to compost. Compared to fresh manure, the risks of soil and water contamination will be reduced and some of the weed seeds may be eliminated. However, semi-composted manure is not true compost by NOP regulations, so rules of raw manure application will apply (refer to Table 4-7). Also, producers should be aware that immature compost may tie up available nitrogen when it is applied to a field.

PRODUCER PROFILE

Here is the fertility management plan of an organic producer from Waseca County. He tests his soil for nutrients and pH on a yearly basis. He uses alfalfa in a rotation of Oats-Alfalfa-Alfalfa-Corn-Soybean-Corn to supply forage and nitrogen for a corn crop. In addition, he adds turkey manure after soybean in the fall before the second corn in the rotation. He tests manure before application—it usually has about 45 pounds N per ton and he applies four tons per acre. He feels that the non-nitrogen nutrients in the turkey manure are beneficial to alfalfa and the other crops.

Table 4-14. C:N ratios of compost materials.

MATERIAL	C:N
dairy manure	20:1
sheep manure	14:1
poultry manure	10:1
straw	80:1
corn stalks	60:1
leaves	45:1
alfalfa	13:1
legume/grass hay	25:1
grass hay	80:1
rotted sawdust	200:1
fresh sawdust	500:1

Table 4-15. NOP rules for producing compost.

FIRST
Establish an initial C:N ratio between 25:1 and 40:1
THEN
Maintain a temperature of between 131° F and 170° F for 3 days using an in-vessel or static aerated pile system
OR
Maintain a temperature of between 131° F and 170° F for 15 days using a windrow composting system, during which period, the materials must be turned a minimum of five times.

Reducing risk: compost. **Have compost tested for nutrient content prior to application. If producing your own compost, keep records to note that the composting was done by NOP rules.**

Other amendments

Organic producers are allowed to use natural, non-synthetic amendments. As opposed to green manures, compost and animal manures, which have a longer history and research that demonstrates effects, other amendments marketed to organic producers do not have a proven track record. It is important to choose and use amendments pru-

Should you compost?

Below is a checklist of questions to think about.

- ✔ Do you have the necessary equipment? Windrow composting will require a loader or other specialty equipment to turn compost. Aerated pile composting will require piping and a mechanical source to blow air. In vessel composting requires units such as bins.
- ✔ Do you have the necessary time? Producing compost can be labor-intensive.
- ✔ If planning to sell compost, do you have a local market? Hauling costs can be prohibitive if buyers are not located nearby.
- ✔ Do you have spare land and equipment space? Compost production occurs over the long-term.
- ✔ Do you have the financial resources? Equipment and facilities can be an added cost.
- ✔ If you are not a livestock producer, do you have local access to raw materials? Hauling costs of raw manure to your farm for composting need to be considered.

Producers who have the raw materials and necessary equipment to turn windrows can experiment with on-farming composting by starting with windrow methods on a small scale.

Adapted from LaCross and Graves, 1992.

JEFF VANUGA, NRCS.

Figure 4-12. ***Composted turkey manure.***

Organic producers say that many amendments to adjust fertility are secondary to long-term management like diverse rotations including green manures and cover crops. Over time, the need for temporary supplementation will lessen.

dently. Producers need to ensure they are using products that are:

Effective. Study research results supporting the use of the amendment. If a nutrient is purported to be present in the product, how available to crops will that nutrient be? Avoid products with vague, generalized claims.

Necessary. Has a need for the amendment been demonstrated via soil testing or plant analysis?

Not cost prohibitive. While an amendment can be effective and its nutrients deemed necessary, it may not provide cost-effective benefits. Explore options to see if acceptable, less expensive alternatives exist. Producers should analyze cost relative to increased yields and/or other parameters like an increase in soil organic matter.

"Buyer beware" is a good motto to follow as alternative products may not be regulated and can be marketed without research evaluation. Some amendments may produce little to no effect on crops and soil, and in addition can be quite expensive. Producers need to carefully evaluate claims and the sources for the claims. It is always a good idea to conduct small-scale trials before committing a large-scale financial obligation to a product.

Producers should verify a new product with their certifiers prior to using amendments. As with manure and compost, apply organic amendments several weeks before the crop needs it.

TYPES OF AMENDMENTS

A general way to classify allowed amendments is by their source. They are either biologically-based like plant- or animal-derived amendments that include fish meal, kelp meal, and others (Table 4-16). Or, they can be mineral-based like rock phosphates or greensand (Table 4-17). When compared to minerals, the nutrients in biologically-based amendments will be available more quickly and contain a greater complement of both macro- and micronutrients. For example, granite dust mainly provides potassium, which is released very slowly, while soybean

PRODUCER PROFILE

A producer from Faribault County uses turkey manure compost (Figure 4-12) which he purchases. The nutrient composition is usually either 5-3-3 or 5-4-3. He applies two tons compost per acre prior to corn and one ton per acre prior to other crops in his rotation. The compost is disked in the fall because his heavy soils get compacted by spring work. He tests the soil for macro and micronutrients every three years.

meal includes a greater complement of nutrients that is more readily available.

Another important difference between amendment types will be price, as some of the biologically-derived amendments can be expensive. Some of the most expensive amendments are used

Table 4-16. Composition and use of biologically-based amendments.
Adapted from Rosen and Bierman, 2005 and others.

MATERIAL	N	P	K	USE	NOTES
Blood meal	12 - 15	1 - 2	1	Primarily N source with P, K	Derived from livestock processing; can burn plants; risk of N loss through volatilization; use is prohibited for markets in Europe and Japan
Bat guano	10	3	1	Primarily N source with P, K	Derived from bat manure; can burn plants
Fish meal	10	4 - 6	0	N, P source	Make sure that source does not contain prohibited substances like preservatives; can contain high levels of PCBs
Fish emulsion	3 - 5	1	1	N, P, K source; micronutrients	Make sure that source does not contain prohibited substances like preservatives; can contain high levels of PCBs
Kelp meal	1 - 1.5	0.1 - 1	2 - 5	N, P, K source; micronutrients	Good for starter fertilizer; high in micronutrients; can be high in salts and heavy metals
Alfalfa hay meal	2.5 - 3.0	0.5	2.5	N, P, K source; micronutrients	Good for starter fertilizer
Soybean meal	7	1.2	2	N, P, K source; micronutrients	Some certifiers and European markets may not allow GMO soybean meal, moderate release rate
Bone meal raw	3	22	0	Primarily P source with N	Use is prohibited for markets in Europe and Japan; slow nutrient release rate
Bone meal steamed	1	15	0	Primarily P source with N	Use is prohibited for markets in Europe and Japan; slow nutrient release rate

Table 4-17. Composition and use of mineral-based amendments.
Adapted from Rosen and Bierman, 2005 and others.

MATERIAL	N	P	K	USE	NOTES
Rock phosphate	0	20 - 32	0	P source, some Ca	2-3% available, will need to apply far in advance of crop needs, may have heavy metal contamination, less availability at pH greater than 5.5
Greensand	0	0 - 1.3	3 - 9.5	P, K source	Very slow availability, best to incorporate 6-8" into soil, contains other trace elements
Colloidal phosphate	0	25	0	P source	P is more available compared to rock phosphates
Granite dust	0	0	3 - 5	K source	Very slow availability
Langbeinite (Sul-Po-Mag or K-Mag)	0	0	22	K, Mg source	Make sure source is not chemically treated, best to incorporate 6-8" into soil
Potassium sulfate	0	0	50	K source	Make sure source is natural and not chemically treated; fairly reactive, best to incorporate 6-8" into soil, better for high magnesium soils than langbeinite

primarily for high-value crops, rather than row crops. Another aspect that factors into price is local availability. Regardless of the type of amendment, it is necessary to verify that it is NOP-approved and not from a synthetic or contaminated source.

USING AMENDMENTS

Natural materials can vary in composition. Producers should obtain a nutrient analysis for all materials from the supplier. If in doubt about composition, samples can be sent to independent laboratories. Before purchasing new materials, producers need to consider how to transport, store, and apply the amendment. Some materials may need special equipment to apply or may be more difficult to spread out evenly than other amendments.

Reducing risk: amendments.

Understand the nutrient composition of the amendment. Be sure that amendments are effective, worth the expense, and necessary for your operation. Verify needs with soil or plant analysis and apply amendments at recommended levels. Never apply amendments above the recommended levels; particularly as some can contaminate soils with salt or heavy metal accumulation. As always, check with your certifier before trying a new product.

Conclusion

The topics of soil and fertility can be complex. Take the fertility quiz to assess your risk in this area.

Quiz: Fertility Management

	Points	Score
1. What is your soil pH?		
Less than 6.0	1	
Greater than 7.0	1	
Between 6.0 and 7.0	5	
I don't know	0	
2. If your soil is acidic, do you add lime?		
Yes	5	
No	0	
3. Are you familiar with the pH requirements of each crop you grow?		
Yes	5	
No	0	
Not sure	0	
4. Do you check with your certifier before using new amendments or new sources for your amendments?		
Always	5	
Sometimes	1	
I don't check with my certifier	0	
5. When using manure or compost, do you monitor phosphorus levels in the soil closely?		
Yes	5	
No	0	
I do not use manure or compost	1	
6. Are you familiar with symptoms that indicate nutrient deficiencies in your crops?		
Yes, for all my crops	5	
Yes, for most crops	3	
No, not really	0	
7. Do you know if you are in a region where micronutrient deficiences tend to occur?		
Yes	5	
No	0	
Not sure	0	
8. What is your soil testing regimen?		
I test yearly	5	
I test on a regular basis, but not yearly	5	
I test when I suspect a problem	3	
I never test my soil (skip next 4 questions)	***0***	
9. What time of year do you conduct soil testing?		
Early spring	3	
Late spring	1	
Summer	1	
Late fall	5	

	Points	Score
10. Do you test your soil at the same time of year each time?		
Yes, always	5	
Yes, usually	3	
No	1	
11. Do you precisely follow the guidelines of your soil testing laboratory when taking samples?		
Yes, always	5	
Yes, usually	3	
Not sure	0	
12. Do you submit your soil samples to the same laboratory every time?		
Yes, always	5	
Yes, usually	3	
No	0	
13. Which of the following sources do you primarily use to supply fertility?		
Green manure ***Answer Questions 14-20***		
Manure ***Answer Questions 21-30***		
Compost ***Answer Questions 31-40***		
Other amendments ***Answer Questions 41-50***		
14. Are you aware of how nutrient availability of green manures are affected by environmental conditions?		
Yes	5	
No	0	
Not sure	0	
15. Do you have an approximate idea of how much nitrogen your green manure is providing initially?		
Yes	5	
No	0	
Not sure	0	
16. Do you have an approximate idea of how much nitrogen your green manure is providing over time?		
Yes	5	
No	0	
Not sure	0	

continued next page

Quiz: Fertility Management

Question	Answer	Points	Score
17. Do you choose green manures that are adapted to your area?	Yes	5	
	No	0	
	Not sure	0	
18. Do you plant the heaviest feeding crop in your rotation after using a green manure crop?	Yes	7	
	No	0	
	Not sure	0	
19. Do you use moldboard plowing to terminate your green manure crop?	Yes, there's no other way for my conditions	2	
	Yes, but I haven't tried another method	1	
	No, I use a chisel plow	3	
	I use green manure crops that winter kill	3	
20. Is the method you use to terminate your green manure crop reliable?	Yes	5	
	No, sometimes the green manure comes back	0	
21. Do you verify if the source of your manure is approved with your certifier?	Yes	3	
	No	0	
22. Is your manure tested prior to application?	Yes, I always get it tested	5	
	Yes, the supplier gives an analysis	5	
	Yes, usually	2	
	No	0	
23. Do you have an approximate idea of how much nitrogen your manure is providing initially?	Yes	5	
	No	0	
	Not sure	0	
24. Do you have an approximate idea of how much nitrogen your manure is providing over time?	Yes	3	
	No	0	
	Not sure	0	
25. If you sell to an international market, do you know their regulations for manure application?	Yes	5	
	No	0	
	Not sure	0	
	I do not sell internationally	5	
26. Do you carefully follow sampling guidelines for manure testing?	Yes	5	
	Not really	0	
	Not sure	0	
	Not applicable - supplier provides analysis	5	
27. Do you use manure as the sole source to provide nutrients?	Yes	0	
	No, I include other sources like green manures	5	
28. Do you apply manure two weeks to one month prior to planting to synchronize nutrient availability?	Yes	4	
	No, doesn't work with my crop due to NOP restrictions	3	
	No, I need to apply at other times of the year	1	
29. Do you use manure to supply all your crops' nutrient needs?	Yes	1	
	No, I also utilize green manures and/or other sources	5	
	Not sure	0	
30. Do you incorporate manure to retain nutrients and to protect environment from runoff and leaching?	Yes, I incorporate immediately	5	
	Yes, I incorporate within 24 hours	4	
	Yes, I incorporate within a few days	2	
	No	0	
31. Do you verify if the source of your compost is approved with your certifier?	Yes	5	
	No	0	
32. Do you use compost to supply all your crops' nutrient needs?	Yes	1	
	No, I also utilize green manures and/or other sources	5	
	Not sure	0	
33. Is your compost tested prior to application?	Yes, I always get it tested	5	
	Yes, the supplier gives an analysis	5	
	Yes, usually	2	
	No	0	

continued next page

Quiz: Fertility Management

	Points	Score
34. Do you carefully follow sampling guidelines for compost testing? Yes	5	
Not really	0	
Not sure	0	
Not applicable - supplier provides analysis	5	
35. Do you have an approximate idea of how much nitrogen your compost is providing initially? Yes	5	
No	0	
Not sure	0	
36. Do you have an approximate idea of how much nitrogen your compost is providing over time? Yes	3	
No	0	
Not sure	0	
37. If you make your own compost, does it reach the required temperatures for the required length of time? Yes	5	
No	0	
Not sure	0	
I don't make compost	5	
38. If you make your own compost, do you keep records on the entire process? Yes	5	
No	0	
I don't make compost	5	
39. Do you apply compost two weeks to one month prior to planting to synchronize nutrient availability? Yes	4	
No, I need to apply at other times of the year	1	
40. Do you incorporate compost? Yes	3	
No	0	
41. Do you verify if the source of your amendment is approved with your certifier? Yes	3	
No	0	
42. Can you verify that your other amendments are effective, worth the expense, and necessary for your operation? Yes	10	
No	0	
Not sure	0	

	Points	Score
43. Do you conduct small-scale trials before you commit to purchasing a new amendment? Yes	5	
No	0	
44. Do you have an approximate idea of the levels of nutrients your amendments are providing initially? Yes	5	
No	0	
Not sure	0	
45. Do you have an approximate idea of the levels of nutrients your amendments are providing over time? Yes	3	
No	0	
Not sure	0	
46. Do you apply other amendments in a timely manner when they are needed by the crop? Yes	5	
No	0	
Not sure	0	
47. Do you document a nutrient deficiency prior to using other amendments? Always	5	
Sometimes	3	
Never	0	
48. Do you verify that amendments are necessary with soil testing or plant/tissue analysis? Yes	5	
No	0	
49. Do you incorporate amendments into the soil? Yes	3	
No	0	
50. If you sell to an international market, do you know their regulations for which amendments are allowed? Yes	5	
No	0	
Not sure	0	
I do not sell internationally	5	
TOTAL		

If your score is:	Your risk is:
39 or less	High
40 to 59	Moderate
60 or more	Low

FOR MORE INFORMATION

Manure Nutrient Availability Calculator—this website can calculate the nutrients available in manure. http://www.agry.purdue.edu/mmp/webcalc/nutAvail.asp

Using Manure as Fertilizer for Vegetable Crops http://www.soils.umn.edu/academics/classes/soil3416/veg_manure.htm

Manure Management Plan: A step-by-step guide for Minnesota Feedlot Operators http://www.pca.state.mn.us/publications/wq-f8-09.pdf

Making and using compost at the Rodale Institute Farm. http://www.newfarm.org/features/0804/compost/index.shtml

Basic On-Farm Composting Manual. http://www.cwc.org/wood/wd973rpt.pdf

The Art and Science of Composting: A resource for farmers and compost producers. University of Wisconsin-Madison. http://www.cias.wisc.edu/wp-content/uploads/2008/07/artofcompost.pdf

Composting on Organic Farms. http://www.cefs.ncsu.edu/resources/organicproductionguide/compostingfinaljan2009.pdf

ATTRA Arsenic in poultry litter: organic regulations. http://attra.ncat.org/new_pubs/attra-pub/PDF/arsenic_poultry_litter.pdf?id=Minnesota

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CHAPTER 5

Weed Biology

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The biggest challenge that organic producers face today is weed management. This chapter is devoted to weed biology, which is an aspect of weeds necessary in understanding how to manage them. The next two chapters, Chapter 6—Weed Management, and Chapter 7—Weed Profiles, address specifics in weed management and identification. Additionally, weed management for specific crops is mentioned in the Soybean, Corn, Small Grains, and Forages chapters.

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Figure 5-1. ***Lambsquarters and other weeds in corn.***

Table 5-1. Risks due to weeds.

Compete with crops for moisture
Compete with crops for light
Use nutrients crops need
Attract detrimental insects
Vector disease
Multiply in soil seed banks creating future problems
Interfere with crop harvest
Reduce crop yield
Reduce crop quality

Weeds become a farming risk when they reduce crop yields or lower crop quality (Table 5-1). Their characteristics allow them to compete with crops for light, moisture, and nutrients (Table 5-2). Fields often have a weed community rather than a single species, requiring a variety of management techniques rather than a single cure-all. Farmers can reduce their risk by learning to recognize weed species, focusing on weed emergence, and reducing weeds and their buildup in the seed bank through sound management and equipment care.

Table 5-2. Characteristics of weeds and crops.
Adapted from Mohler et al. 2001.

WEEDS	CROPS
Very high overall growth rate	High overall growth rate
Low early growth rate	High early growth rate
Very high nutrient uptake rate	High nutrient uptake rate
Small seed size	Large seed size
Small seedlings	Large seedlings
High reproductive rate	Varying reproductive rates
Dormancy mechanisms	No dormancy mechanisms
Germinate in response to tillage	Do not germinate in response to tillage
Often long seed longevity in soil	Short seed longevity in soil
Tolerant to stress	Less tolerant to stress

Some organic producers have had issues with neighbors turning them in to county weed inspectors because of weeds in their fields. Sometimes, being organic can draw extra attention.

There are serious consequences to not managing field weeds, in terms of crop quality and quantity as well as cultural and aesthetic reasons. Every state has a Noxious Weed Law, which lists species that must be controlled if present (see Minnesota Noxious Weeds at right). Additionally, organic farmers may be specifically affected by society's perspective that the presence of weeds equates to farming skill—regardless of crop yield, farm profitability, or environmental concerns.

Minnesota Noxious Weeds

A noxious weed is considered to be injurious to public health, public roads, environment, crops, livestock, and other property. The state of Minnesota has a primary listing of 11 weeds that are noxious statewide (Table 5-3). According to Minnesota law, these primary noxious weeds must be controlled on all private and public land in the state. There is also a secondary listing of over 50 weeds that are noxious depending on the county (Table 5-4).

Table 5-3. Primary noxious weeds

COMMON NAME	SCIENTIFIC NAME
Field bindweed	*Convolvulus arvensis*
Hemp	*Cannibis sativa*
Poison ivy	*Toxicodendron radicans*
Purple loosestrife	*Lythrum salicaria* *L. virgatum*
Leafy spurge	*Euphorbia esula*
Garlic mustard	*Alliaria petiolata*
Perennial sowthistle	*Sonchus arvensis*
Bull thistle	*Cirsium vulgare*
Canada thistle	*Cirsium arvense*
Musk thistle	*Carduus nutans*
Plumeless thistle	*Carduus acanthoides*

Table 5-4. Some secondary noxious weeds

COMMON NAME	SCIENTIFIC NAME
Wild buckwheat	*Polygonum convolvulus*
Giant foxtail	*Setaria faberii*
Redroot pigweed	*Amaranthus retroflexus*
Common ragweed	*Ambrosia artemisiifolia*
Woolly cupgrass	*Eriochloa villosa*
Velvetleaf	*Abutilon theophrasti*
Quackgrass	*Agropyron repens*
Wild oat	*Avena fatua*
Black nightshade	*Solanum nigrum*

What is a weed?

To start thinking in weed management mode, what is a weed? A weed is considered any plant that a person does not want. It might be a particular plant species, or maybe a volunteer crop plant (Figure 5-2). Many weeds fall into broad categories such as agricultural, turf, or roadside weeds. Agricultural weeds are those that have adapted to farm life and the cycle of crop planting. Plants that become weeds have several qualities that promote their success, including high seed production, a rapid growth rate, competitive nutrient uptake, adaptability to climate, seed dormancy mechanisms, good dispersal mechanisms, and self-pollination. Learning more about weedy plant traits helps farmers become better weed managers and reduce risk of crop loss in the long run.

STRAND MEMORIAL HERBARIUM

Figure 5-2. ***Volunteer corn in soybean field.***

WEED LIFE CYCLES

Most plants have one of three main life cycles—annual, biennial, or perennial. An **annual** plant completes its life cycle in one year as it germinates, grows, flowers, sets seed, and dies (Figure 5-3). Most of the weeds in agricultural fields are annuals such as pigweeds and foxtails. Most crops are also annuals.

A **biennial** is a plant that needs two growing seasons to complete its life cycle (Figure 5-4). The first year, biennials produce vegetative growth in the form of a rosette where all the leaves come from the center crown (Figure 5-5). Biennials go dormant over the winter and in the second year, regrow, flower, set seed, and die. Some common biennials are musk thistle and mullein.

STRAND MEMORIAL HERBARIUM

Figure 5-3. ***Redroot pigweed is an annual.***

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Figure 5-4. ***Musk thistle is a biennial weed.***

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Figure 5-5. *The rosette of musk thistle.*

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Figure 5-6. *Canada thistle is a perennial weed.*

A **perennial** is a plant that lives for three or more years as it grows, flowers, and sets seed in a continuous cycle over several seasons (Figure 5-6). Canada thistle and quackgrass are perennials. Additionally, perennials have special underground parts (rhizomes, tubers, stolons) that allow them to spread vegetatively as well as by seed.

REPRODUCTION IN WEEDS

Plants have two main modes of reproduction, by seed or vegetatively. Most annuals and biennials reproduce by seed, and in the case of weeds, the production is often quite prolific. For example, redroot pigweed can produce over 100,000 seeds/plant (Table 5-5).

Perennials can reproduce by seed as well as by vegetatively via rhizomes and stolons. A rhizome is an underground stem that sends out roots and shoots from its nodes (Figure 5-7). A stolon is an aboveground stem that grows from an existing stem at a node, like a strawberry runner. A tuber

Table 5-5. Amount of seed produced per plant by different weed and crop species.
Adapted from Renner, 2000.

	SPECIES	SEEDS/PLANT
WEED	Canada thistle	680/stem
	Giant foxtail	900
	Cocklebur	900
	Wild mustard	1,200
	Wild buckwheat	1,200
	Common ragweed	3,500
	Yellow foxtail	6,500
	Common sunflower	7,200
	Velvetleaf	7,800
	Eastern black nightshade	10,000
	Giant ragweed	10,300
	Hemp dogbane	12,000
	Kochia	14,600
	Dandelion	15,000
WEED	Smartweed	19,500
	Waterhemp	23,000
	Common chickweed	25,000
	Burdock	31,600
	Shepardspurse	38,500
	Common purslane	52,300
	Lambsquarters	72,500
	Redroot pigweed	117,400
	Horseweed (marestail)	200,000
	Common mullein	223,200
CROP	Corn	800
	Soybean	50
	Winter wheat	110

Figure 5-7. *Quackgrass rhizomes.*

is a thickened part of a rhizome or stolon that is used as a place of storage for starch (e.g. Jerusalem artichoke, yellow nutsedge). Many plants that have above ground stolons also form horizontal, belowground rhizomes.

Seeds, rhizomes, stolons, and tubers are all considered *propagules* because they are able to generate entire new plants. Weeds potentially produce very many propagules per plant, but actual productivity is much lower in competition with the crop or at high weed densities. The crop-weed interaction can reduce potential weed seed production dramatically, as much as 50 percent.

Reducing risk: life cycles and reproduction. **Decrease weed risk by identifying the plant life cycle and reproduction mode of your problem weed species. For example, annuals can be contained through tillage or mowing prior to seed production. On the other hand, tillage can increase a perennial by breaking up the roots and creating new plants more quickly.**

WEED SEEDBANKS

It is hard to imagine the number and variety of weed seeds in a field (Table 5-6 and Figure 5-8). Once a weed has produced seed and dispersed them in the soil, the majority of the seeds remain for a long period of time. This reservoir of viable seeds in the soil is called a seed bank. If those weeds are allowed to grow and go to seed, an ugly cycle of weed seed replenishment can frustrate even the most attentive farmer. In any given year, only a small percentage of seeds in the seed bank germinate due to a variety of seed dormancy mechanisms. The rest of those seeds remain waiting for the next opportunity to grow.

A critical aspect of weed management is reducing weed seed production. Crop competition can reduce potential weed seed production (Table 5-7). Thus, weed seedbanks can be decreased in response to good management, while seedbank increases will occur in years with poor weed management. Producers should remember that prevention is better than finding a cure!

Reducing risk: weed seedbanks. **Practice good weed management on the whole farm to prevent increases in weed seedbanks. Prevent weeds from going to seed as much as possible. Clean tillage equipment to prevent movement of underground reproductive structures.**

Table 5-6. Number of viable weed seeds in four agricultural fields in Minnesota.
Soil was sampled to a depth of 6 inches. Adapted from Robinson, 1949.

LOCATION	COUNTY	SEED/FT^2	SEED/ACRE (in millions)
Sacred Heart	Renville	118	5.1
Danube	Renville	184	8.0
Morris	Stevens	586	25.5
Waseca	Waseca	7661	333.7

STEVE HURST—ARS

Figure 5-8. Weed seeds have a variety of sizes, shapes, and colors. *Seeds of 12 weed species are shown. Field bindweed, Canada thistle, giant ragweed, johnsongrass, kochia, orchardgrass, Pennsylvania smartweed, quack-grass, redroot pigweed, velvetleaf, wild proso millet, and woolly cupgrass.*

Table 5-7. Percent reduction of weed seed production *when weeds emerge after crop emergence as compared to when weeds emerge with crop. The amount of seed is dramatically reduced when weeds emerge after the crop. Adapted from Sprague, MSU Extension, 2008.*

WEED	CROP	WEED EMERGENCE (# WEEKS AFTER CROP)	% WEED SEED REDUCTION
Waterhemp	Corn	3	95
Waterhemp	Soybean	3	81
Giant ragweed	Corn	6	99
Giant ragweed	Soybean	6	78
Velvetleaf	Corn	3	60

WEED DISPERSAL

Most agricultural weeds (~75 percent) lack any obvious dispersal mechanisms and fall close to the parent plant. But weeds do move around, and dispersal mechanisms are as varied as the number of weed species. Weed seed dispersed by wind (e.g. dandelion, thistles) usually has structural modifications making them very lightweight in the air (Figure 5-9). Flooding and irrigation are good dispersal mechanisms as most seeds can float and can live in the water for some time. Birds and animals can move seed great distances (Figure 5-10). Seed contamination via weed mimicry (e.g. clover in alfalfa) is also a source of dispersing weed seeds to new sites. Agricultural activities like planting contaminated crop seed, using unclean harvest equipment and tillage equipment, and moving machinery between fields are significant weed seed dispersal procedures (Table 5-8). Spreading manure is another common way to disperse weed seed (Figure 5-11). Composting manure can eliminate some weeds. Knowing the potential sources of weed contamination and cleaning equipment are good starting points to reducing new infestations and lowering farmer risk.

STRAND MEMORIAL HERBARIUM

Figure 5-9. *Bull thistle seed.*

STRAND MEMORIAL HERBARIUM

Figure 5-10. *Eastern nightshade berries are eaten and then dispersed by birds.*

Table 5-8. Scale of distance of weed seed dispersal mechanisms. *Dispersal can be as a result of human activity (irrigation) or as a result of natural activity (wind). Adapted from Mohler et al., 2001.*

	----DISTANCE----		
DISPERSAL MECHANISM	WITHIN FIELDS	BETWEEN FIELDS	BETWEEN REGIONS
Livestock (transported)		✔	✔
Contaminated seed		✔	✔
Irrigation water		✔	
Manure		✔	
Combines	✔	✔	
Livestock (walking)	✔	✔	
Birds	✔	✔	
Plows	✔	✔	
Wind	✔	✔	
Insects	✔		
Rain	✔		

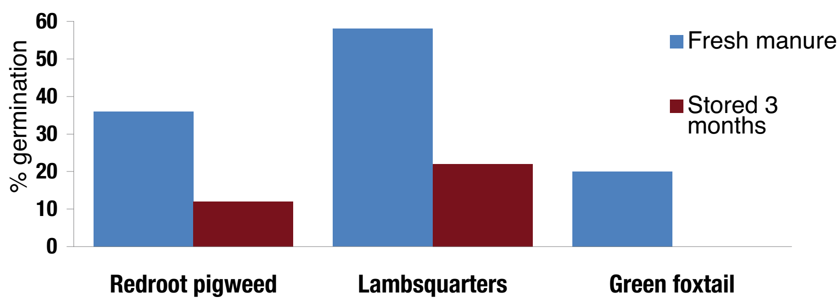

Figure 5-11. Percent germination of three weeds *in fresh manure and manure that has been stored for three months. Green foxtail had zero percent germination after three months. Weed seed can still remain viable after livestock digestion and even after storage. Adapted from Renner, MSU Extension, 2000.*

DORMANCY

Weed seed dormancy is another type of dispersal—dispersal through time instead of space. When seed is dispersed, most does not immediately germinate. It remains dormant in a sort of sleeping stage until conditions are right. The factors that break dormancy are unpredictable and dependent on the species, the weather conditions, even physiological factors within the seed

Reducing risk: weed dispersal. **Be aware of the routes of dispersion. Always start with clean, weed-free seed or certified seed. Inspect and clean machinery. When using compost instead of manure, ensure it has been properly composted to kill as many weed seeds as possible.**

Table 5-9. Weed and crop seed persistence in soil. The approximate number of years it takes to reduce weed seed populations by 50 and 99 percent.

Adapted from Michigan State University, 2005.

	SPECIES	50% REDUCTION	99% REDUCTION
		YEARS	
Broadleaves	Lambsquarters	12	78
	Velvetleaf	8	56
	Cocklebur	6	37
	Pennsylvania smartweed	4	26
	Redroot pigweed	3	20
	Shepardspurse	3	19
	Curly dock	3	17
	Waterhemp	2	16
	Common ragweed	1.5	10
	Wild mustard	1	7
	Common sunflower	0.5	2
	Hemp dogbane	0.5	2
	Giant ragweed	0.5	2
	Kochia	0.5	2
Grasses	Yellow foxtail	5	30
	Barnyardgrass	2	10
	Large crabgrass	1.5	8
	Giant foxtail	1	5
Crops	Wheat	1	2
	Canola	2	4
	Soybean	1	2
	Corn	2	4

itself. Over time seeds that do not germinate go from dormant to non-viable (dead). Weed persistence in the seedbank will vary among species (Table 5-9). Again, this is species and climate condition dependent but can be further manipulated by farmers who have identified their weed problems and are proactive about crop rotation and weed seed burial via tillage.

Table 5-10. Seed size and depths at which inhibition of seed germination or emergence occurs. *There are depths at which weed seed will not be able to emerge, usually corresponding to seed size. Adapted from Benvenuti et al., 2001 and others.*

SPECIES	SEED SIZE (MM)	50% INHIBITION (IN.)	100% INHIBITION (IN.)
Common purslane	0.6	1.5	3.1
Common chickweed	1.0	1.4	3.1
Redroot pigweed	1.0	2.1	3.9
Wild mustard	1.5	1.7	3.9
Lambsquarters	1.5	1.9	3.9
Black nightshade	1.6	2.1	3.9
Prostrate knotweed	2.0	2.1	3.9
Large crabgrass	2.5	1.6	3.1
Jimsonweed	2.5	2.4	4.7
Canada thistle	3.0	2.1	3.9
Velvetleaf	3.0	2.8	4.7
Barnyardgrass	3.5	2.1	3.9
Johnsongrass	4.0	2.5	4.7
Field bindweed	5.0	2.7	4.7

SEED CHARACTERISTICS

Weed seeds have general characteristics that producers can use to manage them. Here are some general rules:

- Seed of broadleaves are more persistent in the soil compared to grasses.
- Annuals and non-rhizomatous perennials tend to be persistent in seed banks.
- Small, round seeds tend to be more persistent than large or elongated ones.
- Small seeds are more likely to go dormant immediately.
- Large seeds are less susceptible to allelopathic compounds such as from a rye crop.
- Small seeds do not emerge well from depths greater than two inches (Table 5-10).

Producers can use traits such as persistence and germination depths of different weeds as a guide to the effectiveness of burying weed seed with tillage. Thus, shallow cultivation will keep seeds on top and reduces germination by not providing them with conditions like adequate moisture that encourage germination. Deep cultivation will bury large seeds like cocklebur. Large seeds are less persistent and if buried deep enough, they will not survive. However, small weed seed survival is increased by burial, as they will go dormant until conditions bring them back to the surface.

Reducing risk: dormancy and seeds.

Be aware that some field operations will expose weeds to conditions that break seed dormancy. Viable buried seed that is brought to the surface via deep tillage may germinate. Reduced or shallow tillage may leave dormant seeds buried, preventing germination, but can also leave small seeds closer to the surface, providing them greater opportunity to germinate.

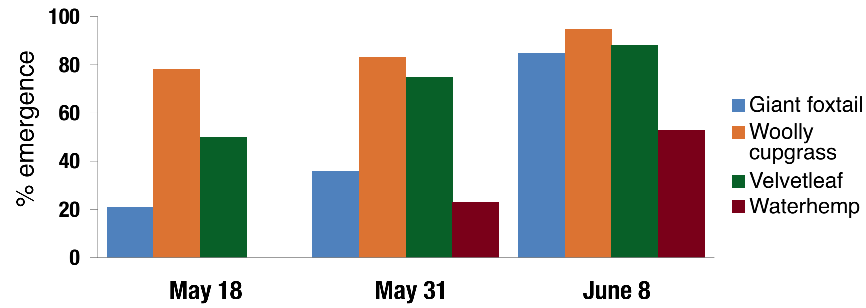

Figure 5-12. Percent emergence by date for four weeds *in Ames, IA. In this example, weeds like giant foxtail, woolly cupgrass, and velvetleaf will mostly be emerged by June 8th, while the waterhemp population is only halfway finished. Adapted from Buhler et al., 1997.*

WEED EMERGENCE

Weeds rarely emerge in a single uniform flush. Emergence for each weed species is based on a wide variety of factors depending on the weather, soil type, tillage system, prior crop, and crop rotation. But year to year emergence, and the duration of emergence, of a known species is fairly consistent (Figure 5-12 & Table 5-11). Some weeds emerge over a span of two to three weeks (giant ragweed and woolly cupgrass), four to seven weeks (lambsquarters, common ragweed, and yellow foxtail), and others over a more prolonged eight to ten weeks (velvetleaf, giant foxtail, and waterhemp). A variety of computer tools, usually based on soil type, growing degree days, and tillage are available to farmers (see Sidebar on decision tools).

Reducing risk: emergence. Be able to identify weed seedlings on your farm. Know the timing and emergence of weeds to synchronize mechanical weed control operations.

Table 5-11. Relative emergence of weeds in Minnesota. *Adapted from Iowa State University, 2000.*

	Group 0	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7
WEED SPECIES	Horseweed Downy brome Field pennycress Shepards-purse Biennial thistles	Foxtail barley Kochia Prostrate knotweed Wild mustard Russian thistle White cockle	Quackgrass Orchardgrass Giant ragweed Pennsylvania smartweed Lambsquarters Wild oats Hairy nightshade Common sunflower	Smooth brome Common ragweed Woolly cupgrass Velvetleaf Wild buckwheat	Canada thistle Giant foxtail Yellow nutsedge Redroot pigweed Cocklebur	Green foxtail Common milkweed Hemp dogbane Barnyard grass Yellow foxtail Wild proso millet	Black nightshade Shattercane Venice mallow Waterhemp Jerusalem artichoke	Fall panicum Crabgrass Jimson-weed Witchgrass
APPROX. DATE IN MINNESOTA	Fall	April	Early May	Early to mid May	Mid to late May	Late May/ early June	Early to mid-June	After mid-June
CONCURRENT FIELD OPERATIONS	Fall tillage	Spring tillage Seedbed prep Small grains planting	Seedbed prep	Pre-emergent weed control Corn planting Seedbed prep	Pre-emergent weed control Corn planting Soybean planting	Post-emergent weed control Soybean planting Alternative crop planting	Post-emergent weed control Cultivation	Cultivation

WEED SEED FATE AND SEEDLING MORTALITY

Like all seeds, a weed seed's fate in a field is no mystery. It can germinate and live, be removed by wind or water, germinate and die, decay over time, become inviable (dead), stay dormant, or get eaten! Weed seed mortality is derived in three main ways: seed predation in the soil, aging of the seed over time, and germination at the wrong depth or time of year (Figure 5-14). The ultimate fate of a weed seed will vary by species (Figure 5-15).

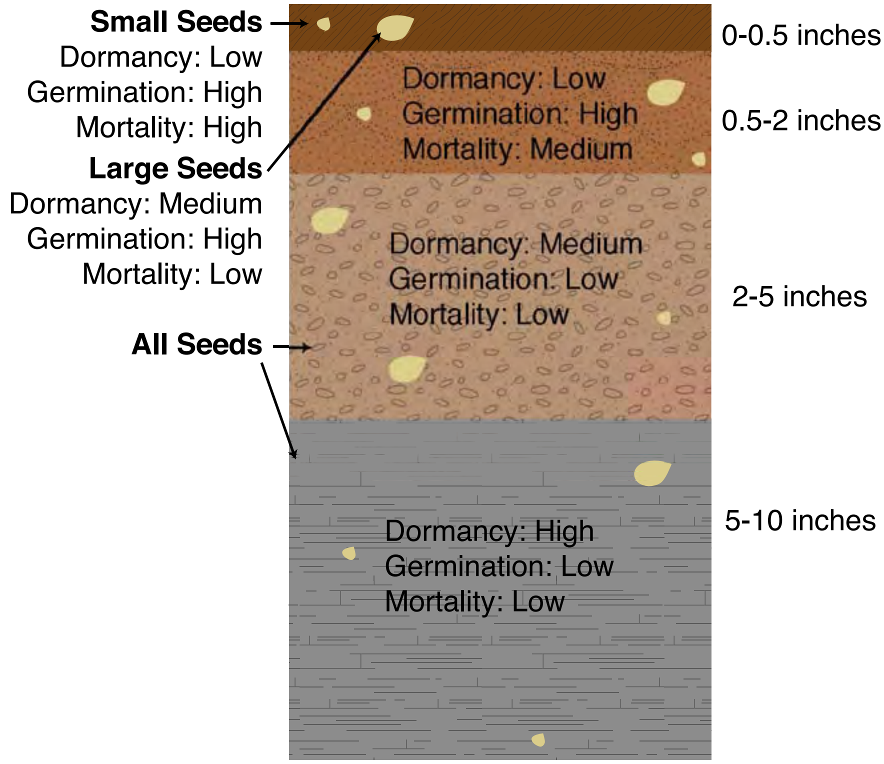

Figure 5-14. Weed seed fate *depends on placement in the soil profile. Once seeds are past 1/2-inch soil depth, fates are similar regardless of size. Adapted from Michigan State University Extension, 2005 and Mohler, 2001.*

Weed Management Decision Tools

One of the most important decisions that organic producers make is when to time weed control operations for effective results. Knowing when the weeds will be present and when they will most easily be controlled is an integral part of this decision. There are several weed software programs that can aid in the decision-making process. WeedCast is an example useful for producers in the Midwest. Weather and site data are entered by a producer and emergence information about particular weeds in their fields are displayed (Figure 5-13). This software is available for free from the following website http://www.ars.usda.gov/services/software/download.htm?softwareid=112#downloadForm

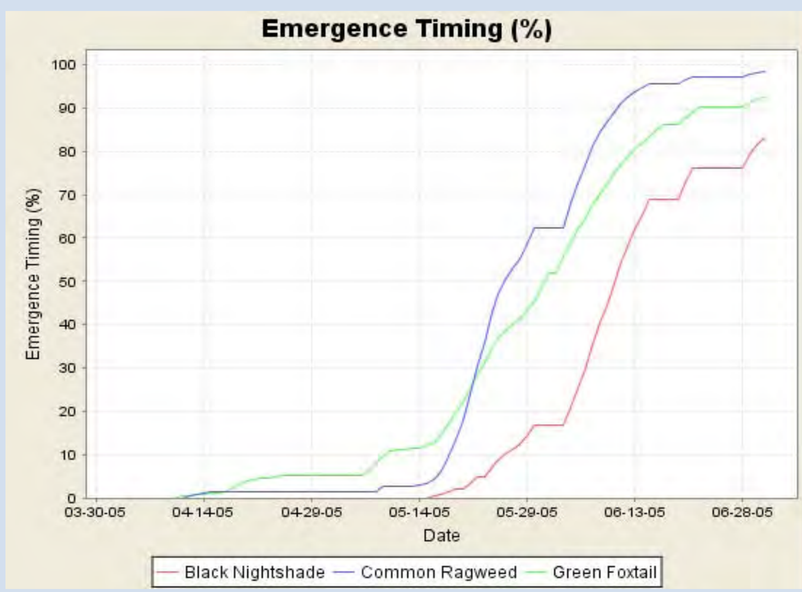

Figure 5-13. Example output from WeedCast *showing emergence timing for black nightshade, common ragweed , and green foxtail.*

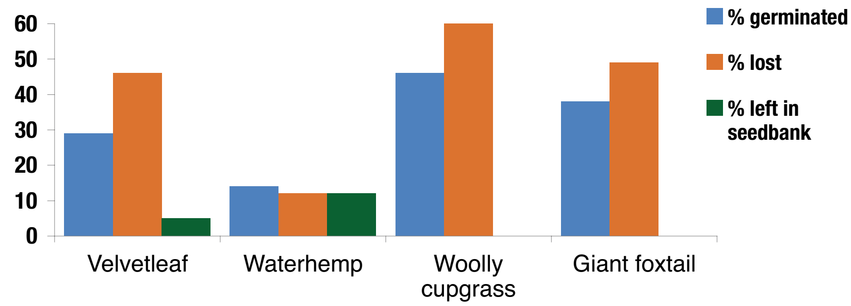

Figure 5-15. Percent of germinated seed, percent remaining in seed bank and percent remaining seed of four weeds in soil after four years. ***Woolly cupgrass and giant foxtail seeds are more quickly depleted from the seedbank compared to velvetleaf and waterhemp seeds. Adapted from Buhler and Hartzler, 2001.***

But for seeds that do germinate and live, weed seedling survival after emergence is very high. Rates of natural mortality due to disease, herbivory and drought are low for established weeds in annual crops. So, if a weed makes it to seedling stage, its rate of survival to maturity is 25-75 percent, up to even 90 percent. Mortality also decreases with increasing plant size and age.

Despite starting small, weed seedlings quickly catch up with crop seedlings—they like the same growing conditions as the crop seed does. Weed seedlings have a very high relative growth rate (amount of growth/biomass) and quickly establish a fine root network for nutrient uptake. Smaller seeds have small reserves compared to crops, making them more dependent on soil nutrients.

WEED DENSITY

Weed density is a function of the weed seedbank and its emergence rate (Table 5-12). The density of a weed cohort has several consequences. Farmer risk with respect to weed density includes yield loss and problems of future weed management. It is worth noting that density, at least at initial germination, may not be indicative of later plant densities, as some plants will die due to crowding, crop competition, and various climate factors.

Weed effects on crops

The negative effects of weeds are well-known. The level of damage to a crop will be dependent on factors relating to weeds such as species present and weed density, but the crop itself will also be a factor. Both the weeds and crop are considered when determining the weed thresholds where management options should be considered.

WEED THRESHOLDS

While weeds may not be wanted, how many are too many? Total eradication, while possible, could be excessively expensive, incur unacceptable environmental damage, and deprive the farmer of some of the ecological services—actual benefits—of having unwanted plants on the farm (see Weed benefits sidebar).

Table 5-12. Weed seed bank densities and seedling emergence in row crops in Morris, MN. ***Densities will be dependent on the weed species and the initial weed populations in the seed bank. Adapted from Forcella et al.,1993.***

	Mean densities per m^2			
	Green foxtail	Redroot pigweed	Lambsquarter	Other weeds
Seeds in seedbank at start of season	972	672	379	59
Seedlings prior to crop planting	16	0	6	4
Seedlings after crop planting	43	10	8	4
Seedlings after interrow cultivation	13	4	7	1

Weeds aren't all bad: weed benefits

It may be difficult to imagine, but weeds can provide ecological benefits (Table 5-13). If seed production can be prevented, producers may be able to take advantage of some of these benefits.

Table 5-13.

WEED BENEFITS
Protect again soil erosion
Fix nitrogen (if weed is a legume)
Add organic matter
Provide habitat for beneficial organisms
Conserve soil moisture
Scavenge nutrients
Contribute forage
Increase biodiversity

A weed threshold is the number of weeds it takes before a producer deems them necessary to control.

In developing thresholds, the number and timing of weed control operations need to be balanced against minimizing crop injury, soil damage, and costs. Good yields rely on the relative timing of emergence of crop versus weeds, the time it takes for the crop to reach a good height over the weeds, and how rapidly the canopy of the crop closes.

Weed thresholds are one of two main categories—competitive or economic. *Competitive thresholds* are the levels at which weeds negatively affect yield. They are determined by weed density, duration of interference, and crop reduction. Crops are not equal in their ability to compete with weeds, and weeds vary in their ability to compete with the crop (Table 5-14). Often, if more than one weed species is present, the competitive effects are not additive. As weed density increases, weeds compete with the crop and each other—making it hard to predict yield loss. Crops can tolerate weeds up to a point—but a critical period arrives at which weeds must be managed to avoid crop loss (Figure 5-16). Critical periods vary between crops.

Economic thresholds examine the value of the management decision—at what point is the cost of management worth the amount of yield gain? Economic thresholds are more difficult to estimate as they must account for a given crop, weed community, cost of management, commodity price, and amount of potential yield loss.

Table 5-14. Risk levels of weed species on corn and soybean yield.

BROADLEAF WEEDS	RISK	GRASS WEEDS	RISK
Giant ragweed	High	Johnsongrass	Moderate
Common sunflower	High	Quackgrass	Moderate
Common cocklebur	High	Barnyardgrass	Low
Velvetleaf	High	Giant foxtail	Low
Lambsquarters	High	Green foxtail	Low
Common ragweed	High	Yellow foxtail	Low
Jimsonweed	High	Large crabgrass	Low
Common waterhemp	Moderate	Fall panicum	Low
Redroot pigweed	Moderate	Witchgrass	Low
Kochia	Moderate		
Pennsylvania smartweed	Moderate		
Canada thistle	Moderate		
Field bindweed	Low		
Horseweed	Low		
Eastern black nightshade	Low		

A producer from Lac Qui Parle County says that crop competitiveness is an important aspect to consider. When choosing a soybean variety, he likes ones with large leaves that will form a canopy in at least one month in his 30" rows. That way, he can cultivate for weeds at two weeks after planting and be done.

Reducing risk: weed thresholds. **Be observant of weeds levels and yields for your farm to develop an idea of weed thresholds for individual situations. Good record keeping will be helpful. When weed thresholds are met, apply appropriate measures. Realize that there will be times when weeds may not need to be controlled.**

CROP COMPETITIVENESS

Weeds and crops are in constant competition in the field. Weed management is confounded by emergence, density, and diversity of species, but crops do have some innate tools against weeds. Crop density (planting rates, row spacing), competitive crops like rye and alfalfa, crop varieties developed for rapid canopy closure, rapid emergence, higher seedling growth rate, and weed tolerance are examples.

Changes in timing of tillage, planting date (early or delayed), increased crop rotation, increased crop variety, interseeding, etc. can break a weed cycle and lower the farmer risk of crop loss. Factors producers can manipulate include all of the following: planting date, cultivation, mulch, use of allelopathic crops, row spacing, planting density, intercropping, and selection of fast-growing cultivars (Figure 5-17).

These topics will be discussed further in the next chapter on Weed Management. Take the following quiz to determine your knowledge of weed biology.

Reducing risk: crop competitiveness. **Choose varieties and cultural practices that promote crop competitiveness.**

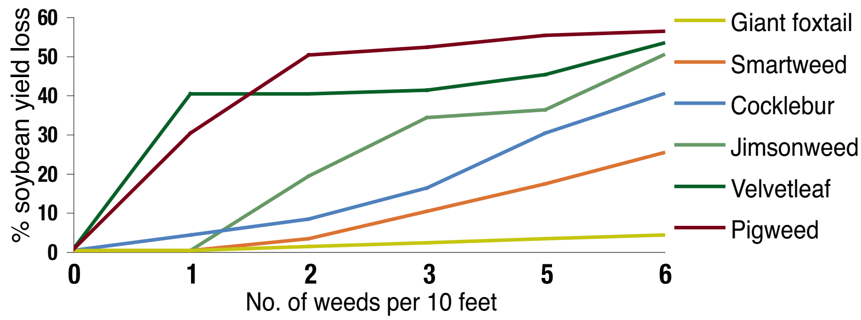

Figure 5-16. Approximate yield effects of early weed infestations in soybean. *Giant foxtail reduces yield much less at low population levels when compared to pigweed or velvetleaf. Adapted from Purdue University, 2007 and Michigan State University, 2005.*

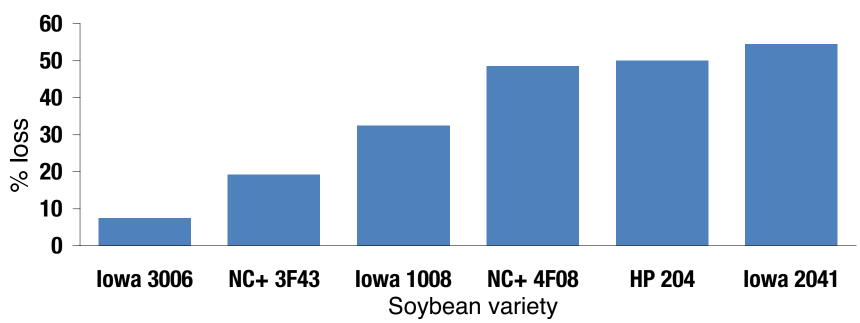

Figure 5-17. Yield loss due to weeds (as compared to weed-free controls) *among six soybean varieties. Some varieties may yield better than others when in competition with weeds. Adapted from Seidel and Hepperly, 2005.*

Weed Biology Risk Management Quiz

	Points	Score
1. Do you have good weed identification skills?		
Yes	3	
No	0	
2. Do you know which weeds are noxious in your county?		
Yes	2	
No	0	
3. Do you know the life cycles of the different weeds on your farm?		
Yes	3	
Yes, for most of them	2	
No	0	
4. Do you know at which stage your weeds are most vulnerable to control?		
Yes	3	
Yes, for most of them	2	
No	0	
5. Do you have an integrated weed management plan for your farm?		
Yes	3	
No	0	
6. Do you have flexibility in your weed management plan to adapt to new weed issues?		
Yes	3	
No, I do the same thing each year	0	
7. Are you attentive to the timing and density of weed emergence in your fields each year?		
Yes, always	3	
Yes, most of the time	1	
No, not really	0	
8. Do you anticipate probable weed pressure in planning your weed management strategy?		
Yes, always	3	
Yes, most of the time	1	
No, not really	0	

	Points	Score
9. Do you clean your equipment before moving from one field to the next?		
Yes, always	3	
Yes, most of the time	1	
No, not really	0	
10. Do you ensure that the seed you plant is clean and does not contain weed seed?		
Yes, always	3	
Yes, most of the time	1	
No, not really	0	
11. Which of these weed management strategies do you currently use?		
Give yourself 2 points for each used strategy.		
Tillage	2	
Diverse crop rotation	2	
Varying planting dates	2	
Varying varieties	2	
WeedCAST modelling	2	
Competitive varieties	2	
Increased planting density	2	
Interseeding	2	
Cover crops	2	
Adequate fertilization	2	
12. Which of the above strategies do you plan on implementing in the future?		
Give yourself 1 point for each strategy you plan to use from the above list.		
	TOTAL	

If your score is:	Your risk is:
29 or greater	Low
28 - 20	Moderate
19 - 0	High

FOR MORE INFORMATION

Applied Weed Science Research. Department of Agronomy and Plant Genetics, University of Minnesota. http://applied-weeds.cfans.umn.edu/

The Eleven Primary Noxious Weeds of Minnesota. Martinson, K., B. Durgan, and R. Becker. http://www.extension.umn.edu/distribution/livestocksystems/DI8489.pdf

The weeds page: integrated weed management. The Rodale Institute. http://newfarm.rodaleinstitute.org/depts/weeds/index.shtml

Weedsoft—software to assist in weed management decisions (primarily for conventional producers, not directly related to MN). http://weedsoft.unl.edu/Index.htm

Weedsoft Yield Loss Calculator—Producers can enter in their crop and weed data and the calculator with figure out the yield losses. http://driftwood.unl.edu/weedsoft/YieldLossCalc/YieldLossOne.php

WeedCast http://www.ars.usda.gov/services/software/download.htm?softwareid=112

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CHAPTER 6

Weed Management

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In Chapter 5—Weed Biology, we discussed how weeds grow and compete with crops. While there inevitably will be a certain level of weeds, it is the grower's task to make sure that the weeds present do not exceed damaging thresholds that limit crop yields. In this chapter, we will address practical weed management techniques for the organic producer.

Weed management for organic crop production falls into two categories: cultural weed control and mechanical weed control. A third type of weed control using chemicals is another option, but will not be discussed in this manual as organic herbicides are not commonly used on a large scale in agronomic crops.

JOHN DEERE

Figure 6-1. *Row crop cultivator.*

Cultural weed control

Cultural weed control includes diversifying rotations, delaying planting, changing planting rate, timing of nutrient application, and using cover crops (see Chapter 13 for more information on cover crops). Cultural methods are the first line of defense in weed management.

ROTATION

Diversifying a rotation is the strongest tool against weeds. Over time, using similar planting dates, and cultivation timing will select for weeds that are adapted to these strategies. Varying crops by different planting date (e.g. wheat is planted several weeks before soybean) or growing a perennial crop in rotation with row crops can prevent weeds from adapting to the planting regimen.

