CHAPTER 2

Rotation

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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.

DAVID L. HANSEN

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

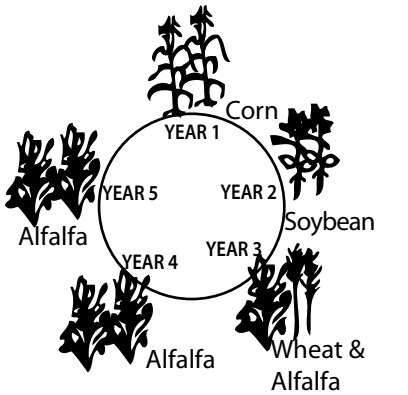


Figure 2-2. *A five-year crop rotation.*

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).

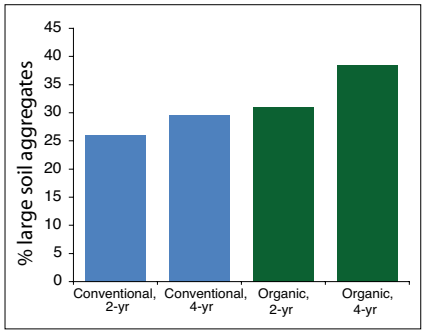


Figure 2-3. Soil aggregation, *a gauge of tilth and water infiltration, under different management systems and rotation lengths in Lamberton, MN. The 4-year rotation managed organically has better soil structure with the highest percentage of large soil aggregates. Adapted from Kuratomi et al, 2004.*

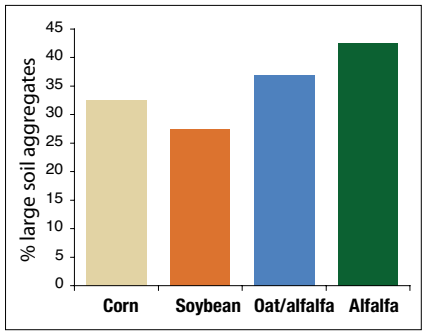


Figure 2-4. Crop effects on soil structure *in Lamberton, MN. In a four-year organic rotation, the soil structure was best after alfalfa. Adapted from Kuratomi et al, 2004.*

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.

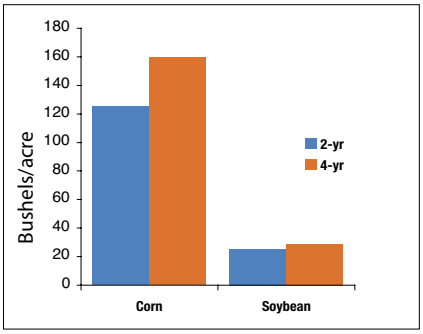


Figure 2-5. Corn and soybean yields *in organically managed 2- and 4- year rotations in Lamberton, MN. Corn and soybeans were grown either in a two-year rotation or in a four-year rotation including alfalfa. The yield of corn was significantly greater in the 4-year rotation. Adapted from Kuratomi et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

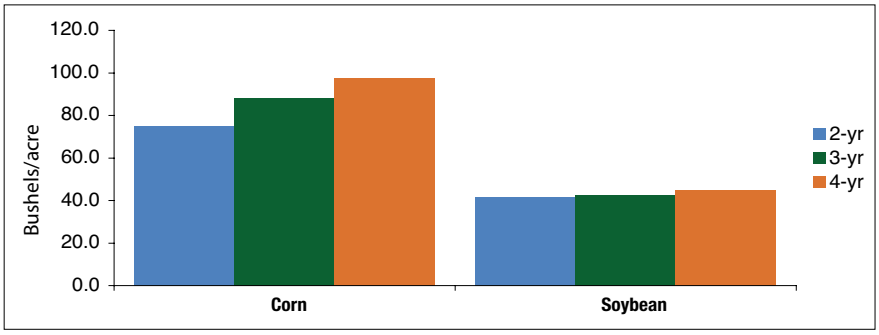


Figure 2-6. Corn and soybean yield *in 2-, 3-, and 4-year rotations in the mid-Atlantic region. The corn yields increase significantly as rotation length increases. Adapted from Cavigelli et al, 2008.*

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.