Competitive perennial crops such as alfalfa are especially effective in reducing seed banks of annual grasses and broadleaf weeds and in suppressing perennial weeds like thistle. The advantage of alfalfa is that it is harvested three or four times during the growing season which prevents annual weeds from flowering or producing seed and depletes root reserves of perennials. In addition, its continuous cover provides a habitat for animals that consume weed seeds. Cover crops in rotations can also play a role in preventing weed infestations.

Because rotation is so important for organic farmers, we have devoted an entire chapter to the topic in Chapter 2.

Crop seed size

Crop varieties vary in seed size and those with larger seed size often have increased competitiveness against weeds. Large seed mass gives an initial head start to the crop at the time it is most critical. Small-seeded weeds are capable of fast initial growth, but are dependent on photosynthesis and outside nutrients. A large crop seed has its own internal resources and can provide a jump start over weeds under the right conditions. Crop seed size is one of many factors to consider in crop variety selection.

COVER CROPS AND SMOTHER CROPS

Winter cover crops and smother crops are two additions to rotations that can have an effect on weeds. Winter cover crops can occupy the niche that exists after a summer crop is harvested and before the next season's crop is planted. They can displace weeds that might otherwise germinate in the fall or very early spring. Winter rye and hairy vetch residue also has been shown to have allelopathic effects on some germinating weeds, but this effect is short-lived and lasts only until the residue decomposes. See Chapter 13 for more information on the benefits and risks of winter cover crops.

A smother crop is a vigorously-growing crop that growers use to suppress weeds. Generally, a smother crop is not harvested, but plowed down instead. Two examples of summer smother crops used in the Upper Midwest include buckwheat and sudangrass (or sorghum-sudangrass). Smother crops may suppress some perennial weeds, but a perennial crop such as alfalfa grown for two or more years generally will be a better choice to affect perennial weeds in the long-term. The primary risk in using smother crops is that their effectiveness in weed control may be inconsistent and unpredictable. Additionally, a smother crop such as buckwheat has potential to become a weed itself.

DELAYED PLANTING

Delayed planting is an option in weed management, but it can reduce crop yields. However, for many organic farmers, delayed planting can be the correct choice in highly weed-infested fields. Delaying planting allows for more mechanical weed control operations to be performed prior to crop planting with the prospect of fewer weeds in the crop.

Organic farmers in the Upper Midwest balance the potential yield gains from improved weed control against potential yield losses from delayed planting by planting corn around May 15 and planting soybean between June 1 and June 15. Cool-season crops like small grains or field pea that are planted early in the spring are not likely to benefit from delayed planting.

Delayed planting can reduce populations of early-emerging weed species (Figure 6-3). See Table 5-11 from the previous chapter for weeds that emerge early in the season. Producers need to monitor their fields and be constantly aware of which weed species (see Chapter 7 for weed identification) are present to decide if a delayed planting strategy is warranted. They also need to consider if a potential decrease in yield is justified.

Figure 6-2. *Sorghum-sudangrass grown as a smother crop.*

PRODUCER PROFILE

SMOTHER CROPS

An organic producer from Wadena County uses buckwheat as a smother crop to control Canada thistle and quackgrass. Buckwheat easily reseeds so he notes that control of buckwheat before it goes to seed is important to prevent volunteers. Oats are not a good choice to plant after buckwheat because of the danger of seed contamination by potential buckwheat volunteer plants in oats. Buckwheat can be planted in June at a rate of up to 50 pounds/acre.

A farmer from McLeod County uses sorghum-sudangrass (Figure 6-2) to suppress Canada thistle and quackgrass, but he finds that large-seeded broadleaf weeds like velvet leaf are not effectively controlled. He plants in the middle of June (no later than June 25th) to get a good stand. Sorghum-sudangrass will winter-kill so it can be tilled in the fall or spring. Sorghum-sudangrass is a warm-season crop planted when soils have warmed in June at a rate of 35 to 40 pounds/acre if drilled or at 40 to 50 pounds/acre if broadcast.

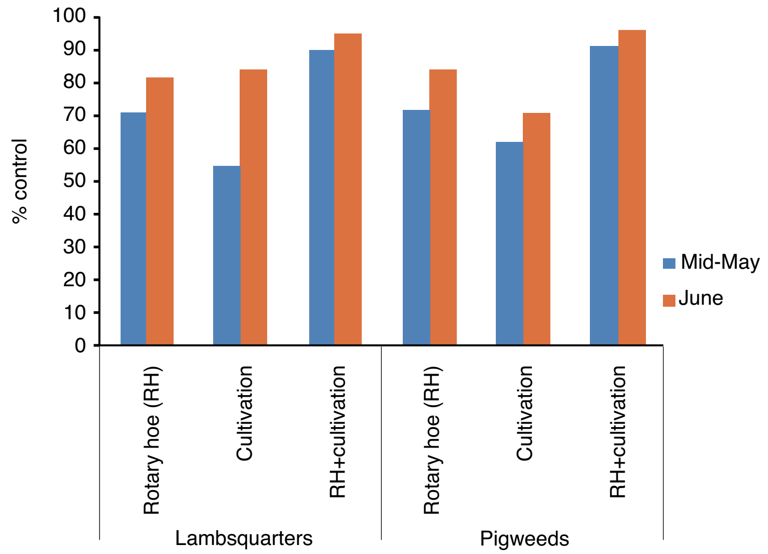

Figure 6-3. *Effect of delayed planting on control of lambsquarters and pigweeds in soybean, 1989-1991, Rosemount, MN. Soybeans were planted mid-May or early June and treated with the rotary hoe, cultivation or both. Delayed planting usually led to increased weed control, particularly in lambsquarters which emerges earlier than the pigweeds. Adapted from Buhler and Gunsolus, 1996.*

PLANTING RATE

Increasing the planting rate is another common strategy for organic growers. Higher crop densities can lead to greater competitiveness against weeds. In addition, higher planting rates can compensate for crop losses that occur during mechanical weed control operations. The bigger the weed problem, the more effective increasing plant population will be. Less competitive crops like flax may show a greater yield increase. For guidelines as to whether to increase crop plant populations, producers should consult the chapters in this manual for individual crops and with local extension personnel for optimum planting rates for their area.

NUTRIENT APPLICATION

Just as nutrients nourish the crop, they can also nourish the weeds. There are two issues with compost and manure application – how the nutrients affect growth of existing weeds in the field and the potential introduction of new weed seeds. Compost application in the spring can stimulate germination of early-emerging weeds. The growth of many weeds like foxtails, pigweed and lambsquarters is stimulated by nutrients such as nitrogen that are intended for crops (Table 6-1). When weeds have a stronger response to high fertility than the crop does, there will be a negative effect on yield because the weeds will become more competitive and subsequently compete for light and water resources. Examples where this most frequently occurs is with small grains like wheat and barley, which is why applying manure or compost before planting these crops is not recommended. For crops with high nutrient needs, providing proper levels of nutrients can lead to increased competitiveness against weeds.

The timing of fertilizer application can be important. When nutrients are applied too early for crop utilization, weeds may be favored. Producers may be tempted to delay fertilization. However, the unpredictable release of nutrients from organic fertilizers will make using nutrients to manage weeds a challenge.

Table 6-1. Effect of nitrogen on weed growth. Increasing nitrogen levels can have a positive or negative effect on weed growth depending on the species. *Adapted from Davis, 2005.*

N INCREASES GROWTH	N INHIBITS GROWTH
Velvetleaf	Common ragweed
Foxtail	Canada thistle
Redroot pigweed	
Lambsquarters	
Giant ragweed	
Pennsylvania smartweed	
Eastern black nightshade	
Quackgrass	

The method of manure application can also have an effect on weeds. When manure is injected, nutrients are placed closer to where the crop (instead of weeds) can use them. Broadcast manure application can favor weeds that emerge from shallow depths. If manure is broadcast applied, harrowing the manure into the soil can help place nutrients closer to crop roots.

Manure application can introduce new weed seeds. When livestock consume weed seed, a percentage of it survives digestion and remains in the manure. Broadleaf weeds with large seeds are more likely to survive digestion than are grass or small-seeded weed species. Additionally, livestock bedding such as straw mixed in with manure can be a source of weed seed. To minimize weed introductions from manure, avoid using manure from livestock that graze on weed-infested fields.

Compost will generally have fewer viable weed seeds than manure. Composting manure at temperatures above 140° F for 2 weeks should kill most weed seed. Seed of weeds such as velvetleaf and field bindweed is not killed until temperatures reach 160-180° F. However, under National Organic Plan rules, the minimum temperature for composting is 131° F. Therefore, some weed seeds will still survive under common composting situations, but the overall number of weed seeds will be less than in raw manure. See Chapter 4 – Soil Fertility for more information on composting.

Reducing risk: cultural weed control. Diversify crop rotations as part of a weed management plan. Avoid deep tillage in late spring when using delayed planting; this can stimulate weed germination at the same time the crop germinates. Choose the correct crop planting rate and obtain good stands to make the crop competitive and to compensate for stand loss due to mechanical weed control operations. Time application of amendments to when the crop (not the weeds) needs it most. If manure is known to be from a weedy source, do not apply to "clean" fields with low weed pressure; instead choose a weedy field if there is no other option. Choose composted manure over raw manure to reduce weed seed establishment.

Mechanical Weed Control

In addition to the use of cultural methods to manage weeds, successful organic producers must master the art of mechanical weed control. Effective mechanical weed control is more effective when using a diversity of equipment that provides options to eliminate weeds at different stages of crop growth. Lack of favorable weather or soil conditions to perform a mechanical weed control operation in a timely manner is one of the biggest reasons for failure; thus, the availability of different implements that allow operation under different conditions can reduce risk. Some general guidelines for mechanical weed control are shown in Table 6-2.

Table 6-2. Mechanical weed control guidelines.
Adapted from Steel in the Field, *2001.*

• Go as shallow as possible
• Do as infrequently as possible; every tillage pass reduces soil moisture
• Control should be specific to weed issue
• Limit soil impact
• Know the weed growth stages that are most vulnerable to control practices
• Get weeds when small

Mechanical weed control can be divided into several categories —primary tillage, secondary tillage, and cultivation. Primary tillage and secondary tillage (or seed bed preparation) are performed before the crop is planted. Cultivation occurs after the crop has been planted; examples include pre-emergence and post-emergence broadcast cultivation (blind cultivation without regard for crop rows) before and after the crop has emerged or inter-row cultivation between rows once the crop is at the correct stage of growth. A common mechanical weed control regime for an organic producer in the Upper Midwest in corn and soybean is tillage (fall or spring), seed bed preparation, two rotary hoe or harrow operations after planting and two cultivations when the crop is larger.

The unpredictability of the weather in the spring greatly affects the risk of not getting cultivation accomplished in a timely manner. It is essential to take advantage of favorable weather and soil conditions for mechanical weed control operations. The consequences are that weeds may become too large to control with any type of cultivation.

Total management effects on weeds

In this chapter, we address distinct management options and how they individually affect weeds. In reality, every decision such as rotation or tillage equipment choices made in the field has an interactive effect on weeds. No matter which choices are made, some weeds will be favored over others, resulting in a field's specific weed communities and weed seed bank. These interactions can appear complex so that the effects of each individual choice can be difficult to discern from other effects. Weed scientists are studying these factors in combination with one another. An example is the experiment by Cardina et al.(2002) where weed seed banks under different conventional rotations (continuous corn, corn-soybean, and corn-oats-hay) and tillage systems (chisel and moldboard) were analyzed on a long-term research site in Ohio (Table 6-3). Some of their other findings were:

- Common chickweed and barnyardgrass seeds were lower in moldboard than in chisel.
- Large crabgrass, yellow foxtail, shepardspurse, Pennsylvania smartweed, redroot pigweed seeds were higher in the corn-oats-hay rotation.
- Giant foxtail seed decreased with more complex crop rotations and more tillage.

Table 6-3. Effect of tillage and rotation on weeds in the seed bank (up to 4-inch depths) in Wooster, Ohio, 1997-1999. *Cardina, et al., 2002.*

		FALL PANICUM	GIANT FOXTAIL	LAMBSQUARTERS	TOTAL WEEDS
TILLAGE	ROTATION	SEEDS/FT^2			
Chisel	Continuous corn	15	20	351	527
	Corn-soybean	12	77	566	870
	Corn-oats-hay	43	57	41	957
Moldboard	Continuous corn	<1	2	144	219
	Corn-soybean	9	20	144	246
	Corn-oats-hay	45	22	59	545

A producer from Waseca County who grows corn, soybean, alfalfa, and small grains found that mechanical weed control was one of the most challenging techniques to master when he transitioned to organic farming. Not only does one need to know when is the best time to perform an operation, one needs to account for how weather can prevent performing operations at the optimum time.

PRIMARY TILLAGE

Primary tillage is the initial step in seedbed preparation. It incorporates residues from the previous crop and can incorporate fertilizers. Primary tillage is performed with moldboard, chisel, and disk plows (Figure 6-4). Primary tillage can have a mixed effect on weeds. In the case of weed seeds, it buries some weed seeds so deeply they cannot germinate, but it also brings other seeds to the surface allowing them greater opportunity for germination. For short-lived weed seeds (see Chapter 5), moldboard tillage can bury the seeds and they may die before they can emerge. However, for some weed species, such as velvetleaf and common lambsquarters, deep burial increases seed longevity due to reduced fungal and bacterial activity and lower oxygen levels. For existing weed plants, primary tillage can kill annual weeds and suppress some perennial weeds, but it also can spread vegetative propagules of quackgrass and Canada thistle.

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Figure 6-4. ***Chisel plow (above) and disk harrow (below).***

The timing of primary tillage will encourage different weed species to predominate (Table 6-4). Fall tillage promotes winter annual and perennial weeds, while spring tillage promotes spring annual weeds. Often, producers will not have an option as to the best time for primary tillage and what type of equipment they use; what will determine this instead are soil conditions in the spring/fall and soil type suitability for certain equipment.

The type of tillage equipment used can also promote different weed species. Chisel plows will not affect seeds that are below four inches. With chisel plowing, the majority of seeds will remain in the top two inches, while with moldboard plowing, the majority of seeds will end up below two inches in depth. Chisel plowing may favor weeds that germinate from shallow soil depths.

Table 6-4. Species associated with fall and spring tillage. *Weed species associated with spring tillage were usually early germinating and C4 grasses. Weeds associated with fall tillage were late germinating forbs and C3 grasses. Adapted from Smith, 2006.*

FALL	SPRING
Common ragweed	Velvetleaf
Mouse-ear cress	Lambsquarters
Marestail or Horseweed	Redroot pigweed
Quackgrass	Common crabgrass
Common plantain	Stinkgrass
Poa	Fall panicum
Prostrate knotweed	Giant foxtail
Red clover	Green foxtail


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Figure 6-5. *Field cultivator.*

Reducing risk: primary tillage. Be aware of how primary tillage affects existing weeds and weed seed banks. Avoid spreading vegetative propagules of perennial weeds with primary tillage.

SEED BED PREP / SECONDARY TILLAGE

Secondary tillage further breaks up the soil to destroy weeds and prepare the seedbed, and can also work in amendments like compost and manure. Field cultivators, disks, and harrows are used for secondary tillage (Figure 6-5). The timing of seed bed preparation affects which weeds are destroyed. Weeds that emerge early like common lambsquarters are susceptible to seed bed preparation. See Table 5-11 or Chapter 7—Weed Profiles for when different weed species germinate. Thus, early weeds can be controlled by seed bed preparation, while later emerging weeds like pigweeds may have to be controlled at a later date with row crop cultivation.

A fundamental aspect to consider in seed bed preparation is the concept of providing the crop with an "even start." An even start means controlling weeds that germinate before the crop germinates. Once seed bed preparation is complete, the crop must be planted as soon as possible because if crop planting is delayed (even for a matter of hours), weeds can germinate and get a head start on the crop. This can provide a competitive advantage for the weeds and have a larger impact on yields.

Secondary tillage weed control techniques include stale and false seedbeds (Figure 6-6). A stale seedbed is when the soil is left as undisturbed as possible prior to crop planting so weed seeds remain dormant. The goal here is to minimize germination by minimizing soil disturbance. Once the crop is planted, the weeds that do germinate can be controlled through flaming (see later in this Chapter) and in-row (inter-row) cultivation once the crop is at the correct stage. Note that flame weeding is not specific to the stale seedbed technique—it can also be used in combination with the false seedbed technique or other weed control regimens.

The false seedbed is another secondary tillage weed control strategy. With a false seedbed, secondary tillage is used repeatedly to stimulate weed germination and subsequently destroying those seedlings in order to deplete the weed seed bank. Much of the effectiveness of false seedbed practices is dependent on warm

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Figure 6-7. *The rotary hoe has an operating depth of one inch or more.*

seedbed soil temperatures levels to promote a flush of weed seed germination. Secondary tillage depth should be shallow to prevent new weed seeds from being brought up to the surface. The false seedbed technique is commonly used in row crops on organic farms in the Upper Midwest.

Reducing risk: seed bed preparation. Prepare a good seed bed to assure the success of subsequent mechanical weed control operations. Plant as soon as possible after seed bed prep to ensure an "even start". Use a false seedbed approach to deplete seed banks. The effectiveness of the false seedbed approach will be reduced on soils with high levels of crop residues that depress soil temperatures. In addition, excessive tillage on wet and cold soils can cause soil compaction.

CULTIVATION

Row crop cultivating tillage is performed after the crop is planted. Cultivation kills weeds by digging them out, burying them, breaking them apart, or drying them out. In addition to controlling weeds, cultivation can break up soil crusting and thus can increase crop emergence, water infiltration, mineralization of nutrients, and soil aeration.

A short window of time usually exists for timely use of cultivation. Weeds that emerge before or with the crop are the most critical to eliminate. Weeds that emerge after crop emergence will have less negative yield impact on yield, but still may contribute to the weed seed bank for problems in future years. When it comes to weeds that emerge with the crop, it is best to be proactive, rather than reactive. Waiting until weeds are noticeable will limit the control options.

The types of cultivation are broadcast cultivation (blind or full-field cultivation without regard for crop rows), inter-row cultivation (between crop rows), and intra-row cultivation (within crop rows).

Pre-emergence broadcast cultivation Broadcast cultivation can be performed before or after the crop emerges. Pre-emergence

STALE SEEDBED

Delayed or no primary tillage⟶ early planting⟶ flame weeding⟶ cultivation

FALSE SEEDBED

Early primary tillage⟶ repeated shallow cultivation⟶ delayed planting⟶ rotary hoe or harrow 3-4 days post planting⟶ second rotary hoe or harrow operation 3-4 days later⟶ cultivation

Figure 6-6. A comparison of stale and false seedbed techniques. ***False seedbed is the more common method for organic farmers in the Upper Midwest.*** *Adapted from MSU, 2005.*

Weed management equipment

In recent years, a resurgence of new and updated implements for mechanical weed control has become available to organic farmers. Choosing new tools (if any) in which to invest can be complicated. Attending field days that demonstrate new equipment and networking with other organic farmers about their experiences are some ways to learn. Below are some additional resources available online that discuss applications of both new and traditional weed management equipment.


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Figure 6-8. *Shovel configuration on a chisel plow used for primary tillage.*

Steel in the Field: A Farmers Guide to Weed Management Tools

This manual, published by Sustainable Agriculture Research and Education, is an excellent resource for investigating the implements used for mechanical weed control. It provides in-depth descriptions and uses of different equipment, as well as farmer's experiences and recommendations. The appendices include a comprehensive list of manufacturers of weed management equipment. This publication is available for free at http://www.sare.org/publications/weeds.htm

New Cultivation Tools for Mechanical Weed Control in Vegetables

This factsheet from Cornell University is geared toward vegetable production, but has good descriptions of cultivation equipment and includes the advantages and disadvantages of various harrows and weeders. Also includes a list of manufacturers. Available at: http://www.vegetables.cornell.edu/weeds/newcultivationmech.pdf

Tillage equipment: Pocket identification guide

This publication from the USDA-NRCS is intended as identification for primary and secondary tillage equipment. Includes many photos with general descriptions of the effects of the implements on soils. http://www.mn.nrcs.usda.gov/technical/ecs/agron/Tillage%20pocket%20guide.pdf

Soil moisture greatly affects the success of rotary hoeing. An organic producer in Lac Qui Parle County says it is preferable to rotary hoe early than to be forced to wait until after a rain. Rotary hoeing is less effective in wet soil.

cultivation is done with chain harrows, flex-tine harrows, spring-tooth harrows, spike-tooth harrows and rotary hoes and affects the top ½ - 1 ½ inches of the soil depending on the equipment (Figure 6-7). These tools are most effective under hot and dry conditions so the up-rooted weeds near the surface will dry out. Pre-emergence cultivation is done three to five days after the crop has been planted. Chain harrows are best for light soils and before crop emergence. Spring-tooth and spike-tooth harrows are aggressive and are best for pre-crop emergence rather than post-emergence. Flex-tine harrows and rotary hoes can be used either pre- or post-emergence (see next section).

Reducing risk: pre-emergence cultivation.

Perform when the soil is dry for maximum weed control. Do not cultivate to a soil depth that is at or below where the crop seed is located.

Post-emergence broadcast cultivation Post-emergence cultivation is an important tool to eliminate weeds that emerge around the same time as the crop. Among the weeds that emerge after planting, these will be the ones that affect crop yield the most. Broadcast or blind cultivation can be performed after the crop has emerged. However, there are several factors to consider such as the type of crop and crop maturity. This type of cultivation has the greatest risk for crop damage and planting rates may need to be increased to compensate for this type of field operation. The best-case scenario for post-emergence cultivation is when the crop is larger than the weeds, which results in the crop being more strongly/deeply rooted and able to withstand the cultivation, and the weeds are smaller and more easily uprooted. Post-emergence broadcast

Table 6-5. Timing by growth stage for rotary hoe operations for individual crops. *Adapted from NDSU.*

CROP	PRE-EMERGENCE	POST-EMERGENCE
Amaranth	Shallow, up to 3-5 days after germination	Not recommended
Buckwheat	Up to 3-5 days after germination	Not recommended
Corn	Up to and including emergence	Emergence to 8 inches tall
Dry Bean	Before crook stage	1-2 trifoliate stage
Field Pea	Epicotyl ½″ or more below surface	Emergence to 4 inches tall
Flax	Shallow, up to 3-5 days after germination	Not recommended
Lentil	Epicotyl ½″ or more below surface	1-4 inches tall, stand reduction will occur
Oats	Before coleoptile near soil surface	Not recommended
Pearl Millet	Before coleoptile near soil surface	2-6 leaf stage
Proso Millet	Shallow, up to 3-5 days after germination	Not recommended
Sorghum	Before coleoptile near soil surface	Emergence to 8 inches tall
Soybean	Before crook stage	1-2 trifoliate stage
Sunflower	Before hypocotyl emergence	2-6 leaf stage
Wheat, Barley	Before coleoptile near soil surface	1-3 leaf stage

Table 6-6. Timing by growth stage for harrow operations for individual crops. *Adapted from NDSU.*

CROP	PRE-EMERGENCE	POST-EMERGENCE
Amaranth	Shallow, up to 3-5 days after germination	Not recommended
Buckwheat	Up to just before emerging	Not recommended
Corn	Up to and including emergence	Emergence to 8 inches tall
Dry Bean	Before crook stage	1-2 trifoliate stage
Field Pea	Epicotyl ½″ or more below surface	Emergence to 4 inches tall
Flax	Shallow, up to 3-5 days after germination	Not recommended
Lentil	Epicotyl ½″ or more below surface	1-4 inches tall, stand reduction will occur
Oats	Before coleoptile near soil surface	Not recommended
Pearl Millet	Before coleoptile near soil surface	2-6 leaf stage
Proso Millet	Shallow, up to 3-5 days after germination	Not recommended
Sorghum	Before coleoptile near soil surface	Emergence to 8 inches tall
Soybean	Before crook stage	1-2 trifoliate stage
Sunflower	Before hypocotyl emergence	4-6 leaf stage
Wheat, Barley	Before coleoptile near soil surface	1-3 leaf stage

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Figure 6-9. ***Flex-tine weeder. This tool is becoming more prevalent among organic producers in the Upper Midwest.***

cultivation is performed with rotary hoes and harrows. Timing of these operations is critical—see Tables 6-5 and 6-6 for the recommended crop stages at which to rotary hoe and harrow.

The best time to rotary hoe is when weeds are newly germinated and have reached the "white thread" stage (also called the "white root" or "white sprout" stage). Weeds in the white thread stage have not emerged from the soil. The top inch of soil must be examined to determine if weeds are at the white thread stage. Grass weeds that are past the one-leaf stage or broadleaf weeds that have formed their first true leaves are too firmly-rooted to be controlled with the rotary hoe. However, harrows and tine weeders are more effective on weeds that are somewhat more mature than is the rotary hoe (Figure 6-9). Perennial weeds like Canada thistle, quackgrass, yellow nutsedge or deep-germinating weeds like cocklebur, velvetleaf, wild proso millet, wild oat, and woolly cupgrass are not effectively controlled by rotary hoes or harrows. Rotary hoes, tine weeders, and harrows are more effective on warm, sunny, and windy days, which help dry out small weed seedlings pulled out of the soil by these operations.

Soil type and condition may determine which tool is best for post-emergence cultivation. Rotary hoes are more effective on crusted soils than are harrows or tine weeders. Rotary hoeing is less effective when the soil surface is rough. Tine weeders, harrows and rotary hoes are all hindered by large amounts (greater than 30% coverage) of surface residue (Figure 6-10). Harrows and tine weeders may be more effective on loamy soils than are rotary hoes. Tine weeders have different tines varying in flexibility and thickness that can be used depending on the heaviness of the soil. Rotary hoes are operated at speeds of seven to twelve miles per hour, while harrows are usually operated at speeds between four to six miles per hour.

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Figure 6-10. ***Large amounts of residue can interfere with flex tine weeders.***

An organic producer from McLeod County says timing is the key to managing weeds in his corn and soybean crops. You must get the first weed flush after the crop is planted with a harrow or rotary hoe. The 1st or 2nd cultivation between the rows can be timed to last the rest of the season.

Rotary hoe versus harrow

Organic producers will often have a preference for a type of tillage implement depending on field conditions. A producer from Waseca County prefers the rotary hoe in his soybeans, although he notes that the rotary hoe is less effective on fields with loamy soils and better tilth. Another organic producer from Waseca County does not use the rotary hoe because it misses spots due to his soil, which is highly variable and has an uneven surface. He harrows instead. He cautions that soybeans are more sensitive to harrowing because of their fragile cotyledons at the crook stage. Yet another organic producer from Lac Qui Parle County is moving away from the rotary hoe and has not used it in 4 years. His reasons are that the rotary hoe requires the use of a big tractor, which can cause soil compaction. He can cover the same width with a harrow and a smaller tractor.

Stand losses—post-emergence operations

Once the crop has started growing, any weed control operations performed will have the potential to damage the crop. Crop stand losses due to post-emergence operations like harrowing or rotary hoeing will range from 1% to 25%. Establishing whether weed control operations are too aggressive is an important aspect to maximizing crop yields. To determine stand losses, producers should take a crop stand count prior to and after post-emergent mechanical weed control. This can aid in planting rate decisions and can ensure that the control is not too aggressive.

Frequency of weed control operations should be dependent on weed pressure. Two or three passes for post-emergence control is usually sufficient and additional cultivations can adversely affect crop stand density in addition to adding to cost of production. Even though more weeds are killed with each successive pass, more of the crop is also being killed. There is a tradeoff between the yield loss potential due to weeds and reduced crop stands. A reasonable loss of crop stand per operation should be less than 5%, but experienced organic farmers say if a few crop plants are not being taken out, the operation is not aggressive enough. Once the crop loss for mechanical weed control is estimated, it can be used as a factor to determine what planting rates should be used in subsequent years, assuming the number of weed control operations is similar.

Reducing risk: post-emergence cultivation.

Use the proper equipment for the soil conditions present. Time operations to the correct crop and weed growth stage—see Tables 6-5 and 6-6. Do not use post-emergence cultivation on soybean at the crook stage; it is too fragile.

Inter-row cultivation Inter-row cultivation controls weeds that grow between the rows, and therefore is only used in row crops (Figure 6-11). Row crop cultivation is secondary to the weed control operations that were performed earlier because the earlier emerging weeds are more critical to control due to their greater potential to reduce crop yield. If the pre- and post-emergence operations were effective, there may be a lag before

PHOTO COURTESY OF JOHN DEERE

Figure 6-11. *Row crop cultivators only affect weeds between these corn rows.*

inter-row cultivations must be done. Inter-row cultivation is done three to five weeks post planting. Tools used for inter-row cultivation include cultivators, rotary tillers, brush weeders, rotary cultivators, rolling cultivators, basket weeders, and rolling harrows.

Inter-row cultivation is low risk to the crop compared to post-emergence broadcast operations. Because cultivation is performed between the rows, the crop should not be directly affected by the machinery. Cultivation is generally performed when the crop is four inches tall and up to the height where equipment will still clear the crop.

Inter-row cultivation is most effective when weeds are not overly mature. Timing of inter-row cultivation is not as critical of an issue as it is for broadcast cultivation. Cultivators can affect weeds up to five inches tall as compared to a rotary hoe which only controls newly germinated weeds. Generally, cultivation is performed at depths less than two inches so that crop roots are not damaged and soil moisture is conserved.

If the young crop is in danger of becoming buried by soil or weeds during cultivation, shields can be used on the cultivator. The goal is to maximize the cultivation area between the crop rows without damaging the crop. Inter-row cultivators also can have modifications that allow soil to be ridged upon the crop row to control within-row weeds. Weeds are buried along with the crop so this method can only be performed on certain crops such as corn and only at certain stages of crop growth.

Organic farmers may need to prove they have effective weed and pest management in order to make an insurance claim. Your organic plan detailing your weed control operations will provide support.

Reducing risk: inter-row cultivation. Do not cultivate too deeply or crop roots can be damaged. Do not rely on inter-row cultivation as your primary method for weed control—use in conjunction with pre- and post-emergence operations.

Intra-row cultivation Intra-row cultivation, also called in-row cultivation, is accomplished through the use of equipment that controls weeds within the crop row. This type of cultivation is more commonly used in horticultural crops, but interest in controlling weeds within a crop row is increasing for those who grow agronomic crops. As mentioned previously, weeds that occur at the same time as the crop can have a great effect on yields and the ones within the crop row are difficult to impossible to control after the crop is past a certain maturity. Equipment for intra-row cultivation is specialized precision tools that include torsion weeders, spring hoes, spyders, and finger weeders. Intra-row cultivation operations must be done precisely to avoid crop damage and may require the use of electronic guidance systems. One drawback is that this equipment must be operated slower than most other weed control equipment and thus is time-consuming and possibly not viable for large-scale operations. For more information, consult the sources in the "Weed management equipment" Sidebar.

Established perennials

Perennial weeds such as quackgrass or Canada thistle are common weed problems in the Midwest and among the most difficult perennial weeds to manage with mechanical weed control because even small pieces of their rhizomes can generate new plants (Table 6-7). Perennials with deep rhizomes will not be affected greatly by typical weed control operations that are done in the spring. At the same time, perennials with shallow rhizomes will only be affected in the short term by typical seed bed preparation and cultivation and bulbs can typically survive these operations.

Quackgrass and field sowthistle are most susceptible to burying when new shoots are at the three-to-four leaf stage in spring, followed with a second tillage operation. As a last resort, perennial weeds can be controlled by fallow cultivation. Most will respond negatively to repeated cultivation at two to four week intervals (Table 6-8). Another alternative is including perennial crops in rotations. Canada thistle can be controlled by growing alfalfa for three years. A taprooted perennial weed species may be impacted by being buried, while a fibrous-rooted species can be chopped or buried during primary or secondary tillage.

Table 6-7. Equipment effectiveness in managing different perennial weeds. ***Tillage for perennial weeds will be more effective when done prior to active growth or flowering to lower plant reserves. Adapted from Liebman et al, 2001.***

WEED SPECIES	GROWTH HABIT	MOLDBOARD PLOW	CHISEL PLOW	FIELD CULTIVATOR
Canada thistle	deep rhizomes	Fair	Poor	Fair
Common milkweed	deep rhizomes	Fair	Poor	Fair
Common plantain	fibrous root	Good	Fair	Fair
Curly dock	taproot	Good	Fair	Fair
Field bindweed	deep rhizomes	Fair	Poor	Fair
Field sowthistle	shallow creeping roots	Fair	Poor	Fair
Nutsedge	bulb	Fair	Poor	Fair
Quackgrass	shallow rhizomes	Fair	Poor	Fair

Table 6-8. Effects of repeated tillage on number of Canada thistle shoots after one year in Lamberton, MN, 2003 and 2004. ***Disking to a depth of four to six inches was initiated in May or June and was repeated every three weeks until fall. Repeated tillage significantly reduced the number of thistle shoots after one season in both 2003 and 2004. The number of shoots increased under the corn crop in both years.***

	% thistle shoot change	
TREATMENT	2003	2004
Repeated tillage, May start	-93	-87
Repeated tillage, June start	-96	-93
Corn, one rotary hoe, 2 cultivations	20	110

Flame weeding

Flame weeding is becoming more popular with organic farmers in Minnesota and the Upper Midwest. This technique uses flaming propane burners to rupture the cells of the weeds, which usually die within three days. In row crops, flame weeding is used as a method of directed, within-row weed control (Figure 6-12). However, it can also be used as a broadcast technique, usually prior to crop emergence, which is most suitable when using the stale seedbed technique. Most organic row-crop farmers in the Upper Midwest use flame weeding to control weeds within the crop rows, as they usually have other mechanical options for broadcast weeding that can be performed faster than flame weeding and may be cheaper to operate.

Two organic growers in Waseca County agree that lack of diverse weed control equipment availability can be a risk factor in weed management. Having different equipment provides greater flexibility in timing operations. The tools that they use for their soybean and corn crops include rotary hoes, harrows, flame weeding equipment, and in-row cultivators.

Figure 6-12. ***In-row flame weeding.***

When used after the crop has emerged, flame weeding is timed when the crop is at the correct stage so that minimal damage occurs. The proper stage for flame weeding varies by crop—see next sections. Ideal conditions to flame are when the crop is bigger than the weeds. Flaming works best on dry, calm days.

Tractor speed and gas pressure are two components that can be modified to optimize weed kill. The slower the speed and/or the higher the gas pressure will increase effectiveness, but potential crop damage must also be taken into consideration. Typical tractor speeds and propane pressures are in the range of three to five mph and 30 – 40 PSI, respectively. There is no single recommended setting; producers will need to gauge their conditions and make adjustments accordingly. Generally, around seven gallons of propane is used per acre.

Producers gauge effectiveness of each flame weeding operation by using the fingerprint method. Weeds are not burned to a crisp, but instead should show a watermark immediately after the flame weeding when a leaf is pressed (Figure 6-13). Corn will also demonstrate the same effect (Figure 6-14).

The age and type of weeds determine flaming effectiveness. Annual weeds are more vulnerable to flame weeding compared to perennial or biennial weeds. Broadleaves are more susceptible than grasses and broadleaf weeds less than two inches tall are the most susceptible. Flaming is more effective on lambs-

Figure 6-13. *Using the thumbprint method to analyze damage, the weed above has been affected as is shown by the dark spot on leaf where a thumb was pressed. The grass is not visibly burnt, but this indicates the correct level of flaming.*

Figure 6-14. *Fingerprint marking on corn leaf.*

Figure 6-15. *This corn is at the proper stage for flaming. The fourth leaf has not yet developed.*

quarters, chickweed, velvetleaf, and pigweed than on mustards, ragweeds, and grasses. Newly emerged grasses are not much affected because their growing point may still be underground at the time of flame weeding. Weeds that have germinated, but are not yet emerged, will also not be affected by flame weeding. Dust and dew on weed leaves may protect weeds and limit flaming effectiveness. Because flaming does not control grasses well, rotary hoeing or harrowing may be a better option for fields where grasses predominate (Table 6-9). Producers should also be aware that warming the soil with flame weeding may stimulate some weed seeds such as pigweeds to germinate.

Of the agronomic crops commonly grown in the Upper Midwest, only corn and soybean are flamed post-emergence. Flaming in these crops is discussed below.

Table 6-9. A comparison of rotary hoe and flame weeding.
Both tools can be equally effective under the right conditions. Producers can minimize risk by having as many weed control implements as possible at their disposal. Adapted from Mutch et al., 2008.

ROTARY HOE	FLAME WEEDING
Soil type can limit effectiveness	Soil type does not matter
Operation takes less time	Operation takes more time
Can be performed in more crops	Few crops can withstand flaming
Disturbs soil structure	Preserves soil structure
Soil must be dry	Soil can be wet or dry
Effects may be longer lasting	Little residual effect
Cheaper	More expensive; dependent on gas prices
Timing of operation is critical	Timing of operation is critical
Stimulates further weed germination	Does not stimulate weed germination
Windiness increases effectiveness	Windiness decreases effectiveness

FLAME WEEDING CORN

There are two options for flaming once corn has emerged. The first is when the growing point is still below the soil when corn is one to two inches high (Figure 6-15). At this stage, nutrients are still being obtained from the seed. Direct flaming corn after the 4-leaf stage will likely lead to damage of the crop. If necessary, corn at later stages (greater than 10 inches) can be flamed by directing the flame under the leaves and protecting the corn plants using shields.

Corn is the crop least susceptible to damage by flaming because for several weeks after emergence the seed and growing point remain below ground. However, corn will have reduced yields if the timing of flaming is wrong, the speed is too slow (e.g. 1 mph), or if flaming is repeated multiple times. Corn will look damaged after flaming, but it generally has enough reserves to recover if the flaming was timed properly.

Figure 6-16. *The soybean plant on the left can survive flame weeding, but any growth stage where the cotyledons are no longer protecting the first leaves as in the soybean on the right is susceptible to injury from flame weeding.*

FLAME WEEDING SOYBEAN

Organic farmers conduct flame weeding of soybean in Minnesota, but the practice is not as established as it is for corn. Overall, flame weeding in soybean presents a high risk of damage to the crop. If flame weeding is used, it is best before the soybeans emerge or at the crook stage before leaves unfurl (Figure 6-16). Soybeans will be damaged if they are flamed anytime after the crook stage. It is important to be aware that after the crook stage, vegetative development can occur quickly. Sometimes it will only be a matter of hours before the growth stage progresses from safe to a high probability of damage. Flame weeding of soybean is a high risk procedure and should be considered an advanced technique for those with an above-average level of flame weeding knowledge and expertise.

Reducing risk: flame weeding. **Use flame weeding on a smooth and flat seedbed rather than an uneven and cloddy seedbed to lower risk for misdirected flames. If weeds are noticeably burnt immediately after the operation, then the operation was excessive—use the fingerprint method to determine if weeds are damaged. Flame weeding of soybeans is extremely high risk compared to flame weeding of corn. Flame weeding can be potentially dangerous to human and animal health; follow all safety precautions for the use of flammable liquids.**

PRODUCER PROFILE

Flame weeding in Faribault County

An organic grower in Faribault County has been flame weeding successfully for over 30 years. He routinely flame weeds corn, but usually will not flame soybean.

This producer flame weeds corn when it is between 10 to 12 inches tall. When flaming corn at the 10-12" stage, the fire is shot underneath the leaves to minimize corn damage. He cultivates and flames at the same time with the same machine, but he notes that most people flame and cultivate separately.

Cultivation and flame weeding is only possible for him because he flame weeds at a later crop stage. Flame weeding and cultivating at the same time when corn is a few inches tall would result in the cultivation burying the crop seedlings. He flames weeds at about 4 miles per hour at 30 to 35 PSI. He will do one round and gauge damage and then sometimes comes back and flames again a week later.

His biggest weed problems are pigweed, foxtail, and Canada thistle. Due to the perennial nature of Canada thistle, he finds that while thistle will appear damaged after flaming, it will grow back quickly. Foxtail will not be controlled unless it is very small. The flame weeder is just one of many tools he uses for weed control. He also utilizes a harrow, cultivator, cover crops, smother crops, and a diverse rotation.

Rescue operations

Inter-row cultivation is usually the final weed management step for the season. However, when timely weed control operations were not able to be performed, as in cases where weather was uncooperative, weeds can escape. If there are spots where weeds were not adequately controlled, producers can have day laborers hand weed. Another option as a last resort is to till under the portion of a field where weeds dominate.

Reducing risk: rescue operations. Make sure that rescue operations are worthwhile. Remove hand-weeded plants from the field if they have gone to seed so they do not contribute to the seed bank. Organic farmers must be prepared to forfeit part of a crop if weeds get out of control to protect their fields from adding an excessive amount of weed seeds to the seed bank.

Scouting

The contribution of scouting in weed management is often underappreciated. Fields should be checked before mechanical weed control operations begin to ensure that the correct implement is chosen to control weeds at their proper growth stages. Once an operation has been completed, fields should be checked after four or five days or sooner to determine if the procedure was successful and to decide if another operation will be necessary.

An organic producer in Lac Qui Parle County has problems with sunflowers at the edge of one of his fields. He will go in with a hand pruner and cut the flower heads off so the seeds do not remain on the field. Organic farmers need to be sensitive to the impact of adding to the weed seed bank.

A producer from Waseca County says he is constantly scouting anytime he goes out. He recommends that transitioning farmers scout often in order to get a feel for when individual weed species or weed flushes occur to determine when harrowing or rotary hoeing should be done. Otherwise, he says, you will always be playing catch-up. In organic farming when dealing with weeds, you need to be ahead of the game.

Reducing risk: scouting. Write memos about scouting activities. Transitioning producers should scout their fields often to determine patterns of weed emergence. Keep records on weed management practices from year to year and note effectiveness of the various mechanical weed control operations performed. Create weed maps for each field noting location and relative density for each weed species.

Conclusion

This chapter has emphasized the risk in not performing mechanical weed control operations at the optimum time. However, it is important to note that it is possible to perform too many operations. The risk in this is damage to soil structure, crop injury and lowered yields, or unnecessary time and labor spent on redundant operations. Producers should try to strike a balance between controlling weeds and maximizing crop yields. An indispensable component of weed management is scouting for weeds. This includes identifying your weeds and determining when those weeds emerge. Weed operations should be timed to coincide with emergence of your problem weeds. For help in weed identification and weed emergence times, see Chapter 7: Weed Profiles.

JOHN DEERE

Figure 6-17. *Disk harrow.*

Quiz: Weed Management

	Points	Score
1. Which of the following is closest to the rotation you follow?		
Two-year rotation with cover crop	0	
Three-year rotation	1	
Four-year rotation	3	
Five or more year rotation	5	
2. Does your rotation include a perennial crop?		
Yes	5	
No	0	
3. Does your rotation include a cover or smother crop?		
Yes	2	
No	0	
4. Do you ensure that the seed you plant is clean and does not contain weed seed?		
Yes, always	3	
Yes, most of the time	1	
No, not really	0	
5. Do you plant your crop as soon as possible after seed bed prep, giving the crop an even start?		
Yes, always	5	
Yes, most of the time	3	
No, not really	0	
6. Which of the following describes your view on delayed planting?		
I always plant at a later date regardless of conditions	0	
I sometimes plant at a later date, especially if weeds are heavy	3	
I usually do not plant at a later date	2	
7. If you delay planting, do you know if you have early-emerging weeds (the ones most affected by delayed planting)?		
Yes, I have early-emerging weeds	3	
No, I don't know if I have early-emerging weeds	0	
I do not delay planting	1	
8. Do you adjust your planting rate to accommodate changes in the number of mechanical weed control operations?		
Yes, always	3	
Yes, usually	1	
No, my planting rate is always the same	0	

	Points	Score
9. Which of the following do you primarily use to provide soil fertility?		
Manure	1	
Compost	2	
Green manures	4	
Other amendments	2	
A mix of above	2	
10. Do you time your nutrient application to coincide with crops' needs?		
Yes	3	
No	0	
I don't know	0	
11. Do you apply nutrients only at amounts at which the crops' needs are met?		
Yes	3	
No	0	
I don't know	0	
12. How do you apply compost or manure?		
Broadcast, no incorporation	0	
Broadcast, with incorporation	2	
Injection (manure only)	3	
Not applicable	2	
13. Do you make an effort to ensure that the manure you apply has relatively few weed seeds?		
Yes, always	2	
Yes, most of the time	1	
No, not really	0	
14. Can you identify the specific weeds that occur in your fields?		
Yes	5	
Yes, most of the them	3	
No	0	
15. Do you know at which stage your weeds are most vulnerable to control?		
Yes	5	
Yes, for most of them	3	
No	0	
16. Are you attentive to the timing and density of weed emergence in your fields each year?		
Yes, always	5	
Yes, most of the time	3	
No, not really	0	

continued next page

Quiz: Weed Management

	Points	Score
17. Do you have a diversity of tools for mechanical weed control?		
Yes	5	
No	0	
18. After performing a weed control operation, do you gauge its effectiveness?		
Yes, always	3	
Yes, most of the time	1	
No, not really	0	
19. Do you gauge how much crop loss is occurring with your mechanical weed control operations?		
Yes, always	3	
Yes, most of the time	2	
No, not really	0	
20. Do you try to account for unpredictable weather conditions when planning mechanical weed control operations for the season?		
Yes, always	3	
Yes, most of the time	1	
No, not really	0	
21. Do you know when the best time to rotary hoe or harrow for each of the crops you grow?		
Yes	5	
Not sure	0	
22. Do you try to time cultivation to warm, dry conditions?		
Yes, always	3	
Yes, most of the time	1	
No, not really	0	
23. Do you know how effective different equipment is on perennial weeds?		
Yes	2	
No, not really	0	
24. If you use flame weeding, how do you gauge its effectiveness?		
Weeds show signs of visible burning	0	
Weeds show watermark when pressed with finger	3	
Do not check weeds after flame weeding	0	
Do not flame weed	3	
25. If you use flame weeding, do you flame weed soybean?		
Yes	0	
No	3	
Do not flame weed	3	

	Points	Score
26. Are you prepared to perform rescue operations if weed escapees become dominant?		
Yes, always	3	
Yes, most of the time	1	
No, not really	0	
27. Do you keep records on your weed management practices and their effectiveness?		
Yes	3	
No	0	
28. Do you scout your fields for weeds before and after weed control operations?		
Yes, always	3	
Yes, most of the time	1	
No, not really	0	
29. Do you feel confident that you are not doing too many mechanical weed control operations?		
My operations are timed to control the weed flushes I know occur in my fields	5	
I always do the same operations regardless of weed pressure	2	
I am not sure	0	
30. Which of the following mechanical weed control strategies do you follow? ***Give yourself 2 points for each strategy.***		
Till or cultivate as shallowly as possible	2	
Till or cultivate as infrequently as possible	2	
Each operation is geared toward specific weed issue	2	
Limit soil impact of weed control	2	
Equipment used is appropriate for weed growth stage	2	
Weeds are targeted when small	2	
31. Which of the strategies do you plan on implementing in the future? ***Give yourself 1 point for each strategy you plan to use from the above list.***		
TOTAL		

If your score is:	Your risk is:
76 or greater	Low
36 to 75	Moderate
35 or less	High

FOR MORE INFORMATION

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Weedsoft Yield Loss Calculator – Producers can enter in their crop and weed data and the calculator with figure out the yield losses. http://driftwood.unl.edu/weedsoft/YieldLossCalc/YieldLossOne.php

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CHAPTER 7

Weed Profiles

KRISTINE MONCADA
SHERI HUERD

This chapter will focus on management of individual weed species that can be problematic in cropping systems. These Weed Profiles describe the species and offer information on their management and the risk in different crops.

The seed emergence times are approximate for central and southern Minnesota. Locations farther north or farther south will need to adjust emergence dates accordingly. Please note that the seed emergence times are relative; individual sites and variations in yearly weather conditions will have an influence.

See also the Weed Biology and Weed Management Chapters for more information.

DAVID L. HANSEN

Common milkweed in small grains.

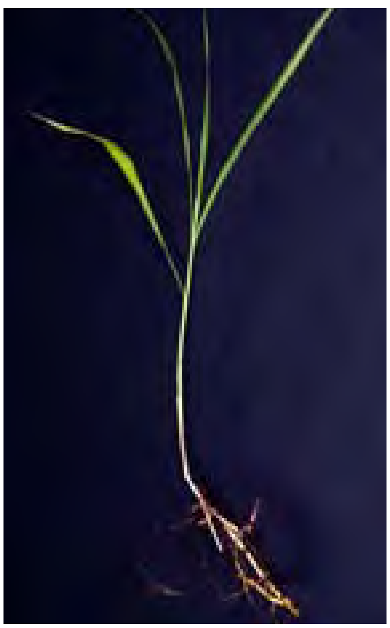
PERENNIAL GRASS

Quackgrass

Elymus repens Poaceae Family

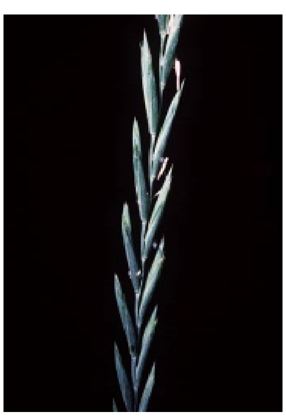
STRAND MEMORIAL HERBARIUM

Seedling.



OHIO STATE WEED LAB

3 to 5 leaf stage.

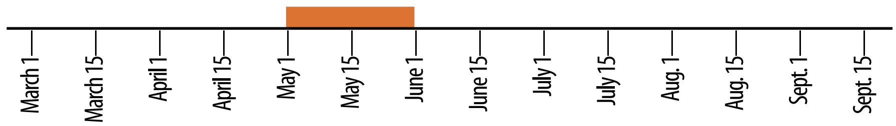


DOUGLAS LADD, NCRS-USDA

Spike.

Also known as: *couchgrass, coutch, creeping quackgrass, dog grass, quick grass, sand lovegrass, scutch, twitch grass*

Seed emergence time: *early May, before crop planting*



ID: **Seedling**—*sheath hairy, also reproduces from rhizomes*
Roots—*fibrous, rhizomes 2-8 inches, roots arise from nodes*
Stems—*1.5 to 3 ft tall, erect, branching at base, creeping laterally*
Leaves—*blades short, ear-like appendages, smooth upper, hairy lower*
Flower—*Dense spike, >1 inch long, ~25 seeds/stem*

Risk to yield:
Wheat: potential losses 10% per 9 shoots/ft^2, up to 57%

Corn: potential losses of 25% to 85%

Soybean: potential losses of 19% to 55%

Risk Level

Corn/Soybean	*MEDIUM*
Small grains	*MEDIUM*
Forages	*MEDIUM*

Other traits:
- *Prefers fertile soils and reduced tillage, but highly adaptable*
- *Most rhizomes emerge from <4 inches; but may emerge from up to 8 inches deep*
- *Seeds have short longevity in seed bank*
- *Rhizomes as small as 1/2 inch can generate new plant*

PERENNIAL GRASS

UNIVERSITY OF MINNESOTA

Plant.

Reducing risk: quackgrass

Management—established populations:

- *Frequent, close mowing in fall or spring*
- *Competitive cover crop*
- *Repeated harrowing*
- *Rototilling 4 to 6 inches deep twice during hot, dry weather*
- *Short fallow in a dry period for 3-6 weeks with repeated tillage to decrease reserves and dry out roots*
- *Moldboard plowing to deep depths*
- *Time mechanical control during hot dry weather*

Preventing establishment:

- *Tillage in spring during seedbed preparation*

Long-term management:

- *Crop rotation with competitive crops in fall or early spring*

CAUTION:

✔ *Many tillage operations will cause root fragmentation and can increase density of established populations*

✔ *Planting date changes usually not an effective management technique*

SUMMER ANNUAL GRASS

Large crabgrass

Digitaria sanguinalis Poaceae Family

UNIVERSITY OF MINNESOTA EXTENSION

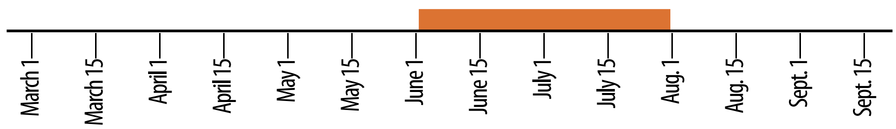
Seedling.

UNIVERSITY OF MINNESOTA EXTENSION

3 to 5 leaf stage.

Also known as: *crab finger grass, hairy crabgrass, northern crabgrass, purple crabgrass*

Seed emergence time: *after corn emergence, mid-late June, 4 to 8 weeks*



ID: **Seedling**—*sheaths and blades densely hairy*
Roots—*fibrous*
Stems—*stout, smooth, up to 3 feet long, when prostrate root at joints*
Leaves—*hairy, 1-8 inches long*
Flower—*3-10 segments, in whorls at top of stem, Aug-Sept*

Risk to yield:
Corn: potential loss of 3 % at 1 plant/ft²
Soybean: potential loss of 3 % at 1 plant/ft²

Risk Level

Corn/Soybean	*LOW*
Small grains	*LOW*
Forages	*LOW*

REBEKAH D. WALLACE, UNIVERSITY OF GEORGIA

Spike.

Other traits:
- *Seed persistence in seed bank is reduced 50% in 1.5 years, 99% in 8 years*
- *Generally germinates from top 1.5 inches of soil; inhibited from germination at 3 inches*
- *Prefers dry, hot conditions*

SUMMER ANNUAL GRASS

Reducing risk: large crabgrass

Management:
- *Deep tillage*
- *Post-row crop emergence cultivation*

Long-term management:
- *Small grains in rotation may suppress*

UNIVERSITY OF MINNESOTA EXTENSION, BOB MUGAAS

Plant.

CAUTION:
- ✔ *Spring tillage will have little effect in managing this weed.*
- ✔ *Flame weeding will not be effective*

ANNUAL GRASS

Woolly cupgrass

Eriochloa villosa Poaceae Family

UNIVERSITY OF MINNESOTA EXTENSION

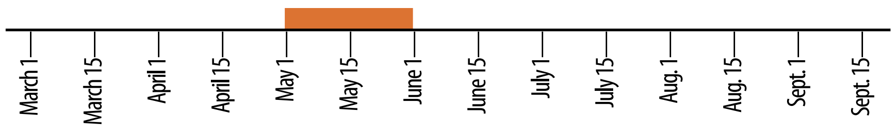
Seedling.

UNIVERSITY OF MINNESOTA EXTENSION

3 to 5 leaf stage.

Also known as: *hairy cupgrass*

Seed emergence time: *at corn planting, early to mid-May,*



ID: **Seedling**—*Wide pointed leaf blade*
Roots—*Fibrous*
Stems—*3-5 feet tall, erect but may lie flat, lower stem purplish on young plants*
Leaves—*dark green, covered with fine soft hairs, one leaf margin often distinctly crinkled*
Flower—*head of several spikes, very woolly, spikelets in 2 rows on one side*

Risk to yield:
Corn: potential loss of 5% at 6 plants/ft-row

Other traits:
- *Stems and stalks very woolly*
- *Prefers moist soils in corn, soybean, small grain, and forage crops*

Risk Level

Corn/Soybean	*LOW*
Small grains	*LOW*
Forages	*LOW*

STRAND MEMORIAL HERBARIUM

Plant.

ANNUAL GRASS

Reducing risk: woolly cupgrass

Management:
- *Seedbed preparation like false seedbed*
- *Early crop planting*
- *Rotary hoeing kills most of first flush*
- *Rye cover crop*

Long-term management:
- *Crop rotation with alfalfa or winter wheat*
- *Plant competitive crops*

STRAND MEMORIAL HERBARIUM

Spike.

CAUTION:
- ✔ *Woolly cupgrass is a prolific seed producer*
- ✔ *Later-emerging cupgrass seedlings will produce less seed and may not be as critical to control*

SUMMER ANNUAL GRASS

Giant foxtail

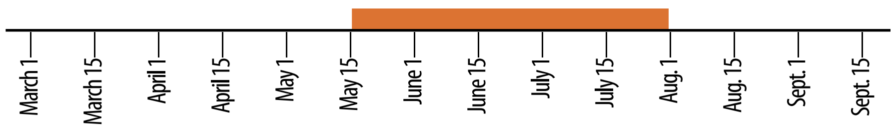
Setaria faberi Poaceae Family

Also known as: *Chinese foxtail, Chinese millet, Faber's foxtail, giant bristlegrass, Japanese bristlegrass, nodding foxtail, tall green bristlegrass*


UNIVERSITY OF MINNESOTA EXTENSION

Seedling.

Seed emergence time: *at corn planting, mid to late May*



ID: **Seedling**—*sheaths without hairs, but blades have many short hairs*
Roots—*Fibrous*
Stems—*very long, slender, weak, 3-7 feet tall, may lodge at maturity*
Leaves—*blades are flat, wide, covered with short hairs on upper surface*
Flower—*3-8 inches long, dense, cylindrical spikelet, drooping at maturity*


UNIVERSITY OF MINNESOTA EXTENSION

3 to 5 leaf stage.

Risk to yield:
Corn: potential losses of 14% at 3 plants/ft row
Soybean: potential losses of 7% at 1 plant/ft row; 13% at 60 plants/ft row

Risk Level

Corn/Soybean	*LOW*
Small grains	*LOW*
Forages	*LOW*


STRAND MEMORIAL HERBARIUM

Plants.

Other traits:
- *Seed bank persistence is low, < 1 yr for 50% seed reduction; 5 yr for 99% seed reduction*
- *Likes compact, fertile soils, higher pH*
- *Emerges from <1 inch depths*

Reducing risk: giant foxtail

Management:

- *Rotary hoeing at < 1/4 inch somewhat effective*
- *Prevent seed production after small grains—seed input happens after small grains harvest.*
- *Tilling soil 10 days after harvest will result in a 50% reduction the following year.*
- *Clean crop off of field.*
- *Winter crops like winter wheat/rye will control foxtail*
- *Use of rye as a cover crop*
- *Delayed planting*

Long-term management:

- *Alfalfa grown for 2 years can suppress*

CAUTION:

✔ *Mowing not effective to stop heading*

✔ *Difficult to control with flaming*

ROBERT H. MOHLENBROCK, NCRS-USDA

Spike.

SUMMER ANNUAL GRASS

Yellow foxtail

Setaria pumila Poaceae Family


UNIVERSITY OF MINNESOTA EXTENSION

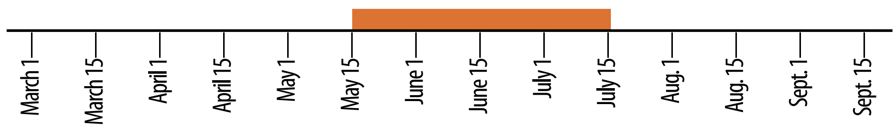
Seedling.


UNIVERSITY OF MINNESOTA EXTENSION

3 to 5 leaf stage.

Also known as: *cattail grass, pigeongrass, yellow bristlegrass*

Seed emergence time: *at end of corn planting, late May to early June, about the time of crop planting, seed can also germinate later in the summer with adequate soil moisture*



ID: **Seedling**—*long hair at base of leaf only*
Roots—*Fibrous*
Stems—*erect, smooth, branch at base, 1-2 feet tall*
Leaves—*flat, often with spiral twist, many long hairs on upper surface near base*
Flower—*dense, erect spikelet, yellow at maturity*

Risk to yield:
Corn: potential losses can occur at densities greater than 1 plant/ft^2; up to 80% loss with large infestations
Soybean: potential losses of 5% at 1 plant/ft^2

Risk Level

Corn/Soybean	*LOW*
Small grains	*LOW*
Forages	*LOW*


STRAND MEMORIAL HERBARIUM

Plants.

Other traits:
- *Moderate persistence of seed: 50% reduced at 5 years; 99% reduced at 30 years*
- *Prefers compact, fertile soils*
- *Intolerant of shade*

SUMMER ANNUAL GRASS

Reducing risk: yellow foxtail

Management:
- *Similar to giant foxtail*
- *Delayed planting*
- *Post emergent tillage*
- *Narrow row spacing may shade out*

Long-term management:
- *Add alfalfa to rotation*


OHIO STATE WEED LAB

Spike.

CAUTION:

✔ *Yellow foxtail may outcompete corn under low nitrogen conditions*

✔ *It can produce seed in as few as 30 days*

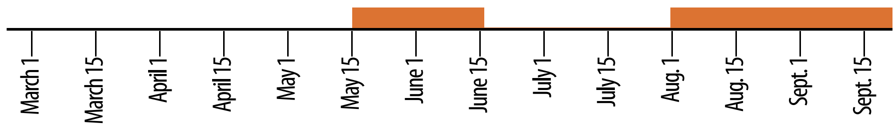
SUMMER ANNUAL GRASS

Green foxtail

Setaria viridis Poaceae Family

Also known as: *bottlegrass, green bristlegrass, pigeongrass, wild millet*

Seed emergence time: *late May to early June, seed can also germinate later in the summer and fall*



UNIVERSITY OF MINNESOTA EXTENSION

Seedling.

ID: **Seedling**—*smooth, finely veined leaf; hairy sheath*
Roots—*fibrous*
Stems—*erect*
Leaves—*smooth/hairless*
Flower—*dense erect spikelet, 1-3 inches long, may have slight bend at tip, 1-3 bristles below spikelet*

UNIVERSITY OF MINNESOTA EXTENSION

3 to 5 leaf stage.

Risk to yield:
Corn: potential loss of 7% at 1 plant/ft^2; 56% at 8 plants/ft^2
Soybean: potential loss of 8% at 1 plant/ft^2

Risk Level

Corn/Soybean	*LOW*
Small grains	*LOW*
Forages	*LOW*

OHIO STATE WEED LAB

Plants.

Other traits:
- *Similar to giant foxtail but 1-3 feet tall; highly variable*
- *Prefers light-textured, fertile, moist soils*
- *Has allelopathic effects on corn*

SUMMER ANNUAL GRASS

Reducing risk: green foxtail

Management:
similar to giant foxtail

- *Delayed planting*
- *Post emergent tillage*
- *Moldboard plowing*
- *Mow before seeding in forages*
- *Narrow row spacing may shade out*

Long-term management:

- *Add alfalfa to rotation*


WENDY VANDYK EVANS.

Spike.

CAUTION:
✔ *Produces a high number of seeds that can germinate right away*

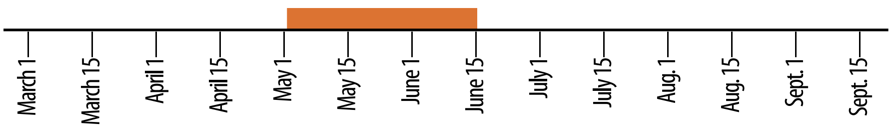
ANNUAL VINING BROADLEAF

Wild buckwheat

Polygonum convolvulus Polygonaceae Family

Also known as: *black bindweed, false buckwheat*

Seed emergence time: *early to mid-May, about the same time as crop planting, most emergence is complete by mid-June*




STRAND MEMORIAL HERBARIUM

Seedling.

ID: **Seedling**—*linear cotyledons, oval- to heart-shaped leaves*
Roots—*taproot*
Stems—*smooth, slender, twining or creeping, branched at base*
Leaves—*alternate, heart-shaped, pointed with smooth edges*
Flower—*small, greenish-white, in clusters in leaf axils*

Risk to yield:
Corn: potential loss of 10% at 1 plant/ft²
Soybean: potential loss of 15% at 1 plant/ft²
Wheat: potential loss of 22% at 3 stems/ft²


STRAND MEMORIAL HERBARIUM

3 to 5 leaf stage.

Risk Level

Corn/Soybean	*LOW*
Small grains	*MEDIUM*
Forages	*MEDIUM*

Other traits:

- *Often mistaken for field bindweed; wild buckwheat has thin membrane around stem and very small flowers*
- *Medium seed dormancy (up to 5 years in seedbank)*
- *Most seeds emerge from 2 inches, but can emerge from up to 8 inches*
- *Disease host*

ANNUAL VINING BROADLEAF

Reducing risk: wild buckwheat

Management:
- *Seedbed preparation via pre-emergent harrowing*
- *False seedbed*
- *Delayed crop planting*
- *Post-harvest cultivating*
- *Planting clean wheat seed*

Long-term management:
- *Forages grown for 2 or more years*

CAUTION:
✔ *Often reduces crop yield and quality*
✔ *Seed difficult to remove from crop seed and is a common seed contaminant*
✔ *Can lead to grain storage issues of spoilage and fungi*


STRAND MEMORIAL HERBARIUM

Plant.


THE WEED SCIENCE SOCIETY OF AMERICA

Flowers.

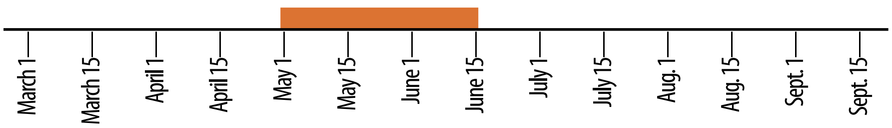
SUMMER ANNUAL BROADLEAF

Pennsylvania smartweed

Polygonum pennsylvanicum Polygonaceae Family

Also known as: *Pennsylvania knotweed, pinkweed*

Seed emergence time: *before corn planting, early May*



UNIVERSITY OF MINNESOTA EXTENSION

Seedling.

ID: **Seedling**—*linear seed leaves, smooth true leaves*
Roots—*taproot*
Stems—*erect, smooth*
Leaves—*smooth, swollen at nodes, branching, 1 to 4 feet tall*
Flower—*bright pink or rose, 5 petals, flowers in short spike*

Risk to yield:

Corn: potential loss of 13% at 1 plant/m^2
Soybean: potential loss of 6% at 2 plants/10ft^2, 36% at 11 plants/10ft^2
Wheat: potential loss of 13% for 2.5 plants/10ft^2

Risk Level

Corn/Soybean	*MEDIUM*
Small grains	*LOW*
Forages	*LOW*

UNIVERSITY OF MINNESOTA EXTENSION

3 to 5 leaf stage.

Other traits:

- *15,000+ seeds/plant*
- *Persistence is moderate with 50% seed reduction at 4 years, 99% reduction at 26 years*
- *Prefers wet spots, high fertility (N, P), acidic soils, poorly drained soils*
- *Emerges from <1 inch*

SUMMER ANNUAL BROADLEAF

STRAND MEMORIAL HERBARIUM

Plant.

STRAND MEMORIAL HERBARIUM

Flowers.

Reducing risk: Pennsylvania smartweed

Management:

- *Seedbed prep—early tillage*
- *Delayed planting*
- *Rotary hoeing at < 1/4 inch height*
- *Flaming effective at < 1 inch height*

Long-term management:

- *Small grain or forage in rotations for suppression*

CAUTION:

✔ *Can be a skin irritant and cause photosensitivity in livestock*

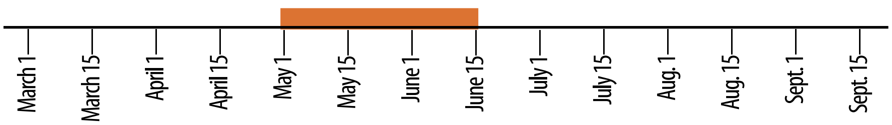
ANNUAL BROADLEAF

Common lambsquarters

Chenopodium album Chenopodiaceae Family

Also known as: *fat-hen, lambsquarters, lambsquarters goosefoot, white goosefoot*

Seed emergence time: *early May, before corn planting; peak emergence at mid-late spring*



UNIVERSITY OF MINNESOTA EXTENSION

Seedling.

ID: Seedling—*whitish cast*
Roots—*taproot, short, much branched*
Stems—*erect, very branched, 3-4 feet tall, smooth, grooved, red-green streaks*
Leaves—*alternate, 1-3 inches long, smooth, white coat underside, toothed edge*
Flower—*small, green, at end of branches and in leaf axils*

Risk to yield:
Corn: potential loss of 13% at <1 plant/ft
Soybean: potential loss of 25% at < 1 plant/ft
Barley: potential loss of 25% at 19 stems/ft²

Risk Level

Corn/Soybean	*MEDIUM*
Small grains	*MEDIUM*
Forages	*LOW*

UNIVERSITY OF MINNESOTA EXTENSION

3 to 5 leaf stage.

Other traits:
- *Seedbank persistence is long, 50% reduced in 12 years, 99% reduced in 78 years*
- *Inhibition to germination is 50% at 2 inches, 100% at 4 inches*
- *Most seedlings emerge from <1 inch*
- *Adaptable to different tillage systems including no-till and compact soils*
- *Prefers fertile soils*
- *Very high seed production*
- *Dormancy mechanisms are overcome by light, strong temperature fluctuations, and nitrogen*
- *10 to 30% of present seed may be able to germinate the next season*
- *Lambsquarters will emerge a few weeks before corn planting*
- *Under the right temperature and moisture regime, will emerge 2-3 weeks after spring tillage*

ANNUAL BROADLEAF

STRAND MEMORIAL HERBARIUM

Plant.

STRAND MEMORIAL HERBARIUM

Flowers.

Reducing risk: common lambsquarters

Management:

- *Rotary hoe will control at < 1/4- inch height*
- *Flaming will kill at < 1/2- inch height*
- *Delayed planting*
- *Increasing tillage can increase emergence, but will decrease emergence the following year*
- *Crops with fast emergence can be more competitive*
- *Underseed small grains with legume*
- *Narrow rows*
- *Higher planting rates*

Long-term management:

- *Small grains, winter grains, or perennial forages can suppress*

CAUTION:

- ✔ *Plants that emerge late can set seed in 6 weeks*
- ✔ *Drought can cause seed to form early*
- ✔ *Host to several crop viruses*
- ✔ *Manure can introduce seed*

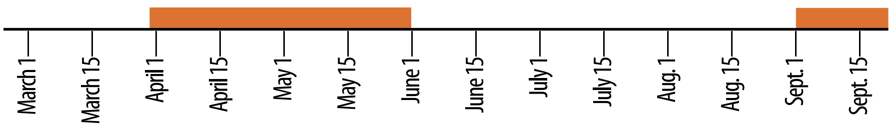
ANNUAL BROADLEAF

Kochia

Bassia scoparia Chenopodiaceae Family

Also known as: *burning bush, Mexican burningbush, Mexican fireweed, mock cypress, summer cypress*

Seed emergence time: *very early, in April prior to crop planting, can continue into late summer*



UNIVERSITY OF MINNESOTA EXTENSION

Seedling.

ID: Seedling—*Linear cotyledons and leaves, very hairy*
Roots—*taproot*
Stems—*smooth, green, much branched, up to 6 feet tall*
Leaves—*simple, hairy, 1-2 inches long, pointed, no petioles*
Flower—*spike with small, greenish flowers without petals in clusters at end of branches or axils*

Risk to yield:
Corn: potential losses can occur at densities greater than 7 plants/ft-row

Small grains: potential loss of 10% at 3 plants/ft^2

Risk Level

Corn/Soybean	*MEDIUM*
Small grains	*MEDIUM*
Forages	*LOW*

UNIVERSITY OF MINNESOTA EXTENSION

3 to 5 leaf stage.

Other traits:
- *Seedbank persistence is short; 50% reduced in <0.5 year, 99% reduced in 2 years*
- *Shallow germinator*
- *Prefers drier, warmer soils*

Reducing risk: kochia

Management:

- *Seedbed prep, early tillage*
- *Delayed planting*
- *Plant clean crop seed*
- *Mowing or cutting*
- *Fall tillage may stop late seeding plants*

Long-term management:

- *Crop rotations that combine early and late sown crops*

CAUTION:

✔ *Can have good forage quality when young, but can cause nitrate poisoning under some conditions and photosensitivity in livestock*

STEVE DEWEY, UTAH STATE UNIVERSITY

Plant.

ROBERT H. MOHLENBROCK. NRCS-USDA

Flowers.

SUMMER ANNUAL BROADLEAF

Redroot pigweed

Amaranthus retroflexus

Amaranthaceae Family

Also known as: *common amaranth, redroot amaranth, rough amaranth, rough pigweed*

Smooth pigweed

Amaranthus hybridus

Amaranthaceae Family

Also known as: *green amaranth, green pigweed, slim amaranth, smooth pigweed*


UNIVERSITY OF MINNESOTA EXTENSION

Seedling, redroot pigweed.


UNIVERSITY OF MINNESOTA EXTENSION

3 to 5 leaf stage, redroot pigweed.

ID:

Seedling—*stem is red to green, smooth to slightly hairy*

Roots—*shallow taproot, reddish*

Stems—*erect, up to 6 feet tall, rough, freely branched if not crowded*

Leaves—*dull green, usually up to 6 inches, ovate*

Flower—*green, small in spikes at end of branches*

Risk to yield:

Corn: potential loss of 5% at 1 plant/ft

Soybean: potential loss of 30% at 1 plant/10ft; 50% at 2 plants/10ft, 56% at 4-8 plants/10ft

Risk Level

Corn/Soybean	*MEDIUM*
Small grains	*LOW*
Forages	*MEDIUM*

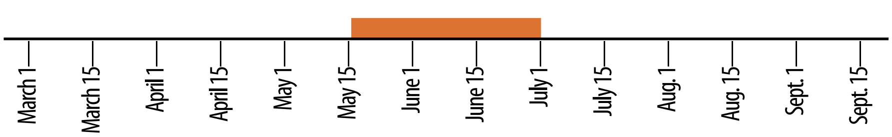

UNIVERSITY OF MINNESOTA EXTENSION

Seedling, smooth pigweed.


UNIVERSITY OF MINNESOTA EXTENSION

3 to 5 leaf stage, smooth pigweed.

Seed emergence time: *mid to late spring, about the time of crop planting*



Other traits:

- *Seedbank persistence is moderate to long: 50% reduction in 3 years, 99% reduction in 20 years*
- *Depth of inhibition is 50% inhibition at 2 inches, 100% inhibition at 4 inches*
- *Most seedlings emerge from < 1 inch*
- *Germinates late, likes warm, fertile soils, usually cultivated sites, but adaptable to compact soils*
- *Does not tolerate low pH*

Reducing risk: pigweed

Management:

- *Early OR delayed planting to avoid emergence period*
- *Rotary hoeing at < 1/4 inch will control*
- *Flaming will control at less than 1.5 inch height*
- *Control by preventing seed production*

Long-term management:

- *Add small grains to rotation*
- *Try a fall-planted crop or 2 years of alfalfa*

CAUTION:

✔ *Buckwheat is not recommended as a smother crop to control pigweeds*

✔ *May cause bloat in livestock*

STRAND MEMORIAL HERBARIUM

Flowers, redroot pigweed.

STRAND MEMORIAL HERBARIUM

Plant, redroot pigweed.

SUMMER ANNUAL BROADLEAF

Waterhemp

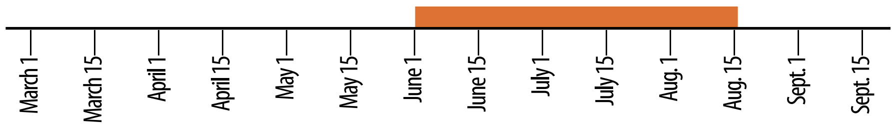
Amaranthus tuberculatus Amaranthaceae Family

OHIO STATE WEED LAB

Seedling.

Also known as: *roughfruit amaranth, roughfruit waterhemp, tall waterhemp*

Seed emergence time: *after corn emergence, early to mid-June, after crop planting*



OHIO STATE WEED LAB

3 to 5 leaf stage.

ID: **Seedling**—*linear cotyledons, leaves shiny*
Roots—*reddish-colored taproot*
Stems—*smooth, erect or trailing, 3 to 8 feet tall*
Leaves—*narrow, egg-shaped, alternate with long petioles, 3-6 inches long*
Flower—*small, greenish, in spike at end of branches, male and female flowers on separate plants*

Risk to yield:
Corn: potential loss of 15% at 30 plants/ft^2
Soybean: potential loss of 44% at 30 plants/ft^2

Risk Level

Corn/Soybean	*LOW*
Small grains	*LOW*
Forages	*LOW*

OHIO STATE WEED LAB

Plant.

Other traits:
- *Very similar to smooth pigweed at seedling stage*
- *Prefers low ground, wet conditions*
- *Seedbank persistence is moderate: 50% reduced at 2 years, 99% reduced at 16 years*
- *Germinate over the entire growing season, often requires late-season control*
- *Rapid growth rate*
- *Small seed emerges from shallow depths*
- *MN study found waterhemp produced seed in corn up to the V10 stage, but produced no seeds after V5 stage in soybean*

Reducing risk: waterhemp

Management:

- *Post emergent tillage and cultivation*
- *Moldboard tillage might bury seed until not viable*
- *Incease in-row cultivation to control*

Long-term management:

- *Include perennials like alfalfa in rotation*

CAUTION:

✔ *Delayed planting less effective*

✔ *Spring tillage will have little effect in managing this weed*

✔ *Waterhemp is adapted to reduced tillage systems*

ROBERT H. MOHLENBROCK. NCRS-USDA

Flowers.

SUMMER OR WINTER ANNUAL BROADLEAF

Wild mustard

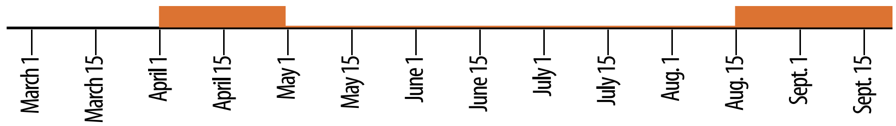
Sinapis arvensis Brassicaceae Family

UNIVERSITY OF MINNESOTA EXTENSION

Seedling.

Also known as: *California rape, charlock, charlock mustard, corn mustard, kedlock, wild mustard*

Seed emergence time: *April, prior to crop planting and late summerto early fall*



UNIVERSITY OF MINNESOTA EXTENSION

3 to 5 leaf stage.

ID: Seedling—*kidney-shaped seed leaves*
Roots—*taproot*
Stems—*erect, branched at top, 8-40 inches, coarse hairs on bottom*
Leaves—*lower coarsely toothed, upper leaves progressively smaller, smooth*
Flower—*yellow, 4 petals, in clusters at end of branches*

Risk to yield:
Corn: potential loss of 18% at 1 plant/ ft^2
Soybean: potential loss of 20% at 1 plant/ ft^2
Wheat: potential loss of 35% at 9 stems/ft^2

Risk Level

Corn/Soybean	*LOW*
Small grains	*HIGH*
Forages	*LOW*

STRAND MEMORIAL HERBARIUM

Plant.

Other traits:
- *Seed bank persistence is low; 50% reduced <1 year, 99% reduced by 7 years*
- *Depth of inhibition is moderate, 50% inhibited at 2 inches, 100% inhibition at 4 inches*
- *Germinates early, continually, very long dormancy*
- *Prefers cool, moist conditions*
- *Prefers uncultivated, less fertile, more acidic soils, often in small grain and flax*

Reducing risk: wild mustard

Management:
- *Seedbed prep/tillage*
- *Control with buckwheat smother crop*
- *Rotary hoeing of small seedlings; larger plants hard to manage*
- *Flaming effective on small seedlings*
- *Delayed planting*

Long-term management:
- *Crop rotation out of small grains, which are not competitive with wild mustard*

CAUTION:
- ✔ *Seeds are very long-lived so it is difficult to deplete the seed bank*


STRAND MEMORIAL HERBARIUM

Flowers.

SUMMER ANNUAL BROADLEAF

Velvetleaf

Abutilon theophrasti Malvaceae Family

UNIVERSITY OF MINNESOTA EXTENSION

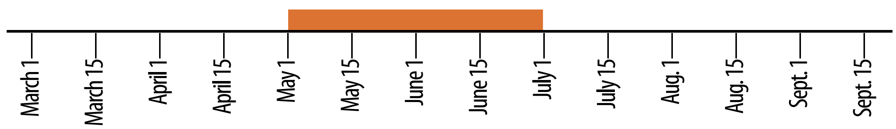
Seedling.

UNIVERSITY OF MINNESOTA EXTENSION

3 to 5 leaf stage.

Also known as: *butterprint, buttonweed, Indian mallow*

Seed emergence time: *at corn planting; early to mid-May*



ID: **Seedling**—*heart-shaped seed leaves*
Roots—*strongly developed taproot*
Stems—*strong, smooth, covered with soft velvety hairs, erect, 6-8 feet tall*
Leaves—*large, heart-shaped, soft, velvety hairy surface*
Flower—*large, 3/4 inch, 5 yellow petals, in axils*

Risk to yield:
Corn: potential loss of 34% at 3 plants/ft row
Soybean: potential loss of 40% at 3 plants/10ft row; 53% at 6-12 plants/10ft row
Wheat: potential loss of 28% at 3 plants/ft row

Risk Level

Corn/Soybean	*HIGH*
Small grains	*LOW*
Forages	*LOW*

STRAND MEMORIAL HERBARIUM

Plant.

Other traits:
- *Seedbank persistence high, 50% reduced in 8 years, 99% reduced in 56 years*
- *Not persistent in seed bank unless very deep in soil profile*
- *Depth of inhibition low, 50% inhibition at 3 inches, 100% inhibition at 5 inches*
- *Most seedlings emerge from <2 inches*
- *Prefers compact, fertile soils, high pH, high N*

Reducing risk: velvetleaf

Management:

- *Seedbed prep, early planting*
- *Rotary hoeing at < 1/4 inch will only be somewhat effective on plants that emerge from 2 inch depths.*
- *Flaming can be effective when small*
- *Reduced tillage systems*

Long-term management:

- *Small grains or forage in rotation*

CAUTION:

✔ *Planting date changes may not be effective due to long emergence period*

✔ *Tillage stimulates germination*

STRAND MEMORIAL HERBARIUM

Flowers.

SUMMER ANNUAL BROADLEAF

Eastern black nightshade

Solanum ptycanthum Solanaceae Family

UNIVERSITY OF MINNESOTA EXTENSION

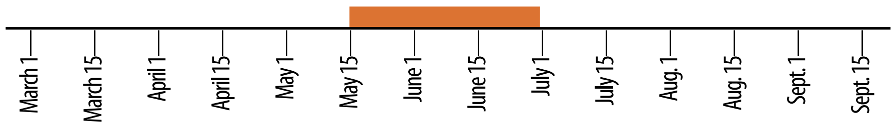
Seedling.

UNIVERSITY OF MINNESOTA EXTENSION

3 to 5 leaf stage.

Also known as: *nightshade, West Indian nightshade*

Seed emergence time: *at end of corn planting, early to mid-June*



ID: **Seedling**—*round seed leaves, leaves sparsely hairy*
Roots—*taproot (stems will also root)*
Stems—*erect to trailing, widely branching, 1-2 feet tall*
Leaves—*oval, 1-3 inches long, edges wavy*
Flower—*white, 5 lobed, star-shaped, yellow center, in small clusters*

Risk to yield:
Corn: potential loss of 7% at 1 plant/ft^2
Soybean: potential loss of 40% at 1 plant/ft^2
Wheat: potential loss of 10% for 10 plants/10ft

Risk Level

Corn/Soybean	*MEDIUM*
Small grains	*LOW*
Forages	*MEDIUM*

Other traits:

- *Depth of inhibition is 50% at 2 inches, 100% at 4 inches*
- *Most seedlings emerge from < 1 inch*
- *Prefers fertile soils*
- *Emerges after lambsquarters*
- *Moderate seed persistence*
- *Not strongly competitive with crop*
- *Shade tolerant*

Reducing risk: Eastern black nightshade

Management:

- *Post emergent tillage and cultivation*
- *Delayed planting*
- *Rotary hoeing at < 1/4 inch will control*
- *Flaming is effective on seedlings*
- *Narrow row spacing*
- *Harvest late to avoid soybean staining*

Long-term management:

- *Small grains or forage rotation very effective*

CAUTION:

✔ *Berries can cause staining during soybean harvest even at low populations*

STRAND MEMORIAL HERBARIUM

Plant and Flowers.

SUMMER ANNUAL BROADLEAF

Common ragweed

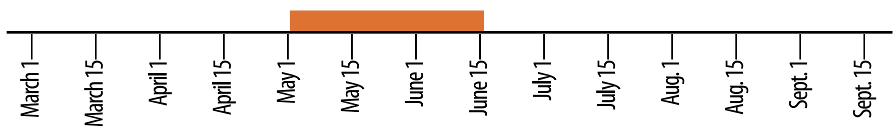
Ambrosia artemisiifolia Asteraceae Family


UNIVERSITY OF MINNESOTA EXTENSION

Seedling.

Also known as: *annual bursage, annual ragweed, short ragweed*

Seed emergence time: *at corn planting, early to mid-May*



ID: **Seedling**—*1st true leaves with 3 lobes*
Roots—*shallow taproot*
Stems—*rough, hairy, erect, branched, 1-4 feet tall*
Leaves—*nearly smooth, deeply cut into many lobes*
Flower—*2 kinds; male (pollen) in small clusters at branch tips, fewer female (seed) found at base of leaves and forks of upper branches*


UNIVERSITY OF MINNESOTA EXTENSION

3 to 5 leaf stage.

Risk to yield:
Corn: potential loss of 21% at 1 plant/ft²
Soybean: potential loss of 30% at 2 plants/10ft
Wheat: potential loss of 30% at 2 plants/10ft

Risk Level

Corn/Soybean	*MEDIUM*
Small grains	*LOW*
Forages	*LOW*


STRAND MEMORIAL HERBARIUM

Plant.

Other traits:
- *Seed persistence is low, 50% reduced = <1.5 years; 99% reduced=10 year*
- *Prefers poor fertility*
- *Emerges from < 2 inches depth*

SUMMER ANNUAL BROADLEAF

JIM PISAROWICZ, NATIONAL PARK SERVICE

Flowers.

Reducing risk: common ragweed

Management:

- *Tillage controls new seedlings but stimulates germination*
- *Early OR delayed planting to avoid emergence period*
- *Rotary hoe controls at < 1/4 inch height*
- *Mowing*
- *High crop plant populations*

Long-term management:

- *Small grains in rotation can suppress*

CAUTION:

✔ *Flaming not effective*

SUMMER ANNUAL BROADLEAF

Giant ragweed

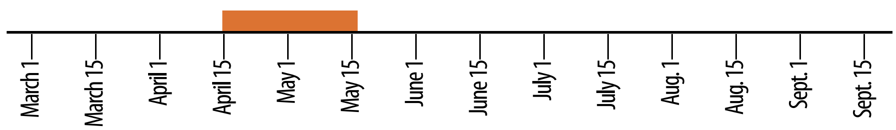
Ambrosia trifida Asteraceae Family


UNIVERSITY OF MINNESOTA EXTENSION

Seedling.

Also known as: *crownweed, great ragweed, horse-cane*

Seed emergence time: *before corn planting, early May*



ID: **Seedling**—*1st true leaves with 5 lobes*
Roots—*taproot*
Stems—*coarse, rough-hairy, 3-15 feet tall*
Leaves—*opposite, large, some hairs, 3 or 5 lobes*
Flower—*2 kinds, many male in clusters on branch tips, few female in axils of upper leaves*


UNIVERSITY OF MINNESOTA EXTENSION

3 to 5 leaf stage.

Risk to yield:
Corn: potential loss of 55% at 1 plant/10ft²
Soybean: potential loss of 52% at 1 plant/10ft²
Wheat: potential loss of 54% at 1 plant/10ft²

Risk Level	
Corn/Soybean	*HIGH*
Small grains	*HIGH*
Forages	*MEDIUM*


STRAND MEMORIAL HERBARIUM

Plant.

Other traits:
- *Prefers fertile, moist soils, and disturbed areas*
- *Weed persistence is low; 50% reduced in <0.5 year; 99% reduced in 2 years*
- *Early emergence but continues to emerge over a long period of time*
- *Emerges from < 6 inches*

Reducing risk: giant ragweed

Management:

- *Seedbed prep*
- *Mowing*
- *Delayed planting*
- *Tillage controls emerged seedlings but stimulates more emergence*
- *Highly competitive crops that can be planted late*

Long-term management:

- *Small grains or alfalfa/red clover in rotation*

CAUTION:

✔ *Rotary hoeing may not be effective*
✔ *Flaming not effective*


STRAND MEMORIAL HERBARIUM

Flowers.

PERENNIAL BROADLEAF

Canada thistle

Cirsium arvense Asteraceae Family

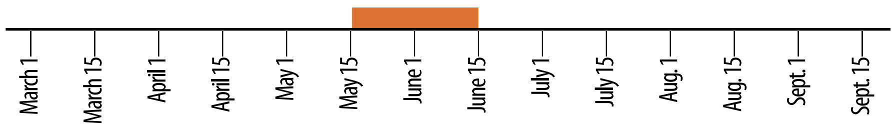
Listed on MN Noxious Weed list

STRAND MEMORIAL HERBARIUM

Seedling.

Also known as: *Californian thistle, creeping thistle, field thistle*

Seed emergence time: *mid to late May, about the time of crop planting*



ID: **Seedling**—*spiny*
Roots—*extend several feet down and horizontally*
Stems—*erect, 2-5 feet tall, branches at top, hairiness increases with maturity*
Leaves—*oblong, crinkled edge, spiny, lobed and hairy beneath*
Flower—*numerous, compact, 3/4 inch, purplish, male and female flowers usually on different plants*

Risk to yield:
Corn: potential loss of 5% at 5 shoots/row-ft
Wheat: potential loss of 38% at 14 shoots/10 row-ft

Risk Level

Corn/Soybean	*MEDIUM*
Small grains	*LOW*
Forages	*HIGH*

STRAND MEMORIAL HERBARIUM

3 to 5 leaf stage.

Other traits:
- *Depth of inhibition: 50% inhibition at 2 inches; 100% inhibition at 4 inches*
- *Most seedlings emerge from <1 inch*
- *Prefers field edges*
- *Most is spread from extensive root system*
- *Not shade tolerant*

Reducing risk: Canada thistle

Management—established populations:

- *Mid-season crop planting*
- *Fall tillage*
- *Frequent moldboard plowing*
- *Mowing to prevent seed set*
- *Take action when flower buds are present to reduce root reserves*
- *Shoots emerge 10 day after disking—will need to be done every 3 weeks or so to deplete reserves.*
- *Rotary hoe/disc/tillage can spread thistle*

Long-term management:

- *Alfalfa, sweet clover, buckwheat, or sudangrass in rotation*

CAUTION:

✔ *Don't rely one management technique to control established populations; Canada thistle will need several levels and modes of managment*

STRAND MEMORIAL HERBARIUM

Plant and flowers.

SUMMER OR WINTER ANNUAL BROADLEAF

Horseweed

Conyza canadensis Asteraceae Family

OHIO STAE WEED LAB

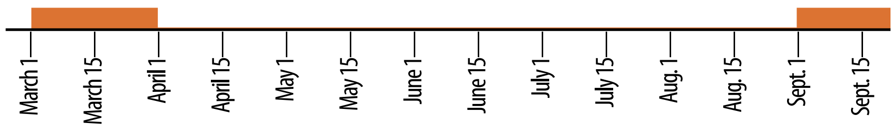
Seedling.

STRAND MEMORIAL HERBARIUM

3 to 5 leaf stage.

Also known as: *Canada horseweed, Canadian horseweed, fleabane, hogweed, fleabane, marestail*

Seed emergence time: *March, very early spring or in the fall, sometimes during summer*



ID: **Seedling**—*ovate seed leaves, hairless*
Roots—*short taproot*
Stems—*erect, stout, unbranched at base, 1 to 6 feet tall, bristly hairs*
Leaves—*numerous, dark green with scattered coarse white bristles*
Flower—*many small, greenish white with yellow centers*

Risk to yield:
Corn: potential loss of 5% at 7 plants/row-ft
Wheat: potential loss of 83% at 11 stems/ft^2

Risk Level

Corn/Soybean	*LOW*
Small grains	*MEDIUM*
Forages	*MEDIUM*

Other traits:
- *Prefers coarse, fertile, or well-drained soils; tolerates drought well*
- *Emerges from < 1 inch*
- *Germinates readily from mature parent plant, wind disseminated*
- *Not shade tolerant*

SUMMER OR WINTER ANNUAL BROADLEAF

Reducing risk: horseweed

Management:

- *Fall tillage*
- *Delayed planting*
- *Narrow rows*
- *High crop populations*

Long-term management:

- *Small grains in rotation can suppress*

CAUTION:

✔ *Seeds can germinate as soon as they drop from parent plant*

©TED BODNER.

Plant.

STRAND MEMORIAL HERBARIUM

Flowers.

SUMMER ANNUAL BROADLEAF

Common sunflower

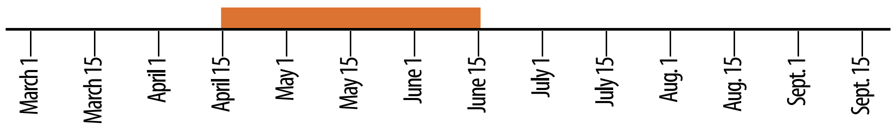
Helianthus annuus Asteraceae Family


UNIVERSITY OF MINNESOTA EXTENSION

Seedling.

Also known as: *annual sunflower, garden sunflower, sunflower, wild sunflower*

Seed emergence time: *early May, before corn planting*



ID: **Seedling**—*large seed leaves, rough leaf surface*
Roots—*fibrous*
Stems—*erect, thick, rough, 2 to10 feet tall, freely branching*
Leaves—*alternate, rough, hairy, toothed margins*
Flower—*1 to 5 inches diameter, yellow with brown disk center*


UNIVERSITY OF MINNESOTA EXTENSION

3 to 5 leaf stage.

Risk to yield:
Corn: potential loss of 5% at 1 plant/row-ft

Risk Level

Corn/Soybean	*HIGH*
Small grains	*MEDIUM*
Forages	*MEDIUM*

Other traits:

- *Seedbank persistence low: 50% reduced at <0.5 year; 99% reduced at 2 years*


STEVE DEWEY, UTAH STATE UNIVERSITY

Plant.

Reducing risk: common sunflower

Management:

- *Seedbed prep*
- *Delayed planting*
- *Moldboard or chisel plowing in spring*

Long-term management:

- *Forages in rotation*

CAUTION:

- ✔ *Sunflower is one of the most competitive weeds*
- ✔ *Can cause nitrate poisoning in livestock*

EXTENSION.MISSOURI.EDU

Plant and flowers.

KARAN A. RAWLINS, UNIVERSITY OF GEORGIA

Flower.

SUMMER ANNUAL BROADLEAF

Cocklebur

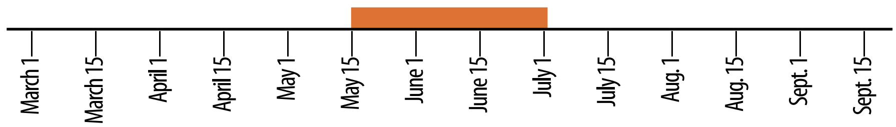
Xanthium strumarium Asteraceae Family

UNIVERSITY OF MINNESOTA EXTENSION

Seedling.

Also known as: *broad cocklebur, burweed, common cocklebur, rough cocklebur*

Seed emergence time: *mid to late May, at the end of corn planting, 4 to 8 weeks*



ID: **Seedling**—*linear seed leaves, leaves rough*
Roots— *stout, woody taproot*
Stems—*erect, usually bushy, ridged, rough, hairy, purple spots, 2-4 feet tall*
Leaves—*triangle to heart-shaped, toothed edges, rough*
Flower—*small, male and female flowers separate but born together in clusters in axils*

Risk to yield:
Corn: potential loss of 10% at 2 plants/ft
Soybean: potential loss of 4% at 1 plant/10ft; 47% at 13 plants/10ft

Risk Level

Corn/Soybean	*HIGH*
Small grains	*LOW*
Forages	*MEDIUM*

UNIVERSITY OF MINNESOTA EXTENSION

3 to 5 leaf stage.

Other traits:

- *Seedbank persistence high: 50% reduced at 6 years; 99% reduced at 37 years*
- *Most competitive with soybean*
- *Stems interfere with harvest*

Reducing risk: cocklebur

Management:

- *Delayed planting*

Long-term management:

- *Crop rotation*
- *Reduced tillage*

STRAND MEMORIAL HERBARIUM

Plant.

CAUTION:

✔ *Plants with immature seed heads left in field can still produce viable seed*

✔ *Difficult to control with shallow tillage, rotary hoeing*

✔ *Seedlings and seed are poisonous to livestock*

✔ *Burying seed can aid in seed emergence*

FOR MORE INFORMATION

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CHAPTER 8

Transitioning

KRISTINE MONCADA
MARY BRAKKE
CARMEN FERNHOLZ

Conventional agriculture produces large quantities of low-value commodities through inputs of energy, machinery, and synthetic chemicals. Although still subject to the risks of weather and fluctuating markets, stability of conventional agriculture is supported by subsidization through government payments and insurance programs. Organic agriculture is inherently riskier than conventional agriculture because of the complexity of dealing with crop management issues such as fertility, weed control and pest control. These challenges are especially evident during transitioning from conventional to organic.

Certified organic acreage in Minnesota has increased by over 50 percent since 2000 and it is expected that the industry will continue to grow in the foreseeable future. While the future of organic agriculture looks bright, there are costs and risks involved. This chapter will help growers who are contemplating adopting organic production practices understand the risks that are associated with organic production and, when possible, make choices that will minimize those risks.

Figure 8-1. *Alfalfa.*

Why go organic?

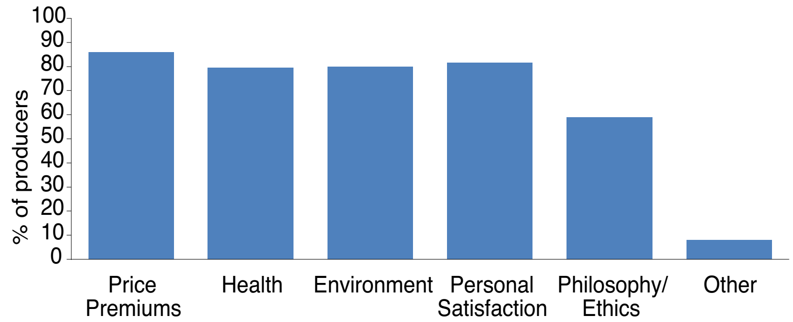

Figure 8-2. ***A 2007 Minnesota Department of Agriculture Survey of Organic Farmers in Minnesota asked producers why they became organic. Most people cited numerous reasons. Adapted from Minnesota Department of Agriculture, 2007.***

Those who chose to switch to organic production cite numerous reasons for doing so (Figure 8-2). For some, price premiums that can run as much as 200 percent of conventionally-grown products are a driving factor. Attractive prices combined with reduced input costs and the opportunity to sell to new markets provides a convincing reason for others. For most organic producers, protecting the environment is a top priority. They cite the negative effects of pesticides and fertilizers on soil and water quality, human health, and wildlife. In addition they are concerned about the use of antibiotics and hormones in meat, and the inclusion of transgenic crops in foods. Farming in the image of nature is important for many of these growers. Understanding the interactions between soil, plants, and living organisms and working with the ecosystem to create a balance from which food is derived is both a challenge and a reward.

PRODUCER PROFILE

This is how one producer from Wright County became organic. He had a background in farming, but was working in another industry when he decided to get back into farming. He began to farm organically at the urging of an acquaintance after he purchased a pasture that was certifiable. The producer is happy with his decision and thinks that organic farming provides answers that are lacking in conventional farming. There is a more reflective and thoughtful process in organic farming that he prefers.

What is organic agriculture?

The USDA National Organic Program (NOP) is responsible for developing rules for organic agriculture in the United States. They also accredit the organic certifiers who are necessary in the process of certification. The term "organic" is defined by federal law so any crop or livestock that is labeled or sold as "organic" must be produced according to the national rules. NOP regulations can be modified over time, so for the most up-to-date information, consult the NOP website at http://www.ams.usda.gov/AMSv1.0/NOP.

Organic agriculture is an ecologically-based management system with the overall goal of optimizing health of soil, animals, and people. Some of the major differences between organic agriculture and conventional agriculture are listed in Table 8-1. Two important areas that vary between the two systems are production and management practices.

ORGANIC PRODUCTION PRACTICES

Organic agriculture is not simply substituting another type of input for synthetic ones; the overall health of the environment is emphasized. Compared to conventional agriculture, organic farmers use a diversity of strategies to develop and manage their farms.

Certified organic operations do not use synthetic fertilizers and pesticides or genetically-modified organisms. Weeds and pests are managed mechanically and culturally and through diverse rotations. A limited number of inputs are approved for pest control and adjustment of soil nutrient status. In fact, on some organic farms, purchased amendments from outside sources may be only rarely used. Fertility can be provided with manure, compost, and green manures, as well as by including legume crops in rotations. The use of practices such as crop rotations to amend soil nutrients and cultivation to control weeds requires on-farm research and innovation to determine the best combination of crops and production practices.

PRODUCER PROFILE

This is why one producer from Faribault County continues to farm organically. He has been organic since 1984 with over 200 organic acres. His philosophy is that the quality of organic crops outweighs the quantity in conventional. He believes in good land stewardship, that fewer pesticides are beneficial, and that the quality of organic feed leads to better quality meat.

Table 8-1. Comparison of organic and conventional agriculture.

	ORGANIC AGRICULTURE	CONVENTIONAL AGRICULTURE
Fertility	Non-synthetic amendments like manure, compost, and green manures; legumes in rotation	Primarily synthetic fertilizers
Weed control	Multiple strategies are employed including: diverse rotations, mechanical weed control, cultural methods	Primarily synthetic herbicides, GMO crops
Insect control	Diverse rotation, some non-synthetic insecticides	Primarily synthetic insecticides, GMO crops
Crops	Non-GMO only	Either GMO or traditionally bred
Rotations	Diverse rotation that includes other crops in addition to corn and soybean	Often includes just corn and soybean; continuous cropping is possible
Profits	Comparable to conventional	Comparable to organic
Inputs	Fewer inputs	Greater inputs
Buffers	Buffers are necessary to protect organic crops from GMO contamination	Buffers are not required, but refuges are required for GMO crops
Time in field	Depending on crop, more time may be spent in the field	Depending on crop, less time may be spent in the field
Yields	Corn and soybean yields have potential to be lower, but small grains and forages can have similar yields	Can be higher yielding depending on crop fertilization, chemical weed control

More detailed information on specific organic practices can be found in other chapters in the manual, specifically Chapter 2: Rotation, Chapter 3: Soil health, and Chapter 4: Soil fertility.

Reducing risk: organic practices. Consult and learn NOP rules that apply to your type of operation. Check the NOP's National List of Allowed and Prohibited Substances before using any substance to make sure it is allowed. Your certifier will be a good information source on what practices are acceptable.

ORGANIC DOCUMENTATION

One thing those transitioning to organic agriculture may find to be different is the amount and type of documentation that is needed. Record keeping is a necessity in becoming certified organic. First, producers are required by the NOP to have an Organic System Plan (OSP), which describes the practices conducted in their operation to produce organic products. The OSP is completed at the start of the certification process and is updated over time. Producers must keep records on the production, harvest, and handling of crops which demonstrate adherence to NOP rules. Records must be accessible and easy to comprehend for inspectors and certifying agencies. Examples of information that must be kept are which materials, such as compost, manure, or other amendments, that are applied to organic fields. The amounts, dates of application, and the source of amendments are other pieces of information that must be tracked. Other examples are which seed were planted and their sources, tillage, weed control operations, and harvesting operations. Individual records must be kept for at least five years. Documentation must also be kept for non-organic crops grown in split operations.

A producer from Lac Qui Parle County says the difference between new organic farmers and established organic farmers is that new ones are kept up at night worrying about weeds, while established ones are worrying about yield.

Reducing risk: documentation. Turn record keeping into a habit from the start. Maintain an organized system of files. When in the field, keep a notebook handy at all times to record information.

PRODUCER PROFILE

This is how one producer from Waseca County became organic. He was farming conventionally when he purchased some land that was already certifiable. A relative convinced him to go organic on that land because of the organic premium. He currently farms both organically and conventionally. He likes that his tasks and labor is spread out with the split operation—for example, the planting dates are different with conventional occurring earlier. He is currently transitioning more of his conventional land. He thinks you really need to believe in organic farming to be an organic farmer; otherwise you will not be successful. He says that when coming from a conventional operation, farmers will need to be tolerant of things like the possibility of more weeds.

Steps in going organic

TRANSITION YEARS

Before a producer can be certified, there is a transition period for three years. No prohibited substances or GMOs can be applied to a field for 36 months prior to harvest of crop needing certification. Crops are grown organically, but no organic premium can be given until after transition. Producers can time the start of transition so that by the end of the third year, that crop will be eligible for the organic premium.

Potentially lower yields during the three year transitioning period combined with the lack of organic price premiums during this period indicates that producers should be ready for the possibility of lower yields (Table 8-2), but not necessarily lower net returns (Table 8-3) because of lower input costs.

Producers need to develop a sound rotation and begin implementing practices that reduce weeds and improve soils in anticipation of transitioning to organic crop production. It is recommended that producers transition their farms to organic production incrementally. A portion of the land can be in transition while conventionally farming the remaining acreage. An incremental approach also minimizes financial risk by providing reliable, albeit potentially reduced, yields during the transition period. Producers should prepare a realistic, multi-year farm budget before transitioning. It is best to start establishing relationships as soon as possible with markets and buyers of the organic crops that will be produced after the transition period.

Table 8-2. Conventional and transitional organic corn and soybean yields. Organic soybean yields were not significantly different, while organic corn yields were lower than conventional. *Adapted from Delate et al., 2006.*

YIELD

CROPPING SYSTEM	ROTATION	CROP	1998	1999
Conventional	Corn-Soybean	**Corn**	**170**	**161**
		Soybean	48	48
Organic	Corn-Soybean-Oat/Alfalfa	**Corn**	**143**	**122**
		Soybean	48	45
	Corn-Soybean-Oat/Alfalfa-Alfalfa	**Corn**	**138**	**120**
		Soybean	50	48

Table 8-3. Costs of production and net returns for conventional and transitioning systems. Net returns were similar for both systems, in part because of the higher costs of production for conventional systems. *Adapted from Delate et al., 2006.*

CROPPING SYSTEM	ROTATION	COST OF PRODUCTION	NET RETURN
		Average per year ($/acre)	
Conventional	Corn-Soybean	160	117
Organic	Corn-Soybean-Oat/Alfalfa	115	118
	Corn-Soybean-Oat/Alfalfa-Alfalfa	109	109

Reducing risk: transition years. Transition gradually one field at a time rather than the whole farm at once. Choose a field with high fertility, good drainage, and low weed pressure to start transition. Plan ahead financially before transition.

"Corn is the most difficult crop in which to begin a successful transition to a nonchemical farming system."
—Dr. Jeff Gunsolus, 1990

CROPS TO PLANT DURING TRANSITION

What should be planted during transition? Because the learning curve for beginning organic growers can be steep, it is often recommended that they start with a crop they know. In general, this is a solid rule of thumb, with the exception of corn. Because corn has a high nutrient demand, it is sometimes recommended that growers transition to organic production with other crops. Crops, such as flax, that are not competitive with weeds may also be risky during transition.

Numerous organic producers in Minnesota recommend alfalfa as a good crop during transition because stands are often maintained for two to three years following the seeding year.

Figure 8-3. *Organic alfalfa harvest at Lamberton, MN. Alfalfa is a low-risk crop to grow during transition.*

Vigorous-growing, nitrogen-fixing forage legumes for pasture or hay make excellent candidates for the transition period. Planting legumes during transition can reduce the risks of inadequate fertility. Growing alfalfa or red clover for two years before growing a row crop like corn provides a low-risk transition because these crops decrease weed pressure and provide nitrogen to subsequent crops. Alfalfa in rotations has an important role in soil improvement and in boosting yields of rotations during the transition period (Figure 8-3). Soybean has also proven to be a good candidate in Iowa with transition year yields that can be equivalent to conventional yields (see Table 8-2). Organic producers, either transitioning or established, need to consider crop needs for nutrients over the long term.

Reducing risk: crops for transition. Growers need to plan ahead and select a crop that they are familiar with and that has lower input needs. A forage crop like alfalfa may be a better choice for transition than corn because established stands are effective against weeds and alfalfa adds N to the soil.

Experienced organic farmers agree that soil testing is especially important during transition.

One couple who farms organically in Wadena County say buckwheat is a good crop for transition. Buckwheat is easy to grow and very competitive with weeds. It is also known as a nutrient scavenger.

Table 8-4. Certifying agencies.
Adapted from MOSES, 2010 and Minnesota Department of Agriculture, 2009.

Global Organic Alliance PO Box 530, Bellefontaine, OH 937-593-1232 www.goa-online.org	Ohio Ecological Food & Farm Association 41 Croswell Rd, Columbus, OH 614-262-2022 www.oeffa.org
Guaranteed Organic Certification Agency 5464 Eighth Street, Fallbrook CA 760-731-0496 www.goca.ws	OneCert, Inc. 2601 B Street, #1, Lincoln, NE 402-420-6080 www.onecert.net
Indiana Certified Organic LLC 8364 S State Route 39, Clayton, IN 317-539-4317 www.indianacertifiedorganic.com/	Oregon Tilth, Inc. - Midwest Office P.O. Box 269, Viroqua, WI 608-637-8594 www.tilth.org
International Certification Services/ FarmVerified Organic 301 5th Ave SE, Medina, ND 701-486-3578 www.ics-intl.com	Organic Certifiers, Inc. 6500 Casitas Pass Road, Ventura CA 805-684-6494 www.organiccertifiers.com/
Iowa Department of Agriculture and Land Stewardship 502 East Ninth Street, Des Moines IA 515-281-7656 www.iowaagriculture.gov/Ag Diversification/organicCertification.asp	Organic Crop Improvement Association - Minnesota Chapter #1 2609 Wheat Drive, Red Lake Falls MN 218-253-4907 www.mnocia.org
Maharishi Vedic Organic Agriculture Institute PO Box 2006, Fairfield, IA 641-469-5477 www.mvoai.com	Organic National & International Certifiers 7301 N. Lincoln Ave, Suite 198, Lincolnwood, IL 847-763-0218 www.on-ic.com
Midwest Organic Services Association PO Box 821, 122 W Jefferson St, Viroqua, WI 608-637-2526 www.mosaorganic.org	Pennsylvania Certified Organic 406 South Pennsylvania Ave, Centre Hall PA 814-364-1344 www.paorganic.org
Minnesota Crop Improvement Association 1900 Hendon Ave, St. Paul, MN 612-625-7766 www.mncia.org	Quality Assurance International 9191 Towne Centre Drive, Ste 510, San Diego CA 858-792-3531 www.qai-inc.com
Nature's International Certification Services PO Box 131, Viroqua, WI 608-637-7080 www.naturesinternational.com	Quality Certification Services PO Box 12311, Gainesville FL 352-377-0133 www.qcsinfo.org
OCIA International, Inc 1340 N Cotner Blvd, Lincoln, NE 402-477-2323 www.ocia.org	Pro-Cert Organic Systems Ltd. Box 100A, RR #3, 475 Valley Road, Saskatoon Saskatchewan, CANADA 306 382-1299 www.pro-cert.org
	QMI-SAI Organic Inc. P.O. Box 20067 – RPO Beverly, Edmonton, Alberta CANADA 780-496-2463 ext. 2 www.qmi.com

GETTING CERTIFIED

An inspection by the certifying agency will be necessary at the minimum in the third year of transition three months before the crop requiring certification is harvested. Producers should select a certifier that currently operates in their area (Table 8-4). Consulting with other local organic farmers is a good way to get recommendations on certification agencies.

Once a certifier is selected, contact the agency for an application and instructions on the process. The certifier will give instructions for how to complete the Organic System Plan. Soon after, producers will need to prepare for the certifier to conduct the first inspection. See Table 8-5 for a list of items needed for an inspection. The certifier will inform the producer of any changes that need to be made before certification is granted. The entire certification process may take a few months so producers should plan accordingly. After that, certification must occur on a continuing, yearly basis for as long as one wishes to be certified.

One thing to note for the transitioning farmers: at the bare minimum producers will have to follow the NOP guidelines for organics, but certifiers may

Table 8-5. Inspection checklist for organic crop producers.
Adapted from ATTRA, 2005.

- List of crops grown
- Maps of fields
- Field history
- Field activity logs
- Yield history
- Input purchase/source records
- Input application records
- Seed records
- Audit trail documents
- Soil management activities
- Pest management activities
- Organic integrity – measures taken to avoid contamination
- Certification documents
- Labels
- Sales invoices
- Lot numbers

also have their own requirements depending on the agency. Sales to Europe or Japan will have additional certification guidelines. It will be good to study these guidelines before proceeding with potential crops to be sold outside of the United States.

Reducing risk: certification. **Plan in advance so that your certifier has time to complete the process before certification is needed. Know NOP rules so that they are followed properly and surprises do not occur at inspection. Have all the items on the checklist ready for when the inspection occurs. Producers pay for inspections so it is in a producer's best interest to help the inspector operate efficiently.**

BOB NICHOLS, ARS

Figure 8-4. *Above, organically grown corn has more weeds late in the season, but yields here were similar to those of conventionally grown corn, below.*

Reducing risks in becoming organic

Producers considering becoming organic often have three major questions on transitioning: Will yields be low? Can organic farming be profitable? How will being organic affect workload? The following sections address what to expect in becoming organic and how to minimize risks in these areas.

ORGANIC YIELDS

Whether or not there are substantial yield differences between organic and conventional producers can be a contentious issue among the proponents and opponents of organic agriculture. Research results on this topic vary. Sometimes yields are lower and sometimes they are comparable. Generally, forages and many small grains will have similar yields, while row crops will vary in yields more (Tables 8-6 &

Table 8-6. Organic yields as a percentage of conventional yields – a summary of experiments that compare the two systems. *Lack of good weed control in the organic systems was often a factor when yields were in the lower range. Adapted from Posner et al, 2008.*

CROP	% OF CONVENTIONAL YIELD (RANGES)
Corn	72 - 114
Soybean	64 - 111
Small grains	90 - 100
Forages	96 - 100

Table 8-7. Yields of conventional and organic crops at Lamberton, MN in 1993-1999. *Oat and alfalfa yields were the same regardless of system. Corn and soybean yields were lower in organic systems; however net returns were not lower (see Table 8-8). Adapted from Porter et al., 2004.*

CROPPING SYSTEM	ROTATION	CROP	YIELD
Conventional	Corn-Soybean	Corn	139 bu/ac
		Soybean	41 bu/ac
	Corn-Soybean-Oat/ Alfalfa-Alfalfa	Corn	137 bu/ac
		Soybean	43 bu/ac
		Oat	52 bu/ac
		Alfalfa	5 T/ac
Organic	Corn-Soybean-Oat/ Alfalfa-Alfalfa	Corn	129 bu/ac
		Soybean	34 bu/ac
		Oat	52 bu/ac
		Alfalfa	5 T/ac

8-7). Weeds are one of the biggest contributors to lower yields in organic systems. See Chapters 5, 6, and 7 for more information on weeds.

In the 2007 MDA survey of organic agriculture, producers indicated that the number one production challenge was weed control. This issue is frequently the topic of discussion among organic farmers.

Reducing risk: organic yields. Develop an effective crop rotation strategy that will reduce weeds and enhance soil quality from year to year. Use legume and green manure crops to reduce weeds, improve soil structure, and enhance nutrient levels. Plant crops at the appropriate time to take advantage of weed control strategies. Timing of weed control operations is critical.

Weeds may be a problem at first when transitioning, but established producers say that these issues become more manageable over time. This is likely to occur because an organic crop rotation reduces the weed seed bank in the soil and because producers become more proficient in weed control using tillage.

ORGANIC CERTIFICATION COST SHARE

The Minnesota Department of Agriculture offers a rebate program for organic certification costs through a program in conjunction with the USDA. Certified producers from Minnesota are eligible for reimbursement of up to 75% ($750 maximum) of their certification expenses. See this website for an application and for more information on the organic certification cost share program: http://www.mda.state.mn.us/food/organic.aspx

Realize that you will be under more scrutiny from your conventional neighbors when you are organic. One organic farmer from Redwood County says that having your field near a highway is a "risk" because people will be able to monitor you more!

ORGANIC NET RETURNS

As there is a potential for lower yields (depending on the crop), the next logical question producers considering an organic system may be "Can an organic agriculture be profitable?" The good news is that while yields sometimes may be lower, the cost for inputs is also lower. As a result, organic production can be just as profitable. Net returns in organic production can be similar to or higher than conventional production (Table 8-8).

The Minnesota Department of Agriculture (2008) and the Center for Farm Financial Management at the University of Minnesota recently issued a report that uses data from organic farmers from the years of 2006 and 2007 to summarize production, finances, and profitability. They found that compared to conventional farmers, organic farmers derive more of their profits from operating efficiency and organic premiums, whereas conventional farmers get their profits from volume of sales. Both systems can be profitable.

Table 8-8. Net returns of conventional and organic crops at Lamberton, MN in 1993-1999. *Even without organic premiums, the annual return per acre for the organic management systems was similar to the conventional management systems. While yields can be lower in the organic system, there are also lower production costs resulting in a net return similar to conventional. Adapted from Mahoney et al., 2004*

CROPPING SYSTEM	ROTATION	ORGANIC PREMIUM	NET RETURN PER ACRE
Conventional	Corn-Soybean	no	$153
	Corn-Soybean-Oat/ Alfalfa-Alfalfa	no	$172
Organic	Corn-Soybean-Oat/ Alfalfa-Alfalfa	no	$175
		yes	$270

Reducing risk: net returns. Reduce marketing risks by identifying your market or establishing contracts in advance of planting. Be aware that prices can be volatile depending on demand relative to supply.

ORGANIC MANAGEMENT ROUTINE

Organic production can place greater demands on the producers' management skills and time compared to conventional production. Producers may need more hours to complete a greater number of field operations (Table 8-9). The demands on time will be magnified as farm size increases.

There is also the issue of timing your operations, particularly weed control operations. There can be less leeway in choosing when to be in the field. Operations will need to be performed when the weather permits

Table 8-9. A comparison of time spent per acre for organic and conventional corn and soybean production in Minnesota and Iowa. *Organic production required more labor, particularly in soybean production. Adapted from the Minnesota Department of Agriculture, 2007 and Delate et al., 2006.*

			LABOR HOURS/ACRE	
CROP	SYSTEM	LOCATION	ORGANIC	CONVENTIONAL
Corn	Organic	MN	2.77	2.57
Corn	Organic	IA	2.19	1.15
Soybean	Organic	MN	3.28	1.89
Soybean	Organic	IA	3.58	1.05

A producer from Waseca County recommends that transitioning farmers get front-wheel drive tractors to be able to get through muddy patches. Weeds have a critical time when they need to be controlled and weather conditions may leave fields wet during this time. Any added flexibility in timing weed control operations will be helpful in management.

and when weeds are at the stage at which they can be managed. Missing critical stages for weed control can have disastrous consequences.

Reducing risk: management routine.

Be prepared to spend more time in the field, depending on the crop. Maintain a flexible schedule, particularly when critical operations need to be performed.

Conclusion

This publication discusses many ways that organic producers can manage risk.

Fortunately, any farmer who desires to become an organic producer will not have to be on their own. It is important to develop relationships with other organic producers to transfer knowledge. There are organic field days, conferences, and workshops sponsored by non-profit organizations, universities, and state and federal agriculture departments throughout the year. In addition, there are programs that have experienced organic farmers who mentor new and transitioning farmers. For further information on these programs, see the "For more information" section at the end of this chapter for details.

Take the following risk management quiz to gauge your risk in transitioning to organic farming.

There are two keys to success for farming organically, according to one experienced organic producer from McLeod County:

- ✔ **Use rotation to manage fertility and weeds**
- ✔ **Properly time your weed-control operations**

Risk Management Quiz—Transitioning

	Points	Score
1. Why are you considering transitioning to an organic system?		
Philosophical reasons	2	
Monetary reasons	0	
Health reasons	2	
Environmental reasons	2	
One or more of the above reasons	5	
Not sure	0	
2. Do you have any previous experience with low-input or sustainable farming?		
Yes	5	
No	0	
Not sure	0	
3. How diverse is your current rotation?		
2 crops	0	
3 crops	2	
4 or more crops	5	
4. Do you know any farmers in your area who are transitioning or already organic?		
Yes	5	
No	0	
Not sure	0	
5. Do you believe there may be a social stigma against organic farming in your area?		
Yes	3	
No	0	
Not sure	0	
6. In which of the following activities have you participated? ***Score one point for each type of activity.***		
Organic conference	1	
Organic field day		1
Organic workshop	1	
Membership in a group such as Land Stewardship Project or Sustainable Farming Association	1	
Organic online community	1	
Organic mentoring program	1	

	Points	Score
7. In which of the following activities will you participate in the future? ***Score one point for each type of activity.***		
Organic conference	1	
Organic field day	1	
Organic workshop	1	
Membership in a group such as Land Stewardship Project or Sustainable Farming Association	1	
Organic online community	1	
Organic mentoring program	1	
8. How flexible is your schedule?		
I have very little extra time	0	
My schedule is flexible; I can make time when necessary	3	
9. Do you enjoy being in the field?		
Yes	5	
No	0	
10. How confident are you in your knowledge of the NOP rules that apply to your operation?		
Very	5	
Somewhat	3	
Not very	1	
Not sure	0	
11. Do you know which amendments are allowed under NOP rules?		
Yes	5	
No	0	
Not sure	0	
12. Have you contacted a certifying agency?		
Yes	3	
Not yet	0	
13. Do you know what items are needed for an inspection?		
Yes	5	
No	0	
14. Do you know where to find organically certified seed?		
Yes	3	
No	0	
Not sure	0	

	Points	Score
15. Do you have a local source for manure or compost?		
Yes	5	
No	0	
Not sure0		
16. Do you plan to conduct regular soil testing during transition?		
Yes	3	
No	0	
Not sure	0	
17. Do you currently have an organized method for keeping records?		
Yes	5	
No	0	
18. Are you financially prepared for transition?		
Yes	5	
No	0	
Not sure	0	
19. How much of your farm do you intend to transition?		
One or two fields	5	
Whole farm	0	
I am purchasing/renting organic land	2	
20. Which of the following crops do you primarily plan to grow during transition?		
Hay or forages	5	
Fallow/CRP	3	
Row crops	1	
Different types of crops	2	
21. Do you have the equipment for planting and harvesting crops for a diverse rotation?		
Yes	5	
No	0	
22. Can you tolerate the prospect of more weeds in your fields?		
Yes, I think so	3	
No, not sure	1	
23. Do you have the equipment for diverse weed control operations?		
Yes	5	
No	0	
24. Do you know where you will sell your organic crops once you are certified?		
Yes	5	
Yes, for most crops	2	
No	0	
	TOTAL	

If your score is:	Your risk is:
71 or above	Low
45 to 70	Moderate
44 or less	High

FOR MORE INFORMATION

USDA National Organic Program. http://www.ams.usda.gov/AMSv1.0/nop

Farm Business Management for Organic Producers. This program provides money for cost-sharing tuition for organic farmers who enroll in the farm business management program. http://www.mda.state.mn.us/fbm

The New Farm Organic Price Report from the Rodale Institute. This website shows the organic premiums by crop by week. http://www.newfarm.org/opx/

The Crop Conversion Calculator – allows producers to compare organic and conventional management at their own location. http://www.tritrainingcenter.org/code/farmselect/

Farm Financial Database – provides financial reports including expenses and costs of production based on information collected from over 70 organic farms in Minnesota. http://www.finbin.umn.edu/

Minnesota Department of Agriculture. Organic certification cost share. http://www.mda.state.mn.us/food/organic.aspx

How to Go Organic. Organic Trade Association. http://www.howtogoorganic.com/

Guidebook for Organic Certification, Third Edition. Midwest Organic and Sustainable Education Service – MOSES. http://www.mosesorganic.org/guidebook.pdf

Organic Agriculture. Minnesota Department of Agriculture. http://www.mda.state.mn.us/food/organic.aspx

Minnesota Organic Conference and Trade Show. This conference is held every January in St. Cloud, MN. http://www.mda.state.mn.us/

MOSES Organic Farming Conference and Organic University. This conference is held every February in LaCrosse, WI. http://www.mosesorganic.org/conference.html

Midwest Organic and Sustainable Education Service. http://www.moses-organic.org/

Organic Ecology, University of Minnesota. Provides information about organic research and activities. http://organicecology.umn.edu/

Minnesota Organic Farmers' Information Exchange (MOFIE). Experienced organic farmers from Minnesota will answer questions on organic production topics. http://mofie.cfans.umn.edu/

MOSES Farmer-to-Farmer Mentoring Program. Transitioning farmers are paired up with experienced organic farmers. http://www.mosesorganic.org/mentoring.html

Natural Resources Conservation Service. Environmental Quality Incentives Program (EQIP) Organic Initiative. This program provides funding to organic and transitioning producers to assist in conservation practices. http://www.mn.nrcs.usda.gov/

eOrganic. A web community where those involved in organic agriculture can collaborate. http://eorganic.info/

University of Minnesota Southwest Research and Outreach Center. Holds an organic field day every July. http://swroc.cfans.umn.edu/index.html

ATTRA, National Sustainable Agriculture Information Service. Organic Crop Production Overview. http://attra.ncat.org/attra-pub/organiccrop.html

The Rodale Institute. Guide to US Organic Certifiers. http://newfarm.rodaleinstitute.org/ocdbt/

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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).

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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

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

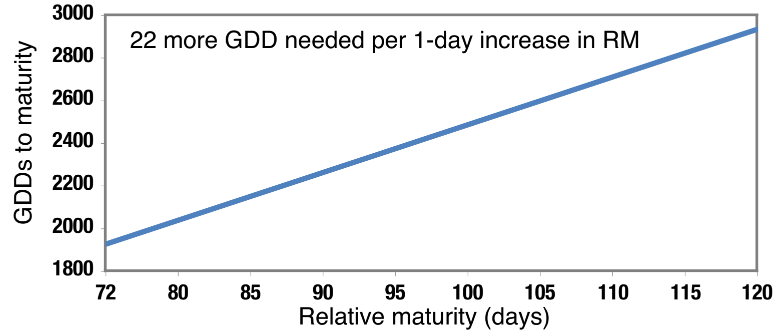

Figure 9-5. ***Relationship between growing degree days (GDDs) required for corn physiological maturity and relative maturity for 480 corn hybrids from four seed companies. Adapted from Coulter and Van Roekel, 2009.***

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.

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.

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

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

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

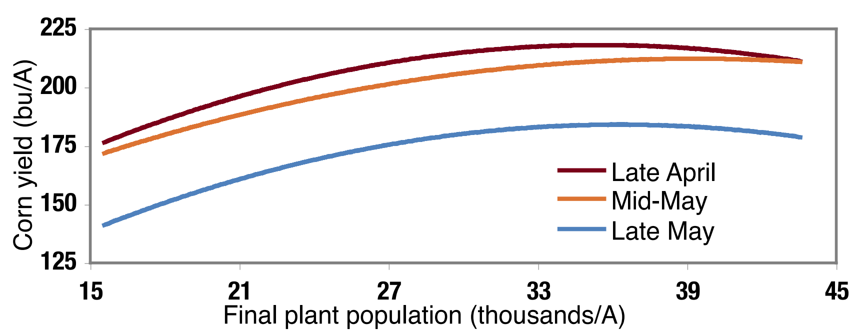

Figure 9-8. ***Response of conventional corn grain yield to final plant population by planting date at Lamberton and Waseca, MN in 2008 and 2009. Adapted from Coulter, 2009a.***

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.

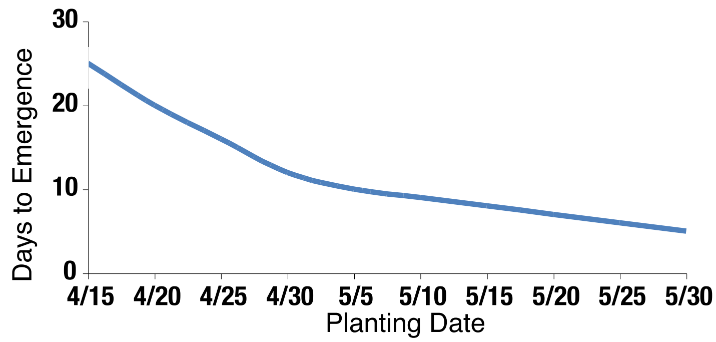

Figure 9-9. *Days to emergence will vary by planting date. When planted on April 15th, seed takes 25 days to emerge, while planting on May 10th (a typical corn planting date for Minnesota organic farmers) seed takes 9 days to emerge. Good weather conditions can sometimes make up for some lost time of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

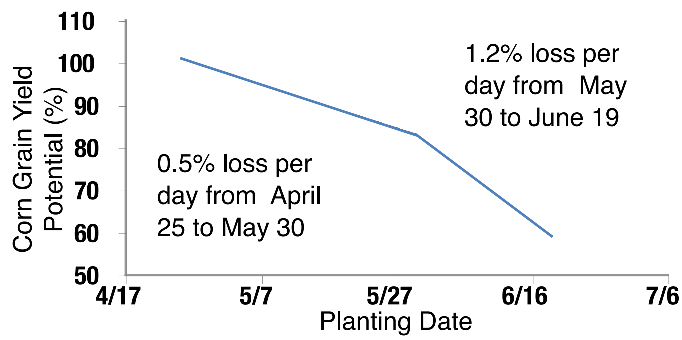

Figure 9-10. *Potential yield loss at later planting dates. Adapted from Hicks et al, 1999.*

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.

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.

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

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.

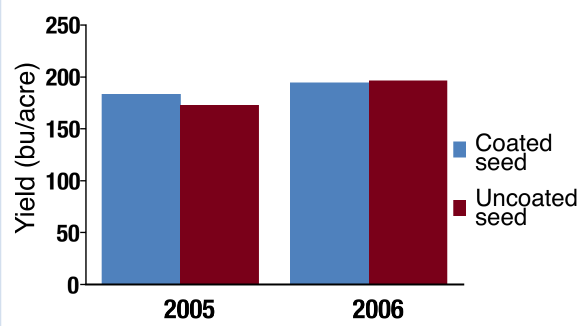

Figure 9-11. *Corn yields of organic coated (Agricoat Natural II) and uncoated seed of the same variety in 2005 and 2006. In 2005, a cooler season, the seed coat treatment had a significantly higher yield, while in 2006, which was warmer, there were no significant yield differences. Delate et al., 2006.*

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.

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

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

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.

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.

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

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

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.

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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CHAPTER 10

Soybean Production

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Minnesota ranks third in the nation for number of acres in soybean production. Organic soybean production in Minnesota ranges from 25,000 to 30,000 acres per year. Net returns for organic soybean production tend to be similar to those for conventional production (Table 10-1).

Organic soybeans are typically divided into two types: food-grade and feed-grade (Figure 10-2). The majority of food-grade organic soybeans are used in products such as tofu, miso, natto, tempeh, or soymilk produced in the U.S. or abroad. Soybeans can be clear-hilum or dark-hilum. Soybeans used for tofu are required to be clear-hilum, but products such as soymilk can utilize clear-hilum or dark-hilum beans. Feed-grade soybeans can be used for organic livestock feed and oil. Food-grade soybeans that do not meet standards (because of staining, immature beans, or other reasons) can be used as

Table 10-1. Net returns per acre of soybean in Minnesota for organic and conventional producers, 2006-2008. *Adapted from FINBIN, 2009.*

Operation	2006	2007	2008
Organic	-$20	$ 95	$163
Conventional	$33	$135	$87

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Figure 10-1. *Soybeans.*

feed. A third type of soybean is a vegetable type used for edamame, where soybean pods are harvested green and soybeans are consumed while immature.

In the Upper Midwest, soybeans are an important part of organic producers' rotations. Soybean has lower fertility requirements than corn and because it is a nitrogen-fixing legume, a productive crop of soybean can provide some nitrogen to a subsequent crop. During the growing season, a crop of soybean can fix well over 100 pounds/acre of nitrogen. However, after harvest only about 30 to 40 pounds/acre of nitrogen remains, because most of the nitrogen is removed from the field with the harvested grain.

SCOTT BAUER, ARS.

Figure 10-2. Soybean types. *The largest soybean above is a tofu type, the one at right is a typical feed-grade soybean, and the smallest one at the bottom is used for fermented soy products.*

An organic producer from Lac Qui Parle County says these are the things he considers in order of importance when choosing a soybean variety:

1. **Maturity date**
2. **Ability to canopy**
3. **Emergence**
4. **Competitiveness**
5. **Height**

Variety selection

Organic producers must use organically grown seed unless unavailable, in which case, conventional seed is allowed if it is untreated and non-GMO.

There are several companies producing organically certified soybean seed as well as conventional non-GMO seed that can be used in organic systems. A list of some organic seed suppliers for the Upper Midwest is given in Chapter 8. Some can provide information from variety trials.

Soybean breeding at the University of Minnesota

Dr. James Orf has produced more than 100 varieties of soybeans during his career at the University, many of which benefit organic producers when they are bred using conventional rather than transgenic techniques. One example is 'MN1001SP', a small-seeded, natto type of soybean. Several superior natto types have been released. Natto types are used a fermented soybean-based food that is very popular in Japan. Other releases include 'MN1601SP', a large-seed type used in tofu and soymilk.

The University of Minnesota soybean breeding program periodically releases non-GMO varieties that are suitable for organic production. Recent examples include 'MN 1410', 'MN1011CN', and 'MN0101', which include disease resistance traits typically only found in GMO varieties. Information on new varieties is available at www.maes.umn.edu .

A portion of Dr. Orf's program includes a research project examining whether organic soybean would benefit from having a separate breeding program from conventional soybean. The results of this experiment may lead to lines of food-grade soybean that are particularly adapted to organic conditions.

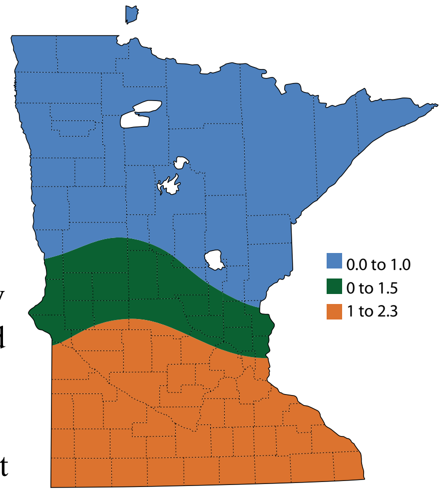
SELECTION FACTORS

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. High-quality seed with good germination that is uniform in size, clean, whole, and lacking discoloration makes for a high quality stand and valuable crop. Certified seed meets these requirements. Growers are encouraged to check with buyers to identify the characteristics (size, color, protein, and oil concentration) they require.

Soybean variety selection has several important considerations listed below in order of importance. These include:

- Maturity
- Yield potential
- Disease resistance
- Other traits

Many Minnesota organic soybean growers from the Southern Zone choose varieties with relative maturities in the range of 1.2 to 1.4.



Soybean Relative Maturities for Minnesota

Figure 10-3. ***Map of Minnesota and recommended maturities of soybean. Organic producers who delay planting will need to choose earlier-maturing varieties. Adapted from University of Minnesota Extension.***

Table 10-2. Soybean maturities recommended for late planting.
Adapted from Hicks and Naeve, 1999.

DATE	SOUTHERN	SOUTH CENTRAL	CENTRAL
June 20	1.5	0.6	0.6
July 1	0.6	0.0	00.7
July 10	0.0	00.7	00.7

Maturity group

Selection of a soybean variety will be based primarily on the relative maturity (RM) required for a given locale. Because soybeans are sensitive to changing day length, the date of maturity will be affected by latitude. Varieties have a narrow range (north to south) of adaptation. A variety must reach physiological maturity (95 percent of pods show their genetically determined mature color) before frost in order to obtain maximum yield and quality.

The recommended soybean relative maturities for the different regions of the state are shown in Figure 10-3. Because many organic farmers delay planting, their choices in relative maturities may be lower than conventional farmers. See Table 10-2 for maturities recommended when planting is delayed past mid-June.

Yield potential

Selecting varieties for high yield and a stable yield across many locations and multiple years will minimize risk. Data from seed company, independent, and University field trials are all good sources of information for assessing whether a variety will yield well over time. The University of Minnesota conducts variety trials under conventional conditions and includes non-GMO varieties in these trials. Occasionally, organic soybean trials are conducted. See http://www.soybeans.umn.edu/ for more information. Other universities in the Upper Midwest also conduct variety trials on soybean (Table 10-3).

Disease resistance

Several soybean diseases including soybean cyst nematode (SCN), sudden death syndrome (SDS), brown stem rot (BSR), iron deficiency chlorosis (IDC), and Phytophthora root/stem rot can seriously reduce soybean yield in the Upper Midwest. Many varieties have good resistance or tolerance to these diseases, and selection for both yield and resistance to known problematic diseases are important criterion for soybean selection. Variety trials often report information on disease resistance.

Other traits

Grain composition, plant height, lodging, and other special use characteristics such as size and color are additional traits the grower will need to consider in selecting a variety.

Oil, protein, and amino acid concentration are among the grain composition traits that need to be determined. The potential for lodging is enhanced with soybeans of taller heights. Lodging increases risk for preharvest losses and makes harvest more difficult. Some food-grade varieties are more susceptible to lodging (Table 10-4).

A producer's market or contract will also affect which variety is used. Most food-grade soybeans are grown under contract and may have special requirements such as grain characteristics or storage practices. Seed costs for food-grade soybean may be higher and yields can sometimes be lower, but they may also have higher premiums.

Table 10-4. Organic soybean variety trial in Clay County, MN, 2003. *Natto types like 'Nornatto' and 'Nannonatto' generally had lower yields and higher lodging. Adapted from Kandel and Porter.*

VARIETY	YIELD (BU/A)	LODGING (1-6)*
Atwood	31.9	1.0
S 08-80	31.6	1.0
Surge	31.3	1.0
Minori	30.4	1.5
Panther	29.9	1.0
Nornatto	27.6	4.0
Bravado	23.8	2.0
Nannonatto	23.6	4.0
Colibri	22.7	2.0

* Lodging score; 1 = no lodging
3 = some lodging
6 = significant lodging

Table 10-3. University soybean variety trials in the Upper Midwest.

UNIVERSITY/WEBSITE	NOTES
University of Minnesota Agricultural Experiment Station *http://www.maes.umn.edu/vartrials/soybean/index.asp*	Includes non-GMOs and specialty varieties
University of Minnesota *http://www.soybeans.umn.edu/*	Occasional organic on-farm trials
Iowa State University *http://extension.agron.iastate.edu/organicag/rr.html*	Dedicated trials to organic varieties
Iowa State University *http://www.croptesting.iastate.edu/soybeans/reports.php*	Includes non-GMOs
University of Wisconsin *http://soybean.uwex.edu/soytrials/printable/index.cfm*	Includes non-GMO varieities and some organic on-farm trials
University of Illinois at Urbana-Champaign *http://vt.cropsci.illinois.edu/soybean.html*	Includes non-GMOs
South Dakota State University *http://plantsci.sdstate.edu/rowcrops/soybean/index.cfm*	Includes non-GMOs
North Dakota State University *http://www.ag.ndsu.edu/varietytrials/soybean*	Includes non-GMOs and specialty varieties

Figure 10-4. *Soybean varieties can vary dramatically in their size. Seeding rates are determined by seeds per acre rather than pounds per acre.*

Reducing risk: variety selection. Choose more than one variety for your farm to spread out the risk. Consider planting different maturities to spread out the timing of field operations. Always choose the correct maturity for a location. Choose disease resistance traits for foreseeable disease issues. Food-grade soybeans generally require an established market. Food-grade soybean will be riskier to grow due to greater stringency in quality requirements. When trying a new variety, plant a small test plot strip before committing to a whole field.

Fertility

Soybean is a nitrogen-fixing legume crop that will provide its own nitrogen when the correct rhizobia bacterium is present in the soil and good nodulation is achieved. Inadequate nitrogen can be an issue if producers have persistent poor nodulation or are located on heavy soils that are commonly saturated, cold, and low in bacterium populations, such as in the Red River Valley in northwestern Minnesota. In such instances, soybean will generally need to be inoculated with the proper rhizobium (which must be approved for organic production) every time that it is planted. However, in most other areas of Minnesota and the Upper Midwest, inoculation is generally not needed if soybean has been grown within the last four years, and most likely will not increase yield.

Potassium and phosphorus will need to be provided when growing soybean if these nutrients are found to be low in soil tests. Usually in Minnesota, other secondary nutrients do not require direct supplementation as supplies in soil are adequate. Manure is a good source of the nutrients that soybean requires and can increase yields. However, manure application can lead to lodging and white mold.

Soil pH in the 6.0 to 7.3 range is optimum for soybean, and a wide variety of soils are tolerated. When soil pH is 7.4 or higher, soybean will exhibit symptoms of iron deficiency. At these pH levels, iron is present in adequate amounts in the soil, but it is not available. As a result, soybean plants will exhibit iron deficiency symptoms that include yellowing (chlorosis) on new growth. Some varieties are more susceptible to iron chlorosis than others, so choosing a variety with better resistance is a tactic to counter iron deficiency on high pH soils.

Reducing risk: fertility. Use soil testing to determine possible deficiencies and use amendments only when necessary. If soil pH is 7.4 or above, choose varieties with resistance to iron chlorosis.

Table 10-5. Organic soybean yield in bu/ac near Pittstown, NJ, under narrow and wide row systems. *In 2001, yields were not significantly different, but in 2002, wide-row systems had higher yields. Adapted from Kluchinski and Singer, 2005.*

	TREATMENT		
Row Width	Mechanical weed control	2001	2002
Narrow	1 rotary hoeing	45	27
Narrow	2 rotary hoeings (2nd hoeing 4 days later)	40	23
Narrow	2 rotary hoeings (2nd hoeing 8 days later)	40	33
Wide	2 rotary hoeings (2nd hoeing 8 days later)	46	39
Wide	1 rotary hoeing, 1 late cultivation	45	44
Wide	1 rotary hoeing, 2 cultivations	37	54

Planting

SEEDING RATE

Growers need to plant at a seeding rate to optimize yield and to make the crop competitive with weeds. The effects of lower planting rates on yield are shown in Figure 10-5. Seeding rate depends on a number of factors, including the variety grown and the productivity of the soil. Many organic producers in Minnesota plant at least 160,000 seeds/acre or more. A higher planting rate can help counter seedling losses that occur during weed control operations.

The row widths that organic producers use for soybean in Minnesota vary. Some plant in 22-inch rows, and feel that the narrower rows lead to soybeans that are more competitive because a faster-forming canopy closure will shade weeds better. Others plant in wider rows (30- to 38-inches). Wide-row systems may provide greater flexibility in equipment and timing for weed control operations (Table 10-5).

PLANTING DEPTH

An optimal planting depth for soybean is typically one to one-and-a-half inches depending on soil conditions. Soybeans should never be planted deeper than two inches. Soybean emergence results from elongation of the hypocotyls, or the region of the stem between the primary root and the cotyledons. The region of the hypocotyl nearest the cotyledons appears as an arch, and pulls the cotyledons out of the soil. When planted too deep, the hypocotyls may not be able to elongate enough. In addition,

PRODUCER PROFILE

A producer from Pipestone County uses 36-inch rows and plants soybean around May 20th. He uses bin-run seed of a clear hilum type. His goal is to rotary hoe at least twice for mustard control. He tends to get good yields of soybean, around 40 bushels/acre. After harvest, he sells his soybeans to an organic dairy.

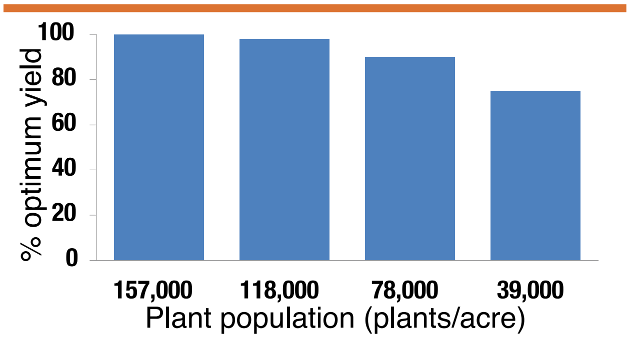


Figure 10-5. *Effect of population on yield. Less than optimum plant populations will lower yields. However, soybean can make up some yield under lower plant densities. Adapted from Hicks and Naeve, 1999.*

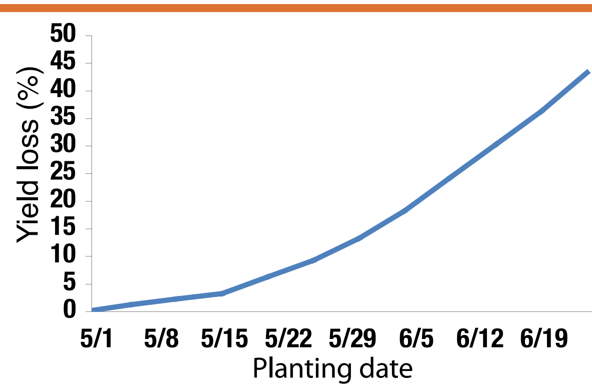


Figure 10-6. *Soybean losses due to late planting in Waseca and Lamberton, MN. Adapted from Hicks, 1999.*

Figure 10-7, at left. *Soybean rate and date study in Rosemount, MN. The larger soybean plants were planted earlier than the smaller ones.*

Soybean rate and date of planting study

With a grant from the Risk Management Agency, an experiment was conducted using various soybean varieties under different planting dates and seeding rates in organic production (Figure 10-7). The goal was to evaluate risks associated with delayed planting and seeding rates. The experiment was conducted in Rosemount, Waseca, and Lamberton, MN during 2006 to 2008. There were three planting dates: May 15, June 1, and June 15; and two seeding rates: 160,000 and 220,000 seeds per acre. The varieties included were IA1006, MN0901, MN1401, MN1503 and MN1604.

It was found that delayed planting resulted in lower yields (Figure 10-8). However, it was also found that delayed planting reduced weed populations. Plant population did not affect yield or weeds (Figure 10-9). MN1401 and IA1006 had the highest yields and MN1604 the lowest (Figure 10-10). Based on this study, it is not recommended that organic producers plant at the higher rate of 220,000 seeds per acre. Producers should plant soybean as early as they can, particularly on fields with low weed pressure, but delayed planting is still a valid option to manage weeds.

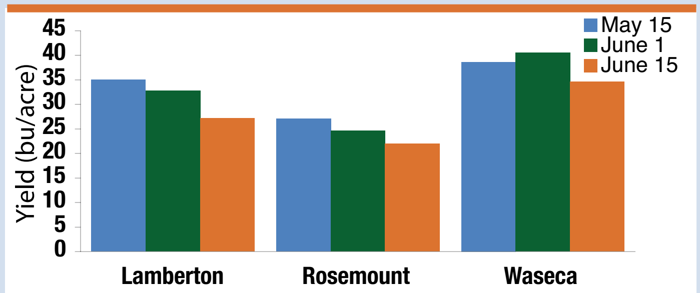


Figure 10-8. *Organic soybean yield by planting date at Lamberton, Rosemount, and Waseca, MN, in 2006-2008. The trend was for the earlier planting dates (May 15 and June 1) to yield better than the latest planting date (June 15).*

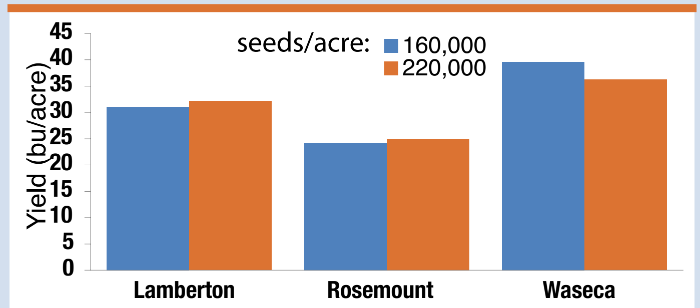


Figure 10-9. *Organic soybean yield by planting rate at Lamberton, Rosemount, and Waseca, MN, in 2006-2008. Increasing planting rate from 160,000 to 220,000 seeds/acre did not significantly increase yields.*

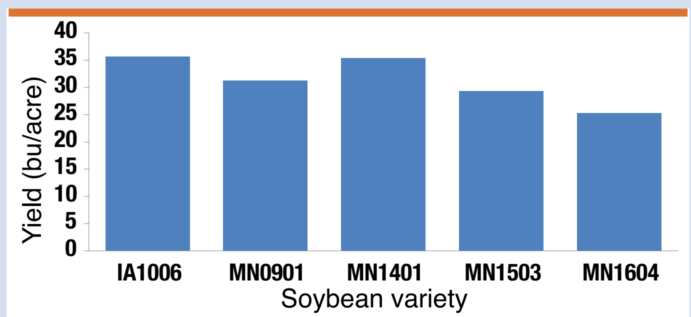


Figure 10-10. *Soybean yield by variety across Lamberton, Roasemount, and Waseca, MN. MN1401 and IA1006 had the highest yields and MN1604 the lowest.*

this hypocotyl arch can break during emergence when soybean is planted deep or if a soil crust is present. Soil crusting can result from heavy rains on recently tilled soil, particularly if the soil has high clay content. Soybean varieties are given emergence ratings based on their ability to emerge when planted deeper than two inches. Growers should be especially careful to avoid deep planting when using varieties with poor emergence ratings.

PLANTING DATE

Organic producers tend to plant soybean one to two weeks later than conventional growers, generally between May 20 and June 1. While delayed planting will reduce yield (Figure 10-6), it gives producers more time to manage weeds. Organic producers should choose earlier-maturing varieties when using later planting dates.

Reducing risk: planting. Plant one to one-and-a-half inches deep, and never plant deeper than two inches. Adjust seeding rate to compensate for losses in stand resulting from weed control operations. Adjust maturities when planting late.

Weed management

Weed management is important for maximizing organic soybean yield. Weeds that are problematic in organic soybean production include velvetleaf, giant ragweed, and cocklebur, among others. Tactics to manage weeds organically can be divided into cultural and mechanical control.

CULTURAL WEED CONTROL

Two effective cultural techniques for weed management are delayed planting and crop rotation. Delayed planting 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-Rotation for more information.

MECHANICAL WEED CONTROL

Early-emerging weeds are the most competitive with soybean and are the most important ones to control. The first five weeks after soybean emergence are most critical for weed control in order to avoid yield reductions. Seedbed preparation to kill early-emerging weeds is the first step. Weed control operations can include a rotary hoe, harrow, or tine weeder. Rotary hoeing or harrowing and the first row cultivation are the most important operations to reduce losses to weeds (Tables 10-6 and 10-7). Rotary hoeing can be done post emergence, but it is important to not perform this operation when soybeans are just starting

PRODUCER PROFILE

Here's how an organic producer from Faribault County controls weeds in soybean. He practices pre-emergence harrowing. At soybean emergence, he does one rotary hoeing. This is followed by two to three in-row cultivations, depending on weed pressure. He times the cultivations to weeds being less than 1 inch in size. Although it can be risky, he will flame soybean when weeds get a jump on the crop as a rescue operation. He finds it is okay to flame soybean at cotyledon stage. He will not flame at the trifoliolate leaf stage as this causes considerable damage to the soybean.

An organic producer from Cottonwood County believes there is not just one row width at which to plant soybean. He says there will be a tradeoff regardless of choosing wide (longer for canopy closure) or narrow rows (fewer cultivations). Although he is happy with his results in using 22-inch rows, he thinks there may be an advantage for wider rows in controlling perennial weeds because they allow more chances to cultivate.

to emerge and at the crook stage (when the stem of the seedling is shaped like a hook and the cotyledons are closed). Rotary hoeing can be done after the crook stage once the soybeans are at the trifoliate stage, and can continue until the soybeans are three inches tall. Postemergence rotary hoeing can be risky because the seedlings are delicate and some will be lost due to the operation; however, producers can compensate for losses with higher seeding rates.

When soybeans are in the third trifoliolate stage (four to five inches tall), row cultivation can begin. A variety of options for mechanical in-row weed control exist, but soil conditions, equipment, and operator skill will determine which practices

Table 10-6. Influence of planting date and mechanical weed control on lambsquarters, pigweed and velvetleaf in soybean at Rosemount, MN, during 1989 - 1991. *Rotary hoeing with row cultivation was the most successful tactic compared to either operation on its own. Late planting particularly decreased velvetleaf. Adapted from Buhler and Gunsolus, 1996*

PLANTING DATE	WEED CONTROL	LAMBSQUARTERS	PIGWEEDS	VELVETLEAF
			% control	
Mid-May	Rotary hoe (RH)	71	72	44
	Cultivation	55	62	51
	RH + Row cult.	90	91	78
Early June	RH	82	65	64
	Cultivation	84	71	63
	RH + Row cult.	95	96	95

Table 10-7. Planting date and mechanical weed control effects on giant foxtail in soybean in Rosemount, MN during 1989 - 1991. *Rotary hoeing with row cultivation was the most successful tactic compared to either operation on its own. Late planting sometimes decreased giant foxtail. Adapted from Buhler and Gunsolus, 1996.*

PLANTING DATE	WEED CONTROL	1989	1990	1991
			% control	
Mid-May	Rotary hoe (RH)	61	36	77
	Row cultivation	59	48	70
	RH + Row cult.	89	75	93
Early June	RH	65	71	85
	Row cultivation	68	71	66
	RH + Row cult.	91	92	98

Table 10-8. Scouting for weeds in soybean.
Adapted from Potter, 1999.

SOYBEAN GROWTH STAGE	SCOUTING / PLANNING
Pre-plant	Plan pre-plant weed control operations based on field history
Emergence to seedling	Evaluate effectiveness of pre-plant weed control operations
	Examine conditions for post-emergent weed control operations
	Note factors that may affect subsequent crops
Canopy to early-flowering	Evaluate for rescue operations
Harvest	Evaluate weed escapees, plan fall tillage

are best suited to a given field. Row cultivation will be most effective when weeds are less than one inch in size. Many organic producers cultivate two to three times per season. After this, mechanical weed control is complete. If rescue operations for weeds are needed after this point, it will entail laborers to walk the rows.

Scouting for weeds in soybean is a good risk management strategy. It is important to assess the predominant weeds in midsummer of the previous year to be able to plan for weed management in the next year. Scouting for weeds in soybean is critical before canopy closure, or about six weeks after planting, in order to determine if rescue operations are needed for weed control (Table 10-8).

Reduce risk: weed management. Weeds are easiest to control when they are small. Use a diversity of mechanical weed control methods. Rotate with non-row crops if possible.

Pest Management

Soybean aphid, soybean cyst nematode, and white mold are some of the common pests that organic producers in the Upper Midwest have to manage. Crop rotation and selecting resistant varieties are the first lines of defense in organic pest management.

SOYBEAN APHID

Soybean aphids (Figure 10-11) can now be found in every soybean-growing county of Minnesota. Organic producers have stated in the Minnesota Department of Agriculture's survey of organic agriculture that soybean aphid is their top insect problem.

JIM KALISCH, ARS

Figure 10-11. *Soybean aphid.*

Identification: Soybean aphids are less than 1/16 inch in length when mature and yellow in color. There are winged and wingless forms. They are commonly found on the underside of the youngest leaves (Figure 10-12).

Life cycle: Soybean aphid lays its eggs on common buckthorn in the fall to overwinter. Eggs hatch in the spring and the aphids move to their secondary hosts, which include soybean and several other species, including crimson clover and red clover. Soybean aphid is also able to survive on Kura clover, white sweet clover, and yellow sweet clover.

PRODUCER PROFILE

An organic producer from Lac Qui Parle County, MN, likes planting soybean earlier (compared to some organic producers) and using a later-maturing variety. Depending on seasonal conditions, he would be comfortable planting soybean as late as May 20th. The soil is usually warm enough then for quick emergence. In his experience, the planting date for organic soybean is more flexible than for organic corn.

He plants at 160,000 seeds per acre. He used to plant at 140,000 seeds per acre, but now prefers higher rates because it allows soybean to be more competitive with weeds. He finds that weed management in soybean is easier than in corn.

Crop damage: Although the pest is small in size, the buildup of large populations causes significant damage to plants. Feeding diverts sugars produced by photosynthesis and results in reduced growth, pod set, and yield. In addition to direct damage to the plant, soybean aphid can transmit diseases that hinder growth or kill the plant. Honeydew, the sugary excretion produced by aphids, attracts sooty mold, a fungal pathogen that covers leaves and reduces photosynthesis.

Reducing risk: soybean aphid. Choose resistant varieties when available. Maintain natural grass or woodland areas to attract beneficial predators of soybean aphids. Beneficial predators include minute pirate bugs, lacewings, assassin bugs, and Asian lady beetles. Organic growers are limited in their options once aphids are established in a soybean field. While there are organically-approved products available to treat soybean aphid, results may vary under field conditions (Tables 10-9 and 10-10). Use caution when evaluating products that claim to control soybean aphid, and assess economic costs of these products carefully.

Table 10-9. Effect of compost tea on soybean aphid at Lamberton, MN, in 2007.
The compost tea treatment was not significantly different from the control in aphid population level or soybean yield.

TREATMENT	APHIDS/ PLANT	YIELD (BU/ACRE)
Compost tea	239	41
No treatment	301	43

Figure 10-12. *Soybean infested with soybean aphid.*

Table 10-10. The effect of Neem, insecticidal soap, and Pyganic on soybean aphid in Clay County, MN, in 2007.
Products were applied at a 50 aphids per plant threshold. None of the organic insecticides reduced the population growth of the aphids. Adapted from Glogoza, 2008.

PRODUCT	APHID POPULATION DOUBLING TIME (DAYS)
Neem	3.4
Insecticidal soap	3.1
Neem + insecticidal soap	3.3
Pyganic	3.3
No treatment	3.2

Biocontrol control of soybean aphid

One way to reduce population levels of pest insects is through the use of natural predators and parasites. The University of Minnesota is conducting research on *Binodoxys communis*, a parasitoid wasp of soybean aphid that was found in China. This wasp lays eggs inside soybean aphids, eventually causing death to the aphid. Since this biological control insect occurs in regions of China with climate that parallels Minnesota, and because it is very effective in controlling soybean aphid in that country, it holds considerable promise as a biological control method for organic producers in Minnesota. Field trials are currently underway in Minnesota to determine if this wasp will be effective in reducing populations of soybean aphid, and if it can survive the winter. Other parasitic wasps are also being investigated.

Figure 10-13. *Female soybean cyst nematodes can be visible on plant roots.*

SOYBEAN CYST NEMATODE

Nematodes can be found in almost any soil sample. Most are beneficial, but a few, including soybean cyst nematode (SCN), are plant parasites. The known distribution on SCN is shown on Figure 10-14. It is predicted that this nematode will continue to spread throughout the rest of Minnesota. Organic farms are not immune from SCN (Table 10-11).

Figure 10-14. *Known distribution of soybean cyst nematode in Minnesota. Adapted from University of Minnesota Extension.*

Identification: Soybean cyst nematodes are a type of roundworm. They are generally microscopic, but in July and August, adult female nematodes can be seen on soybean roots. They are lemon-shaped and about 1/40 inch long. Positive identification of soybean cyst nematode may require a soil sample to be submitted to a lab that tests for nematodes. Growers will generally see damage from SCN when eggs in the soil are above the threshold of 500 eggs per 100 cubic centimeters of soil.

Life cycle: Once a SCN hatches from its egg into the soil, it goes through several juvenile stages. The nematode attaches to a host plant's root, where it feeds and completes its life cycle. These nematodes can be found on other plant species in addition to soy

Table 10-11. Soybean cyst nematode in organic systems in MN. *108 organic fields in southeast, southwest, west central, and northwest Minnesota were sampled for SCN in 2006. 37% of the organic fields had SCN. Some organic growers in the southeast and southwest had fields with damaging thresholds. No SCN were found in the northwest, but growers should not be complacent because the organism is spreading. Data courtesy of Senyu Chen, 2007*

REGION	% FIELDS with SCN	% FIELDS ABOVE THRESHOLD
Northwest	0	0
West-central	11	0
Southeast	45	23
Southwest	88	58

Table 10-12. Some hosts and non-hosts of the soybean cyst nematode. *Adapted from Chen et al, 2001.*

NON-HOST CROPS	HOST CROPS	HOST WEEDS
alfalfa	common vetch	common chickweed
barley	cowpea	common mullein
corn	dry edible bean	henbit
oat	snap bean	medics
potato	soybean	milk vetch
sorghum	pea (poor host)	mouse-ear chickweed
sugar beet	sweet clover	purslane
sunflower	alsike clover	crown vetch
red clover	crimson clover	
wheat	birdsfoot trefoil	
canola	hairy vetch	
white clover		
rye		
forage grasses		

Table 10-13. Levels of soybean cyst nematode on organic farms in Minnesota in 2006 as affected by crop rotation. *Three different organic rotations were compared. The least diversified organic rotation (corn-soybean with cover crop) was significantly higher in SCN egg counts. Rotations with soybean every three years or more had SCN below the damage threshold. Data courtesy of Chen, 2007.*

ROTATION	SCN level (eggs/100cc)
Soybean every other year	3657
Soybean every two years	1306
Soybean every three years	496
No soybean	0

bean, but there are a number of other crops that do not serve as hosts (Table 10-12).

Crop damage: Infected plants are stunted and chlorotic. The nematodes damage roots and restrict uptake of water and nutrients by the plant.

Reducing risk: soybean cyst nematode.

Prevention is the first line of defense. Thoroughly clean all soil from potentially contaminated equipment before using. Options for organic farmers who have SCN in their fields primarily include crop rotation and resistant cultivars. A diversified rotation will help SCN levels stay below damaging thresholds (Table 10-13). At least three years of non-host crops will be needed to lower the nematode populations below the damage threshold. Some crops are better than others in reducing SCN populations. Be aware that once fields are infested, even five years of a non-host crop will not eliminate SCN.

WHITE MOLD

White mold (*Sclerotinia sclerotiorum*) is a pathogenic fungus with a wide host range including soybean, green and dry beans, sunflower, canola, forage legumes, tomatoes, potatoes and many other vegetable crops. It can also infect weeds like pigweed, ragweed, lambsquarters, and velvetleaf.

Identification: The fungus can be seen on the stem in the form of a white cottony growth. Hard and black, irregularly-shaped structures are formed within the stem. Leaves turn brown and die prematurely, but remain attached to the stem.

Life cycle: This fungus persists in the soil for years. Under cool and moist conditions, the fungus forms fruiting bodies that release spores and infect plants.

Crop damage: White mold can reduce yield and cause plant death. The black fungal structures within the stems of infected plants can contaminate harvested soybeans.

Reducing risk: white mold.

Management practices are vital for reducing the risk of white mold in organic soybeans. Row spacing and planting population are critical factors. Narrow rows and higher plant populations increase the risk of white mold in soybean. Rotation with non-susceptible crops such as corn or wheat will reduce the organism in the soil. Because of its wide host range and its ability to survive for many years in the soil, controlling it through the use of rotation is only slightly effective. Selecting resistant varieties is the best way to reduce risk.

Reducing SCN

Research at the University of Minnesota found that some crops in a rotation may be better than others for reducing SCN (Table 10-14). Non-host or poor host crops may stimulate hatching, but not development and reproduction. They were superior in decreasing SCN populations.Grasses were the least effective in decreasing SCN numbers.

Table 10-14. Non-host crop effectiveness in reducing soybean cyst nematodes. *Adapted from Miller et al, 2006.*

MOST EFFECTIVE	LEAST EFFECTIVE
Alfalfa	Barley
Red clover	Corn
Pea	Oat
	Sorghum
	Wheat

JOHN DEERE

Figure 10-15. *Soybean harvest.*

SCOTT BAUER, ARS

Figure 10-16. *These soybeans are past physiological maturity. Pods are brown and leaves have fallen.*

Harvesting

An indication of physiological maturity for soybean is when the pods have no green color remaining. Harvest will generally occur about two weeks after physiological maturity (Figure 10-16). Soybean is traded at a standard 13 percemt moisture concentration, but soybean grain moisture drops rapidly after physiological maturity. Soybeans can be harvested at up to 18 percent moisture, but artificial drying will be necessary. A general guideline is to begin harvest when grain moisture drops below 15 percent. Mold can occur when soybeans are harvested at moisture levels higher than 13 percent, while harvesting at lower moistures can cause beans to split and increases gathering losses resulting from shattering of pods when stems are hit by the combine's cutterbar.

Combine adjustments are critical when harvesting soybean. Harvest losses can be substantial if equipment settings are not optimized. Monitor losses regularly while in the field and make adjustments when necessary. Clean, intact soybeans will get the highest prices.

Soybeans can be kept at 13 percent moisture for short-term storage and at 11 percent for long-term storage. Once dry, aerate grain to maintain temperatures of 50° F or less. During the winter, stored soybeans should be checked at least once or twice a month.

Reducing risk: harvesting. Timely harvest is critical for minimizing harvest losses. Begin harvest when seed moisture drops below 15 percent. The potential for gathering losses and seed damage increase greatly as seed moisture decreases. Store at correct moisture and temperature, depending on the length of storage time.

Conclusion

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

Soybean Risk Management Quiz

	Points	Score
1. What type of seed do you usually use when growing soybean?		
Conventional, untreated	3	
Organic	4	
Saved seed	1	
2. What type of soybean do you usually grow?		
Feed grade	4	
Food grade	2	
Specialty	2	
3. Which of the following do you use to choose a new soybean 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 varieties using maturity and yield potential as the primary determining 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 your soil tested before growing soybean to ensure there are adequate nutrients for a good yielding crop?		
Yes, always	3	
Yes, usually	2	
No	0	
7. What is your soil pH?		
Below 7.3	5	
Above 7.3	0	
Not sure	1	
8. Do you inoculate your soybeans when grown on fields that have not had soybean for four years or more?		
Yes	3	
No	0	

	Points	Score
9. Do you consider weather and field conditions prior to planting so seed will come up quickly?		
Yes	1	
No	0	
10. How long is your rotation?		
3 years	0	
4 years	3	
5 or more years	6	
11. What planting rate (seed/acre) do you use for soybean?		
Less than 120,000	1	
120,000 to 140,000	2	
140,001 to 160,000	3	
161,001 to 180,000	4	
More than 180,000	1	
12. What your typical planting date for soybean?		
At the same time as conventional producers in my area	2	
One week later than conventional	3	
Two weeks later than conventional	3	
More than two weeks later than conventional	1	
13. What is the latest you would plant soybean for grain (in Minnesota)?		
End of May	5	
First week of June	5	
Second week of June	2	
Third week of June	0	
14. Do you vary maturities and varieties to spread out risk?		
Yes	3	
No	0	
15. Can you identify insect pests that attack soybean?		
Yes	3	
No	0	
16. Can you identify disease pests that attack soybean?		
Yes	3	
No	0	
17. Do you choose pest-resistant soybean varieties when available when those pests are in your fields?		
Yes	3	
No	0	

continued next page

Soybean Risk Management Quiz

	Points	Score
18. White mold can be managed by:		
Narrow rows	0	
High seeding rates	0	
Resistant varieties	2	
19. When using products to control soybean aphid, do you try the product on a test plot first to determine effectiveness under your conditions?		
Yes	5	
No	0	
Don't use these products	4	
20. If you live in an area where soybean cyst nematode (SCN) is found, have you tested for SCN?		
Yes	3	
No	0	
SCN not in my area	3	
21. Do you know which plants are hosts for SCN?		
Yes	3	
No	0	
22. How many different tools (i.e. equipment types) do you have for weed control?		
1	0	
2	3	
3	4	
4 or more	5	
23. How many weed control operations do you typically perform during the soybean growing season?		
1 to 2	1	
3	3	
4	5	
5 or more	3	
24. Do you scout your soybean fields at least 4 times throughout the season?		
Yes	3	
No	0	
25. Do you monitor harvest losses in the field and make adjustments as necessary?		
Yes, always	3	
Yes, usually	2	
No	0	

	Points	Score
26. Do you clean harvesting and grain transportation equipment thoroughly, particularly when using rented or borrowed equipment?		
Yes	2	
No	0	
27. Do you inspect and clean units prior to soybean storage?		
Yes	1	
No	0	
28. Do you ensure that GMO-crops are segregated during storage from non-GMO crops?		
Yes	1	
No	0	
Not applicable	1	
29. Do you keep samples of seed, harvested crop, and delivered crop until buyer is certain of quality?		
Yes	1	
No	0	
Not applicable	1	
30. What is your target harvest moisture for soybean?		
15%	1	
14%	2	
13%	3	
12% or less	2	
31. Do you monitor stored grain regularly?		
Yes, always	3	
Yes, usually	2	
No	0	
	TOTAL	

If your score is:	Your risk is:
71 or above	Low
45 to 70	Moderate
44 or less	High

FOR MORE INFORMATION

Just for Growers – MN Soybean Production. http://www.soybeans.umn.edu/

Minnesota Crop Diseases – Soybean Diagnostic. http://www.extension.umn.edu/cropdiseases/soybean/diagnostic.html

Minnesota Crop Diseases – Soybean Diseases. http://www.extension.umn.edu/cropdiseases/soybean/index.html

Soybean aphid biocontrol project. www.entomology.wisc.edu/sabc/

North Central Region Soybean Aphid Suction Trap Network. www.ncipm.org/traps/

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CHAPTER 11

Small Grains

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A diversity of small grains is grown by organic farmers. In 2005, Minnesota organic growers led the nation in rye production and were number two in organic oat production. Acreages for all grains have made modest increases from 2000-2005. Wheat, followed by oat, are the most commonly grown small grains in Minnesota.

Small grain crop profiles

The four main small grain crop species that are grown in Minnesota and the Upper Midwest region include wheat, barley, oat, and rye. Triticale is a man made crop that combines the advantages of wheat and rye and may have potential in organic production systems.

The Grain Inspection, Packer and Stockyard Administration (GIPSA) is the regulatory body in the United States that sets and maintains the classes and grade standards. There are eight basic classes of wheat based on color and kernel characteristics. For barley there are two

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Figure 11-1. *Wheat.*

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Figure 11-2. ***Wheat plants and seed.***

classes, feed and malt, and there are single classes for oats, rye and triticale. Within each class there are four, or in the case of wheat, five grades.

The quality parameters used to set the grades do not necessarily predict end-use quality. In recent years, more and more buyers are demanding additional information to predict functional quality better. Examples of these quality requirements are falling number, wet gluten content, and vomitoxin content. This trend is likely to continue with the need for additional information about the functional qualities for the end-user of the crop.

WHEAT

The genus *Triticum* encompasses all of the cultivated wheat species that are grown today. The genus is very broad and contains many species and subspecies, including wild and primitive wheat species that preceded our modern wheat. Based on make-up of the genome of the species, the domesticated wheat species and their wild ancestors can be separated in three groups. In the first group, only einkorn is a cultivated species. Emmer and durum wheat are the crop species in the second group, while spelt and common or bread wheat are the two important crop species in the third group. Each class of the eight wheat classes has its own area of adaptation and end-use characteristics. The three classes of wheat most commonly grown and best adapted to the Midwest are:

Hard Red Spring wheat (HRSW)

HRSW is an important bread wheat that generally has the highest protein content of any class, usually 13 to 14 percent, in addition to good milling and baking characteristics. This spring-seeded wheat is primarily grown in the north central United States including North Dakota, South Dakota, Minnesota and Montana. HRSW comprises just over 20 percent of U.S. wheat exports. Subclasses are based upon the dark, hard and vitreous kernel content and include dark northern spring, northern spring and red spring.

Hard Red Winter wheat(HRWW)

HRWW is an important bread wheat which accounts for almost 40 percent of the U.S. wheat crop and wheat exports. This fall-seeded wheat is produced in the Great Plains, which extend from the Mississippi River west to the Rocky Mountains and from the

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Figure 11-3. ***Six-row and two-row barley and seed.***

Dakotas and Montana south to Texas. HRWW has a moderately high protein content, usually averaging 11 to 12 percent, and good milling and baking characteristics. In Minnesota and eastern South and North Dakota, HRWW is grown on limited acreage because it will not consistently overwinter.

Durum wheat

Durum wheat is the hardest of all wheat classes and provides semolina for spaghetti, macaroni and other pasta products. This spring-seeded wheat is grown primarily in the same northern areas as hard red spring. It is especially adapted to drier growing conditions. Durum comprises nearly five percent of total U.S. wheat exports. Subclasses are hard amber durum, amber durum and durum.

SPELT

Spelt is a hulled subspecies of bread wheat that is thought to be the ancestor of our modern wheat. There are no GIPSA standards for spelt at this time. Spelt can be used as an alternative feed grain to oats and barley and is gaining in popularity as an alternative to bread wheat for human consumption. It contains moderate amounts of gluten and can be used for baking. The nutritional value is close to that of oats. The commercially available spelt varieties all have a winter annual growth habit but are less winter hardy than common HRWW varieties. It is more tolerant of low fertility and wet soils than other wheat types.

BARLEY

Barley can have both a winter and spring growth habit. Spring barley is the most commonly grown in the Upper Midwest. Currently available winter barley varieties have only marginal winter hardiness to survive the winters in the Upper Midwest.

A second characteristic used to differentiate barley varieties is the culm or spike. In two-rowed varieties only the central spikelet is fertile, while in the six-rowed the lateral spikelets are also fertile. Six-row barley varieties are most commonly grown in the Upper Midwest. The two-row barley varieties that are adapted to the Upper Midwest tend to be less disease resistant and earlier maturing than adapted six-rowed varieties. Two-rowed varieties tend to also have lower grain pro-

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Figure 11-4. ***Oat plants and seed.***

tein content, higher test weight, and a higher percent of plump kernels than comparable six-rowed varieties.

A third characteristic that can be used to differentiate barley varieties is hulled versus hulless or naked varieties. Analogous to spelt and common wheat, hulless varieties of barley varieties have no hull or glumes that enclose the grain. Hulled barley can be processed (pearled) to remove the hull and bran.

Barley matures earlier than wheat, is an excellent weed competitor, demands less fertility than wheat, and can produce a high quality forage. Harvested for grain, barley can provide a high quality feed or food with malt being the most important use. Quality standards for malting barley are stringent and require that not only the desired varieties are grown but also that minimum quality standards, including absence of fungal toxins, are met. Producers should ask potential buyers what their needs are.

OAT

Oat can have both a winter and spring growth habit. Spring oat is the most commonly grown in the Upper Midwest. Currently there are no winter oat varieties that have enough winter hardiness to survive the winters in the Upper Midwest. Like hulless barley, there are also hulless varieties of oat. Grain protein content is approximately 12 percent, but increases three or more percentage points in hulless varieties because of the missing hull. The grain is grown mostly used for livestock feed and to a lesser extent for processing for human food. The straw is highly absorbent and desirable source of bedding or can be left in the field to enhance soil organic matter and soil structure. Oat is the most commonly used nurse crop for small-seeded legume establishment and green manure. The early dough stage is the optimum growth stage if oat is to be harvested for as a forage (refer to Chapter 12 – Forages).

RYE

Rye, like the other small grains, can have both a winter and spring growth habit. Winter rye is the most winter hardy of all the small grain species and most commonly grown in the Upper Midwest. It is the only of the four species that is cross pollinating instead of self pollinating. This means that

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Figure 11-5. ***Rye plants and seed.***

rye varieties are not only genetically more diverse than varieties of other small grains (which all are true breeding lines), the crop itself is more susceptible than the other small grain species to the fungal disease ergot (caused by *Claviceps purpurae*). The sclerotia or ergot bodies that ultimately replace the developing kernel in an infection can contaminate the harvested grain and are difficult to separate. Grain containing too much ergot is unfit for feed or food usage as the ergot bodies contain alkaloids that are toxic. Rye can be grazed as forage, used as a cover crop, and provides excellent weed control.

TRITICALE

Triticale is a man-made crop. It is a hybrid of either bread wheat or durum wheat and rye in an attempt to combine the drought resistance and yield of rye with the quality of wheat. The first report of a hybrid of wheat and rye was in 1876. By the 1930s, breeders and geneticists across Europe were working on triticale. After initial problems with sterility of the offspring, breeders were able to produce a stable, fertile progeny and in essence a new species. Triticale can be an excellent substitution for rye or wheat, especially in drought prone areas or areas with poorer fertility.

Table 11-1. Small grain adaptation.

	TOLERANCE TO:							
Small grain	**Heat**	**Drought**	**Wet/Poor drainage**	**Acidity**	**Alkalinity**	**Salinity**	**Weeds**	**Low fertility**	**Winter hardiness**
Spring wheat	Moderate	Moderate	Moderate	>5.0	<8.2	Moderate	Moderate	Low	--
Winter wheat	Moderate	Moderate	Moderate	>5.5	<8.2	Moderate	Moderate	Low	Moderate
Durum wheat	Moderate	Moderate	Moderate	>5.0	<8.2	Moderate	Moderate	Low	--
Spelt	Moderate	Moderate	Moderate	>5.0	?	?	Moderate	Moderate	--
Barley (spring)	Moderate	Moderate	Low	>5.0	<8.2	High	Moderate	Moderate	--
Oat (spring)	Low	Low	Low	>5.0	<8.0	Moderate	Low	Moderate	--
Winter rye	Low	Moderate	Moderate	>5.0	<7.0	High	High	Moderate	High

Table 11-2. Optimum growth temperature ranges for small grain species. *Adapted from Wiersma and Ransom, 2005.*

CROP	MINIMUM	MAXIMUM	OPTIMUM
	Temperature °F		
Wheat	37-39	86-90	75-77
Barley	37-39	82-86	68-70
Oat	37-39	82-86	68-70
Rye	37-39	82-86	65-70
Triticale	37-39	82-86	68-70

Reducing risk: selecting small grains. Choose a small grain species that is adapted to your growing conditions (see Table 11-1) and market needs.

Variety selection

All the small grain species and varieties described above are cool season annuals. Photosynthesis is optimum around 70°F and a maximum around 85°F, depending on the species (Table 11-2).

For this reason, varieties that mature before the heat of summer should be selected. Producers should consult variety trials that evaluate grain yield potential of small grains (Tables 11-3 and 11-4). Although many variety trials are not conducted under organic conditions, these tests still provide useful information to start the process of selecting a variety. See Chapter 9 – "Selection Factors" section for more details on the process of variety selection.

While grain yield is an important criterion in variety selection, grain quality is as important as grain yield if the harvested grain is to be marketed. For all small grains, plant diseases are a major factor affecting yield in conventional and organic systems. Grain quality and disease data for varieties of barley, oat, hard red spring wheat and hard red winter wheat are published in variety trials and are a good starting point for varietal selection (Table 11-5).

Table 11-4. Organic oat variety trial, Polk County, MN in 2003 and 2004. *'Ebeltoft' and 'HiFi' performed among the top varieties each year. Adapted from Kandel and Porter, 2004 & 2005.*

	2003	2004	Average
	bushels/acre		
Morton	112	115	114
HiFi	111	121	116
Youngs	108	111	109
Ebeltoft	107	131	119
Wabasha	97	113	105
Richard	93	114	104
Sequi	92	123	108
Leonard	86	116	101
Hytest *	73	91	82
Buff *	66	72	69

* hull-less variety

Table 11-3. Small grain variety trials in the Upper Midwest.

UNIVERSITY	WEBSITE	SMALL GRAINS INCLUDED
University of Minnesota	*http://www.maes.umn.edu/vartrials/*	Wheat, oat, barley
North Dakota State University	*http://www.ag.ndsu.edu/varietytrials/*	Spring and winter wheat, durum, spelt, oat, barley
South Dakota State University	*http://plantsci.sdstate.edu/varietytrials/*	Spring and winter wheat, oat, barley
University of Wisconsin	*http://soybean.uwex.edu/wheattrials/printable/index.cfm*	Winter wheat, oat, barley
Iowa State University	*http://www.croptesting.iastate.edu/smallgrains/*	Winter wheat, oat, barley
University of Illinois	*http://vt.cropsci.illinois.edu/wheat.html*	Wheat, oat
Michigan State University	*http://www.css.msu.edu/varietytrials/*	Wheat
Ohio State University	*http://www.ag.ohio-state.edu/~perf/index.html*	Wheat

Table 11-5. Organic wheat variety trial, Polk County, MN in 2003, 2004 and 2005.
'Alsen' and 'Oklee' were among the highest yielding varieties. Adapted from Kandel and Porter, 2004, 2005, & 2006.

	2003		2004		2005		AVERAGE	
	Yield (bu/ac)	% protein	Yield (bu/ac)	% protein	Yield (bu/ac)	% protein	Yield (bu/ac)	% protein
Alsen	35	13.7	69	14.3	39	15.5	48	14.5
Oklee	43	13.4	65	14.1	35	15.1	48	14.2
Walworth	44	13.3	35	13.3	34	15.1	38	13.9
Hanna	--	--	61	13.4	32	13.9	47	13.7
Dapps	35	14.1	67	15.6	30	16.0	44	15.2
BacUp	33	15.0	51	15.6	--	--	42	15.3
Glupro	30	16.0	44	16.6	--	--	37	16.3

Reducing risk: variety selection. Select varieties based on use or markets and growing conditions in your region. Consult results from variety trials to aid in variety selection. Plant several disease-resistant, high-yielding varieties on your farm to spread out risk. When selecting winter grains for planting in Minnesota, choose only the most winter hardy.

An organic producer from Lac Qui Parle County says that planting small grains following corn can lead to inadequate fertility for the small grain. He believes that if you plant wheat after corn, you should supply nutrients for the wheat with manure or compost.

Quality seed

Profitable grain production begins with planting of high quality seed. Seed quality is determined in terms of germination, test weight, and freedom from seed-borne diseases. It is best to use seed from registered and certified seed classes of known varieties. Certified seed must be sold with an accompanying blue tag that lists the variety name germination, weed seed, and inert matter percentage; seed lot number; and source of production. Certified seed must meet purity requirements and typically contains less than one percent seed of other same crop varieties or other crops.

Reducing risk: seed selection. Avoid seed sold as VNS (variety not stated) because the seed could be a varietal mixture, an unknown variety, old seed that did not sell well, or a disease-susceptible variety.

Soil fertility

A consideration of all plant nutrient needs is important for small grains, but N fertility management is especially important in wheat and barley. Excess N fertilization can lead to increased vegetative yield and decreased grain yields, weak stems and lodging, and a grain protein content that is too high for it to be considered suitable for malt in barley. Of the small grains grown in the Upper Midwest, wheat and rye are moderate users of nutrients, while barley and oats use less nutrients in rotations. Generally, compost and manure should not be applied in the same year as oats and barley are grown. Producers should refer to soil testing results for specific fertilizer recommendations for their fields. Soil fertility for organic production is discussed further in Chapter 4 – Soil fertility.

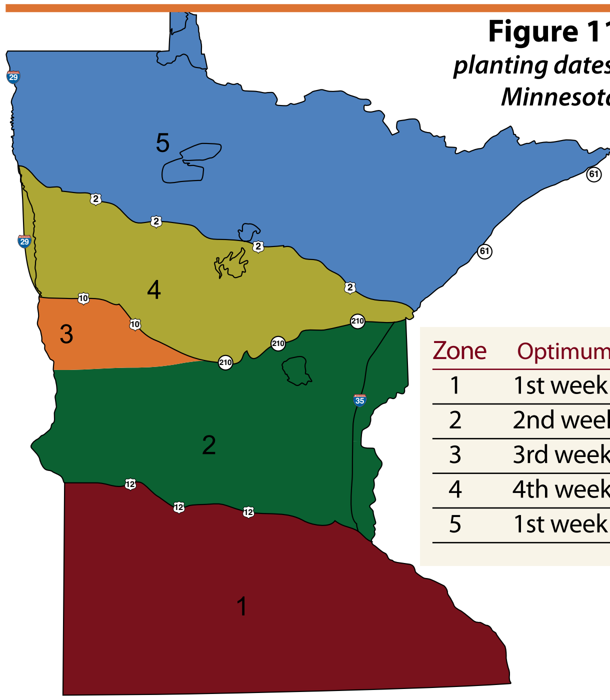


Figure 11-6. *Optimum and latest planting dates for spring small grains in Minnesota. Adapted from Wiersma and Ransom, 2005.*

Zone	Optimum Planting	Last Planting Date
1	1st week of April	1st week of May
2	2nd week of April	2nd week of May
3	3rd week of April	3rd week of May
4	4th week of April	4th week of May
5	1st week of May	1st week of June

Reducing risk: soil fertility. Include legumes in your rotation to supplement nitrogen. Apply organic amendments for small grains only as recommended by soil test results.

Planting

PLANTING DATE

The planting date for small grains will be dependent on whether it is a spring or winter type.

Spring-seeded small grains

Spring-seeded small grains are summer annuals that include HRSW, spring barley, oat, spring triticale. Spring-seeded small grains should be planted as early as possible to maximize yield (Figure 11-6). Grain yields decrease an estimated percent per day when planting past the optimum planting dates as the odds of heat stress later in the growing season will increase. Unlike corn and soybean where organic producers often use delayed planting as a strategy for weed management, organic small grains are often planted at the same time in early spring as conventional small grains. Yield losses due to delayed planting can partially be offset by increasing the seeding rate about 1 seed per square foot for each week planting is delayed past the optimum planting date.

Fall-seeded small grains

Fall-seeded small grains are winter annuals that include HRWW, spelt, winter barley, winter rye, and winter triticale. Fall-seeded small grains are planted in the late summer and early fall. Establishment is a balance between allowing for adequate growth for the stand to get established and store reserve in the crown that will aid in the winter survival and avoiding the introduction of insect and disease problems that can affect the crop the following growing season. Optimum planting dates for winter wheat are shown in Figure 11-7. The same recommendations can be used for spelt, winter barley, winter triticale or rye. Planting past the optimum window will increase winterkill and likely result in slow spring development and delayed maturity as the vernalization requirements were not met the previous fall. Planting prior to the optimum planting date will create too lush a growth. This not only increases the chances of winter kill but also increases

An organic farmer from Lac Qui Parle County prefers winter wheat over spring wheat. He finds that winter grains seem to promote better soil tilth because he doesn't need to work the soil with spring tillage. He also likes that winter grains have lower protein market demands.

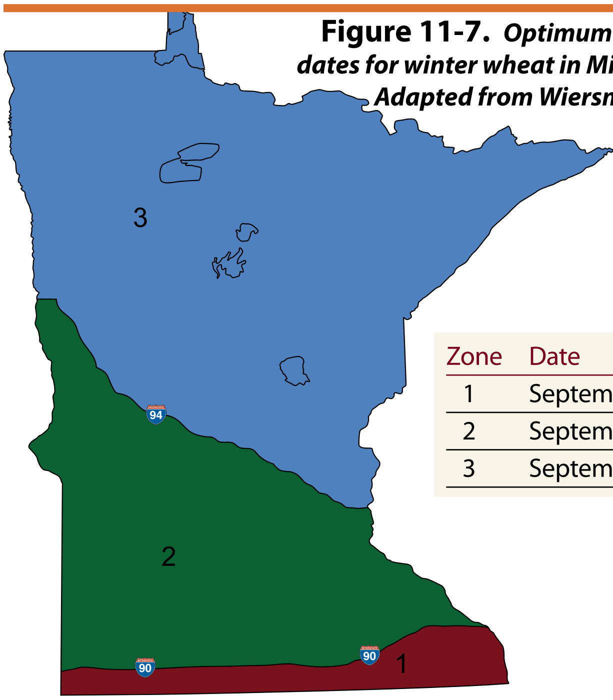


Figure 11-7. ***Optimum planting dates for winter wheat in Minnesota. Adapted from Wiersma, 2009.***

Zone	Date
1	September 20 to October 10
2	September 10 to September 30
3	September 1 to September 15

An organic producer in Pipestone County plants his winter grains by September 15th at the latest.

Reducing risk: planting date. **To avoid yield loss, plant spring small grains as early as possible and winter small grains in the late summer or early fall. Planting winter wheat into standing stubble lowers the risk of winter kill substantially compared to planting in a field with little residue because the standing stubble traps and retains snow cover. Snow greatly insulates the crowns from lethal freezing temperatures.**

the odds that diseases, such as tan spot in wheat and Barley Yellow Dwarf virus or Wheat Streak Mosaic Virus in wheat, spelt, rye, or triticale, which are transmitted into the young crop by aphids or the wheat curl mite, respectively, can develop.

Legume companion crops

Organic producers often underseed small grains with red clover or alfalfa. Red clover tends to be less competitive with small grains and is more easily terminated, but alfalfa can be used as an acceptable alternative (Tables 11-6 & 11-7). Red clover can be underseeded at six to ten pounds per acre, while alfalfa can be underseeded at eight to ten pounds per acre. Underseeding legumes is an excellent, low-risk way for organic farmers to incorporate green manures into their rotation. See Chapters 4 and 12 for more information on underseeded legumes.

Table 11-6. Organic oat with alfafa underseeding variety trial in Clay County, MN in 2003 and 2004. *Good yields were obtained when oats were underseeded with alfalfa. Adapted from Kandel and Porter, 2003 & 2004.*

	YIELD (bu/ac)		
Variety	2003	2004	Average
Leonard	138	128	133
Sesqui	136	128	132
Wabasha	124	122	123
HiFi	129	118	123
Ebeltoft	127	112	120
Richard	116	108	112
Youngs	117	104	110
Morton	139	96	118
Hytest	97	90	94

Table 11-7. Organic wheat with alfalfa underseeding variety trial in Clay County, MN in 2003, 2004, and 2005. *Good yields were obtained with wheat underseeded with alfalfa. Adapted from Kandel and Porter, 2003, 2004, & 2005.*

	YIELD (bu/ac)		
Variety	2003	2004	2005
Walworth	60	46	46
Oklee	50	41	43
Dapps	58	40	41
Alsen	53	40	43
Hanna	--	44	38

An organic grower from Cottonwood County says that the organic small grain production is actually very similar to conventional production in his experience. The main difference is organic producers sometimes use a higher seeding rate.

PLANTING RATE

Optimal plant populations are important to maximize grain yields (Table 11-8). Plant populations below optimum can result in increased weed pressure, excess tillering and uneven maturity, and lower grain yield potential; above-optimum populations can result in lack of tillering, weaker stems, and increased risk of lodging. Recommended seeding rates have been established for conventional systems and these also apply to organic farming (Table 11-9).

Additionally, a farmer can calculate planting rates for a particular situation based on the following formula (Figure 11-8). Using this calculation would be especially helpful in situations where a higher than normal planting rate is needed (poor seed vigor, planting beyond the recommended dates, weed suppression, or due to harrowing). Planting rate can also be adjusted when planting is delayed past the optimum planting date. The seeding rate should be increased by about 1 percent per day of delay up to 1.6 million seeds per acre. This will compensate for reduced yields in spring-planted small grains that occur due to reduced spikelet formation and tillering in late plantings.

Table 11-8. Optimum plant population at harvest. *Adapted from Wiersma and Ransom, 2005.*

CROP	PLANTS PER ACRE	PLANTS PER FT^2
Winter wheat	900,000 to 1,000,000	21 to 23
Spring wheat	1,300,000 to 1,400,000	30 to 32
Durum	1,300,000 to 1,400,000	30 to 32
Barley	1,250,000 to 1,300,000	28 to 30
Oats	1,250,000 to 1,300,000	28 to 30

Table 11-9. Pounds of seed to be planted per acre assuming 15% stand loss and 95% seed germination. *Adapted from Wiersma and Ransom, 2005.*

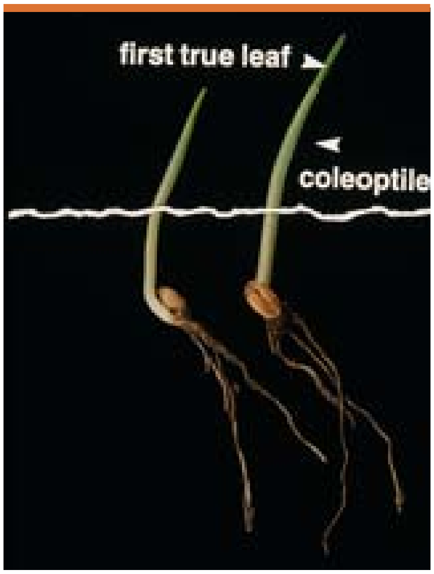
	DESIRED STAND (TIMES 1 MILLION)							
SEEDS/LB	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5
	LBS/ACRE							
10,000	96.8	108.9	121.1	133.2	145.3	157.4	169.5	181.6
11,000	88.0	99.0	110.0	121.1	132.1	143.1	154.1	165.1
12,000	80.7	90.8	100.9	111.0	121.1	131.1	141.2	151.3
13,000	74.5	83.8	93.1	102.4	111.7	121.1	130.4	139.7
14,000	69.2	77.8	86.5	95.1	103.8	112.4	121.1	129.7
15,000	64.6	72.6	80.7	88.8	96.8	104.9	113.0	121.1
16,000	60.5	68.1	75.7	83.2	90.8	98.4	105.9	113.5
17,000	57.0	64.1	71.2	78.6	85.5	92.6	99.7	106.8
18,000	53.8	60.5	67.3	74.0	80.7	87.4	94.2	100.9

Reducing risk: planting rate. Calculate and use the optimum planting rate for your crop and circumstances.

One organic producer from Wadena County always plants small grains at an extra 1/2 bushel rate to make up for losses due to harrowing.

Figure 11-8. Formula for calculating seeding rate.
Expected stand loss is 10-20% under good seedbed conditions.

$$\text{Seeding rate (lb/acre)} = \frac{\text{Desired stand (plants/acre)} \div (1 - \text{Expected stand loss})}{(\text{Seeds/lb}) \times (\text{\% Seed germination})}$$



DAVID L. HANSEN

Figure 11-9. *First true leaf emerging from the coleoptile in wheat. Coleoptile length will vary depending on species and variety.*

Figure 11-10. *Canada thistle and other weeds growing in oats.*

PLANTING DEPTH

The optimum planting depth for small grains is one and a half to two inches. Seed should be placed deep enough to have access to adequate moisture yet shallow enough to emerge as quickly as possible. Seeds too close to the surface absorb moisture but are at risk of dying because roots cannot reach moisture quickly enough to sustain the germination and seedling growth. Deeper seeding can reduce stand density and plant vigor because the inability of the coleoptile to reach the surface. The maximum coleoptiles lengths differ between varieties within each of the species (Figure 11-9). The average plant height of varieties as reported in the variety trials correlates reasonably well with the length of the coleoptile and can be used guidance to assess the risk of planting too deep. Oat is the most tolerant too planting deep.

Reducing risk: seeding depth. Seeding equipment should be calibrated to deliver seed to the desired depth for a specific seedbed. Prepare an even seedbed to allow uniform planting depth and routinely check the depth of the seeding as conditions vary.

Weed management

Crop rotation is a key component in any weed control strategy (see Chapters 2 and 5). Small grain crops can get infested with a wide variety of weeds. The most troublesome grass weeds in cereals are wild oats, downy brome, jointed goatgrass, foxtail species, and quackgrass. The most troublesome broadleaf weeds are the buckwheat family, wild mustard, kochia, Russian thistle, and Canada thistle. Fall-seeded cereals are better weed competitors than spring-planted cereals with spring barley generally more competitive than HRSW or oat. In addition, there are varietal differences in weed competitiveness of wheat and barley. In general, taller varieties, varieties with higher tillering capacity, and varieties that grow rapidly and mature early, tend to suppress weed growth better. Weed suppression is not the result of any one competitive growth trait but the result of a number of traits. However, in general, planting rate manipulation is a more dependable strategy for reducing weed competition than selecting cultivars that tolerate or suppress weeds.

Organic producers may be tempted to use delayed planting to manage weeds in spring-planted small grains. While early-emerging weed populations (such as wild oats) can be reduced, substantial yield losses will occur, making the practice counterproductive. Overall, a better strategy is to plant early, which allows the small grain crop to compete more successfully with weeds.

Pre-emergence tillage can be used to control weeds that start growing prior to the crop. For spring small grain crops, blind harrowing after germination but before emergence can be performed. If the crop has emerged, post-emergence operations should be delayed until tillering is underway and crown roots are anchoring the young seedling, but prior to jointing as the growing point is more prone to injury. A harrow or rotary hoe can be used at the four- or five-leaf stage, especially if broadleaf annual weeds are problematic.

Weed management can continue after spring-seeded small grain harvest. Post-harvest tillage in the fall can help control of winter annual, biennial and perennial weeds. In addition to killing existing weeds, fall tillage may even encourage germination of some weed seeds that will then winter kill.

See Chapter 6 – Weed Management for more information on weed control.

Reducing risk: weed management. Crop rotation, planting rate, and early planting are the main cultural weed control options in organic small grains. Cultivation can be used, but it must be timed early and at the proper growth stage of the small grain. A primary tillage operation prior to seeding in the spring can reduce weed pressures of winter annuals and cool season annual weeds such as wild oats, wild mustard, kochia, and the different pigweed species.

Pest management

There are a number of pests that cause serious problems on small grains in the Midwest. Most of these are managed by crop rotation and resistant varieties (Table 11-10).

There are a few pesticides approved for use in certified organic production systems. However, the cost of these organically-approved pesticides is usually cost prohibitive for field crop production and some of these products have not been proven particularly effective. Organic small grain producers in the Midwest generally rely on cultural methods to deal with insects and diseases.

Diverse crop rotations are extremely important in organic small grain production. Organic producers are not allowed to plant the same crop two years in a row in a field, which in of itself aids in pest management as a two-year break between small grains greatly decreases the risk of foliar and head diseases. At a minimum, wheat and barley should not follow another small grain or corn due to the risk of Fusarium Head Blight. Fusarium spores overwinter on the corn,

ROGER JONES

Figure 11-11. ***Fusarium Head Blight on wheat.***

ROGER JONES

Figure 11-12. ***The wheat seeds on the right are infected with Fusarium Head Blight disease, while the wheat on the left is healthy.***

wheat, or barley residues and can infect the subsequent crop if weather conditions just prior and during anthesis are favorable for the development of the disease (Figures 11-11 and 11-12). Oats are much less susceptible to the same soil or residue borne diseases that affect wheat or barley, but for most of the diseases in wheat or barley, there are other closely-related fungi that will only affect oats.

Cropping sequence data has been developed for MN and ND to assist growers in making good rotation decisions to maximize yield. See Table 11-11 for the best crops to precede small grains in rotations. Refer to Chapter 2 – Rotations for more information of how crop rotations and crop sequence can benefit yield, soil quality, weed pressure, and overall farm success.

Other cultural control methods for pests include choosing resistant small grain varieties or a diversity of varieties. Depending on the pest, stubble management may be a another control option. Fall tillage to reduce crop residue can decrease populations of a pest that overwinters, thus reducing certain pest levels for the next year. Unfortunately, fall tillage also leaves the soil unprotected in the winter.

Table 11-11. ***Crops in the first column are recommended to precede small grains in the rotation. Crops in the second column are not recommended to precede small grains. Adapted from Wiersma and Ransom, 2005.***

RECOMMENDED BEFORE SMALL GRAINS IN ROTATION:	NOT RECOMMENDED BEFORE SMALL GRAINS IN ROTATION:
Field pea	Corn
Sunflower	Sudangrass
Alfalfa	Millet
Soybean	Wheat
Flax	Barley
Buckwheat	Oats
Dry bean	Rye

Table 11-10. Diseases and insects that affect organic small grains are primarily controlled by crop rotation and other cultural methods. ***Adapted from Wiersma and Ransom, 2005.***

PEST TYPE	PEST NAME	CROP(S) AFFECTED	CONTROL METHOD(S)
Disease	Common root rot	wheat, barley, oat	rotation
	Ergot	Wheat,rye	rotation, tillage
	Bacterial blights	wheat, barley, oat	rotation
	Fusarium head blight	wheat, barley	rotation, resistant varieties
	Tan spot	wheat	rotation, resistant varieties
	Septoria	wheat, barley, oat	rotation, resistant varieties
Insect	Wheat stem maggot	wheat	rotation
	Wheat stem sawfly	wheat	rotation
	Hessian fly	wheat	rotation


BRUCE FRITZ, USDA-ARS

Figure 11-13. *An organic producer windrows wheat near Morris, Minnesota.*

Reducing risk: pest management. Utilize rotations and crop sequences that reduce the risk of disease. Check with your certifier before using new pesticides—conditions for use of a pesticide must be documented in the organic system plan. Always use good quality seed and choose resistant varieties whenever possible. Using certified seed ensures that the seed is free or nearly free of a number the economically important seed-borne diseases such as loose smut.

Harvesting

The harvesting process begins once the small grain crop has reached physiological maturity. The most obvious sign of physiological maturity is when the peduncle (the stalk below the spike) loses its green color just below the spike or panicle. Grain moisture is around 35 to 40 percent at this point. Windrowing or swathing can be initiated at that time. If straight combining, grain moisture should be no more than 16% if aeration is not available immediately and no more than 18 percent if aeration and/or drying capacity is available.

When combining, producers should determine how much grain is being left on the field. A simple method is to count the number of seeds per square foot, then consult Table 11-12, which gives an estimate of the number of bushels that are lost. Zero percent harvest losses are unattainable, but well-adjusted combines should be able to limit harvest losses to well under three percent.

Table 11-12. Number of kernels per square foot that equals one bushel per acre loss. *For example, finding 20 kernels of oat per square foot indicates the loss of two bushels per acre. Adapted from Wiersma and Ransom, 2005.*

SMALL GRAIN	KERNELS/FT^2
Hard red spring wheat	20
Durum	16
Barley	14
Oats	10

The correct moisture at which to store small grains will depend on which crop it is and for how long the grain is to be stored. See Table 11-13 for storage guidelines.

Reducing risk: harvesting. Harvest at the correct moisture level depending on method. Make sure that combine is properly adjusted by gauging harvest losses. Store at the correct moisture for the correct time it will be stored. Monitor stored grain regularly.

Take the following quiz to determine your risk in small grain production.

Table 11-13. Small grain recommended storage moistures. *Adapted from Wiersma and Ransom, 2005.*

	UP TO 9 MONTHS	OVER 9 MONTHS
Wheat	14.0	13.0
Barley	13.5	12.5
Oat	14.0	12.0
Rye	13.0	12.0

Quiz: Small Grains Risk

	Points	Score
1. Which of the following do you use to choose a new small grain 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	
2. Do you select seed using maturity and yield potential as the primary deterimining factors?		
Yes	3	
No	0	
3. Do you use certified seed?		
Yes, always	3	
Yes, usually	2	
No	1	
4. Do you vary maturities and varieties to spread risk?		
Yes	3	
No	0	
5. How long is your crop rotation?		
2 years	0	
3 years	3	
4 years	4	
5 or more years	6	
6. Which of the following small grains are in your rotation? Score 1 point for each answer.		
Spring wheat	1	
Winter wheat	1	
Barley	1	
Oats	1	
Rye	1	
7. How many years do you have between growing another small grain on the same field?		
1	0	
2	1	
3 or more	5	

	Points	Score
8. Which of the following crops would you plant before small grains in your rotation? ***Check all that apply.***		
Another small grain	0	
Flax	2	
Soybean	2	
Corn	0	
Alfalfa	2	
Red clover	2	
Sudangrass	0	
Field pea	2	
Sunflower	2	
9. Do you plant your spring small grains as early as possible in the spring?		
Yes	3	
Yes, usually	2	
No	0	
10. If you live in Minnesota, when do you plant winter rye?		
Late August	2	
Early September	3	
Mid September	3	
Late September	3	
Early October	1	
Don't plant rye	2	
11. If you live in Minnesota, when do you plant winter wheat?		
Late August	2	
Early September	3	
Mid September	3	
Late September	2	
Early October	0	
Don't plant winter wheat	2	
12. Do you apply manure or compost to a field in years when barley or oat are grown?		
Yes	0	
No	3	
Do not grow these crops	2	
13. Do you have a target plant population for each small grain you grow?		
Yes	3	
No	0	

continued next page

Quiz: Small Grains Risk

	Points	Score
14. Do you underseed your small grains with a legume?		
Yes	**2**	
No	**0**	
15. Do you adjust your planting rate depending on individual circumstances such as delayed planting or more weed control operations than usual?		
Yes	3	
No, I always use the same planting rate	0	
16. To what depth do you plant small grains?		
1/2 inch	0	
1 inch	1	
1 1/2 inch	2	
2 inches	2	
2 1/2 inches	0	
17. When you plant winter small grains, does the seed bed have leftover crop residue?		
Yes	3	
No	1	
I don't plant winter grains	3	
18. Which of the following weed control operations do you use in small grains? *Check all that apply.*		
Blind cultivation before crop emergence	3	
Cultivation post-emergence before four-leaf stage	0	
Cultivation post-emergence at four- to five-leaf stage	3	
Cultivation post-emergence after the five-leaf stage	0	
19. Can you identify insect pests that attack small grains?		
Yes, many of them	3	
No	0	
20. Which would be the best method to manage Hessian fly?		
Rotation	3	
Resistant variety	0	
Tillage	0	
All of the above	0	
21. Can you identify small grain diseases?		
Yes	3	
No	0	

	Points	Score
22. Which would be the best method to manage bacterial blights?		
Rotation	**3**	
Resistant variety	**0**	
Tillage	**0**	
All of the above	**0**	
23. At what moisture do you windrow small grains?		
At physiological maturity (35%)	0	
20 to 30%	3	
under 20%	0	
I direct combine, not windrow	3	
24. At what moisture do you combine small grains?		
30%	0	
20%	0	
15%	3	
I windrow, not direct combine	3	
25. During harvest, do you estimate crop loss to ensure that the combine is properly adjusted?		
Yes	3	
No	0	
26. What would be a reasonable amount of crop loss during harvest?		
0%	0	
3%	3	
6%	0	
9%	0	
27. Which moisture level is best to store small grains?		
16%	0	
15%	0	
14%	2	
Depends on which grain and for how long it will be stored	5	
28. Do you monitor stored grain regularly?		
Yes, always	3	
Yes, usually	2	
No	0	
TOTAL		

If your score is:	Your risk is:
65 or above	Low
46 to 64	Moderate
45 or below	High

FOR MORE INFORMATION

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CHAPTER 12

Forages

CRAIG SHEAFFER

There are several legumes and grasses that are used in organic cropping systems in the Midwest. The emphasis in this chapter is on small-seeded legume and grass use for hay or silage.

Choosing forages

Overall, grasses are longer-lived and more tolerant of adverse management and environmental conditions compared to legumes, but grasses require nitrogen fertilization to promote yield. Grasses and legumes also differ in composition that affects forage quality. For livestock feeding, legumes are valued for their protein content and digestibility.

LEGUME SELECTION

Selection of legumes for cropping systems is based on several factors. These include use as well as adaptability to climatic conditions and soil (Table 12-1).

DAVID L. HANSEN

Figure 12-1. *A mixture of white clover, birdfoot trefoil and perennial grasses. Legumes and grasses are grown in mixture to reduce risk.*

Legume species

The following legumes are among the best suited for Upper Midwest. See Table 12-1 for a summary of traits for other legumes.

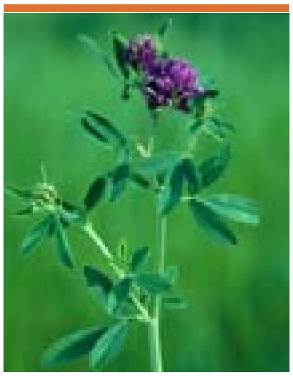

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Figure 12-2. *Alfalfa.*

Alfalfa is the leading perennial forage legume in the Midwest. Stands typically last from three to five years with maximum yields in the first two years after seeding. Alfalfa can be harvested for hay, silage, or more frequently by grazing. Its herbage is high in protein and a good source of fiber for livestock rations. It has an extensive tap-root system that can extend to a depth of 20 feet. Alfalfa conducts biological nitrogen fixation and incorporation of herbage and roots can contribute nitrogen for following crops. Alfalfa is affected by several diseases and is damaged by the potato leafhopper. Disease resistant and potato leafhopper resistant varieties with appropriate levels of winter hardiness should be grown.

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Figure 12-3. *Red clover.*

Red clover is a short-lived perennial that usually persists only two years. It is often used as a hay and pasture crop alternative to alfalfa especially on heavy soils with a low pH. Red clover herbage is succulent and harder to dry than alfalfa. There are two general types of red clover. "Medium" or multiple cut types are most widely grown in the north central region while "Mammoth" red clover produces only one crop of hay per season.

Table 12-1. Characteristics of various legumes for the Upper Midwest.

	TOLERANCE TO:							
LEGUME	Heat/ drought	Wet	Winter injury	Cutting/ grazing	Soil acidity	Low fertility	Seedling vigor	Bloat inducing
Alfalfa	E	P	G	F	P	P	G	Yes
Alsike clover	P	E	P	P	G	F	G	Yes
Birdsfoot trefoil	F	E	F	G	G	F	P	No
Cicer milkvetch	G	F	E	F	F	F	P	No
Crownvetch	G	P	F	P	G	F	P	No
Kura clover	F	G	E	E	F	G	P	Yes
Red clover	F	F	F	F	G	G	E	Yes
Sweetclover	E	P	E	P	P	F	G	Yes
White clover	P	G	F	E	G	G	G	Yes
Berseem clover	P	E	P	G	P	G	E	No

E = excellent, G = good, F = fair, P = poor

Figure 12-4. *White clover.*

White clover is a short-lived perennial legume most often used for pastures because it grows close to the ground. It spreads by horizontal aboveground stems called stolons. White clover is poorly rooted and grows best with adequate soil moisture. There are several types of white clover: tall, large-leafed types are more productive than smaller types (called white Dutch or wild white clovers). White clover is prone to winter injury but will persist in pastures through natural reseeding.

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Figure 12-5. *Birdsfoot trefoil.*

Birdsfoot trefoil is a perennial legume that is noted for its tolerance of waterlogged soils and low soil pH. Its long-term stand persistence is related to its natural reseeding. Birdsfoot trefoil is a good pasture legume and will not cause bloat.

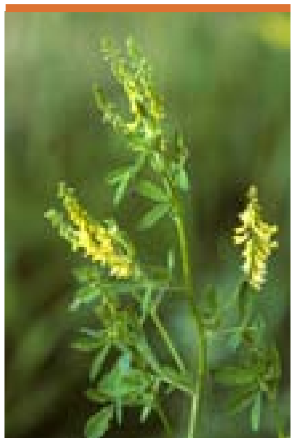

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Figure 12-6. *Sweet clover.*

Sweet clover is a tall-growing biennial or annual legume. It is a traditional green manure crop and when unharvested it will contribute more N and biomass for incorporation than any other clover or alfalfa. However, sweet clover possesses several undesirable traits: 1) plants tend to be succulent and stemmy and are slow to dry if the forage is cut for hay; 2) plants contain coumarin, a chemical responsible for bleeding disease in cattle and horses that consumed spoiled hay; and 3) sweet clover is a prolific seed producer that can become a weed in cropping systems.

Legume adaptation

Several adaptive traits, including tolerance to soil pH, soil fertility, soil moisture, and winter hardiness will influence the success in growing forage legumes. Soil pH affects soil microbial activity and nutrient availability. Most legumes grow best at a soil pH of 6 to 7, but will tolerate soils below that range. While some like alfalfa grow poorly at a pH of less than 6; others like red clover and birdsfoot trefoil tolerate a lower soil pH.

Alfalfa can provide great benefits to organic farmers. One producer from Lac Qui Parle County has found that his operation truly began to turn around once he incorporated alfalfa into his rotation. He finds better soil, better yields, and greater weed control.

For good yields and persistence of all legumes, potassium, phosphorus, and sulfur need to be applied at recommended levels, based on soil testing, using approved organic fertilizers or manures.

Saturated or poorly drained soils inhibit root growth and nitrogen fixation of legumes and promote diseases. Alfalfa is not tolerant of wet soils; red clover has greater

Figure 12-7. Alfalfa winter injury. ***Winter injury occurred in the low-lying areas of this field where ice formed during the winter.***

A producer from Faribault County prefers red clover over alfalfa for its consistency under his conditions. He plants at 8-10 pounds/acre and uses a medium red clover type.

tolerance, while birdsfoot trefoil has very good tolerance. No legume will tolerate flooding for more than a few days especially when air temperatures exceed 50° F. Poorly drained soils can also develop ice sheeting during winter. Legumes have poor tolerance to ice sheeting that continues for greater than a week (Figure 12-7).

All plants and sometimes varieties vary in winter hardiness. In the North Central Region, winter injury occurs due to a combination of low temperatures and lack of snow cover. Winter injury is also greater in poorly-drained soils than well-drained soils.

Reducing risk: legume adaptation. If soil pH is too low for alfalfa, grow red clover or birdsfoot trefoil instead. Test soil nutrients and apply amendments accordingly. Plant red clover or birdsfoot trefoil, instead of alfalfa, if soil lacks good drainage. Choose legume varieties with proper winter hardiness for your area. (edited)

Legume use

An essential component in choosing a forage legume will relate to the ultimate use. Factors to consider include frequency of cutting, hay quality, persistence, nitrogen contribution, and ease of establishment.

Frequent cutting stimulates regrowth and can deplete energy reserves. Producers should plant alfalfa if planning more than two cuts. Market is another important consideration.

When growing as a hay crop, forage quality will be vital. All legumes can produce hay of high nutritional value if harvested at immature stages. However, some legumes contain anti-quality components.

If planning to grow the crop for more than one year, long-term persistence will be important. Because of variability in winter hardiness and disease resistance, legumes vary in persistence. For example, red clover can provide good short term yields, but most varieties do not typically persist beyond the second year after seeding.

Contribution of nitrogen to subsequent crops in rotation will vary by species and the amount of herbage incorporated. Alfalfa and red clover are best for most organic rotations. Sweet clover is a traditional green manure crop for non-harvested systems.

If seedbed conditions tend to be poor at the time of forage establishment, seedling vigor will be something to consider. Seedling vigor affects the success of establishment especially during periods of less than ideal seedbed conditions. Red clover has greater seedling vigor than alfalfa and other legumes and is therefore more useful for frost seeding.

Reducing risk: legume use. Use only alfalfa if planning to cut forage more than three times or if planning to grow for more than two years. White clover and sweet clover are not good choices for hay. Red clover, berseem, and sweet clover are excellent green manures. See Table 12-2 for a summary of risk in forage legume production.

Table 12-2. Risk factors in the production of alfalfa, red clover, and white clover.

	Soil pH			Soil fertility			Soil moisture			
	5.5	6.5	6.5	low K	low P	low S	Dry	Wet	Cutting more than 3 times	Poor establishment
Alfalfa	high risk	very low risk	low risk	moderate risk	moderate risk	no effect or risk variable	low risk	moderate risk	very low risk	moderate risk
Red clover	no effect or risk variable	very low risk	low risk	moderate risk	moderate risk	no effect or risk variable	low risk	low risk	high risk	low risk
White clover	no effect or risk variable	very low risk	low risk	moderate risk	moderate risk	no effect or risk variable	low risk	low risk	high risk	no effect or risk variable

= very low risk
= low risk
= no effect or risk variable
= moderate risk
= high risk

GRASS SELECTION

Timothy, smooth bromegrass, reed canarygrass, and orchardgrass are most frequently grown in mixture with legumes or alone for hay or pasture. Kentucky bluegrass is a low-growing species that is used mostly in pastures.

Grass species

The following grasses are among the best suited for Upper Midwest. See Table 12-3 for a summary of traits.

JOHN CARDINA, OSU

Figure 12-8. *Smooth bromegrass.*

Smooth bromegrass is a long-lived, cool-season, tall-growing, sod forming perennial. It is frequently grown in mixture with alfalfa although in some regions pure stands exist. For haymaking, stands of smooth bromegrass are typically harvested three times per season with stems produced at all harvests. It has excellent winter hardiness and drought tolerance.

A producer from McLeod County uses a medium red clover type, which does better in his high magnesium and low calcium soils, but prefers alfalfa for feeding his livestock.

Table 12-3. Characteristics of various grasses for the Upper Midwest.

	TOLERANCE TO:						
GRASS	Heat/ drought	Wet	Winter injury	Frequent cutting/ grazing	Soil acidity	Seedling vigor	Maturity*
Kentucky bluegrass	P	G	E	E	F	F	Early
Orchardgrass	G	F	G	E	G	E	Early-medium
Perennial ryegrass	P	F	P	E	G	E	Early-medium
Reed canarygrass	E	E	E	E	E	P	Medium-late
Smooth bromegrass	E	F	E	P	F	E	Medium-late
Tall fescue	G	G	F	E	E	E	Medium-late
Timothy	P	P	E	P	G	G	Late

* Relative time of seed head appearance in spring. Will also depend on variety.

E = excellent, G = good, F = fair, P = poor

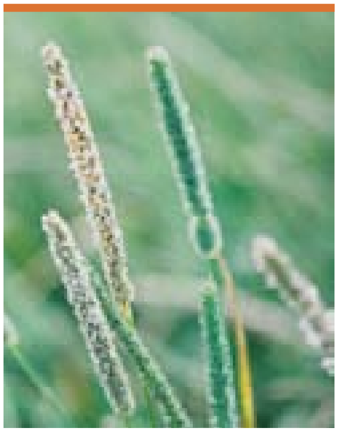

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Figure 12-9. *Timothy.*

Timothy is a tall, long-lived, cool-season bunch grass. Timothy is used in mixture with alfalfa and other legumes. It grows best under cool and moist conditions and does not yield well in regions with hot, dry summers.

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Figure 12-10. *Orchardgrass*

Orchardgrass is a cool-season, perennial bunch grass. Its growth habit results in an open sod. It is used in pastures or as a hay crop and often in mixture with alfalfa. Spring regrowth is stemmy but summer and fall growth is mostly leaves. Orchardgrass can suffer winter injury during years without snowcover. Some producers dislike orchardgrass because it matures early and its first growth is stemmy with low palatability. Also, it can be clumpy on the field.

Figure 12-11. *Reed canarygrass.*

Reed canarygrass is a tall, cool-season, sod-forming perennial. It can be used in pastures or harvested for hay. It is known for its productivity in wetlands but also has good heat and drought tolerance. It has excellent forage yield potential. Reed canarygrass is slow to establish. The forage is very stemmy if allowed to mature and the spring regrowth must be harvested before flowering. It can become an invasive species if allowed to go to seed. Wild types of reed canarygrass can contain alkaloids that are undesirable chemicals that affect livestock performance. Growers should purchase only low-alkaloid varieties.

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Figure 12-12. *Perennial ryegrass.*

Perennial ryegrass is a short-lived, cool-season grass used for pasture and haymaking. It has excellent nutrition for livestock and is highly palatable. Its value is limited because of lack of winter hardiness and limited heat and drought tolerance. Perennial ryegrass is used alone and in mixtures with legumes.

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Figure 12-13. *Kentucky bluegrass.*

Kentucky bluegrass is a low-growing species used for continuous or rotational grazing. However, its yields are lower than the tall growing grasses. It has poor heat and drought tolerance and under-goes a pronounced summer slump. Kentucky bluegrass is frequently found in mixture with white clover in perennial pastures.


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Figure 12-14. *Tall fescue.*

Tall fescue is a perennial bunch grass that is best adapted to grazing. For the North Central Region, its use is limited by lack of winter hardiness except where reliable snow cover occurs.

Grass adaptation

As with forage legumes, soil pH, soil fertility, soil moisture, and winter hardiness will influence the success in growing forage grasses. For best establishment and production of grasses, a pH of 6.0 – 7.0 is recommended; however, grasses are much more tolerant of lower and higher pH than legumes and will grow well with the pH of most agricultural soils.

For good yields and persistence, N, K, P, and S need to be applied at recommended levels. Nitrogen is essential for grass growth and can be supplied by legumes growing in mixture or by fertilizers.

Grasses have a range of moisture tolerances. Only reed canarygrass can tolerate periods of prolonged flooding. Smooth bromegrass is the most drought-tolerant grass. Timothy lacks drought tolerance.

As described for legumes, winter hardiness is an important trait. Orchardgrass, perennial ryegrass, and tall fescue are among those grasses with lower levels of winter hardiness and may suffer winter injury.

Reducing risk: grass adaptation. Test soil nutrients and apply amendments accordingly. Choose grasses with proper drought tolerance, maturity, and winter hardiness for your area. Long-term yield and persistence of tall-growing grasses can be increased by cutting at three to four inches instead of one inch. Of course, Kentucky bluegrass can tolerate a one-inch cutting height.

Grass use

Factors to consider when growing forage grasses include frequency of cutting or grazing, as well as persistence. Frequent mechanical cutting can deplete the energy storage reserve of grasses, but grasses differ in the amount of energy storage. Reed canarygrass is most tolerant of frequent (three to four times per season) cutting, while timothy is less tolerant.

As with frequent cutting, continuous grazing by livestock can deplete grass energy reserves. Low-growing Kentucky bluegrass has greater tolerance of continuous grazing than tall growing grasses.

Because of variation in storage reserves and growth habit, grasses differ in persistence. Winter hardiness can also be a factor. Reed canarygrass and smooth bromegrass have greater long-term persistence (four+ years) than other grasses.

Reducing risk: grass use. Use reed canarygrass, orchardgrass or smooth bromegrass if planning to cut forage for hay more than three times. Choose Kentucky bluegrass under continuous grazing conditions. If planning to grow a grass for more than two

Figure 12-15. *An alfalfa and reed canarygrass mixture.*

years, reed canarygrass and smooth bromegrass are better choices.

GRASS AND LEGUME VARIETY SELECTION

For most grass and legume species, organically produced varieties are available. Varieties differ in traits and should be selected using the same criteria as discussed previously.

Reducing risk: variety selection. It is less risky to purchase a variety with known traits than a blend or a product with no variety identified. It is best to select varieties that reach your target maturity when you normally harvest.

GRASS-LEGUME MIXTURES

Mixtures of legumes and grasses are frequently used for forage (Figure 12-15). Growing a diversity of plants provides several risk reduction advantages compared to pure stands. Advantages are more pronounced when plants can be selected with diverse growth habits, competitiveness, and adaptation to environmental conditions.

Benefits of Mixtures

Mixtures enhance resource utilization. Grasses have fibrous root systems that remove nutrients and water mostly in the top foot of soil, while legumes typically have a tap root system that can penetrate deep in the soil profile and extract nutrients and water. Alfalfa with its deep tap root has greater drought tolerance than most grasses (Figure 12-16).

Legumes conduct biological nitrogen fixation; whereas grasses require nitrogen. Legumes can transfer nitrogen to grasses in mixture. However, legumes are generally more sensitive to low fertility compared to grasses. Mixtures of legumes with grasses are often more productive than either plant grown alone. This especially occurs as stands age and the stands of some species decline.

Mixtures promote survivability. Should winter injury or disease eliminate one species in the mixture, another will likely survive insuring stand persistence. Seeding grasses in mixture with alfalfa has been shown to reduce alfalfa winter injury by protecting the alfalfa crowns.

Figure 12-16. *Fibrous grass roots (left) and alfalfa taproots (right)—the nodules on alfalfa are the sites of nitrogen fixation.*

A producer from Lac Qui Parle County grows alfalfa in a mixture. He has problems with weeds when he grows alfalfa by itself.

Table 12-4. Growth habits of legumes and grasses.

CROWN-FORMERS	SPREADERS
Alfalfa	White clover
Red clover	Smooth bromegrass
Birdsfoot trefoil	Kentucky bluegrass
Orchardgrass	Reed canarygrass
Timothy	
Tall fescue	
Perennial ryegrass	

Legume forage tends to be more succulent than grass forage. Mixing grasses with legumes will increase the rate of drying of the total forage.

Legumes like alfalfa and red clover can cause bloat in ruminants like cows and sheep. Inclusion of a grass with the legume will reduce the incidence of bloat.

Mixtures can provide better weed control. Grasses have fibrous root systems and a spreading growth habit that covers the soil surface by filling in around crown-forming legumes like alfalfa and red clover. The combination of grasses and legumes can resist encroachment of weeds.

Mixture guidelines

One way to benefit from forage mixtures is to include species with diverse growth habits. Two types of growth habits are crown-forming versus spreading plants (Table 12-4).

Keep mixtures simple. Start with a legume and a grass that are most productive in your region. Shotgun mixtures that contain five or more species are typically not the most productive or persistent.

Forage mixture seeding rates

Here are some example forage mixtures with seeding rates for different uses.

Mixtures for plow down only (seeding year only):

Alfalfa (15 lb/acre) or Red clover (10 lb/acre)	*with*	Annual ryegrass (2 lb/acre)

Mixtures for hay or silage production:

Alfalfa (8 lb/acre) or Red clover (8 lb/acre)	*with*	Smooth bromegrass (8 lb/acre) or Timothy (4 lb/acre) or Orchardgrass (10 lb/acre)
Alfalfa (10 lb/acre)	*with*	Perennial ryegrass (6 lb/acre)

Mixtures for pasture:

Red clover (7 lb/acre) and Alsike clover (3 lb/acre) and White clover (1 lb/acre)	*with*	Orchardgrass (4 lb/acre) or Smooth bromegrass (6 lb/acre) or Perennial ryegrass (2 lb/acre)
Kura clover (6 lb/acre) and Birdsfoot trefoil (2 lb/acre)	*with*	Orchardgrass (4 lb/acre) or Reed canarygrass (4 lb/acre)

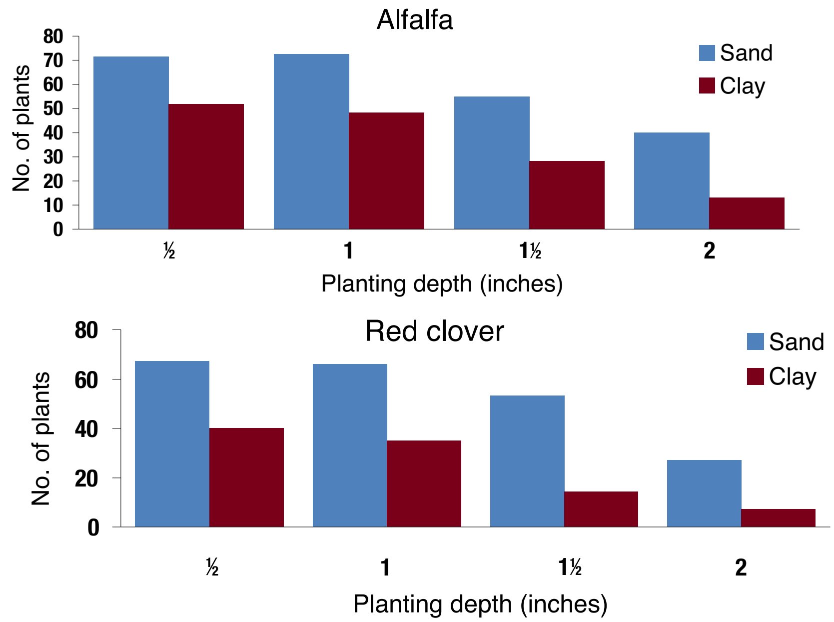

Figure 12-17. Alfalfa and red clover stands *produced by planting 100 seeds at four planting depths. Shallow seeding of alfalfa and red clover provides the greatest stands for sand and clay soils. At depths beyond 1/2 inch, seedling numbers decrease dramatically for the clay because of compaction. Adapted from Sund et al., 1966.*

Components of mixtures need to be selected for compatibility with mechanical harvesting versus pasture usage. Select species and varieties with similar maturity and palatability. This will provide mixed forage of uniform quality and insure that all portions will be consumed.

Reducing risk: forage mixtures. Choose mixtures with two or three species with diverse growth habits and adaptation to soil types. Species and varieties of grasses and legumes should have similar maturities to make harvest scheduling easier. For example, orchardgrass matures in mid-May, while alfalfa reaches target maturity at the beginning of June.

Forage establishment

SEEDBED PREPARATION

Small seeded grasses and legumes need fine yet firm seedbeds to insure good soil-seed contact. Ideally, the seedbed should be firm with some residue remaining as occurs with conservation tillage (>30 percent residue). This is usually achieved by disking or field cultivation followed by harrowing.

Rough uneven seedbeds reduce soil-seed contact and do not allow uniform planting depths. Excess crop residue can reduce seed contact with the soil and the seed will not germinate in a timely way. If rainfall occurs and the seed germinates on the residue, it will die if the root cannot reach the soil. Overworked seedbeds with no crop residue can result in soil crusting that prevents seedling emergence. This is particularly a problem on fine-textured (clay and silty) soils.

Reducing risk: seedbed. Prepare a firm seedbed with some residue. Ideally, your shoes should not sink greater than one inch into the seedbed.

PLANTING DEPTH

Small-seeded grasses and legumes are typically seeded 1/4 to 1/2 inch deep on most fine textured soils but somewhat deeper on drier, sandy soils (Figure 12-17). This provides moisture for germination of the seed and the seedling can reach the soil surface upon germination. Seed placed on the soil surface can absorb water following rainfall and begin to germinate but may die before the root can enter the soil. Seed planted too deep depletes its energy reserves before reaching the soil surface.

Table 12-5. Seeding rates for forage legumes and grasses alone and in mixtures.

	SEEDING RATE (BU/AC)	
	Pure stands	In mixtures
LEGUMES		
Alfalfa	13	5
Birdsfoot trefoil	8	6
White clover	4	2
Red clover	9	5
Sweet clover	10	3
GRASSES		
Bromegrass	16	5
Orchardgrass	10	3
Reed canarygrass	7	5
Tall fescue	15	5
Timothy	6	3
Perennial ryegrass	15	6
Kentucky bluegrass	10	5

Reducing risk: planting depth. Seed needs to be planted 1/4 to 1/2 inch deep on most soils and up to one inch deep on sands. Calibrate your seeding equipment. Seed on the soil surface will be a greater risk.

Figure 12-19. *Oat as a companion crop with alfalfa.*

PLANTING RATES

Planting rate recommendations are focused on establishing a target grass or legume population in the seeding year when all risks to establishment are considered. Target seeding year populations are from 25-50 plants/square foot. With a typical survival of about 60 percent, this provides adequate plant populations for the first production year. To achieve these populations, seeding rates are shown in Table 12-5.

Reducing risk: planting rates. Exceeding the recommended seeding rates creates an economic risk because farmers bear the cost of applying more pounds of expensive seed. Inadequate seeding rates due to lack of seeder calibration results in seeding year populations that reduce yields and lower stand life.

Legume and grass emergence

Legumes and grasses have different types of emergence (Figure 12-18). Legumes have epigeal emergence that results in the seed cotyledons being pulled from below the soil surface. Exposure of all the leaves and growing point can lead to defoliation and frost damage. Grasses have hypogeal emergence and the seed stays below ground protecting the growing point from damage.

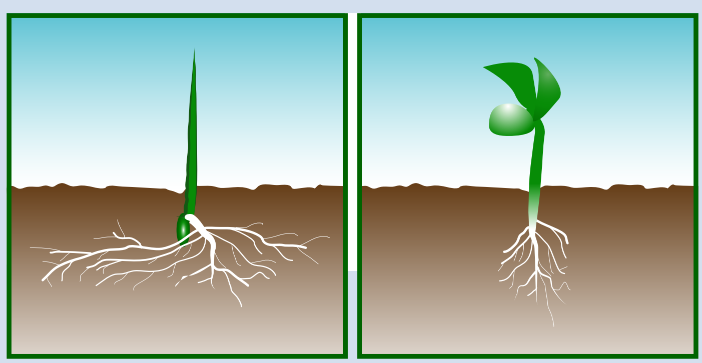

Figure 12-18. *Grasses have hypogeal emergence (left) while red clover and alfalfa have epigeal emergence (right).*

Figure 12-20. ***Barley and oat companion crops used for alfalfa and red clover establishment.***

ESTABLISHMENT: COMPANION CROPS VS. SOLO SEEDING

Small-seeded legumes and grasses are established by two approaches: companion crops and solo seeding. Of these approaches, companion crops are most commonly used for spring seedings, whereas solo seeding is used for late summer plantings after small grain harvest.

Companion crops

Companion crops (also called nurse crops) are planted with small-seeded legumes and grasses and can be harvested for forage, straw, and grain (Figure 12-19). They are either small grains like spring oats, spring wheat, and spring barley or flax (Figure 12-20).

Using companion crops when establishing forages has several advantages. Companion crops cover and stabilize the soil and minimize seedling loss due to wind and water erosion. They are essential for hilly sites or sandy, wind-blown soils. Companion crops suppress weeds and seedling loss due to competition with weeds can be lessened (Figure 12-21).

Companion crops provide a product (e.g., forage, grain, and straw) for farm use and economic return during the seeding year when forage crop yields are normally low.

Companion crops can have disadvantages, too. They compete for light and water with small seedlings and can reduce establishment and yields. In addition, forage or straw from mature small grains can smother the legumes if left in rows on the field (Figure 12-22). Volunteer small grain can result from shattering of mature grain during harvest. The shattered grain can germinate with favorable moisture conditions and compete with and smother the forage seedlings.

Figure 12-21. ***A comparison of flax (left) and barley (right) companion crops. Barley is a better competitor with weeds than is flax, as is evident from the weed canopy over-growing the flax crop.***

Reducing risk: companion crops. Do not leave rows of straw or cut forage on longer than three days. Allowing small grains to grow to maturity will prolong competition with forage, leading to greater risk. Choose earlier maturing companion crops. Choose oats or flax, which will be less competitive with forages, instead of semi-dwarf varieties of wheat or barley. Do not apply N fertilizers to small grains with companion crops, as this may cause lodging. Lodged small grains can smother the forage seedlings.

Figure 12-22. *When companion crops are used for alfalfa and red clover establishment, it is important to promptly remove the straw following small grain harvest. After a week, the straw can kill the alfalfa seedlings.*

Alfalfa establishment with companion crops

Organic alfalfa establishment with companion crops was examined at three sites in Minnesota. The companion crops used were oats, wheat, barley, pea, and flax. It was found that small grains performed similarly with alfalfa, while peas were the most competitive with alfalfa (Table 12-6). Reducing small grain seeding rates is sometimes recommended to reduce competition with legume seedlings, but this research found no effect of small grain seeding rate on legume populations or stands (Table 12-7).

In the same experiment, alfalfa was seeded by August 15 after small grain harvest. This also can result in good establishment of the legume if moisture is adequate (Table 12-8).

Table 12-7. Effect of reducing seeding rates on companion crop grain and alfalfa yield.

GRAIN	SEEDING RATE (BU/AC)	GRAIN YIELD (BU/AC)	ALFALFA YIELD (TON/AC)
Oat	2.5	84	6.3
	1.3	78	5.7
Wheat	2.0	48	6.9
	1.0	33	6.7
Barley	1.8	78	5.9
	0.9	71	6.6
Pea	3.0	54	4.8
	1.5	38	5.1

Table 12-6. Alfalfa seeded with small grain: cover crop grain and alfalfa yield.

COVER CROP	GRAIN (BU/AC)	ALFALFA (TON/AC)	
	2006	2006	2007
Spring oat	84	0.4	6.3
Spring wheat	48	0.5	6.5
Spring barley	78	0.4	5.9
Field pea	54	0.2	4.8
Flax	19	0.4	6.7
No companion crop	--	--	6.1

Table 12-8. Alfalfa seeded after small grain harvest: cover crop grain and alfalfa yield.

COVER CROP	GRAIN (BU/AC)	ALFALFA (TON/AC)
	2006	2007
Spring oat	91	2.7
Spring wheat	42	4.7
Spring barley	66	3.4
Field pea	74	2.7
Flax	14	4.8
No companion crop	--	6.2

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Figure 12-23. *Oats.*

Small grains for spring forage establishment

Oat is the most traditional companion crop in the Midwest. It is frequently grown for production of grain and straw for bedding. The grain is the least energy dense of the small grains, thereby reducing the risk of overfeeding of energy to horses. Oat is also the least competitive small grain and will have less impact on small forage seedlings. Only spring oats are grown in the Midwest.

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Figure 12-24. *Six-row barley.*

Barley is primarily grown for production of grain for livestock feeding or, if high enough quality, for malting. Semi-dwarf varieties produce a high quality forage. Many barley varieties mature ahead of other small grains and that allows earlier harvest and reduces the period of competition. Semi-dwarf barley produces multiple tillers and can provide high levels of competition.

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Figure 12-25. *Wheat.*

Wheat is valued for grain processed for food products. Spring varieties are used as companion crops. Semi-dwarf varieties can provide significant competition with small legume seedlings. Winter varieties of wheat are sown in the fall, but may winter-kill in northern latitudes. Frost seeding of legumes into winter wheat during winter is not recommended because of excess competition.

A producer from McLeod County finds it difficult to start alfalfa with solo seeding. He establishes alfalfa with an oat companion crop, grows the alfalfa for three years, fall plows the alfalfa, then plants corn. This practice provides nitrogen and reduces weed pressure on the corn.

Figure 12-26. *Winter rye.*

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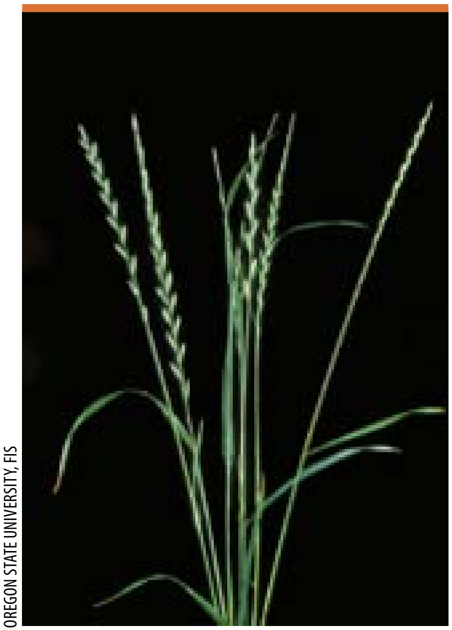


Figure 12-27. *Annual ryegrass.*

Winter rye is the only winter grain that reliably overwinters in the Midwest. It will not flower if planted in the spring. Therefore it is not useful as a spring-seeded small grain. Winter rye can be used as a spring-planted companion crop if a vegetative forage is desired. When planted in the spring, winter rye remains vegetative and can be harvested as forage. It will be killed by disease and summer temperatures. However, winter rye can compete with forages.

Annual (Italian) ryegrass is a forage-type rye that is spring seeded and used as a companion crop. It produces a very high quality forage and can enhance total forage yields. Annual rye can compete with alfalfa and red clover seedlings if seeding rates are greater than 10 pounds per acre.

Winter grains: Winter wheat and rye are seeded in the fall, overwinter, and vigorously grow in the spring. Frost seeding of legumes into winter grains is not recommended because of the excessive competition provided by these grains.

Solo seeding

Solo seeding is the direct seeding of small-seeded legumes or grasses in the spring or late summer without companion crops. Solo seeding provides the greatest opportunity to maximize seeding year yields if seeding occurs in the spring. Late summer solo seeding provides no yields in the seeding year but can result in vigorous stands the following year.

Reducing risk: solo seeding. Solo seeding is best in fields with low weed populations because weeds can provide significant competition with small-seeded legumes and grasses. Wind and water erosion can be greater when planting small-seeded grasses and legumes on sandy, windblown, or erodible soils.

Planting date

There are a number of options for time of establishing forages, including frost, spring, or summer seedings.

FROST SEEDING

Frost seeding takes advantage of the freezing and thawing action of the soil to bury small seeds. Typical times of frost seeding are late fall when average air temperatures are less than freezing, in midwinter, and in very early spring. Frost seeding is inexpensive and requires little equipment. Research in Minnesota has shown that frost seeding can be risky in Minnesota (Table 12-9 and Figure 12-28).

Figure 12-28. *Plants frost seeded in winter germinated only in the cracks of the soil (above) and led to an unsuccessful planting (top).*

Reducing risk: frost seeding. Before committing to frost seeding, realize that this will be a risky practice in many areas. Winter temperatures on bare soils may reach levels to promote germination of seeds that are later killed. Late spring frosts that occur after seedling germination also can kill seedlings. Risk can be minimized by buying inexpensive seed.

Table 12-9. Alfalfa and red clover mix yields *in summer when frost seeded in early winter (December), late winter (March), and spring (April) at Rosemount and Lamberton. Frost seeding in winter often resulted in no plant establishment and no yield.*

		ROSEMOUNT		LAMBERTON	
Date of seeding	Forage	2007	2008	2007	2008
		YIELD IN TONS/ACRE			
Early winter	Alfalfa	0.2	0	0	1.9
	Red clover mix	0	0	0	1.7
Late winter	Alfalfa	0.3	0	0	1.4
	Red clover mix	0.2	0	0	1.4
Spring	Alfalfa	0.4	1.3	0.1	1.0
	Red clover mix	0.5	0.8	0.2	1.2

SPRING SEEDING

Spring seeding provides the opportunity for seedlings to grow and produce forage in the first year. Generally, crops are sown at a time to take advantage of the seasonal patterns of precipitation, favorable moisture, and to capture the maximum amount of solar energy. For solo or companion crop seeding, see Figure 12-29 for the optimum times for seeding in the Upper Midwest. Recommended planting date shifts about one week later or earlier per 100 miles north or south.

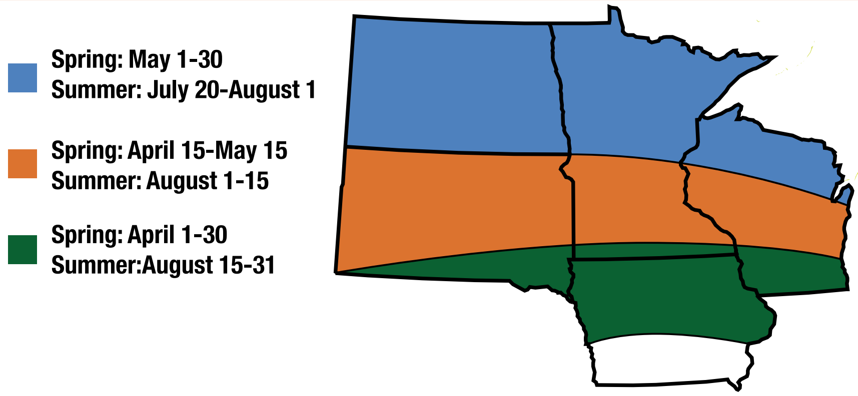


Figure 12-29. *Optimum times for spring or summer seeding of forages.*

Reducing risk: spring seeding. Plant at the recommended time for your region. Planting before the recommended date will lead to an increased risk of frost damage. Planting after will increase risk of moisture deficit, high temperatures and competition with annual weeds.

SUMMER SEEDING

Late summer seedings are typically sown after harvesting a spring-seeded crop such as a small grain. Successful summer seeding depends on adequate soil moisture, as well as adequate heat units for plants to develop more than three leaves and a crown before the onset of freezing temperatures. This typically takes from six to eight weeks. Therefore, the decision is influenced by the climate in a region. For most of the North Central region, the optimum time to summer seed forages is August 1 – 15 (Figure 12-29).

Reducing risk: summer seeding. The least risky time to summer seed in Minnesota is at the beginning of August, unless significant weed pressure is anticipated. Planting at the end of August may leave plants an inadequate time to develop. After the beginning of September, there is a great risk of winter kill to seedlings and yield reduction the following year. For winter survival, legumes and grasses must develop a crown and have three to five leaves formed. Snow cover of six inches during the winter can protect summer seedings from winter injury.

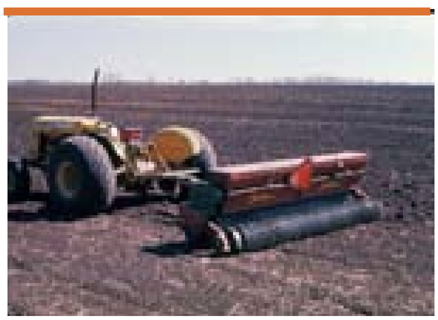


Figure 12-30. *A cultipacker consists of two rollers.*

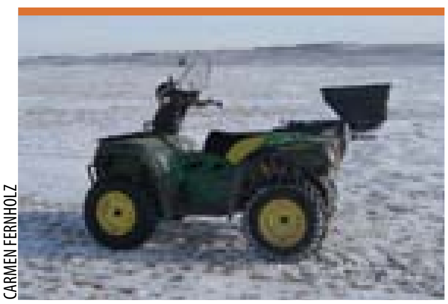
Seeding equipment

Broadcast seeding and drill seeding are two approaches to seeding of small-seeded legumes and grasses. Each can result in successful seeding if proper seeding depth and soil seed contact occur.

BROADCAST SEEDING

Broadcast seeding can be achieved by aerial, manual or mechanical sowing or by using a cultipacker seeder (Figures 12-30 and 12-31). With broadcasting of seed, distribution and coverage are risk factors. Excessive residue from the previous crop on the soil surface can prevent the seed from reaching the soil.

Producers sometimes incorporate legume seed by light harrowing. Dragging can incorporate seed but carries a high risk of burying seed too deep.



CARMEN FERNHOLZ

Figure 12-31. *Frost seeding can be done using a ATV on frozen ground. Frost seeding depends on the freezing and thawing of soil to cover seed.*

A couple from Stevens County successfully establishes alfalfa by broadcast seeding and harrowing it after they have drilled wheat. They have livestock and usually have 100 acres of alfalfa.

Reducing risk: broadcast seeding. **Consider drilling if there is excessive residue. Dragging can be risky, depending on conditions. Cultipacker seeders can compact clay soils if the soil is moist. Cultipacker seeders pack the soil and cover the seed ensuring shallow seed placement into a firm seedbed.**

Alfalfa autotoxicity

Autotoxicity is a risk when trying to establish alfalfa after alfalfa. The result of autotoxicity is poor establishment of new seedlings. Autotoxicity is likely related to the presence of chemicals that are produced by decaying herbage. Growers should plant corn or other crops requiring N fertilization to utilize nitrogen, but sometimes alfalfa is planted after alfalfa. Take the **Alfalfa Autotoxicity Quiz** at the end of the chapter to assess your autotoxicity risk.

Figure 12-32. *For successful seeding of small-seeded legumes and grasses with a grain drill, risks are reduced if the drill has a small-seeded legume box, tubes which deliver the seed behind the coulters and press wheels that increase soil-seed contact.*

DRILL SEEDING

Seeding with a grain drill or specialized seeder places in rows that are typically six to seven inches apart (Figure 12-32). With drills, coulters open the soil and deposit the seed (Figure 12-33). This can occur with small grain drills equipped with legume seed attachments or with specialized drills designed to insert seed into untilled seedbeds.

Reducing risk: drill seeding. **Reduce risk of improper planting depths by adjustment of drop tubes from legume seed boxes to insure shallow seed placement. Visually inspect the depth of seeding. Use drills with depth control bands. Use press wheels that follow the coulters to increase soil-to-seed contact.**

Figure 12-33. *A grassland drill can be used for seeding legumes and grasses into grass sods or small grain stubble. Note that it has a coulter for slicing the soil, openers to make a place to deposit the seed and press wheels for getting soil-seed contact.*

Weed control in forages

Annual and perennial weeds can affect forage crop establishment, forage persistence, and forage quality. Forage production is an effective way to reduce weed populations. Many annual weeds can be controlled by routine harvesting or grazing that coincides with harvesting of the forage crop. Likewise, even weeds like Canada thistle can be controlled by forage harvest.

Producers need to be aware that weeds may provide yield and have good levels of forage quality (Tables 12-10 & 12-11). Therefore, their control may be unnecessary unless weeds compete with the crops for resources and reduce their yield.


COURTESY OF JOHN DEERE.

Figure 12-34. *Forage harvest.*

Reducing risk: weed control. Poor weed control in annual crops will increase risk in forages because of buildup of weed seed banks and increasing perennial weeds. Increase diversity in crop rotation; rotating different crops will reduce weed populations.

Table 12-10. Forage quality of alfalfa and annual weeds. *Adapted from Maten and Anderson, 1975.*

SPECIES	DIGESTIBILITY	ACID DETERGENT FIBER	CRUDE PROTEIN
Alfalfa	72	24	27
Redroot pigweed	73	21	25
Lambsquarters	68	22	25
Common ragweed	73	25	25
Pennsylvania smartweed	51	22	24
Yellow foxtail	69	30	20
Giant foxtail	62	33	18
Barnyardgrass	70	33	18

Table 12-11. Palatability of oats and weeds for sheep. *Adapted from Maten and Anderson, 1975.*

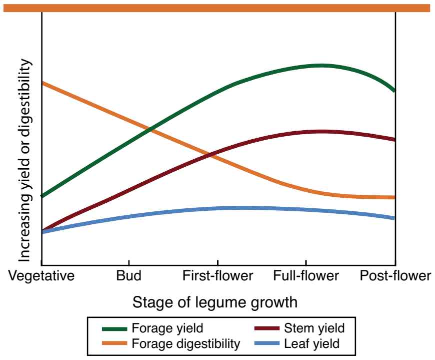
CATEGORY	SPECIES	% OF FORAGE CONSUMED
Crop	Oats	73
Palatable grasses	Yellow foxtail	90
	Barnyardgrass	83
	Green foxtail	60
Palatable forbs	Redroot pigweed	80
	Pennsylvania smartweed	75
	Lambsquarters	72
Unpalatable grass	Giant foxtail	35
Unpalatable forbs	Wild mustard	3
	Giant ragweed	0
	Cocklebur	0

Successful harvests of forages

HARVEST DECISIONS

For both legumes and grasses, crop development influences the forage yield and forage quality. For any given harvest, forage yield increases with crop maturity and forage quality declines (Figure 12-35). These changes are related to changes in the leaf/stem proportion as the crop matures. Therefore, growers should harvest at a maturity to reach a specific forage yield or quality goal. Harvest of forages at vegetative stages will provide a high quality, leafy forage but will sacrifice yield and persistence. Harvest at flowering or later stages will prove high yield of stemmy, low quality forage.

On a seasonal basis, producers typically harvest forage crops from two to four times (Figure 12-36). A seasonal cutting schedule considers the forage yield and quality relationships at an individual harvest as well as the growing conditions within a region. Some sample harvest schedules for southern Minnesota are shown in Figure 12-37.



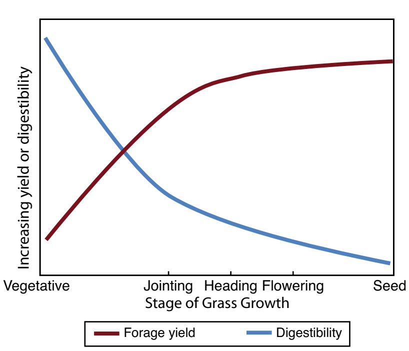


Figure 12-35. ***With increased maturity, yield increases as digestibility decreases in both legumes (top) and grasses (bottom).***

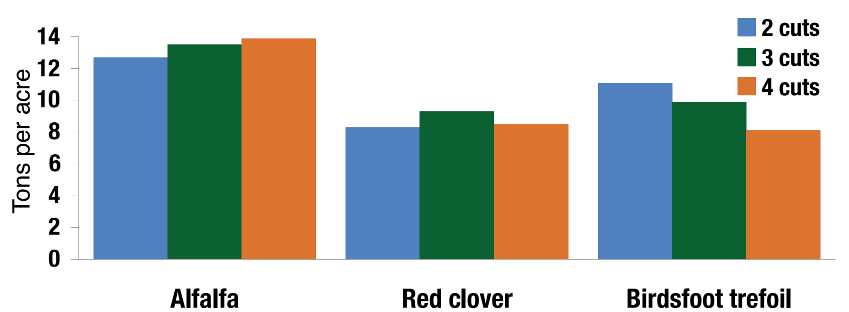


Figure 12-36. ***Effect of cutting schedules on alfalfa, red clover and birdsfoot trefoil at Lamberton, MN, in 1987-1989.***

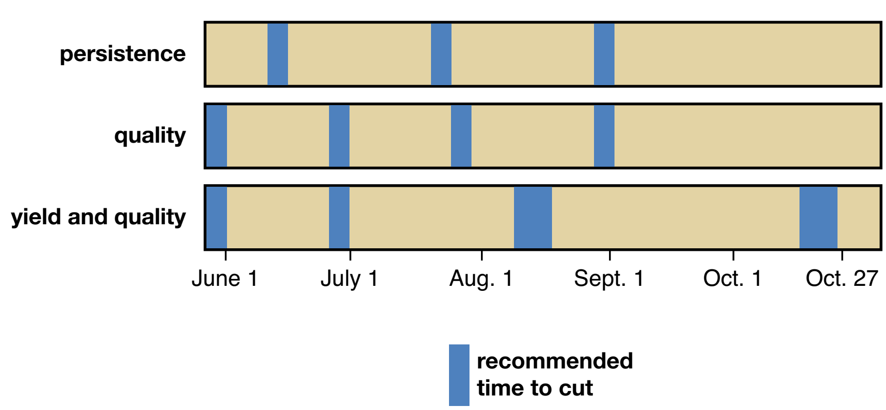


Figure 12-37. ***Cutting schedules can be selected for providing persistence, forage yield, and forage quality. These dates of alfalfa cutting apply for southern Minnesota and much of Wisconsin. For more northern sites, cutting will be delayed with fewer harvests per season. Adapted from Undersander et al., 2004.***

Figure 12-38. *Organic alfalfa at two stages of maturity. Alfalfa on left is flowering and lower quality than the vegetative alfalfa on the left.*

Reducing risk: harvest decisions. Seasonal schedules must be timed to allow the maximum number of harvests during the growing season to reach harvest and quality goals.

FALL CUTTING OF LEGUMES

Complicating harvest schedules for legumes are the risks associated with fall cutting. Generally this refers to harvest anytime after early September. Cutting after early September has the potential to lead to winter injury of legumes. Removing legume herbage stimulates regrowth from the crown. Such regrowth depletes carbohydrate reserves required for overwintering of the crop. Fall cutting removes herbage that catches snow and insulates the soil over winter.

Reducing risk: fall cutting. Take the Fall Cutting quiz at the end of the chapter to determine the risk of fall cutting.

HARVESTING OF FORAGES FOR HAY OR SILAGE

Forages are harvested for storage as hay or silage (Figure 12-39). Hay is stored in the air (aerobically) at a moisture level of 20 percent or less. In silage making, the forage is stored at moisture levels greater than 40 percent in structures or packages that exclude air (anaerobically). Both hay and silage making can lead to losses in forage yield and quality. In haymaking, losses as high as 30 percent occur due to weather exposure and to mechanical handling (Figure 12-40). Field losses are less for silage making because of shorter field exposure and because silage is handled at higher moisture content than hay. However, storage losses are higher because of biochemical reactions during storage.

Standing forage contains about 80 percent moisture. For successful storage, moisture levels must be decreased by field drying (Figure 12-41). This process is dependent on solar energy to drive moisture from plant herbage. Other climatic factors such as air temperature, wind speed, and relative humidly influence the drying rate. In the Midwest, one to three days are typically required for drying to safe storage moistures.

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Figure 12-39. *Large square hay bales are being loaded for transport.*

Forage quality: what is it?

Forage quality describes the potential feeding value of a forage. Ultimately, livestock convert potential feeding value into products humans use such as meat, milk, wool, or work. Nutritive value, intake, and antiquality factors are the three components of forage quality.

Nutritive value describes the nutrient content of the forage. Nutrients include crude protein, energy, and minerals are important for growth and sustenance of animals (Table 12-12).

Table 12-12. Average composition of forages *(on a dry matter basis). Legumes and grasses differ in their nutrient composition, which results in differences in forage quality. For livestock feeding, legumes are valued for their protein content, high intake potential, and digestibility. For both legumes and grasses, maturity affects forage quality. Adapted from Sheaffer, 1996.*

SPECIES / GROWTH STAGE	CRUDE PROTEIN	NEUTRAL DETERGENT FIBER*	ACID DETERGENT FIBER**	DIGESTIBILITY
Alfalfa				
- pre-bloom	22	41	31	65
- early bloom	18	48	38	58
- mid-bloom	16	50	40	56
- full bloom	15	52	42	54
Alfalfa-Grass mixture	17	52	36	55
Bromegrass (boot)	11	68	40	56
Red Clover (full bloom)	15	56	41	59
Orchardgrass (boot)	15	61	34	62
Timothy (boot)	9	61	32	59

* A predictor of forage intake potential; greater concentrations mean lower intake.
** A predictor of digestibility; higher concentrations mean lower digestibility.

Intake describes how much of a forage an animal will eat. Two forage factors affecting forage intake are its palatability and its fiber content.

Palatability describes the relative preference of a animal for one forage versus another. For example, grazing livestock will typically select immature ryegrass compared to thistle. Palatability is somewhat of an adaptive trait; i.e. animals can learn to eat a forage they initially reject.

Fiber in forages is made up of cell walls that are composed mostly of cellulose, hemicelluloses, and lignin. Compared to high energy feeds like corn, the bulky nature of forage fiber lowers the rate of digestion and passage of forage. Fiber is typically measured as neutral detergent fiber (NDF) that is a measure of the cell wall concentration.

Table 12-13. The effect of hay grade on medium square bale prices per ton (conventional). *Adapted from Martens, 2009.*

RFV	2007	2008
176-200	$ 123	$ 210
151-175	$ 111	$ 194
126-150	$ 97	$ 164
101-125	$ 81	$ 142

Antiquality factors include chemical compounds that reduce intake or cause detrimental affects to animal health or performance. For example, the soluble protein in alfalfa can cause bloating. Nitrates in sudangrass, sorghum, and some weeds can damage the hemoglobin and kill livestock. Alkaloids in reed canarygrass are bitter and reduce palatability, and if ingested cause digestive system disorders.

Two terms that you may encounter when evaluating overall forage quality are Relative Feed Value (RFV) and Relative Forage Quality (RFQ). The Relative Feed Value index ranks forage quality based on potential digestible dry matter of forages and the intake potential. RFV is used to establish a grade for selling and buying hay (Table 12-13). Relative Forage Quality is an index like RFV except that it ranks forages by potential digestible dry matter intake calculated by NDF and NDF digestibility.

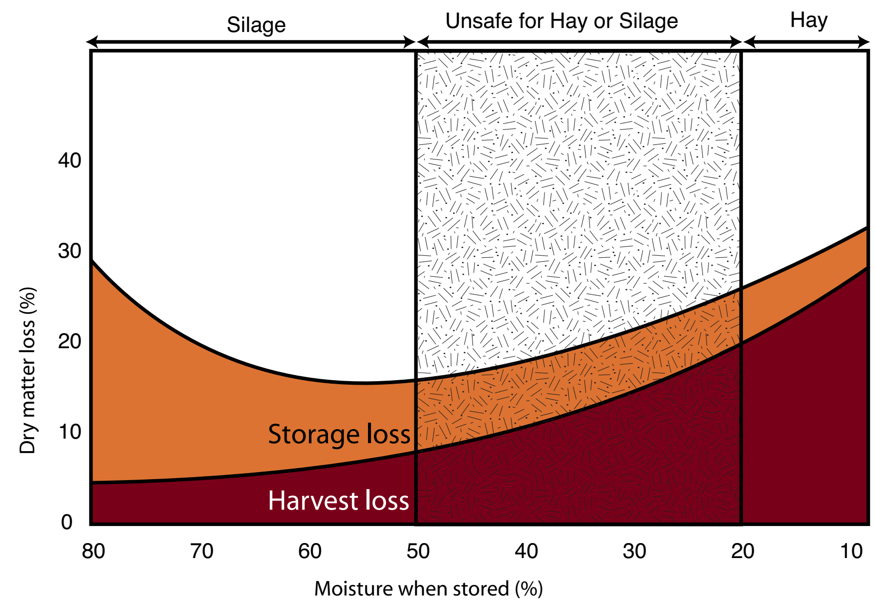

Figure 12-40. *Losses in dry matter with making of hay or silage. In the unsafe moisture range, forage is too wet for hay and too dry for silage. Adapted from Sheaffer and Moncada, 2008.*

Figure 12-41. *Mold growing on hay that was packaged too wet.*

Table 12-14. Changes in alfalfa quality with rain damage.
Adapted from Pitt, 1990.

	CP	DIGESTIBILITY	NDF	DM YIELD
	-------------- % --------------			TONS/ACRE
Standing crop	23	70	43	2
Hay	20	64	46	1.7
Rain-damaged hay	20	57	54	1.5

CP = Crude protein, NDF = Neutral detergent fiber, and DM = Dry matter

Heavy dew and rainfall during curing can cause significant losses in forage yield and quality by shattering leaves and leaching of nutrients (Table 12-14 & Figures 12-42 and 43). Legumes, especially the clovers, are wetter and dry slower than the grasses. Therefore, it takes longer to dry cut legume forage than grass forage. Planting grasses in mixtures with legumes will increase forage drying rate.

Reducing risk: harvesting of forages. **Avoid exposure to rain during drying by timing harvest during dry weather. Grasses dry quicker and are less of a risk of losses due to moisture.**

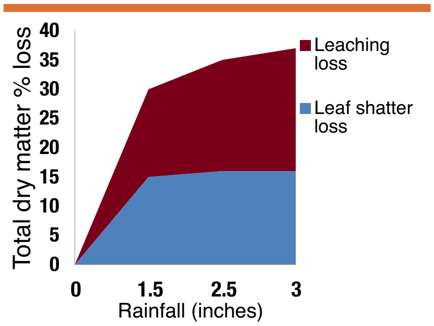

Figure 12-42. *Dry matter losses from leaching of nutrients and from leaf shatter during rainfall of varying amounts. Adapted from Pitt, 1990.*

Figure 12-43. *Alfalfa hay with rain damage. It was re-raked to facilitate drying. Note regrowth before harvest.*

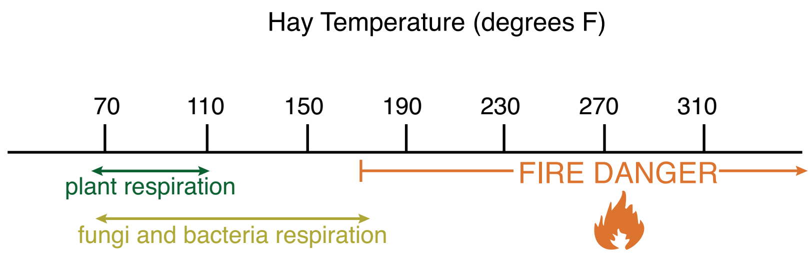

Figure 12-44. ***Plant respiration and microorganisms are responsible for the heating of hay that leads to spontaneous combustion.***

Hay

Heating and spontaneous combustion are major risks in hay making (Figure 12-44). For safe long-term storage of all hays a target moisture content should be less than 20 percent for small square bales (about 50 pounds) and less than 17 percent for larger bales (greater than 500 pounds). While heating and "sweating" occurs to some extent in all forage baled at above 15 percent moisture, the extent of heating is highly correlated to the moisture content at baling. Heat generated by plant respiration, molds, and chemical reactions can lead to losses in dry matter and forage quality, and if high enough, spontaneous combustion and barn fires can occur. In addition to changes in feeding value, handling of dusty, moldy hay can affect human and animal respiratory systems and cause health problems such as farmers' lung disease.

Reducing risk: hay.
See Table 12-15.

Silage

Successful silage making involves two important steps. The first is excluding oxygen from the forage. Oxygen exclusion occurs by using air-tight containers that can be plastic bags or wrappings, structures, or piles (Figure 12-45). Each ensiling system has advantages and disadvantages based on economic, environmental, and logistic concerns.

The second step is to rapidly develop a fermentation that reduces the pH and preserves the forage. During fermentation sugars in the forage are converted to lactic acid by bacteria normally present on the forage. Lactic acid reduces the pH to about 4.0-5.0 and pickles the forage inhibiting further microbial growth.

Reducing risk: silage.
See Table 12-16.

Figure 12-45. ***Silage can be successfully made in disposable plastic containers. The key to successful silage making is to exclude air.***

Table 12-15. Recommended hay-making practices to reduce risk. *Adapted from Pitt, 1990.*

PRACTICE	BENEFITS
Monitor weather forecast	Avoid rain damage
Mow forage early in day	Allows full day's drying. Less likelihood of rain damage.
Form mowed forage into wide swath	Increase drying rate. Faster drop in moisture. Less likelihood of rain damage.
Rake at 40 to 50 percent moisture content	Increased drying rate. Faster drop in moisture. Less likelihood of rain damage. Less leaf shatter.
Bale at 18 to 20 percent moisture	Optimum preservation. Less leaf shatter. Inhibition of molds. Low chance of fire.
Store under cover	Protection from rain, sun. Inhibition of molds. Less loss from rain damage.
Monitor new hay for heating	Indicates fire damage risk

Table 12-16. Recommended practices to reduce risk for hay crop grass-legume silage.
Adapted from Pitt, 1990.

PRACTICE	BENEFITS
Minimize drying time	Reduced nutrient and energy losses. More sugar to prolong fermentation.
Chop at correct length (3/8 inch). Fill silo quickly. Compact. Seal silo carefully.	Minimal exposure to oxygen. Reduced nutrient and energy losses. Reduced silo temperature and heat damage. Faster pH decline and lower pH.
Ensile at 60 percent dry matter content.	Optimum fermentation. Reduced nutrient and energy losses. Prevents leaching of water from silage.
Leave silo sealed for at least 14 days	Allows complete fermentation. Lower silage pH
Unload 2 to 6 inches per day. Keep smooth surface	Minimal spoilage
Discard deteriorated silage	Avoids animal health problems

COURTESY OF JOHN DEERE

Figure 12-46. *Baling hay.*

MEASURING FORAGE MOISTURE CONTENT

The ability to determine forage moisture will reduce risks in hay and silage production. There are three ways to measure moisture content—by hand, with a moisture tester, or using the microwave technique.

The hand method estimates forage moisture by compressing forage by hand to gauge its status. See Table 12-17. This method is very subjective and therefore most risky.

The second method is to use a moisture tester. The two types of moisture testers are heat and electronic conductance. The electronic testers are faster, but less accurate when compared to the heat moisture tester. The last method is the microwave technique. See **http://pubs.ext.vt.edu/442/442-106/442-106.html** for more information on this method. This method will give a good approximation of moisture and will be more accurate than electronic testers.

Regardless of the method used, it is important to obtain a sample that is representative of the forage to be tested.

Table 12-17. Hand method for estimating forage moisture concentration.

CHARACTERISTIC OF FORAGE SQUEEZED IN HAND	MOISTURE (%)
Water is easily squeezed out and forage holds shape	> 80
Water can just be squeezed out and forage holds shape	75 - 80
Little or no water can be squeezed out but forage holds shape	70 - 75
No water can be squeezed out and forage falls apart slowly	60 - 70
No water can be squeezed out and forage falls apart rapidly	< 60

Figure 12-47. *Cutting forages.*

MECHANICAL OPERATIONS

Mechanical operations of hay and silage making typically include baling or chopping (Figure 12-46). Leaves, which make up about half of forage mass, are fragile and are often the fraction that is lost (Table 12-18). Unfortunately, because leaves contain more nutrients and less fiber than stems, their loss leads to a significant change in forage quality.

Reducing risk: mechanical operations. **Minimize field operations and excessive handling of forages, especially when the forage is dry.**

Table 12-18. Mechanical operations and dry matter and leaves lost. *Adapted from Pitt, 1990.*

OPERATION	% DRY MATTER LOST	% OF LEAVES LOST
Mowing	1	2
Mowing/conditioning:		
- reciprocating mower, fluted rolls	2	3
- disc mower, flail conditioner	4	5
Raking:		
- at 70% moisture	2	2
- at 50% moisture	3	5
- at 20% moisture	12	21
Baling, pickup + chamber:		
- at 20% moisture	4	6
- at 12% moisture	6	8
Baling at 18% moisture:		
- conventional square baler/ejector	5	8
- round, variable chamber	6	10

Alfalfa Autotoxicity Quiz

Adapted from Undersander, et al, 2004.

	Points	Score
1. Amount of previous alfalfa topgrowth incorporated or left on soil surface		
Fall cut or grazed	1	
0 to 1 ton	3	
More than 1 ton	5	
2. Irrigation or rainfall potential prior to reseeding		
High (greater than 2 inches)	1	
Medium (1 to 2 inches)	2	
Low (less than 1 inch)	3	
3. Soil type		
Sandy	1	
Loamy	2	
Clayey	3	
4. Tillage prior to reseeding		
Moldboard plow	1	
Chisel plow	2	
No-till	3	
5. Age of previous alfalfa stand		
Less than 1 year	0	
1 to 2 years	1	
More than 2 years	2	
6. Reseeding delay after alfalfa kill/plowdown		
12 months or more	0	
6 months	1	
2 to 4 weeks	2	
Less than 2 weeks	3	
TOTAL		

ALFALFA RESEEDING RISK

If you score:	The autotoxicity risk is:
4 to 7	low
8 to 11	moderate
> 12	high

Alfalfa Fall Cutting Quiz

Adapted from Undersander, et al, 2004.

	Points	Score
1. What is your stand age?		
> 3 years	4	
2-3 years	2	
1 year or less	1	
2. Describe your alfalfa variety:		
a. What is its winter hardiness?		
Higher than recommended for region	3	
Recommended for region	2	
Lower than recommended for region	1	
A. TOTAL		
b. What is the resistance to important diseases in your region?		
No resistance	4	
Moderate or low resistance	3	
High level of resistance	1	
B. TOTAL		
Alfalfa variety total score (multiply a and b)		
3. What is your soil exchangeable K level?		
Low (80 or less)	4	
Medium (81-120)	3	
Optimum (121 - 160)	1	
High (161 or more)	0	
4. What is your soil drainage?		
Poor (somewhat poorly drained)	3	
Medium (well to moderately drained)	2	
Excellent (sandy soils)	1	

		Points	Score
5. Describe your harvest frequency:			
Cut interval	Last cutting		
< 30 days	Sept. 1-Oct. 15	5	
	After Oct. 15	4	
	Before Sept. 1	2	
30-35 days	Sept. 1-Oct. 15	4	
	After Oct. 15	2	
	Before Sept. 1	0	
6. For a mid-September or late October cut, do you leave more than 6 inches of stubble?			
	No	1	
	Yes	0	
YOUR TOTAL SCORE (sum of points from questions 1-6)			

WINTER INJURY RISK

If you score:	Your risk is:
3 to 7	low
8 to 11	moderate
12 to 17	high
> 17	very high

Forage Establishment Quiz

	Points	Score
1. What is the status of your seedbed?		
Firm	1	
Soft	2	
2. How much crop residue is on your seedbed?		
20-30% residue	1	
>30% crop residue	2	
no crop residue	3	
3. At what depth do you plant forages?		
1/4-1-/2 inch	1	
1/2-1 inch	2	
1 inch or more	3	
4. When do you plant forages?		
Spring seeding	0	
Summer seeding	1	
Frost seeding	5	
5. If you plant in spring, at which date do you plant?		
15 April-15 May	0	
15 May-1 June	2	
1 June-15 june	3	
Not Applicable - go to next question		
6. If you plant in summer, at which date do you plant?		
1-15 August	0	
15 August-1 September	1	
After 1 September	3	
Not Applicable - go to next question		
7. If you frost seed, at which date do you plant?		
December to January	3	
February to March	3	
March to April 15	1	
Not Applicable - go to next question		

	Points	Score
8. Do you use a companion crop?		
Yes	0	
No	5	
9. Which companion crop do you use?		
Flax	0	
Oat	0	
Barley	1	
Wheat	1	
Not Applicable - go to next question		
10. Do you fertilize the small grain companion crop with nitrogen fertilizer?		
Yes	1	
No	0	
Not Applicable - go to next question		
11. When do you remove the small grain companion crop?		
Vegetative stage	0	
Boot stage	0	
Soft dough	1	
Mature-seed	2	
Not Applicable		
TOTAL		

FORAGE ESTABLISHMENT RISK

If you score:	Your risk is:
15-23	High risk
9-14	Moderate risk
3-8	Low risk

Harvesting Forages Quiz

	Points	Score
1. At what stage do you harvest forage when your goal is to maximize forage quality?		
bud stage	0	
early bud	1	
first flower	3	
full flowering	4	
2. At what stage do you harvest forage when your goal is to maximize forage persistence?		
bud stage	3	
early bud	2	
first flower	1	
full flowering	0	
3. At what moisture do you rake forage?		
50% + moisture	0	
25-50% moisture	1	
>20% moisture	3	
4. How many raking operations do you do?		
Swathing only	0	
Raking once	1	
Raking twice	2	
Raking 3 times or more	3	
5. How do you gauge hay moisture content before baling?		
Microwave a subsample	0	
Portable moisture tester	1	
Feel and visual	2	
Do not gauge moisture	3	
6. What is the moisture content at hay baling?		
<17%	0	
<20%	1	
20-25	3	
>30%	4	
7. How is hay stored?		
Inside, off the soil	0	
Outside, plastic covered, off the ground	1	
Outside, on the ground	2	
YOUR TOTAL SCORE (sum of points from questions 1-7)		

HARVESTING RISK

If you score:	Your risk is:
15-22	High risk
9-14	Moderate risk
0-8	Low risk

Test Your Knowlege: Forage Grasses

	Points	Score
1. Which grass has the most winterhardiness and least risk of winterkill?		
Smooth bromegrass	a	
Kentucky bluegrass	b	
Reed canarygrass	b	
Timothy	c	
Orchardgrass	d	
Tall fescue	e	
Perennial ryegrass	f	
2. Which grass has the greatest persistence and least risk when cut frequently for hay?		
Reed canarygrass	a	
Tall fescue	b	
Orchardgrass	b	
Perennial ryegrass	c	
Smooth bromegrass	e	
Timothy	f	
3. Which grass has the most drought tolerance and least risk of yield reduction and death?		
Smooth bromegrass	a	
Reed canarygrass	b	
Tall fescue	c	
Orchardgrass	d	
Timothy	e	
Kentucky bluegrass	e	
Perennial ryegrass	f	
4. Which grass has the most tolerance to excess moisture and flooding and least risk of injury?		
Reed canarygrass	a	
Smooth bromegrass	b	
Kentuckybluegrass	c	
Timothy	c	
Orchardgrass	c	
Tall fescue	c	
Perennial ryegrass	d	
5. Which grass has the greatest seedling vigor and least risk of establishment failure?		
Perennial ryegrass	a	
Tall fescue	b	
Orchardgrass	b	
Smooth bromegrass	b	
Kentucky bluegrass	c	
Timothy	c	
Reed canarygrass	e	
YOUR TOTAL SCORE (sum of points from questions 1-5)		

Score 0 for each “a”

Score 1 for each “b”

Score 2 for each “c”

Score 3 for each “d”

Score 4 for each “e”

Score 5 for each “f”

If you score:	Your grass knowledge is:
0 - 7	High
8 - 14	Moderate
15 - 22	Low

Test Your Knowlege: Forage Legumes

	Points	Score
1. For a low soil pH, 5.0-6.0, the best adapted legume for hay is:		
Birdsfoot trefoil	a	
Alsike clover	b	
White clover	b	
Red clover	b	
Alfalfa	c	
Sweet clover	d	
2. For long-term persistence for hay, which legume has the least risk?		
Alfalfa	a	
Birdsfoot trefoil	b	
White clover	c	
Alsike clover	d	
Red clover	d	
3. For general ease of establishment, which legume has the least risk?		
Red clover	a	
Alfalfa	b	
White clover	c	
Alsike clover	c	
Birdsfoot trefoil	d	
4. For tolerance of excess soil moisture, which legume has the least risk?		
Birdsfoot trefoil	a	
Alsike clover	b	
White clover	b	
Alfalfa	c	
Red clover	c	
5. For tolerance to low fertility (K, P), which legume has the least risk?		
Red clover	a	
Alsike clover	b	
Birdsfoot trefoil	b	
White clover	b	
Alfalfa	c	
6. For fast drying rate and least potential for hay molding, the legume with the least risk is:		
Alfalfa	a	
Birdsfoot trefoil	b	
Alsike clover	c	
White clover	c	
Red clover	d	
YOUR TOTAL SCORE (sum of points from questions 1-6)		

Score 0 for each "a"

Score 1 for each "b"

Score 2 for each "c"

Score 3 for each "d"

Score 4 for each "e"

Score 5 for each "f"

If you score:	Your forage legume knowledge is:
0 - 7	High
8 - 14	Moderate
15 - 22	Low

FOR MORE INFORMATION

University of Minnesota Extension Forages. http://www.extension.umn.edu/forages/

University of Wisconsin - Extension Forage Resources. http://www.uwex.edu/ces/crops/uwforage/uwforage.htm

Midwest Forage Association. http://www.midwestforage.org/

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CHAPTER 13

Winter Cover Crops

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Winter cover crops are planted into or after harvest of a cash grain, oilseed, or vegetable crop before the next crop is planted the following spring. In this context, winter cover crops are not grown for harvest. Cover crops can also fit into other niches like a summer fallow, but this chapter will focus on winter cover crops such as winter rye and hairy vetch, used in grain cropping systems. See the section on green manures in Chapter 4 on fertility and Chapter 12 on forages for other cover crop-related information.

LYNN BETTS, NRCS

Figure 13-1. *Cover crop on a field in Black Hawk County, Iowa.*

Table 13-1. Potential benefits and risks of winter cover crops

BENEFITS	RISKS
Nutrient enhancement	Additional management and labor
Soil nutrient capture	Additional expense for seed cost
Soil moisture retention	Interference with primary crop establishment
Erosion protection	Soil moisture depletion (if cover crop actively growing in spring)
Weed control	Cooler soil temperatures in spring because of plants on surface
Improved soil structure	Competition with primary crop
Disease control	Nutrient depletion by non-legumes
Nematode control	Nutrient availability not timely for subsequent crop
Increased soil organic matter	Allelopathic effects on primary crop

Table 13-2. Important functions of winter cover crops in cropping systems. *These cover crops are recommended for the Upper Midwest.*

FUNCTION	WINTER COVER CROPS
Nitrogen source	Hairy vetch, red clover
Nitrogen scavenging	Winter rye
Provide soil organic matter	Winter rye
Erosion control	Winter rye, oats, annual ryegrass
Improved soil structure	Brassicas
Control weeds	Winter rye, hairy vetch, oats, annual ryegrass, brassicas
Control diseases	Brassicas

Winter cover crops can provide several benefits but have several risks (Table 13-1). Winter cover crops are best adapted to areas with a long enough time to establish in the fall and without soil moisture deficits in the spring.

Selecting cover crops

This chapter will focus on the species most commonly used in the upper Midwest. The first step in selecting a cover crop species is to determine the main goal of the cover crop (Table 13-2). Many organic producers select cover crops to add nitrogen, control weeds, protect soil, and/or to increase soil organic matter. There are two main categories to consider—cover crops that overwinter and regrow in the spring, and those that do not.

WINTER HARDINESS

In northern climates, many cover crop species will not survive the winter. Winter rye and hairy vetch are cover crops that have the best potential to overwinter in the upper Midwest. Oat planted in the fall is an example of a cover crop that will winter kill. Of course, there is potential for any winter cover crop to have low survival rates, even if it is hardy (Figure 13-2). Producers will need to choose if overwintering is a desirable winter cover crop characteristic. There will be different risks associated with either strategy.

Reducing risk: winter hardiness. If an overwintering cover crop is selected, ensure that it is winter hardy for the location. Using local seed can reduce your risk of cover crop failure, but poor winter conditions will always be a hazard to survival.

NITROGEN SOURCE

Leguminous cover crops will provide nitrogen to subsequent crops. This nitrogen can increase yield in corn (Figure 13-3). Red clover (see Forages chapter) and hairy vetch are the best choices.

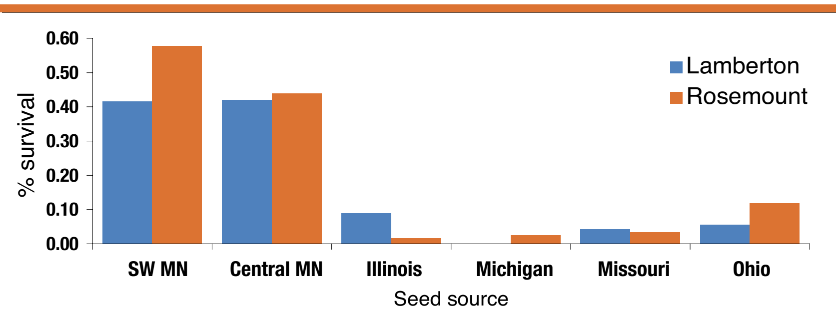

Figure 13-2. Hairy vetch winter hardiness. *The origin of hairy vetch seed is important to winter survival. Research conducted at Lamberton and Rosemount, MN, found that Minnesota seed has better survival than seed from other locations.*

When grown in the upper Midwest as a winter cover crop, hairy vetch will produce 40 to 80 pounds nitrogen per acre depending on the amount of biomass. The nitrogen that is fixed by legumes is not entirely available to the next crop until the residue decomposes. A large amount of the nitrogen is released within a week of killing a cover crop. Incorporated biomass will decompose more quickly than biomass left as mulch. Scavenged nutrients in grass cover crops like winter rye are usually not as available to subsequent crops as legume nutrients because the residue takes longer to decompose.

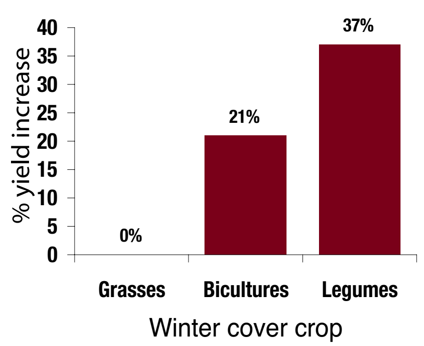

Figure 13-3. Winter cover crop effects on corn yield. *In an analysis of winter cover crop studies, legumes and legume-grass bicultures had a positive effect on yield in corn. Grass cover crops did not increase or reduce yield. Adapted from Miguez and Bollero, 2005.*

Reducing risk: nitrogen. Choose a legume versus a grass or brassica for nitrogen. Non-legume cover crops have the potential to deplete soil nitrogen. The timing of nitrogen release may not coincide with subsequent crop needs so supplementary soil amendments may be necessary.

SOIL ORGANIC MATTER

Cover crop species that produce high biomass will be the best contributors to soil organic matter. Winter rye will be the best choice. Hairy vetch can also produces high biomass, but legume biomass tends to degrade quickly without making great contributions to soil organic matter. Oat, annual ryegrass, and the brassicas also do not contribute greatly to soil organic matter when compared to winter rye.

Reducing risk: organic matter. Choose a cover crop species that will produce high-quality biomass under your conditions.

SOIL PROTECTION

Any cover crop that leaves residue over the winter will provide some soil protection and can reduce nutrient leaching. Winter rye grown following corn can scavenge excess nutrients, thereby reducing loss through leaching (Figure 13-4). Overwintering cover crops like winter rye will provide the ultimate in erosion control. Cover crops such as spring oats that do not overwinter but are allowed to produce adequate growth before frost can aid in soil protection.

Reducing risk: soil protection. Choose a cover crop that will produce high biomass in the fall to offer soil protection over the winter.

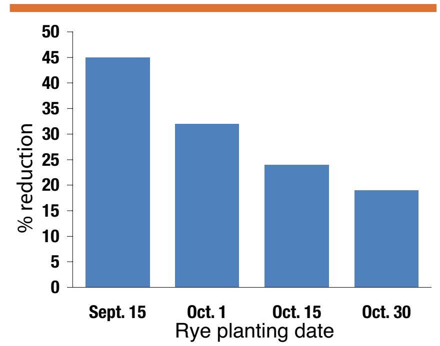

Figure 13-4. Rye and nitrate leaching. *Including winter rye in a corn-soybean rotation can reduce nitrate leaching up to 45% compared to without rye. The amount of reduction is dependent on rye planting date. Adapted from Feyereisen et al., 2006.*

IMPROVED SOIL STRUCTURE

Compacted soil can be improved by cover crops with deep taproot. The best example would be brassica cover crops. The roots can go down several feet (Figure 13-5). In the spring, those roots decompose, leaving channels in the soil that aid in aeration and water filtration.

Reducing risk: soil structure. Plant brassicas by September 1st in southern Minnesota to produce extensive root systems and herbage for ground cover.

WEED CONTROL

Cover crops help control weeds in spring and fall by out-competing them for resources, by not allowing a niche for them to germinate and through allelopathic compounds. Be aware that all weeds and all weed species will not be controlled, even under ideal cover crop growth. Season-long weed control cannot be expected; early season control of weeds is more likely. Small seeded annual weeds are controlled more than other weeds by cover crops. Cover crop residue can have allelopathic effects that inhibit the germination of some weed species (Table 13-3). However, this effect will be more efficient with high amounts of residue.

CARMEN FERNHOLZ

Figure 13-5. ***Roots of oilseed radish at different growth stages.***

Reducing risk: weed control. Expect to use mechanical weed control operations in addition to cover crops. Ensure that cover crops can produce adequate growth.

OTHER PEST CONTROL

Some cover crops, especially the brassicas, can have negative effects on pests other than weeds. They can suppress nematodes and some pathogenic fungi. Fresh residue must be worked into the soil for this effect, which then limits the soil protection that would be available if the residue overwintered. Generally, consider these benefits to be minimal under the climate of states such as Minnesota.

Table 13-3. Cover crops and the weeds on which they have shown allelopathic effects. *Compiled from various sources.*

COVER CROP	WEEDS INHIBITED
Brassicas	Pigweeds
	Shepardspurse
	Green foxtail
	Kochia
	Hairy nightshade
	Barnyardgrass
Winter rye	Wild oat
	Dandelion
	Crabgrass
	Barnyardgrass
	Common ragweed
	Lambsquarters
Hairy vetch	Common chickweed
	Redroot pigweed
	Wild carrot
	Knotweed

Reducing risk: pest control. Do not rely on cover crops solely to meet pest control needs. They should be part of a diverse rotation.

SOIL MOISTURE

Cover crops can also preserve soil moisture by shading the soil and reducing evporation. However, cover crops that are actively growing in the early spring can use soil water that may be needed by the cash crop (Table 13-4). Soil water depletion due to cover crops is a concern in areas that receive less than 30 inches of precipitation. Mean annual precipitation is 35 inches in extreme southeast Minnesota, an amount that gradually decreases to 19 inches in the extreme northwest portion of the State. Timing of killing the cover crop becomes more critical as the probability of rainfall decreases.

At times when there is excess spring soil moisture, a cover crop may increase the time it takes for soil to be dry enough for field operations. This can delay planting.

Reducing risk: moisture. **To prevent soil water deficits or surplus in spring, plant a non-overwintering cover crop or terminate overwintering cover crops in early spring.**

One organic producer in Redwood County has tried using winter rye, but in two years out of three, the moisture has limited establishment in the fall. He believes fall moisture will always be a risk for this crop in his area.

PRODUCER PROFILE

An organic producer from Faribault County uses cover crops in his cropping system. He utilizes winter rye, hairy vetch with oats, and red clover underseeded in oats. For rye, he uses an airplane to broadcast seed into corn in the fall. The rye re-grows in spring and it is terminated by disking at four to eight inches tall because he finds that a high rye biomass can lead to seed maggot. Soybeans are planted 7 to 10 days after rye is disked. This step is essential; otherwise there will be negative yield effects on his soybeans. He does not use a cover crop after soybeans. Moisture can be an issue for cover crop success in his area.

When he grows hairy vetch and spring oats as a winter cover crop, the winter-killed oats provide some protection for the overwintering vetch. The vetch is controlled in the spring by disking twice.

Another combination he uses is oats underseeded with red clover. He really likes red clover for his farm. After the oats are taken off, the clover is clipped if it is growing well. In the fall, compost is spread and the clover is disked. Any red clover that comes back in the spring is killed by disking before corn planting.

Table 13-4. Winter rye competition for spring moisture.
In research conducted in Morris, Lamberton, and Waseca, MN, winter rye used as a winter cover crop reduced yields in a subsequent soybean crop when moisture levels were too low. Adapted from Warnes et al, 1991.

SOIL CONDITIONS	AVAILABLE WATER IN INCHES	EFFECT ON SOYBEAN
Dry	10	yield reduction
Average	15	no yield reduction
Excess moisture	20	no yield reduction

Establishing cover crops

When and how cover crop planting occurs is determined by the cover crop growth rate, the length of the growing season, and the previous crop. There are different options for establishing winter cover crops, either while the row crop remains or after summer crop harvest. Establishing can be done either by broadcast seeding or drilling, dependent upon whether the cash crop is still standing.

PLANTING DATE

To maximize fall biomass production, most cover crops require 40 to 60 days of growth before a killing frost (Table 13-5). For southern Minnesota, this requires planting by September 1. Timely planting will lead to increased soil cover and biomass (Figure 13-6). However, there may be constraints to planting at the ideal time. Row crops like corn and soybean will still be in the field during the best times to plant. Planting too early in the season will mean competition with the row crop or interference with harvest, while planting too late is risky for cover crop establishment before winter.

The period after small grain harvest allows more time to establish a cover crop. This option is lower risk relative to planting a cover crop during or after a row crop.

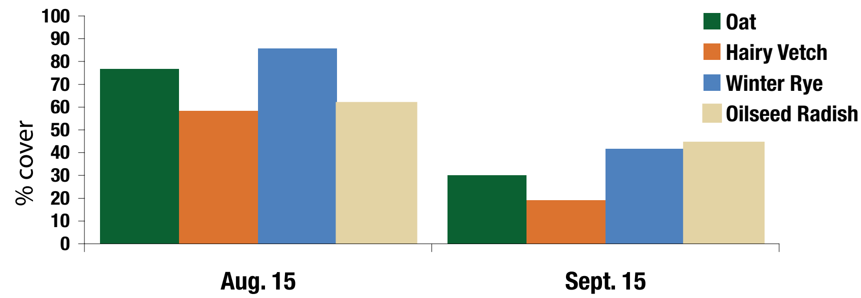

Figure 13-6. Cover crop planting dates. *In research conducted in Lamberton, MN, cover crops were planted into standing soybean on two dates. Earlier planting led to increased cover for all the species.*

Reducing risk: planting date. Match the correct cover crop species to the correct time to plant in your rotation in order to provide time for adequate growth in the fall. Plant cover crops after small grains, instead of row crops which are harvested later, to ensure establishment success.

Table 13-5. Risk to successful establishment of winter cover crops by planting date.
Other factors that will affect planting date risk are limiting soil moisture, method of planting, and winter hardiness.

Risk level	
(red)	High
(tan)	Moderate
(green)	Low

SPECIES	July	Aug 1-15	Aug 16-31	Sept 1-15	Sept 16-30	Oct 1-7	Oct 8-14
Winter rye	High	Moderate	Low	Low	Low	Moderate	High
Hairy vetch	High	Moderate	Low	Low	Moderate	High	High
Oat	High	Moderate	Low	Low	Low	Moderate	High
Annual Ryegrass	High	Moderate	Low	Low	Moderate	High	High
Brassicas	High	Moderate	Low	Low	Low	Moderate	High

PLANTING METHOD

Cover crops can be either planted into the summer crop by broadcast seeding or planted after harvest by drilling or broadcasting.

Broadcast seeding into row crop.

Cover crop seed can be broadcast into standing corn or soybean (Figure 13-7). Broadcast seeding is less efficient than drilling in establishing a cover crop. More seed is needed, up to twice as much, when compared to drilling. Other things to consider are whether a cover crop will tolerate shade from a standing crop or if dry conditions in late summer will hinder establishment.

Reducing risk: broadcast seeding. Use the proper seeding rate when using the broadcast method (see cover crop profiles in this chapter). Dry weather after seeding will be a great risk to establishment. Plant in a timely manner that will not cause interference with cash crop harvest.

Planting post grain crop.

Planting post harvest can be accomplished either by drilling or broadcast seeding. Generally, this will lead to better initial establishment compared to planting into a standing row crop. However, it may not be feasible timewise; it depends on when the primary crop is harvested and which winter cover crop is used.

Post harvest planting using no-till methods may fit into a cropping system better after small grains than after row crops. In the case of planting after small grain harvest, seed can be broadcast and lightly harrowed or disked to incorporate the seed. Another option is to drill cover crop seed into the grain stubble. Waiting until after corn or soybean harvest is generally not recommended because most cover crops will not have enough time to establish and form adequate cover. However, corn harvested for silage or sweet corn will be the exception.

Figure 13-7. *Oilseed radish cover crop that was broadcast into soybean.*

Reducing risk: planting after crop. Dry weather after seeding will be a great risk to establishment. Planting post harvest after a small grain will reduce risk compared to planting after row crop harvest.

ADVANCED TECHNIQUE: Early varieties to accommodate cover crops

Producers may choose to plant earlier-maturing row crops in order to accommodate cover crop integration into their rotations. Early-maturing corn and soybean may leave more time to establish a winter cover crop (Table 13-6). This may result in reduced grain yield; varieties that mature early yield less. However, the benefits to soil health through using cover crops may outweigh small yield reductions. This will be an option that organic producers will need to evaluate for their individual operations.

Table 13-6. *Cover crop performance in early and late maturity soybeans in Lamberton, MN (2007). The early soybean variety allowed for greater cover crop growth and dry weight compared to the later variety. In this case, there was no loss in yield.*

VARIETY	COVER (%)	COVER CROP DRY WEIGHT (g/ft^2)	SOYBEAN YIELD (BU/ACRE)
Early Soybean	46.7	5.5	43.2
Late Soybean	30.3	2.3	41.2

Terminating cover crops

A fall-planted, winter-hardy cover crop will need to be killed or controlled in the spring before the next crop can be planted. For the organic producer, cover crops can be terminated in the spring by mowing, chopping, rolling, undercutting, or plowing to incorporate (Table 13-7). Combinations of the above techniques like mowing followed by chisel plowing can also be used. Effective termination is one of the riskiest aspects in organic cover crop management.

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Figure 13-8. *An organic producer flail-mows a rye and vetch cover crop.*

TERMINATION WITH TILLAGE

Tillage is more effective for killing cover crops when compared to no-till methods, but tillage is more detrimental to soil health. The weed control benefits of a cover crop may be lessened when tillage incorporates mulch leaving the soil uncovered. Tilled-under cover crops break down rapidly once they are incorporated into the soil and this quicker decomposition may lead to nutrient losses through leaching.

Cover crops can be incorporated using a chisel or moldboard plow (Figure 13-9). A cover crop can be terminated whenever the soil can be worked. The benefit to using tillage is that there will be more flexibility when a cover crop is terminated compared to other methods. The only mechanical control method effective at vegetative stages will be incorporation.

The type of tillage needed to incorporate a cover crop will be dependent on soil type and cover crop. A cover crop such as winter rye, which produces a large amount of spring biomass, may reduce soil temperature and reduce the growth of the next crop. Therefore, more aggressive tillage may be preferred to prevent these effects.

Table 13-7. Summary of termination options *for overwintering cover crops and their associated risks of regrowth. Risk will be dependent on timing of termination.*

TERMINATION OPTIONS		RISK
With incorporation	Moldboard plow	Low
	Chisel plow	Moderate
No incorporation	Disking	Moderate
	Flail chop	Moderate
	Rotary mow	High
	Roll and crimp	High

Figure 13-9. *Moldboard plow.*

Reducing risk: termination with tillage. **Use a tillage approach that will allow the same weed control operations as when there is not a cover crop. Ensure that soil conditions permit tillage in spring. Tillage will require more labor and energy than non-tillage termination methods.**

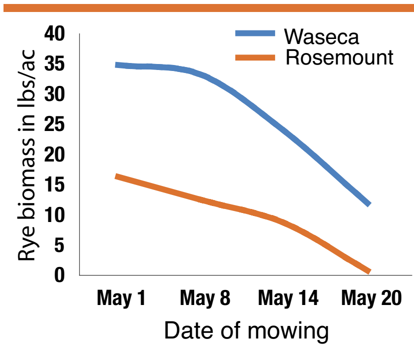

Figure 13-10. Rye regrowth after mowing different dates. *Rye regrowth was substantial when mowed in early May. When mowing occurred near anthesis at the end of May, there was little regrowth. Adapted from DeBruin et al, 2005.*

TERMINATION WITHOUT TILLAGE

When tillage is not used to terminate a cover crop, the timing of termination is very important. Hairy vetch will need to be controlled mechanically at flowering, which occurs in mid-June. Rye is best controlled at or before flowering (Figure 13-10). This occurs in late May. These times may be late for starting a subsequent corn or soybean crop.

Non-tillage cover crop termination methods are mowing/chopping and roller-crimping (see "No-till cover crop system" section). Mowing can be accomplished with a flail mower, rotary mower, or sickle-bar mower. Flail mowing will cut closer and be more effective than a rotary mower. A sickle-bar mower may not work with hairy vetch, which has viny growth. Mowed foliage will decompose more rapidly than roller-crimping because of the smaller plant segments produced. Rye may be harder to kill with mowing. Rye must be cut below the developing inflorescence.

Cover crop mulch will be left on the surface, which provides good weed control and slower decomposition. A winter cover crop used for the purpose

Many organic producers state that the greatest risk for cover crops that overwinter is controlling them, especially when there is significant herbage growth.

of weed control has to produce adequate residue. Mulch does not need to be incorporated fully to get nitrogen benefits. Roller-crimping is better for weed control than flail chopping due to heavier mulch.

Reducing risk: termination without tillage. **Attempting to control cover crops at immature stages will result in cover crop re-growth. However, waiting until flowering increases the risk of seed set and cover crop volunteers in the subsequent crop.**

Incomplete termination of a rye cover crop may not be all bad. A producer from Polk County says volunteer rye at low densities does not compete greatly with soybean and provides seed as a bonus. Rye and soybean seeds are easily separated at harvest.

Planting the next crop

Cover crops that are winter-killed will generally not interfere with planting in the spring. For over-wintering cover crops, when using tillage to terminate a cover crop, wait one week after incorporation before planting next crop to reduce allelopathic effects. Wait longer, a minimum of 10 days, when cover crops are left as surface mulch. However, methods such as the roller-crimper plant the primary crop at the same time as terminating the cover crop. Some crops like soybean may be more tolerant of being planted into fresh mulch. Be aware that soil temperatures will stay cooler under mulch.

Reducing risk: planting next crop. Delay planting after cover crop termination if possible. Plant an earlier maturing variety of the primary crop if conditions necessitate.

No-till cover crop system: roller-crimper

Figure 13-11. *Roller-crimper attached to the front of a tractor.*

No-till cover crop systems are used extensively in conventional systems through the use of herbicide to kill the cover crop before no-till drilling of grains into the mulch. An organic variation on the no-till scheme is to use the roller-crimper (Figure 13-11) developed at the Rodale Institute (http://www.rodaleinstitute.org/no-till_revolution). The University of Minnesota began experiments using the new system in 2008.

The roller-crimper is used to terminate cover crops while planting cash crops like soybean (Figure 13-12). Mounted on the front or rear of a tractor, a large roller with blades crimps and flattens cover crop vegetation, killing the cover crop and leaving a thick layer of mulch (Figure 13-13). At the same time, a crop like soybean can be planted into the mulch using a high-residue planter or drill.The crop grows within the mulch (Figure 13-14) and does not require plowing or cultivating, which can save producers time and money. Other benefits: the mulch of the cover crop can suppress weeds, build soil organic matter, prevent erosion, and conserve moisture.

continued on next page

Figure 13-12. *A roller-crimper rolling down a biculture of winter rye and hairy vetch while planting soybeans.*

Figure 13-13. *Winter rye after rolling-crimping.*

Figure 13-14. *Soybean growing into killed cover crop mulch.*

As with many new techniques, the learning curve is steep and lack of success can lead to crop failure. The cover crop may not be fully controlled by the roller-crimper operation. This can lead to delayed planting or poor establishment of the cash crop. Perennial weeds may not be controlled, and insects like cutworms may become issues. In Minnesota, the soil may take much longer to get warm, delaying development of warm season crops. In areas with low soil moisture, the cover crop may use up moisture that the primary crop needs. Residue can also leave the soils too wet, especially when the soil is poorly drained.

Table 13-8. Soybean yields in a no-till roller-crimper rye cover crop system and mowed rye cover crop system *in 2008 at Lamberton, MN. Yields were significantly lower when compared to the no cover crop control.*

COVER CROP TREATMENT	SOYBEAN YIELD (BU/ACRE)
Rolled rye	7
Mowed rye	3
No cover crop	22

Preliminary research conducted at Lamberton and Rosemount, MN, has demonstrated the following risks:

Delayed planting – the rye needs to be rolled following anthesis, which typically does not occur until late May to early June.

Moisture depletion – due to growth of the rye in the spring.

Inconsistent planting depth led to poor establishment – the no-till drill was not properly adjusted.

Significant regrowth of the rye – the rye was not killed well with the roller-crimper.

The subsequent soybean yields were negatively affected by the rolled-crimped rye cover crop (Table 13-8). Results from 2009 were somewhat more encouraging. Soybean yields were 26.5 bushels per acre, although the planting rate (300,000 seeds/acre) was twice that as compared to 2008. This system has potential, but because it can be high risk, it will need refinement before it can be recommended for widespread use in Minnesota.

ADVANCED TECHNIQUE:
Rye as a cover crop prior to no-till organic soybeans in Minnesota

Dr. Paul Porter at the University of Minnesota conducts research using winter rye as a cover crop with no-till soybeans. A rye cover crop is planted in the fall after small grains or corn harvest. Soybeans are no-till drilled into rye the next spring. Rye is controlled with mowing and shredding. He has the following recommendations for organic producers who want to try this technique:

STEPHEN AUSMUS, ARS

Figure 13-15. *Rye cover crop*

Rye planting. Ideally, plant rye in late August to early September at 1.0 to 1.5 bushels per acre. If planting later, use a rate of 1.5 to 2.5 bushels per acre. Drilling is best, but broadcasting and light harrowing also work if a slightly higher seeding rate is used.

Soybean planting. Plant soybean into rye about the time you would normally plant soybean, or slightly later. Increase seeding rate above normal—180,000 to 400,000 seeds/acre. The higher seeding rates can give good results if soybeans are planted late. No-till drill the soybeans at < 7.5" row width using a good drill. Cross-seeding (planting in two-directions) can be used to give a good spatial distribution of soybean plants and can adequately control/shred the rye by laying down the rye on the first pass and cutting it up on the second pass. It is desirable to have adequate seed-furrow closure.

Rye mowing/shredding. Wait until the rye has headed; it is best when pollen shed is or has occurred. Typically this will be in June, and the soybeans will be at the first or second visible trifoliolate growth stage. Shred rye as low to the ground as possible, but above the height of the soybeans. You can use a flail mower, a sickle mower, or a rotary mower, but avoid creating windrows with the residue. This step is unnecessary if cross-seeding is done.

Harvesting the soybean. There will be rye seed in the soybean seed harvested, but this can be cleaned out and sold for feed.

Reducing risks: no-till soybeans. Have the proper equipment for seeding the soybeans and mowing/shredding the rye. If rye stand is poor in spring, consider turning under the rye, but do this before rye stem elongation. Wet or dry conditions may delay soybean planting, but this is okay if a short-season soybean variety is used. Timing field operations is very important—controlling rye too early will lead to re-growth. Use good quality rye and soybean seed.

Cover crops species profiles

WINTER RYE

Use: Over-wintering cover crop

Planting date: Early September is ideal. Rye needs four to six inches of growth before a killing frost in the fall.

Planting rate: Drilled – 60-120 pounds/acre, broadcast – 90-160 pounds/acre

Planting depth: One to two inches

Preferred conditions: Prefers sandy or loamy soils, but is tolerant of clay; pH of 5.8 or higher; tolerant of drought. Minimum temperature for germination is 34° F.

Termination: Mow at anthesis to soft dough stage; chop and disk; plow or disk at 20 inch height; roller-crimper at anthesis to soft dough stage. Do not plant next crop for at least 10 days after terminating rye.

Subsequent crop: Soybean

Overview: A rye winter cover crop can control weeds, scavenge nutrients, protect soil from erosion, and improve the soil. Rye is the most winter hardy and tolerant of the late-planted winter cover crops suitable for Minnesota. It is adaptable to a variety of soils and is easy to establish by overseeding. However, tied-up nitrogen inthe rye forage will not be immediately available to the next crop, and rye can deplete soil moisture. Winter rye is susceptible to ergot.

Reducing risk: Winter rye. **Rye may not be the best choice on low fertility fields. Don't plant rye under low moisture conditions. Plant soybeans after rye, rather than corn. Rye can produce a large amount of biomass which can lead to difficulties in residue management. There is a risk of reduced yield in subsequent crops.**

HAIRY VETCH

Use: Over-wintering cover crop

Planting date: 30 – 45 days before killing frost, Aug 15 to Sept 15.

Planting rate: Drilled – 15-20 pounds/acre, broadcast – 25-30 pounds/acre

Planting depth: 1/4 to 1/2 inch

Preferred conditions: Prefers sandy or loamy soils; needs good levels of P, K, and S; snow cover benefits winter survival; tolerant of acidic soils. Minimum temperature for germination is 60° F.

DAVID L. HANSEN

Figure 13-16. ***Hairy vetch.***

Termination: Best time to control is at 75-100 percent bloom. Kill with rotary mowing, flailing, cutting, undercutting, or roller/crimper to produce mulch for weed and moisture control or incorporate with tillage for higher N contribution to next crop in the short term.

Subsequent crop: Corn

Overview: Hairy vetch is an excellent source of nitrogen; it suppresses weeds and improves and protects soil (Figure 13-16). It provides much of the nitrogen needed for a subsequent corn crop. The nitrogen credit is 40 to 80 pounds per acre. It will improve soil tilth, but does not add much to soil organic matter in the long term. Drought is usually not an issue in Minnesota for growing hairy vetch. Winter annual and perennial weeds can be an issue. Hairy vetch may be an alternate host of soybean cyst nematode (SCN).

Reducing risk: Hairy vetch. **Vines can interfere with machinery. Don't grow in fields with high levels of SCN. Not reliably winter hardy for northern Minnesota. Verify seed is from a local source. Hairy vetch has 10-20% hard seed and can become a weed, especially in small grains (Figure 13-17). Winters without snow cover can lead to winter kill, especially on poorly drained soil. It can be planted in grain stubble, which may provide some protection over winter by retaining snow cover. Sowing seed on dry ground can lead to ineffective inoculation by the rhizobium strain. It can be difficult to kill unless incorporated.**

Figure 13-17. *Hairy vetch weed in wheat.*

SPRING OATS

Use: Winter-killed cover crop

Planting date: Aug 15 – Sept 15, will need 6-10 weeks of growth

Planting rate: Drilled – 64-96 pounds/acre, Broadcast – 96-128 pounds/acre

Planting depth: 1/2 -1 inch

Preferred conditions: Needs adequate moisture, pH range 5.5-7.0 is best but will tolerate a wider range, moderate fertility. Minimum temperature for germination is 38° F.

Termination: NA, will winter-kill

Subsequent crop: Corn, Alfalfa, Soybean

Overview: Oats can suppress weeds, protect soil, and scavenge nutrients. Soil water infiltration in the spring may be enhanced. Oats planted as a winter cover crop in the fall will not produce grain because of winter kill. They are tolerant of wet conditions. Oats are inexpensive. It can be beneficial for the soil to plant oats into soybean because of how soybean produces little residue (Figure 13-18). Oats will need to be seeded before soybean harvest. The best time to establish oat is when the soybean is still standing (leaf-yellowing stage) by broadcast seeding between August 15 and September 1, depending on soybean variety, planting date and weather. If conditions permit, disk lightly for seed incorporation. Seeding at harvest is risky. Light disking in spring will prepare the seed bed for the next crop.

Reducing risk: Oats. **Oats will be one of the lowest risk options for a winter cover crop in Minnesota. They produce enough biomass with timely planting to provide soil protection, but do not require termination operations in the spring. They are inexpensive and establish quickly and easily. Fall-planted oats have not been found to impact yield in soybean or a subsequent corn crop.**

Figure 13-18. *Oats planted into soybean in the fall.*

ANNUAL RYEGRASS

Use: Winter-killed cover crop

Planting date: 40-60 days before killing frost, Aug. 15 – Sept. 1

Planting rate: Drilled – 10-20 pounds/acre, broadcast – 20-30 pounds/acre

Planting depth: 1/4 inch

Preferred conditions: Optimum soil pH is 6 to 7, but will tolerate pH of 5 to 8; needs moisture; prefers loamy soil but will tolerate sandy and clay soils. Minimum temperature for germination is 40° F.

Termination: NA, will winter kill

Subsequent crop: Soybean

Overview: Annual ryegrass can be confused with winter rye, but annual ryegrass (*Secale multiflorum*) is a different species that does not over-winter in Minnesota. Annual ryegrass establishes very quickly under cool conditions. It provides good erosion control over winter and increased water filtration in the spring. It can be broadcast seeded into corn at final cultivation or after harvest, or overseeded into soybean at leaf-yellowing stage or later. Rust can be a problem. Annual ryegrass has the potential to produce greater biomass than oats.

Reducing risk: Annual ryegrass. Dry soil conditions will be a risk to establishment. To produce adequate soil cover, it will need to be planted 40-60 days before a killing frost. Drilling will establish ryegrass better than broadcasting. It is more expensive than oats.

BRASSICAS

Use: Winter-killed cover crop

Planting date: Aug. 15 – Sept. 30. Plant at least four weeks before 28° F freeze.

Planting rate: Refer to Table 13-8

Planting depth: Refer to Table 13-8

Preferred conditions: pH range of 5.5 – 8.5; do not do well with poor drainage; require high level of sulfur, and sufficient nitrogen. Refer to Table 13-8 for more information.

Termination: NA, will winter-kill

Subsequent crop: Soybean or corn

Overview: Brassicas are a group of related plants that can be used as cover crops. They can be divided into four types including mustards, turnips, rapeseed/canola, and radish (Figure 13-19). Brassicas are tap-rooted and

Table 13-9. Planting information for brassicas.

SPECIES	PLANTING DEPTH	DRILLING RATE	BROADCAST RATE	PREFERRED CONDITIONS
Mustards	1/4-1/2 inch	5-12 lbs/ac	10-15 lb/ac	Minimum temperature for germination is 40° F Best in neutral soils Not tolerant of drought or of excess moisture
Rapeseed	1/2-3/4 inch	5-10 lbs/ac	8-14 lbs/ac	Minimum temperature for germination is 41° F Best in neutral soils Not tolerant of drought or of excess moisture
Radishes	1/4-1/2 inch	8-12 lbs/ac	12-20 lbs/ac	Somewhat drought tolerant Minimum temperature for germination is 45° F
Turnips	1/2 inch	4-7 lb/ac	10-12 lb/ac	Minimum temperature for germination is 42° F

some can penetrate the soil a few feet. Thus, one of the strongest benefits to using these species will be in improving soil tilth. One unique quality of the brassicas is the potential to biofumigate soil, meaning that certain disease pathogens and nematodes may be suppressed. Brassicas can also be used to prevent erosion, scavenge nutrients, and control pests. These traits will not fulfill their potential completely in northern areas because of winter kill; residues decompose quickly so erosion may be higher, weed control may be lower, and nutrient release may not be concurrent with crop needs. Cost of seed is moderate to high. Planting date is very important (Table 13-10). After mid-September, it will be too late. Drilling will lead to better establishment. Broadcast seeding into corn and soybean can work, but incorporating the seed by harrowing will improve this method. Rapeseed will winter kill at 10° F, while mustards, radishes, and turnips winter kill at 25° F.

ADRIA FERNANDEZ

ADRIA FERNANDEZ

Figure 13-19. *Oilseed radish (left) and mustard (right) are common brassica cover crops.*

Reducing risk: Brassicas.

Suppression of pests is not consistent among species or varieties. Plant before September 15. Be aware that weed control may be limited in spring because of how quickly the residue decomposes. If planted too early, plants can set seed leading to volunteers in subsequent crop. Don't plant brassicas more than two years in a row in same field. Seed may not be easy to find—buy seed early.

Table 13-10. *Fall above ground biomass produced by different brassica species planted on September 1 in Lamberton, MN. (unpublished data from Adria Fernandez)*

BRASSICA COVER CROP	BIOMASS (TON/ACRE)
Florida broadleaf mustard	0.61
Tendergreen mustard	0.68
Dorsing mizuna mustard	0.82
Oilseed radish	0.69
Purple globe white top turnip	0.82
Dwarf Siberian kale	0.76

Figure 13-20. *Winter rye and hairy vetch mix.*

BICULTURES

Another cover cropping option is two complementary crops grown together as a biculture. The most feasible option for bicultures that overwinter in Minnesota is a combination of winter rye and hairy vetch (Figure 13-20). One possible benefit of a biculture is there is a higher chance that at least one of the species survives the winter. Drawbacks include that the species may differ in time of maturity and thus may be more difficult to control than a monoculture. In the case of a winter rye and hairy vetch biculture, the rye benefits from the legume's nitrogen, and the rye contributes more than vetch alone to the soil organic matter. The biculture can produce higher biomass than monocultures. Rye mixed with hairy vetch can slow down decomposition and nitrogen release which may cause nutrient availability to synchronize with the next crop better.

OTHER SPECIES

Red clover, alfalfa, and perennial grasses are forages that can provide many of the same functions as winter cover crops in cropping systems. They overwinter, protect the soil and the legumes provide N benefits to the next crop. For more information on these crops, see the Forages chapter. Non-wintering legumes like berseem or crimson clovers can be planted as a winter cover crop, but they will need to be planted earlier than mid-August to have time to make substantial growth. These species may be best used after a small grain crop.

Conclusion

Using cover crops can involve different risks. Take the following quizzes to assess your risk in growing cover crops.

Cover Crops Risk Management Quiz #1

If you are planting a non-overwintering cover crop, take this quiz.
If you are using hairy vetch, take Quiz #2 on the next page.
If you are using winter rye, take Quiz #3 on the following next page.

NON-OVERWINTERING COVER CROPS

	Points	Score
1. Which cover crop will you use?		
Oats	5	
Annual ryegrass	3	
Brassica	3	
2. What is your primary goal?		
Provide nitrogen	0	
Provide soil organic matter	1	
Improve soil structure	5	
Prevent erosion	5	
Control weeds	1	
3. When will you plant the cover crop?		
August 15	5	
September 1	4	
September 15	3	
October 1	1	
4. How will you plant the cover crop?		
Broadcast	1	
Drill	3	
TOTAL		

QUIZ # 1:

If your score is:	Your risk is:
5 - 7	High
8 - 11	Moderate
12 - 18	Low

Cover Crops Risk Management Quiz #2

If you are planting a non-overwintering cover crop, take Quiz #1 on the previous page.
If you are using hairy vetch, take this quiz.
If you are using winter rye, take Quiz #3 on the next page.

HAIRY VETCH

	Points	Score
1. What is your primary goal?		
Provide nitrogen	5	
Provide soil organic matter	2	
Improve soil structure	3	
Prevent erosion	3	
Control weeds	2	
2. When will hairy vetch be planted?		
August 15	5	
September 1	3	
September 15	3	
October 1	1	
3. How will you plant hairy vetch?		
Broadcast	1	
Drill	3	
4. How and when will you terminate the hairy vetch?		
Vegetative stage with tillage	3	
Flowering stage with tillage	5	
Vegetative stage without tillage	0	
Flowering stage without tillage	1	
5. What equipment will be used to terminate the hairy vetch?		
Mower/chopper	1	
Roller-crimper	1	
Other/combination of techniques	3	
Chisel plow	5	
Moldboard plow	5	
6. What will be the subsequent crop?		
Corn	5	
Soybean	1	
Other	3	
7. When will the subsequent crop be planted?		
At vetch termination	1	
Less than 1 week after termination	3	
1 to 2 weeks after termination	5	
TOTAL		

QUIZ # 2:

If your score is:	Your risk is:
7 -15	High
16 - 25	Moderate
26 - 33	Low

Cover Crops Risk Management Quiz # 3

If you are planting a non-overwintering cover crop, take Quiz #1 on the previous page.
If you are using hairy vetch, take Quiz #2 on the previous page.
If you are using winter rye, take this quiz.

WINTER RYE

	Points	Score
1. What is your primary goal?		
Provide nitrogen	0	
Provide soil organic matter	5	
Improve soil structure	3	
Prevent erosion	5	
Control weeds	3	
2. When will winter rye be planted?		
August 15	3	
September 1	5	
September 15	3	
October 1	1	
3. How will you plant winter rye?		
Broadcast	1	
Drill	3	
4. How and when will you terminate the winter rye?		
Vegetative stage with tillage	3	
Flowering stage with tillage 5		
Vegetative stage without tillage	0	
Flowering stage without tillage	1	
5. What equipment will be used to terminate the winter rye?		
Mower/chopper	1	
Roller-crimper	1	
Other/combination of techniques	3	
Chisel plow	5	
Moldboard plow	5	
6. What will be the subsequent crop?		
Corn	0	
Soybean	5	
Other	3	
7. When will the subsequent crop be planted?		
At rye termination	1	
Less than 1 week after termination	3	
1 to 2 weeks after termination	5	
	TOTAL	

QUIZ # 3:

If your score is:	Your risk is:
4 -15	High
16 - 25	Moderate
26 - 33	Low

FOR MORE INFORMATION

An Introduction to Cover Crop Species for Organic Farming Systems.http://www.extension.org/article/18542

Managing Cover Crops Profitably, Sustainable Agriculture Network. http://www.sare.org/publications/covercrops/covercrops.pdf

Legume Cover Crops in Wisconsin: A Guide for Farmers. http://www.cias.wisc.edu/wicst/pubs/legume_seeding.htm

Small Grain Cover Crops for Corn and Soybean, Iowa State University Extension. http://extension.agron.iastate.edu/soybean/documents/PM1999._covercrops.pdf

UC SAREP Online Cover Crop Database, University of California Sustainable Agriculture Research and Education Program. http://www.sarep.ucdavis.edu/ccrop/

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Midwest Cover Crops Council

The Midwest Cover Crops Council (MCCC) is a diverse group from academia, production agriculture, non-governmental organizations, commodity interests, private sector, and representatives from federal and state agencies collaborating to facilitate adoption of cover crops.

Regional and state information is available about cover crop species, current research, and upcoming cover crop events. Soon to be available are a cover crop selector tool, cover crop seed suppliers, and an "ask the expert" feature. Visit their website— http://www.mccc.msu.edu/ —for more information.

Ngouajio, M. and D.R. Mutch. April 2004. Oilseed radish: A new cover crop for Michigan. Michigan State University. Extension Bulletin E-2907.

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CHAPTER 14

Alternative Crops

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For the Upper Midwest, alternative crops may be considered as any crop besides corn, soybean, small grains, or alfalfa. A renaissance of interest in cultivating alternative crops is occurring, primarily among small-scale and organic producers. Organic producers naturally have more diversified systems into which alternative crops can fit. In addition to the direct benefits to plant growth of rotations that utilize diverse crops, the incorporation of alternative crops may provide environmental benefits such as reduced pesticide use, enhanced soil and water quality, promotion of wildlife diversity, as well as economic benefits including the opportunity for producers to take advantage of new markets and premium prices, to spread economic risk and to strengthen local economies and communities.

TOM AND DEETTA BILEK

Figure 14-1. *Grain sorghum (front) and grain amaranth (back).*

While the adoption of alternative crops can provide real advantages, it also carries real risks. Special requirements, variable yields and shifting markets can be expected. The smart grower will carefully research their market options before investing the time, effort and money required. Before adopting one or more alternative crops for full-scale production, there are several steps producers need to take (Table 14-1).

HOWARD F. SCHWARTZ, COLORADO STATE UNIVERSITY

Figure 14-2. *Tractor-driven cutter used to harvest dry beans.*

Selecting alternative crops

GOALS

There can be a number of reasons for growing an alternative crop (Table 14-2). While producers need to consider the economics involved with alternative crops, sometimes the primary factor in choosing to grow an alternative crop is not the direct economic value. Instead, the main consideration can be the benefit to the whole farming system like increased soil fertility, weed control, or other benefits of increased diversity. In addition, some producers who appreciate the value of local food production may grow crops with unique nutritional traits for local markets and consumption.

Table 14-1. Steps to take before choosing to grow an alternative crop

• Identify your goals
• Assess your resources
• Assess the crop growth and production requirements
• Get connected to others with experience
• Develop a marketing plan
• Seek start up funds
• Assess production costs, yields, and prices
• Begin with a small test plot

Table 14-2. Why grow alternative crops?

• Adding extra income
• Produce forage or feed for on-farm use
• Improve soil conditions
• Diversify operation
• Reduce disease or insect problems
• Enhance environmental sustainability

RESOURCE ASSESSMENT

Producers need to assess the fertility and drainage characteristics of their soil as well as climate conditions relative to an alternative crop before committing. Other considerations are available equipment and labor, special labor and equipment needs for planting, cultivating and harvesting, transporting, and marketing. Seed and some varieties may be difficult to find. Producers should also consider their financial resources before trying a new crop. For some crops, there will be an initial investment of purchasing or renting new equipment (Figure 14-2).

PRODUCTION REQUIREMENTS

Alternative crops may have unique temperature, nutrient and water requirements. Disease and insect pests may also be new (Figure 14-3). Producers need to examine what, if any, pest control options are available that are organic and whether the options are reliable and effective. It is also important to consider the timing of operations and amount of labor required fit into the current system.

Figure 14-4. ***Carmen Fernholz discusses flax at the Organic Field Day at the Southwest Research and Outreach Center in Lamberton, MN, in 2009.***

SOURCES OF INFORMATION

Local growers, buyers and agricultural agencies are all starting places for more information. Networking with other producers who have experience is one of the best ways to learn about alternative crops. Other resources include joining organizations that focus on specialty crops, attending workshops and meetings for growers, and getting connected with the local extension office. Field days can also be a great source of information (Figure 14-4). A host of web resources for individual crops are usually available (see *For More Information* section at the end of this chapter).

MARKETING

Marketing is one of the trickiest aspects in beginning to grow a new crop. Producers may have the desire to grow an alternative crop, but they need to ensure that there is a market for it. Growers need a marketing plan before committing to an alternative crop; waiting until the crop is in the field is not the best time to figure out what to do with it! An element of added risk is that markets for these crops may not be consistent from year to year.

BRADY VICK

Figure 14-3. ***Sunflower plant infected with Sclerotinia head rot.***

PRODUCER PROFILE

MARKETING

A producer from Wright County has these tips for what to know before deciding to grow an alternative crop:

- **What the market is**
- **The market requirements**
- **The distance to the market and costs of transport**
- **What type of equipment is required**
- **What kind of dry down the crop needs**

He says organic producers need to consider things over the long term like how the alternative crop fits into the rotation. He notes that location will often be a determining factor with alternative crops. In Minnesota, canning green peas will be easier to sell when producers are within 50 miles of Owatonna; otherwise it may be impossible. Another example is winter rye, which can be difficult to sell, but again this depends on location.

A producer from Waseca County points out that marketing is not always an issue when growing an alternative crop. If you are just feeding your own livestock, you have a built-in "market."

Producers will need to assess the demand and identify the crop varieties or qualities that are required by the buyer. This process will be aided if there is a local market and infrastructure for handling the alternative crop. If not, feasible methods of transport will be needed to get the crop to processors. The next step is to begin building relationships with buyers and understand market trends. It pays to have a backup plan if the crop does not meet buyer standards. One option may be to use the crop as feed when it does not meet food standards.

Some alternative crops may require direct marketing to consumers or selling to retailers rather than selling to wholesalers, but some are grown under contract. Determine the volumes for which contracts exist. For very small markets, one new grower can flood the market. It may be beneficial to have storage options to wait to sell alternative crops when market conditions improve.

START UP FUNDS

Producers should consider applying for a grant to assist with start up costs. Possible sources include state departments of agriculture or natural resources, Sustainable Agriculture Research and Education (SARE), the Farm Service Agency, and organic farming organizations.

ECONOMICS

Growers should analyze whether the alternative crop will be profitable in their farming system and under their soil and climatic conditions. Factors that need to be determined are production costs, expected yields and expected prices. As prices will vary significantly from year to year, producers should examine prices from several years to determine trends.

Purchasing crop insurance is one strategy for managing the economic risk in alternative crops. Consult with your local Farm Service Agency office about insurance options. Visit the Risk Management Agency website for more information—www.rma.usda.gov.

Table 14-3. Nutritional composition of various crops.
Adapted from the USDA-ARS, 2009.

CROP	PROTEIN	FAT	FIBER	CARBO-HYDRATES	CALCIUM	PHOS-PHORUS
	% OF TOTAL WEIGHT					
Dry field pea	22.8	1.2	25.5	60.4	0.06	0.37
Flax	18.3	42.2	27.3	28.9	0.26	0.64
Sunflower (kernels)	20.8	51.5	8.6	20.0	0.08	0.66
Buckwheat	13.3	3.4	10.0	71.5	0.02	0.35
Triticale	13.1	2.1	17.5	72.1	0.04	0.36
Proso millet	11.0	4.2	8.5	72.9	0.01	0.29
Grain sorghum	11.3	3.3	6.3	74.6	0.03	0.29
Grain amaranth	13.6	7.0	6.7	65.3	0.16	0.56
Pinto bean	11.3	1.2	15.5	62.6	0.11	0.41
Navy bean	22.3	1.5	24.4	60.8	0.15	0.41
Kidney bean	23.6	0.8	24.9	60.0	0.14	0.15
Soybean	36.5	19.9	9.3	30.2	0.28	0.70
Corn	9.4	4.7	7.3	74.3	0.01	0.21
Wheat, hard red spring	15.4	1.9	12.2	68.0	0.03	0.33
Oats	16.9	6.9	10.6	66.3	0.05	0.52
Barley, hulled	12.5	2.3	17.3	73.5	0.03	0.26

PREPARING FOR ALTERNATIVE CROPS

Producers should test multiple varieties with test plots, preferably at more than one location. Cooperating with neighbors with similar interests in alternative crops will enhance the impact of this experimentation. Preparation for planting can begin before seeds go in the ground. Soil fertility can be enhanced using green manure crops, which can help control perennial and other difficult weeds. A firm seed bed is recommended for small-seeded crops. Fall tillage will create these conditions. Growers should locate a source of organic seeds if possible.

Reducing risk: Selecting alternative crops.

Learn as much as possible about new alternative crops you are considering. Connect with others who have experience with the alternative crop you choose. Test new crops on small-scale plots first. Unless you are growing the crop as feed for your own animals, do not grow a new alternative crop without a contract.

JIM RIDDLE

Figure 14-5. *Field Peas.*

Alternative crop profiles

Alternative crops can be categorized by their use for feed, forage, fiber, fuel, or oil. Nutritional values of alternative grains are shown in Table 14-3. This chapter will summarize production for some of the more commonly grown alternative crops with proven adaptation to the Upper Midwest.

DRY FIELD PEA

Overview and use

Field peas have been grown successfully throughout the North Central region and Canada. Peas are grown for human consumption, animal feed, as well as a soil building crop. The grain contains 18 to 25 percent protein. Dried peas or pea flour are used for human consumption. Cream-colored varieties are grown in the North Central region for animal feed or forage. Because of their high protein concentration, dry field peas or pea flour can be used to fortify grain-based animal feed. Field peas can be substituted for soybean in hog rations. Peas lack the enzyme inhibitors found in soybean and do not require roasting or processing before feeding.

Pea forage is high in protein and low in fiber and can be used for pasture, hay or silage. It can be grown in a mixture of oat, barley, or triticale and used as a protein fortified forage. A mixture of two-thirds field pea and one-third oat is frequently used as a companion crop for alfalfa or clover. Peas leave minimal amounts of organic residue that breaks down quickly. When field pea is used as a green manure, the nitrogen contribution can be 25 to 50 pounds per acre.

Table 14-4. Field pea variety trial yields and traits.
Variety trials were conducted from 1997-1999 in Red Lake Falls, Fosston, Oklee, Kennedy, and Baudette, MN. Adapted from Kandel, 2007.

VARIETY	YIELD (BU/AC)	LEAF TYPE	MATURITY RATING	VINE LENGTH	SEED COLOR
Spitfire	63	Reduced leaves	Medium	Medium	Yellow
Carneval	58	Semi-leafless	Early	Medium	Yellow
Carrera	56	Semi-leafless	Early	Short	Yellow
Grande	56	Normal	Medium	Medium	Yellow
Highlight	55	Semi-leafless	Early	Short	Yellow
Majoret	52	Semi-leafless	Medium	Short	Green
Mustang	52	Semi-leafless	Very early	Short	Yellow
Profi	50	Semi-leafless	Early	Medium	Yellow

One producer from Lac qui Parle County says 'Mozart' is a good pea variety. Another variety he has had recent success with is 'Commander', which is from South Dakota. A different producer from Pipestone County has good results from 'DS Admiral'. All are yellow, semi-leafless varieties.

Types

Peas are characterized by seed color (yellow and green for human consumption; cream, brown or grey for animal feed) or growth habit. There are two main types of growth, climbing types that produce vines three to six feet long and dwarf or semi-leafless types that produce shorter vines two to four feet long. The leaflets of dwarf types are reduced to tendrils. They are widely grown in industry. Semi-leafless types lodge less and can be harvested more easily, but they tend to be less competitive with weeds.

Determinate and indeterminate types of field peas are found. Both types begin flowering 40 to 50 days after planting. Determinate varieties mature in 80 to 90 days. Indeterminate varieties flower over a longer period of time than determinate varieties and mature in 90 to 100 days, similar to wheat. In Minnesota, determinate varieties are generally used (Table 14-4). Indeterminate varieties may have immature green seed when harvesting.

Preferred conditions

Field pea is a cool season annual crop. Optimum temperatures for growth are between 55 and 65º F. They can withstand considerable frost exposure. If damaged by frost, they are able to re-sprout from nodes below the soil surface. The amount of moisture required for growth is similar to that of cereal grains. Early rains are best, followed by dry conditions during pod fill and ripening. Field peas are adapted to many soil types including sandy and clay soils, but they do not tolerate saturated or saline soils. The ideal pH is 5.5 to 6.5.

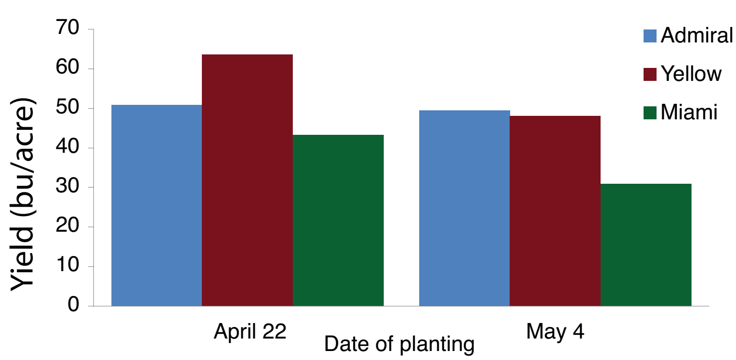

Figure 14-6. *Field pea yields at different planting dates. Three varieties of field pea were planted on April 22 and May 4 in Lamberton, MN in 2009. Earlier planting dates usually lead to greater yields.*

Planting date

Plant as soon as the soil can be worked in the spring. In the North Central region, pea is planted in mid-March to mid-April, as soon as soil temperature in the upper inch reaches 40 to 50 º F. It blooms in about 60 days and matures in 95 to100 days, similar to wheat. High tempera-

Field peas can be under-seeded with red clover, which is what one producer from Lac qui Parle County does. The field peas are harvested in late July. The red clover is cut back with a flail chopper, followed by chisel plowing. Some red clover remains to offer protection to the soil over winter.

tures slow growth and reduce seed set. Yields may decrease significantly when planting is delayed beyond mid-May (Figure 14-6). Fall plowing may aid in earlier spring planting.

Planting depth and rate

Pea is planted with a grain drill one to two and a half inches deep in six to twelve inch wide rows. Careful monitoring of grain drill seeding is required to avoid cracking seeds. Cracked seeds will not germinate. Rate of seeding is from 115 to 175 pounds per acre, depending on variety. A stand count of eight to nine plants per square foot is recommended as "competition" from weeds can become severe at lower plant densities. Seed should be sown into a firm seed bed that is relatively free of residues that can harbor pathogens.

Nutrient requirements

Peas are grown on a wide range of soil types. As a legume, pea uses bacterially fixed atmospheric nitrogen. Pea derives about 80 percent of its nitrogen through this symbiotic relationship. Inoculation of seed with the bacteria, *Rhizobium leguminosarium* will increase nodulation. Peas require phosphorous and potassium in relatively large amounts. Sulfur may be needed to enhance nitrogen fixation. Manganese may also be required.

Pest control

Peas are poor competitors with weeds. Both emergence and canopy development are slow.

PRODUCER PROFILE

Field pea experiences

A producer from Pipestone County has found that organic field peas are more popular now; they are used in organic feed for calf starter, pet food, and conventional hog feed. Field peas require much less processing for feed than soybeans, but they do not provide as large of a nitrogen credit as soybeans and it can be difficult to find organic seed. He likes to plant field peas at the end of March at two bushels/acre. He also has tried frost seeding them. One year he planted as late as April 29th (Figure 14-7). He was not happy with this stand because it was not as thick as he would like. He averages yields of 30-40 bushels/acre (field peas have 60 pounds to the bushel).

Figure 14-7. *Field peas prior to harvest in Pipestone County. A later than normal planting date led to increased weeds.*

One producer from McLeod County cannot plant field peas because fungal diseases are such a problem.

Weeds must be controlled prior to planting. Blind harrowing may be done, but pre-emergent cultivation can result in crop damage. If post-emergent weed control is performed it should be cultivation with a harrow at the four- to six-leaf seedling stage to lessen damage. Cultivation should be avoided once seedlings start branching but if it is necessary, a rotary hoe rather than harrow, should be used.

Field pea can be affected by severeal diseases. It is only moderately susceptible to Sclerotinia; normal-leaf, climbing types of pea are more susceptible than semi-leafless pea. A four-year rotation is generally recommended for Sclerotinia-susceptible crops including pulses. Crop rotation and early planting help to reduce the occurrence of powdery mildew *(Erysiphe polygoni)*.

Pea aphids may be a problem and can infect plants with viruses.

Harvesting

Timing of harvest is very important for field peas. Harvest usually occurs in late July or August. Harvesting pea is complicated by the prostrate growth habit and tendency of dry pods to shatter. Shattering can be reduced by harvesting before pods are completely dried or during times when atmospheric moisture is high such as early morning or at night. Field pea can be swathed or straight combined. Either way, the cutting platform should be set close to the ground. Careful combining is critical to avoiding seed damage. If there is severe weed pressure, consider swathing the peas before they are dry. Then allow the swaths to dry along with the weeds. The greatly improves harvesting and leaves cleaner peas in the hopper.

Field pea is harvested at 16 to 18 percent moisture. Swath yellow varieties when most of the seeds have turned yellow. Green peas are harvested at a slightly higher moisture content to maintain seed color. Green peas are susceptible to bleaching when pods are in contact with moist soil. Bleaching reduces seed quality. Field peas should be stored at 14 percent moisture.

PRODUCER PROFILE

Field pea + barley

JIM STORDAHL

Figure 14-8. *Barley and peas just prior to combining.*

Another option is to grow field peas in mixture with a small grain of similar maturity. One producer from Faribault County grows these crops together. The mix is sold to an organic dairy for feed. He recommends an early-maturing barley variety so the two crops will mature together. He plants at a rate of 70 pounds peas and 50 pounds barley to generate a 1:4 ratio of peas to barley (20 percent peas and 80 percent barley). He warns that individual species' yields can vary greatly so exact ratios are hard to predict.

A producer from Lac qui Parle County who grows field pea finds that in many cases the field pea yield will be made before lambsquarters or kochia really flush. Although these weeds create a harvest challenge, they will not impact the yield as severely as one might think.

Reducing risk: field pea. **Do not plant field peas into flax stubble. The stubble is long-lasting and will interfere with swathing. Seedbeds with little residue are best. To avoid disease, do not plant peas within four years of oilseeds and legumes. Avoid planting field peas in fields with cool season, early-emerging weeds like lambsquarters, kochia, wild mustard, and wild oats. Also avoid fields with buckwheat, nightshade, and Russian thistle, which will interfere with harvest. They will be too competitive with field peas and nightshade berries can stain field pea seed. To reduce risk, choose varieties with shorter vines or semi-leafless types that are more harvestable. Low planting rates can lead to weed issues because field pea is uncompetitive. Planting after mid-May is not recommended.**

DAVID L. HANSEN

Figure 14-9. *Flax.*

FLAX

Overview and use

Two main types of flax are grown: brown-seeded varieties for oil or feed and golden-seeded varieties for human consumption. Flax is grown primarily for the oil content of its seeds. Flax seed contains about 40 percent oil that is high in omega-3 fatty acid. Human consumption of flax seed has increased significantly in recent years as a result of research illuminating the health benefits of flax oil. Flax seed is also used in bakery products and as feed for chickens. The eggs are marketed for their high omega-3 fatty acid content and are sold for a premium price. Flax meal contains about 35 percent protein and is fed to livestock. Another traditional product of flax is fiber or linen cloth. In some areas, there may be a small niche market for flax fiber, but generally flax has been replaced by synthetic fibers. Flax is not used as a forage crop due to its high cellulose and lignin content.

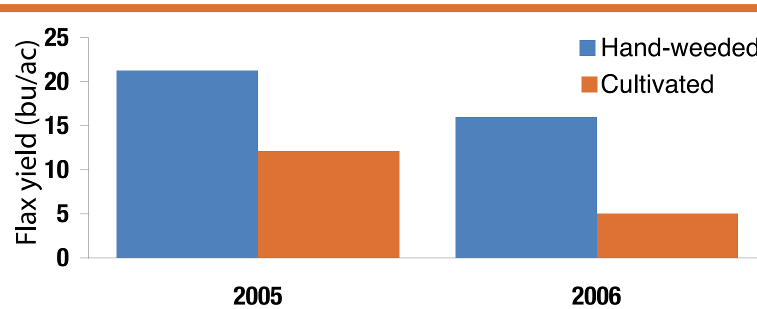

Figure 14-10. *Drought effects on organic flax yield. 'Norlin' flax was planted in 2005 and 2006 on an organic farm in Fertile, MN. The 2006 season was extremely dry and weeds became dominant. Subsequently, yields were lower than they were in 2005, particularly with typical weed control. Adapted from Kandel and Porter, 2006 and 2007.*

Table 14-5. Planting date effects on organic flax grown in Grygla, MN, in 2005. *Yields were significantly better and weed biomass was less at the earlier planting date. Adapted from Kandel and Porter, 2006.*

DATE OF PLANTING	YIELD (BU/ACRE)	WEEDS (% OF TOTAL BIOMASS)
May 12	18	38
May 13	9	53

Flax is a good crop in rotation with small grains. Three years between flax crops is recommended. It should not be grown on fields following brassicas, sugar beets or potatoes. It is often followed by clover or barley. It is a good companion crop for clover or alfalfa, as it is not competitive.

Preferred conditions

Flax is a cool-season annual that is planted in the spring in North Central states. It does well on soils that produce a good wheat or barley crop. Flax is adapted to well-drained loam to clay loam soil and does poorly on soil prone to erosion or high in soluble salts. It is not tolerant of overly wet or poorly-drained conditions. Droughty conditions that interfere with flowering and pollination will lead to dramatic reductions in grain yields (Figure 14-10). Flax grows best at a pH of 6 to 6.5.

Planting date

Early seeding is best. Planting from late April to late May is recommended for best yield, oil content, and straw. In Minnesota and North Dakota, flax is planted about the same time as oats. It will tolerate light frosts. When planting is delayed, yields are reduced (Table 14-5). Flax generally takes 90 to 110 days to mature.

Planting depth and rate

Plant at a depth of one-half to one inch into well-worked soil with little residue. A roller can be used to create a firm seed bed and will help achieve a uniform planting depth. Seed that is planted too deeply will delay emergence and result in weakened seedlings. The seeding rate for organic flax is 40 to 70 pounds per acre. Some organic producers plant at the higher ranges to promote flax competition with weeds. However, unless high levels of weeds are anticipated, higher planting rates may not be necessary (Figure 14-11). Yellow-seeded varieties tend to have lower seedling vigor and should be seeded at a higher rate.

Nutrient requirements

Flax is a light to moderate feeder with nutrient requirements generally close to small grains. In some parts of the Midwest, zinc deficiency in flax has been observed. Phosphorus levels are not

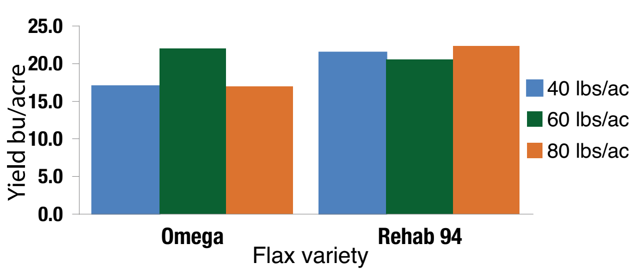

Figure 14-11. *Organic flax seeding rates and yield. Two varieties of flax, Omega (yellow type) and Rehab 94 (brown type) were planted at three different seeding rates in Rosemount, MN in 2007. The higher planting rates did not consistently increase yield.*

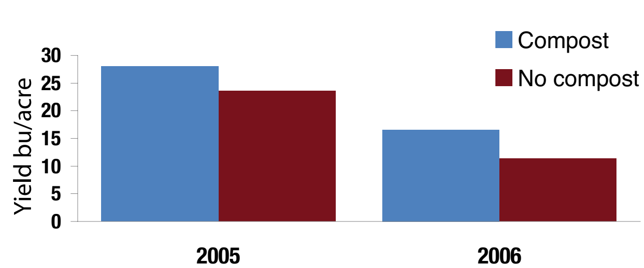

Figure 14-12. *Compost effects on organic flax in Iowa in 2005 and 2006. Compost was applied at four tons/acre in early spring. Yields were greater with compost application. Adapted from Delate et al 2005 & 2006.*

usually a problem. Planting flax after corn is not recommended for organic systems because of the nutrient depletion due to corn. Flax may have increased yields when following legumes in rotation or after compost application (Figure 14-12).

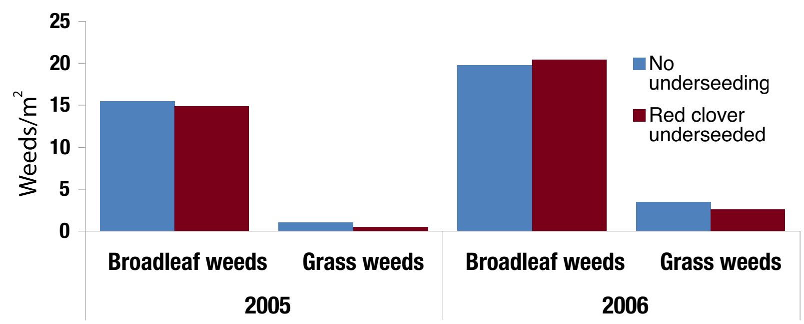

Figure 14-13. *Underseeded red clover effects on weeds in organic flax in Iowa in 2005 and 2006. Red clover did not significantly reduce weeds while flax was growing. However, the red clover had no negative effects on flax yield and it provided weed suppression and contributed nitrogen after the flax was harvested. Adapted from Delate et al, 2005 & 2006.*

Pest control

Small-leaved flax seedlings do not compete well with weeds. Weed control prior to planting is essential. Grow flax in weed-free fields if possible; avoid fields infested with quackgrass. Fall tillage can help suppress perennial weeds. When possible in the spring, cultivate twice before planting to control early season weeds. Underseeding with red clover or other forages is a common approach to weed control (Figure 14-13 and Table 14-6).

Planting in two directions or cross-planting is another method for weed management. With this technique, seed is planted at a half rate in one direction, followed by a second pass at a half rate in another direction across the first seeding. The goal is for the flax to shade the ground more quickly to be more competitive with weeds.

Disease is generally not a problem in flax as disease resistant varieties are available. Insects also tend not to be problematic.

Table 14-6. Organic flax underseeded with legumes.
Flax varieties were planted in Fertile, MN in 2005. In this trial, Carter performed significantly better than many of the other varieties. Adapted from Kandel and Porter, 2006.

VARIETY	COLOR	UNDERSEEDING	%WEED BIOMASS	YIELD (BU/AC)
Norlin	Brown	Red clover	45	13.3
		White clover	48	12.5
		None	51	12.1
Carter	Yellow	Red clover	41	14.4
York	Brown	Red clover	51	11.4
Bethune	Brown	Red clover	49	11.1
Hanley	Brown	Red clover	58	11.1

Harvesting

Flax is ready to harvest when stems turn yellow and bolls are brown. Seed should be at less than 12 percent moisture before combining. Flax with green stems requires a sharp cutter bar. Green weeds and uneven ripening of the crop can further complicate harvest. Because of this, flax is usually windrowed prior to combining until the seed has reached 8 to 10 percent moisture. A tall stubble (higher than for small grains) is recommended to facilitate pickup. Careful monitoring of combine settings is necessary to reduce seed damage.

Reducing risk: flax. Plant at adequate rates; low planting rates can lead to weed issues because flax is not competitive. Rotations should be three years long or longer. Maintain good weed control prior to planting flax.

PEA-FLAX MULCH EXPERIMENT

Field pea and flax are both crops that are uncompetitive with weeds. A study was conducted in Lamberton and Rosemount, MN, to determine if weeds could be controlled in these crops by using winter-killed cover crops. Spring oats, field pea, oilseed radish, berseem clover, and crimson clover were planted in the fall (Figure 14-14). In the spring, either field pea or flax were no-till planted into the mulch (Figures 14-15 and 14-16). Yields were greatly reduced by the mulch treatments and by the warm and droughty conditions. (Tables 14-7 and 14-8). The mulch effects on weeds were inconsistent.

Figure 14-14. *Berseem clover planted in the fall.*

Table 14-7.
Field pea harvest following fall cover crops in 2007

	ROSEMOUNT		LAMBERTON	
Fall cover crop	Yield bu/ac	% Weed Cover	Yield bu/ac	% Weed Cover
Spring oat	7.2	16	5.5	18
Field pea	5.2	22	4.1	20
Oilseed radish	8.6	5	4.1	6
Berseem clover	4.5	11	3.5	29
Control	4.5	25	4.9	28

Figure 14-15. *Field pea planted into winter-killed mulch in spring.*

Table 14-8.
Flax harvest following fall cover crops in 2007

	ROSEMOUNT		LAMBERTON	
Fall cover crop	Yield bu/ac	% Weed Cover	Yield bu/ac	% Weed Cover
Spring oat	0.1	5	1.8	24
Field pea	0	35	1.0	32
Oilseed radish	0.1	4	0.8	38
Berseem clover	0.1	22	0.5	39
Control	0	29	0.3	40

Figure 14-16. *Flax planted into winter-killed mulch in spring.*

SUNFLOWER

Overview and use

Sunflower is grown primarily for oil or seed. Two types of sunflower are grown: oilseed types and confectionary sunflower types used for baking, snacks, and bird food. Oilseed sunflowers are black-seeded and are either linoleic or oleic types. Confectionary sunflower varieties have a thick, striped hull and seeds are larger than those of oilseed varieties (Figure 14-18). Sunflower meal can be substituted for soybean meal in livestock feed.

DAVID L. HANSEN

Figure 14-17. ***Sunflowers.***

Types/varieties

Most sunflower varieties are hybrids. They exhibit increased yield, uniformity, pest resistance, stalk quality, seed quality and self compatibility. Producers should select varieties with a maturity rating appropriate to the growing season for your area. Semi-dwarf sunflowers are available and are 25 to 35 percent shorter than other varieties. Reduced seed and oil yield in semidwarf varieties has been found during years with drought stress.

Preferred conditions

Sunflower prefers well-drained soils with good water-holding capacity and neutral pH. Yields can be reasonably good on a range of soils including soils with low moisture, high salinity or poor drainage. In dry years, sunflower can yield somewhat well because it is deep-rooted and thus able to extract water from a greater volume of soil. The critical period for sunflower to receive moisture is 20 days before and after flowering. It uses less water than corn or soybean, but more than small grains. Good yields have been obtained on soils with pH ranging from 5.7 to over 8.

STRAND MEMORIAL HERBARIUM

Figure 14-18. ***Confectionary (left) and oilseed (right) types of sunflower.***

Planting date

Sunflower will germinate at 39° F but a soil temperature of 50° F at a four-inch depth is required for uniform germination. Planting too early, when soil temp is below 50° F, will delay germination and increase susceptibility to seedling diseases. Sunflower will take longer to emerge compared to grains. In Minnesota and Wisconsin, planting occurs from early to mid-May. It produces best in temperatures from 65 to 90° F.

Planting depth and rate

Plant seed one-half to two inches, but not more than three inches, deep. Semidwarf varieties should not be planted more than two inches deep. Plant density varies by variety from 12,000 to 25,000 plants/acre (Table 14-9). Similar to soybean, sunflower compensates over a range of populations and yield does not increase above than 29,000 plants/acre. Oilseed

HOWARD F. SCHWARTZ, COLORADO STATE UNIVERSITY

Figure 14-19. *Verticillium wilt in sunflower.*

hybrids are planted at 15,000 to 25,000 plants/acre, depending on soil type, precipitation, and yield goals. Confectionary varieties are planted at lower populations, between 14,000 to 20,000 plants per acre, to produce large seeds.

Nutrient requirements

Sunflower is a medium to high feeder but requires less nutrients than corn. Nitrogen tends to be most limiting. 20 to 100 pounds of nitrogen generally will meet needs, depending on previous crop. Sunflower responds well to organic sources of nitrogen and seems to respond better to additional P than K.

Pest control

Sunflower is a good competitor with weeds after it has become established. The critical period for weed control is during the first four weeks after emergence. In the North Central states, wild mustard, wild oats and kochia are particular problems. Preplant, preemergence and postemergence tillage are all important for effective weed control. Weeds that emerge before the crop can be controlled with preemergence tillage using a spike tooth harrow, a coil spring harrow, or a rotary hoe up to one week after planting. Sunflowers can be harrowed or rotary hoed post emergence at the four to six leaf stage with an attrition rate of five to seven percent per operation. Sunflowers can be cultivated once or twice between the rows until the plants are six inches high.

Sclerotinia stalk, head rot (white mold), and Verticillium wilt can be problems (Figure 14-19). Choose resistant varieties when available. Rotations should be at least four years between sunflower crops. Non-susceptible crops include small grains, sorghum, and corn.

Rotations will also help to reduce, but will not eliminate, insect problems. Adjacent fields should not be planted with sunflower in subsequent years due to insect pests that overwinter in the soil.

Birds are also a pest of sunflowers (Figure 14-20). However, control options are limited as birds are adaptable to deterrents.

Table 14-9. Recommendations for sunflower plant populations for different parts of Minnesota.
Adapted from Robinson et al., 1982.

TYPE	LOCATION/SOIL	PLANTS PER ACRE
Oilseed	North	20,000
Oilseed	Central	20,000
Oilseed	Southwest	15,000
Oilseed	Southeast	20,000 - 25,000
Oilseed	Sandy soils	15,000
Oilseed	Irrigated soils	20,000 - 25,000
Confectionary	Droughty soils	15,000 - 20,000
Confectionary	Non-droughty soils	10,000

Harvesting

Seeds are physiologically mature when the back of the sunflower head turns yellow. Harvesting occurs after this point because the fleshy head requires additional drying time. Harvest at 18 to 20 percent moisture. Harvesting at lower moistures may lead to yield loss. Grain combines will need a

HOWARD F. SCHWARTZ, COLORADO STATE UNIVERSITY

Figure 14-20. *Bird damage on sunflower.*

sunflower head attachment and a pan for collecting shattered seed. Store between nine and twelve percent moisture for long-term storage.

Reducing risk: sunflower. **Select varieties that mature within the growing season, provide seed quality for the desired market and have resistance to common diseases and insect pests. Rotation is essential to avoid disease problems. Rotation will also reduce the buildup of weed species that are problematic in sunflower, in particular, mustard. Although modern sunflower hybrids have increased self compatibility, seed yield can be increased with pollination from honeybee colonies.**

Figure 14-21. *Buckwheat.*

BUCKWHEAT

Overview and use

Buckwheat is a fast-growing annual that is used as a grain crop, green manure, and smother crop. Its flowers provide a source of nectar for the production of buckwheat honey. Buckwheat grain is milled and the flour and groats are used for human consumption. It can also be combined with corn, oats or barley and used as a feed for livestock. Because the grain is high in the amino acid lysine, it provides a more complete protein than cereal grains.

Buckwheat makes an excellent green manure crop. It produces relatively large amounts of biomass in six to eight weeks. It has a dense root system in the top ten inches of soil and tap roots that can reach a depth of three feet. It is able to absorb relatively insoluble mineral nutrients by increasing the acidity of the soil in the root zone. When it is plowed under, the tissues decay rapidly and release nitrogen and other nutrients making them available to the following crop.

A producer from Redwood County uses buckwheat as a grain crop plus as a smother crop for Canada thistle. He wishes the market were stronger for the grain so he could utilize it more often.

Because of its rapid growth, buckwheat is also used as a smother crop to control weeds. It emerges in two to five days, establishes rapidly, and has a dense canopy. It may suppress quackgrass, Canada thistle, sowthistle, and others. It has been found to have allelopathic effects on barnyardgrass and common purslane.

While buckwheat is not a part of many breeding programs, there are several varieties available of buckwheat (Table 14-10).

THE BUCKWHEAT GROWERS ASSOCIATION OF MINNESOTA

Organic and sustainable producers in Central and Northern Minnesota formed a co-op to promote buckwheat production. They started out by developing facilities to clean buckwheat. They have since expanded their focus to include other alternative crops. Their services and products now include feed for livestock, seed and supplies, grain cleaning, corn drying, and grain storage. For more information, visit their website at http://www.buckwheatgrowers.com/index.htm.


STRAND MEMORIAL HERBARIUM.

Figure 14-22. *Buckwheat has flowers, immature seed (green) and mature seed (brown) all at the same time.*

Preferred conditions

Buckwheat prefers cool and moist growing conditions. It does well on a wide range of soil types. It tolerates infertile soil, acidic soil and does well on soil with a high residue. It does not grow well on heavy soil, poorly drained soil or soil with high levels of limestone. It is susceptible to drying winds and drought. Excessive nitrogen, heavy rainfall and wind can cause buckwheat to lodge. Buckwheat is very susceptible to frost (below 32º F).

Planting date

Buckwheat germinates over a wide range of temperatures (45 to 105° F). Yields are best when planted in early spring after all danger of frost is past. One of the advantages of buckwheat is that the planting date is flexible as long as frost and high temperatures during flowering can be avoided. Buckwheat requires 10 to 12 weeks after planting to reach maturity, so it can be planted in the spring or in mid-summer. Spring seeding from May 25th to June 10th is recommended in North Dakota and Minnesota. Planting late can result in reduced yield if high temperatures occur during flowering. When planted in mid-summer (July), buckwheat is typically harvested after frost.

Planting depth and rate

Seed can be planted with a grain drill or broadcast. Seed is planted at a depth of one to two inches. A seeding rate of 40 to 55 pounds per acre is recommended, depending on variety. Large-seeded varieties are planted at the higher rate. Planting at overly high rates can lead to poor stands that lodge and produce lower yields. Cross-planting with a grain drill results in better spacing and reduced lodging. Preplant cultivation and good seed bed preparation help to ensure rapid emergence and establishment. A firm seedbed

Table 14-10. Variety trials of buckwheat conducted at several sites in North Dakota in 2004 – 2007.
Adapted from Berglund, 2007.

VARIETY	LODGING *	YIELD (LB/ACRE)
Mancan	5.6	1253
Koma	5.0	1312
Manor	4.7	1344
Koto	3.5	1325

* on a score of 0 to 9, with 0 = complete lodging and 9 = no lodging

is best for planting buckwheat. If broadcast seeding, drag field to incorporate.

Nutrient requirements

Buckwheat has moderate fertility requirements. In fertile soils or after alfalfa, no additional nutrients will be required. In fact, buckwheat is not recommended for very rich soils, as it will lodge. Buckwheat will produce higher yields on less fertile soils with the addition of the equivalent of 15 pounds N per acre.

Pest control

Weeds should be controlled with tillage prior to planting. Weeds are typically not a problem after the crop has become established but volunteer canola, mustard and sunflower can readily establish and be difficult to control in buckwheat.

Disease and insect pests do not present serious problems for buckwheat production.

A Redwood County producer says harvesting buckwheat is slow. It can take three weeks to dry down.

Harvesting

Because buckwheat is an indeterminate plant, flowers, green seed and mature seed are present on the same plant at the same time (Figure 14-22). Harvest occurs about 10 weeks after planting. At this point, 70 to 75 percent of the seeds will be mature but still retained on the plant. With delays, mature seed will drop. Swathing is necessary to hasten drying if the crop hasn't been killed by a frost. It should be cut in early morning to lessen shattering and left to dry. Buckwheat that was planted in mid-summer can be harvested after a light frost and then direct combined. A moisture content of less than 16 percent is required for safe storage.

When grown as a green manure crop, it is incorporated before seed sets, about four to seven weeks after planting. After being disked, it is left to dry for a few days and then tilled under.

A producer from Cottonwood County does not find volunteer buckwheat to be a problem. Flaming in the spring controls the volunteers well for him.

Reducing risk: buckwheat. **Avoid planting buckwheat following wheat, oats, barley or flax. Seed of volunteer plants of these crops will cause problems when cleaning the buckwheat crop. Removal of soil nutrients by a buckwheat crop can depress yield of the following crop. Care is needed to ensure that soil nutrient levels, especially phosphorus, are adequate for the following crop. Plant after the average date of frost in your region. Avoid planting late as high temperature and dry conditions during flowering can reduce yields. Control buckwheat used as a green manure early before most of seed matures, especially if the succeeding crop is not competitive with volunteer buckwheat. To reduce chances of volunteer plants in the subsequent year, the field should be tilled to incorporate residue and then tilled a second time one to two weeks later.**

STRAND MEMORIAL HERBARIUM.

Figure 14-23. *Triticale.*

TRITICALE

Overview and use

Triticale is the product of crossing two closely related species, wheat (*Triticum*) and rye (*Secale*). Triticale combines the characteristics of high yield potential and tolerance to dry conditions from wheat with those of disease resistance and tolerance to low temperature and poor soil from rye. Like wheat, there are winter and spring varieties of triticale, but the winter types generally do not survive winters in Minnesota (Table 14-11).

Triticale is grown as a grain or forage crop. The grain is milled and used in bread and pastry production. Although the protein content is higher than that of wheat, the gluten fraction (the protein that entraps carbon dioxide and causes bread to rise) is less which restricts its use as bread flour.

Triticale grain has a higher protein content than wheat, with slightly higher lysine and threonine (Table 14-12). This, combined with its high starch digestibility, makes it a better feed grain for livestock than wheat. Feeding trials have shown that weight gain for pigs fed triticale-based diets are similar to those fed corn-based diets.

As a component of a rotation, triticale has potential to contribute to reduce risks related to weather, to contribute to soil improvement and increase overall system productivity. However, producers need to establish a market before growing triticale.

Preferred conditions

Triticale yields best on fertile, well-drained soils and in climates suitable to small grain production. However, it tolerates acidic soils and low soil fertility and is better adapted to harsh conditions such as low temperatures or hot, dry weather.

Planting date

Triticale is a cool-season annual. It does well under planting conditions and practices similar to those for wheat. In the North Central region, spring triticale is planted in late April to mid-May. Where practical, winter varieties are planted in the fall, similar to winter wheat.

Planting depth and rate

Triticale is seeded at a depth of one and a half to two inches. A rate of 75 to 100 pounds/acre is seeded to establish a stand of 1,000,000 plants/acre.

Table 14-11.
Variety trials of triticale in North Dakota and Iowa.
Yields for North Dakota averaged over four sites and three years (2004-2006) and yields for Iowa are averaged over three sites and two years (2003-2004).
Adapted from Gibson et al., 2005; and Endres and Kandel, 2008.

VARIETY	LOCATION	YIELD (BU/ACRE)
Laser	ND	51
	IA	60
Wapiti	ND	53
	IA	61
Marvel	ND	44
Companion	ND	53
Trical 2700	ND	51
Banjo	IA	50
Pronghorn	IA	72
AC Ultima	IA	67
99 TV 71119	IA	59

Nutrient requirements

Triticale is a moderate feeder. Soil fertility requirements are similar to those of small grains. It requires slightly higher nitrogen levels than wheat and adequate levels of phosphorus.

Pest control

Proper seeding rate, pre-emergence and post-emergence (at the one to three leaf stage) tillage are primary weed control approaches.

Triticale is susceptible to infection by ergot, a fungus that alters the grain appearance and produces toxins. Ergot, scab and rust are common disease problems. Use rotation to avoid these. Insects usually do not cause severe damage.

DON TANAKA, AGRICULTURAL RESEARCH SERVICE

Figure 14-24. *Harvesting triticale in Mandan, North Dakota.*

Harvesting

Harvesting and storage requirements are similar to rye.

Triticale can be swathed or straight combined (Figure 14-24). When grown for silage or hay, it should be cut at early-boot stage. Store grain at 13 percent or less moisture.

Table 14-12. Amino acid composition of various crops. *Adapted from USDA-ARS, 2009.*

Crop	*Amino Acid (% of total weight)* Isoleucine	Leucine	Lysine	Methionine	Phenylalanine	Threonine	Tryptophan	Valine	Arginine	Histidine
Dry field pea	1.014	1.760	1.772	0.251	1.132	0.872	0.275	1.159	2.188	0.597
Flax	0.896	1.235	0.862	0.370	0.957	0.766	0.297	1.072	1.925	0.472
Sunflower (kernels)	1.139	1.659	0.937	0.494	1.169	0.928	0.348	1.315	2.403	0.632
Buckwheat	0.498	0.832	0.672	0.172	0.520	0.506	0.192	0.678	0.982	0.309
Triticale	0.479	0.911	0.365	0.204	0.638	0.405	0.157	0.609	0.671	0.311
Proso millet	0.465	1.400	0.212	0.221	0.580	0.353	0.119	0.578	0.382	0.236
Grain sorghum	0.433	1.491	0.229	0.169	0.546	0.346	0.124	0.561	0.355	0.246
Grain amaranth	0.582	0.879	0.747	0.226	0.542	0.558	0.181	0.679	1.060	0.389
Pinto bean	0.871	1.558	1.356	0.259	1.095	0.810	0.237	0.998	1.096	0.556
Navy bean	0.952	1.723	1.280	0.273	1.158	0.711	0.247	1.241	1.020	0.507
Kidney bean	1.041	1.882	1.618	0.355	1.275	0.992	0.279	1.233	1.460	0.656
Soybean	1.971	3.309	2.706	0.547	2.122	1.766	0.591	2.029	3.153	1.097
Corn	0.337	1.155	0.265	0.197	0.463	0.354	0.067	0.477	0.470	0.287
Wheat hard red spring	0.541	1.038	0.404	0.230	0.724	0.433	0.195	0.679	0.702	0.330
Oats	0.694	1.284	0.701	0.312	0.895	0.575	0.234	0.937	1.192	0.405
Barley, hulled	0.456	0.848	0.465	0.240	0.700	0.424	0.208	0.612	0.625	0.281

Reducing risk: triticale. **Triticale has better disease resistance than wheat, but newer varieties should be planted and rotated with crops other than small grains to minimize problems with ergot. Straight cutting rather than swathing will reduce risk of pre-harvest sprouting.**

Alternative crops in a corn and soybean rotation

Crop diversification by including crops other than corn and soybean can be a powerful tool by which farmers can reduce weed populations and gain rotation benefits. Research was conducted to determine how alternative crops responded within a corn and soybean rotation. Alternative crops were grown in rotation either following corn or soybean. Field experiments were conducted at Lamberton, Waseca, and Rosemount, MN, in 2006 through 2008.

The previous crop did not have a large effect on the alternative crops' yields (Tables 14-13 and 14-14). Instead, it was found that weeds and weather conditions were the largest risks. Amaranth and flax suffered due to lack of effective weed control. Dry, warm conditions also took its toll on flax yields in some years. Other alternative crops such as sunflower performed more competitively. Growers should be aware that some alternative crops will have greater production risks than others.

Table 14-13. Alternative crop yields after soybean averaged across locations and years

CROP	MEAN YIELD	RANGE OF YIELDS (BU/ACRE)
Amaranth	18	0 to 45
Buckwheat	19	8 to 39
Flax	10	0 to 24
Spring wheat	26	12 to 33
Sunflower	90	33 to 140
Proso Millet	20	6 to 49
Oat	46	17 to 73

Table 14-14. Alternative crop yields after corn averaged across locations and years

CROP	MEAN YIELD	RANGE OF YIELDS (BU/ACRE)
Amaranth	15	0 to 47
Buckwheat	24	6 to 39
Flax	5	0 to 22
Spring wheat	26	14 to 42
Sunflower	91	41 to 141
Field Pea	28	8 to 52
Grain sorghum	58	43 to 89

Figure 14-25. *Alternative crops trial, 7-9-08.*

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Figure 14-26. *Proso millet.*

DAVID L. HANSEN

Figure 14-27. *Foxtail millet.*

MILLETS

Overview and use

The term 'millet' is used to refer to several different grass species that are grown for grain production. They include proso, foxtail, barnyard (or Japanese), browntop, and pearl millet. The most commonly grown types of millet in the North Central region are proso millet and foxtail millet (Table 14-15). Proso millet grain can be used in livestock feed and compares nutritionally to oats and barley. It is also used in caged and wild bird feed mixes. Foxtail millet is used for hay or silage. Proso millet can yield 2,500 to 2,800 pounds/acre of grain. Foxtail millet can yield three to four tons/acre of forage.

Table 14-15. Proso millet variety trials. *Yields are an average of four sites in North Dakota. Adapted from Endres and Kandel, 2009.*

VARIETY	YIELD (LB/ACRE)
Horizon	1368
Sunrise	984
Sunup	1244
Red Waxy	424

Preferred conditions

Both proso and foxtail are annual, short-season grasses. They mature rapidly and use water efficiently. Consequently, they can often avoid late summer drought and moisture deficits that occur on sandy soils. Millets do not tolerate poorly-drained soils. Soil pH should be at 5.6 or higher.

Planting date

Proso millet matures in 70 to 100 days. Foxtail is ready to harvest in about 50 to 65 days from emergence. Millets need warm soil temperatures (68 to 86° F) for germination and growth and do not tolerate frost. Millets are generally planted mid-June to mid-July in the North Central region. Later seeding reduces yields and increases the risk of exposure to early frost.

SCOTT BAUER, AGRICULTURAL RESEARCH SERVICE

Figure 14-28. *Planting foxtail millet.*

Planting depth and rate

Seed proso millet at 20 to 30 pounds/acre and foxtail millet at 15 pounds/acre at a one-inch depth (Figure 14-27). Millets do not compete well with weeds so a high seeding rate should be used when heavy weed competition is expected. Seedbed preparation is similar to that for small grains. A grain drill with press wheels is recommended to ensure a firm seedbed and good emergence.

Nutrient requirements

Adequate nitrogen, phosphorus and potassium levels are essential for optimum yield. Excess nitrogen can result in lodging.

Pest control

Similar to small grains, a clean seed bed is important for emergence and early establishment. Because of their late planting date, there is ample time for mechanical weed control operations prior to planting. Avoid excessive tillage to conserve soil moisture.

Millets are susceptible to head smut, kernel smut, and bacterial stripe disease. Rotation is the best control.

Harvesting

Timing of harvest is important. Proso millet can be harvested when the seeds on the upper half of the panicle are brown and no longer soft. Shattering and lodging increase when harvest is delayed. Millet should be swathed prior to combining to allow straw to dry. Foxtail millet is cut at late boot to late bloom stage for forage. If it has been heat or water stressed it can accumulate nitrate to levels dangerous to livestock and should be checked prior to feeding. For storage, millet seed should be at 13 percent moisture or less.

Reducing risk: millets. **Plant before June 25 if growing millet for seed. Excessive nitrogen can result in lodging. Rotate crops to control smuts. Time harvest properly for best yields.**

CAMELINA

Camelina, a member of the mustard family, is a hardy oilseed crop that shows better drought tolerance and greater freezing tolerance than canola or soybean. The plants are heavily branched, growing to heights of 1 - 3 feet loosely resembling canola or flax. Camelina oil has unique properties very high in alpha-linolenic acid (ALA), an omega-3 fatty acid which is essential in human and animal diets.

Camelina is a cool season crop that produces greatest yields when sowed early. Seed is simply broadcast, or drilled, at rates of 6 to 8 lbs/acre and requires only modest amounts of fertilizer. Camelina has been promoted as a low-input, low-fertility crop, but yields may increase with total soil N up to 80 lbs N/acre. Crop harvest is similar to small grains or canola and does not require any specialized equipment.

Two organic dairy farmers in northwest Minnesota are experimenting with camelina as an alternative crop and using it to replace soybean meal in their dairy rations. Following harvest, the oil is extruded at a local feed mill providing these farmers with meal containing 40% crude protein and 10-12% oil. In their initial on-farm feeding trials, milk production increased slightly when substituted for the equivalent rates of organic soybean meal. However, camelina meal reportedly contains anti-nutritive compounds called glucosinolates which may limit the inclusion rate. No problems were found with palatability or acceptance. These farmers find that camelina is easy and inexpensive to grow, competes well with weeds, and may provide another option to soybean meal in organic dairy rations.

GRAIN SORGHUM

Overview and use

Grain sorghum is used mostly for livestock feed and it has similar nutrition to corn. Grain sorghum feed values are 90 to 100 percent that of corn. It is often grown in areas that are too hot and dry for corn production. Grain sorghum can be mixed with soybeans to produce a high protein silage.

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Figure 14-29. *Grain sorghum.*

Preferred conditions

Cool temperature is the most limiting factor to sorghum production in the North Central region. Grain sorghum requires average (day + night temperature average) temperatures of 80° F. Maximum photosynthesis occurs at about 90° F. Thus, sorghum is best adapted to the southern part of Minnesota. Cool temperatures (below 55° F) during heading and pollination will reduce seed set. Early maturing hybrids of 80-85 day relative maturity are recommended for the North Central region.

Sorghum tolerates short periods of drought better than corn. Tillering will compensate for lower planting populations. It also tolerates wet soils and flooding better than other grains. It tolerates saline soils better than corn.

In dry years, sorghum offers the following advantages over corn production: self-pollination reduce the risk of poor seed set; sorghum's tillering capacity results in yield potential that can be supported by moisture levels; the waxy material on sorghum leaves contributes to greater water use efficiency. Yields can reach over 100 bushels/acre. Sorghum often produces higher yields than corn in dry conditions, but corn will out-yield sorghum under moist and fertile conditions.

Planting date

Soil temperatures should be in the range of 60 to 65° F for maximum emergence after planting. This typically occurs between May 15 and early June. It takes 80 to 120 days to mature depending on the variety. Seedlings can be slow to emerge.

Planting depth and rate

Plant one inch deep in heavy soils, one and a half to two inches in sandy soils. On fertile, moist soils, plant at eight to ten pounds/acre in rows 30 to 40 inches wide for a final plant population of 100,000 to 120,000 plants/acre. Studies with narrow rows (10-inch) in Minnesota showed improved yields in wide rows compared to narrow rows. Because cultivation is not possible with narrow rows, this option is less attractive for organic systems. On dry, less fertile soil, a lower seeding rate, five to six pounds/acre, should be used.

Nutrient requirements

Fertility requirements for grain sorghum are similar to corn. Adequate nitrogen, phosphorus and potassium are particularly important.

Pest control

Prepare the seed bed in early spring followed by one or more cultivations. Sorghum competes poorly with weeds during early emergence. Cool soil will result in slow establishment and give early weeds an advantage. After planting, sorghum can be cultivated prior to emergence and up to 6 inches tall.

Disease and insects generally are not problematic.

Harvesting

Sorghum is harvested when grain moisture is 20 to 25 percent. A frost will help grain to dry. Sorghum is harvested with a combine. Store at a moisture level at or below 13 percent.

Reducing risk: grain sorghum. Choose earlier maturing varieties. Grow grain sorghum only in areas to which it is adapted.

Figure 14-29. *Amaranth.*

GRAIN AMARANTH

Overview and use

Amaranth is a grain that is high in protein and lysine, the essential amino acid lacking in cereal grains. It is used as a grain crop and leafy vegetable and has potential as a forage crop. The grain is ground and the flour used in many products including noodles, pancakes, and pastries.

Two species of grain amaranth are grown. The most common variety is 'Plainsman'.

Preferred conditions

Amaranth is adapted to a wide range of conditions and is grown throughout the Midwest. It performs well on lighter soils and on slightly acidic to basic soils. It tolerates drought and heat.

Planting date

Plant in late May to early June, or when the soil temperatures are 65° F. With the short summers in the Upper Midwest, planting as early as feasible may increase yields (Table 14-16).

Planting depth and rate

Seeds of amaranth are extremely small so seedbed preparation is important. Fields should be worked with a cultivator or disk and prepared using a cultipacker or harrow. Seeds are planted one-half inch deep using a planter with press wheels. Planting depth depends on soil type and moisture conditions. Emergence is generally low and is reduced on heavy soils. Plant amaranth at rates of between one half to two pounds/acre. Trials in Minnesota showed the best yields were obtained at planting rates between 1.6 and 4 pounds/acre.

Nutrient requirements

Amaranth has fertility requirements similar to sunflower. Phosphorus and potassium should be in the medium to high range.

Table 14-16. Management practices effects on amaranth production.

Research in eastern Canada found that many management practices had little significant effect on yield. Planting early, however, did positively affect yields. Adapted from Gelinas and Seguin, 2008.

MANAGEMENT PRACTICE		YIELD LB/AC
Seeding date	Mid-May	856
	Early June	777
	Mid-June	718
Cultivar	K432	756
	K593	718
	Plainsman	878
Seeding rate (lbs/acre)	0.9	781
	1.8	832
	3.6	817
Row spacing (in.)	15	820
	23	800
	30	809
N-rate (lbs/acre)	0	854
	45	871
	89	844
	134	916
	178	896

Pest control

Amaranth is very susceptible to competition from weeds. Therefore, it is essential to include it in a crop rotation that minimizes weeds seed bank development. Seedlings grow slowly, so three to four cultivations may be necessary. Avoid planting this crop in lambsquarter or pigweed infested fields. Grain amaranth usually does not become a weed in following crops.

Disease issues are rare. The tarnished plant bug is sometimes a problem.

Harvesting

Over 1,000 pounds per acre can be obtained in the Midwest, but some seed can be lost to shattering. Amaranth should be exposed to a killing frost (which functions as a desiccant) before harvest, followed by seven to ten days of good drying weather. High moisture grain will cause problems with the combine. Because of the small seed size, cleaning the grain is important. Store at 11 percent moisture.

Reducing risk: Amaranth. Use rotations that reduce weed populations. Avoid planting amaranth in heavy soils. Harvest carefully to minimize lost seed. Late planting dates may lead to more difficulties in harvesting and storage due to increased grain moisture.

STRAND MEMORIAL HERBARIUM

Figure 14-31. *Field beans.*

FIELD BEAN

Overview and use

Like soybeans, field beans are warm season annual legumes. Market classes of field beans include black turtle, cranberry, great northern, kidney, navy, pink, pinto, small red, and small white. Pinto, navy and kidney are the most widely cultivated species. They are produced for human consumption and are purchased in dried, canned or cooked forms. They are the second most important legume in the world (soybeans are first) in terms of amount produced. Beans must be cooked to destroy an inhibitor that prevents the trypsin enzyme from breaking down protein in the digestive track of non-ruminants.

Determinate and indeterminate (vine) types may be found depending on the market class. Indeterminate types produce new vegetative growth at the same time as they produce flowers.

Preferred conditions

Field beans will do best in areas with 14 to 20 inches of rainfall. Overly humid conditions will lead to disease. Fertile sandy, well-drained loam soils with a pH between 5.8 to 6.5 are best. Above a pH of 7.2, iron and zinc deficiencies in some varieties can result in chlorosis. Soils that are temporarily flooded, easily compacted, or form a crust are not suitable.

Planting date

Plant after all danger of frost is past, between May 15 and 26. Field beans require between 85 to 120 days to mature. They do best when temperatures range from 50 or 60° F for lows to 80° F for highs. When planted early, flowering and pod set occur in early July, before the period of high temperatures and reduced moisture. Early planting also allows harvest to be completed before fall rains.

Planting rate and depth

Planting rate varies from 75,000 to 105,000 seeds/acre and depends on seed size, growth habit, germination rate, and soil conditions (Table 14-17). Narrow rows are preferable. Plant between one to two inches deep.

Nutrient requirements

Good fertility is required to obtain high yields. Although field beans fix atmospheric nitrogen, effective nodulation by *Rhizobium phaseoli* is difficult in some soil types and under some environmental conditions. Inoculation is recommended. In some cases, nitrogen fertilization can be used to enhance yields. A soil test should be performed to determine that other nutrients are in the recommended range. Micronutrient deficiencies can occur. Field beans require relatively high levels of manganese.

Pest control

Field beans are not competitive with weeds. The late seeding date will allow multiple cultivations of early germinating weeds. Mechanical weed control should be

Table 14-17. Planting rates for different bean types. *Adapted from Hardmann et al., 1990.*

CLASS	RATE (lb/acre)	RATE (seeds/acre)
Black Turtle	45	105,000
Cranberry	85	105,000
Great Northern	100	105,000
Kidney	90-115	105,000
Navy	30	105,000
Pink	60	105,000
Pinto	60-80	105,000
Small Red	75	78,000
Small White	35	78,000

completed before bloom, after about five to six weeks of crop growth.

Field beans are susceptible to potato leafhopper and aphids; however, no organic control measures exist for these insects.

Harvesting

Yields average between 1,200 and 2,000 pounds/acre. Field beans are cut, windrowed and then combined (Figure 14-33). Cutting when humidity is high will reduce shattering. Combining beans directly can result in significant losses and seed damage. Store at 16 to16.5 percent moisture.

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Figure 14-32. *Pinto beans before harvest.*

Reducing risk: dry beans.

High quality seed is a priority for optimum growth. Disease resistant varieties should be used and residue left in the field should be buried to reduce disease incidence in subsequent years. Mottled beans like pinto may be less risky to grow because of fewer issues with off markings that can occur with white beans.

Conclusion

Alternative crops can be good additions to organic systems. Producers need to carefully consider markets and production requirements before adding a new crop to their rotations. Take the following quiz to determine your risk.

Alternative Crops Risk Management Quiz

	Points	Score
1. What is your primary reason for growing alternative crops or what do you hope to accomplish?		
Higher income	1	
Grow feed for own livestock	5	
Diversify system	5	
Improve soil	3	
Improve pest situation	3	
2. Which of the following resources do you have to support production of this alternative crop? Choose all that apply.		
Proper equipment	1	
Time and labor	1	
Ideal field conditions	1	
Financial stability	1	
Market	1	
Seed source	1	
3. Do you presently have any crops that can be considered an alternative crop in your rotation?		
Yes	5	
No	0	
4. Do you personally know someone who grows this crop?		
Yes	3	
No	0	
5. Has the crop been proven to be adapted to your conditions?		
Yes	5	
No	0	
Not sure	0	
6. Which of the following do you know about the growing requirements of this alternative crop? Choose all that apply.		
Fertility requirements	1	
Climate requirements	1	
pH requirements	1	
Moisture requirements	1	
Soil drainage requirements	1	
7. Does the alternative crop require new or specialty equipment?		
Yes	0	
No	2	
Not sure	0	

	Points	Score
8. Does the production schedule of the alternative crop complement your existing production schedule (i.e. is there little overlap in tasks?)?		
Yes	5	
No	0	
Not sure	0	
9. Do you plan to sell this alternative crop?		
Yes	0	
No, I will use on-farm	5	
If you answered "No" to Question 9, skip Questions 10 - 16.		
10. Is there infrastructure for transportation to available markets?		
Yes	5	
No	0	
Not sure	0	
11. Which of the following best applies to this crop?		
Existing market is relatively stable	3	
Market potential is emerging	1	
Not sure	0	
12. Which of the following best applies to this crop?		
Markets are available, but no contracts	1	
Contracts are available	3	
Direct marketing is a valid option	1	
None of the above	0	
Not sure	0	
13. At what level does the market for this crop operate?		
The crop has a local market	3	
The crop is sold to markets in other states	2	
The crop is sold to buyers overseas	1	
Not sure	0	
14. Do you know the market requirements for the crop?		
Yes	3	
No	0	
15. Do you know which varieties are suitable for your market?		
Yes	3	
No	0	

Alternative Crops Risk Management Quiz, continued

	Points	Score
16. Do you have a backup plan if the buyer requirements are not met?		
Yes, I have places to sell as feed	3	
Yes, I can use myself as feed	5	
No, I will need to investigate	0	
17. Do you have options for storing the crop?		
Yes	3	
No	0	
18. Have you lined up a seed source?		
Yes	3	
No	0	
19. Have you investigated start-up funds for your crop?		
Yes	3	
No	0	
20. Do you have an idea of how your yields may compare to typical yields?		
Yes	3	
No	0	
21. Have you assessed production costs and compared them to your expected yields and market prices?		
Yes	5	
No	0	
22. Have you researched prices and trends for the alternative crop in question over at least the last three years?		
Yes	5	
No	0	
23. Does the alternative crop fit well into your existing rotation?		
Yes	5	
No	0	
Not sure	0	
24. How vigorous is the alternative crop relative to weeds?		
Very competitive	5	
Somewhat competitive	3	
Not competitive	0	

	Points	Score
25. Does the alternative crop have potential to become a weed in your row crops?		
Yes	0	
No	3	
Not sure	0	
26. Is there potential for poor weed control in the alternative crop that could lead to increased weed issues in general?		
Yes	0	
No	2	
Not sure	0	
27. Will the alternative crop be a host for disease or insect pests that afflict your cash crops?		
Yes	0	
No	3	
Not sure	0	
28. Do you have access to additional labor if necessary for the production of the alternative crop?		
Yes	2	
No	0	
Not applicable	2	
29. Have you grown the alternative crop in small-scale plots?		
Yes	5	
No	0	
30. Have you tried multiple varieties of the alternative crop if available?		
Yes	5	
No	0	
Not applicable	3	
	TOTAL	

If you answered Questions 10 - 16

And your score is:	Your risk is:
39 or less	High
40 - 70	Moderate
71 or greater	Low

If you did NOT answer Questions 10 - 16

And your score is:	Your risk is:
39 or less	High
40 - 55	Moderate
56 or greater	Low

FOR MORE INFORMATION

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