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.

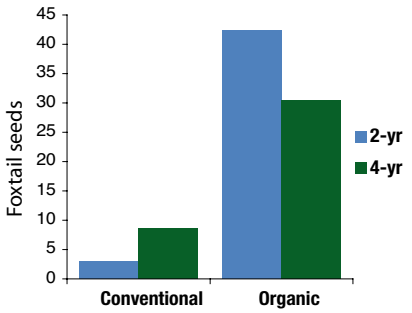


Figure 2-8. Rotation effects on foxtail *seed bank in Lamberton, MN. The four-year organic rotation has significantly fewer foxtail seeds compared to the two-year rotation. Adapted from Haar et al, 2008.*

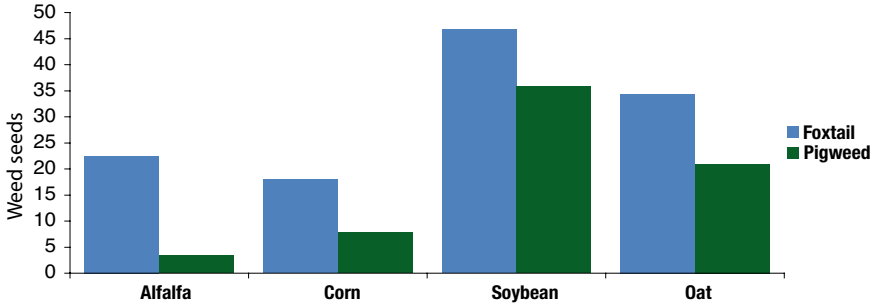


Figure 2-9. Crop sequence effects on weed *seed banks in Lamberton, MN. Fewer foxtail and pigweed seeds were found after alfalfa and corn compared to soybean and oat. Adapted from Haar et al, 2008.*

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.

KEITH WELLER USDA-ARS

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

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.

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.

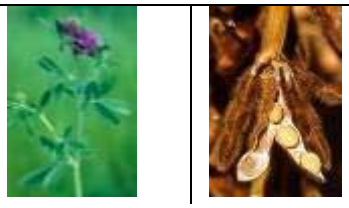
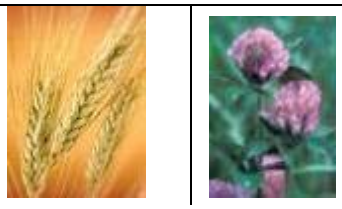
Reducing risk: sequence. Vary species in rotation. Do not plant closely related species right after another.

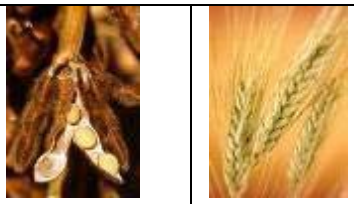
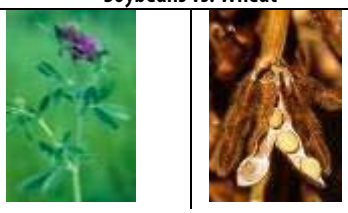
Table 2-4. Risk levels of individual crop sequences.

Crop 1	*followed by*	Crop 2	Disease	Weeds	Insect	Fertility	Moisture
Corn		Corn	NA	NA	NA	NA	NA
		Soybean					
		Small grain					
		Forage legume					
Soybean		Corn					
		Soybean	NA	NA	NA	NA	NA
		Small grain					
Small grain		Forage legume					
		Corn					
		Soybean					
		Small grain					
		Forage legume					
Forage legume		Corn					
		Soybean					
		Small grain					
		Forage legume					

= 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
Nitrogen use: vary crops with high N needs with ones with low needs	 Corn vs. Red clover
Rooting depth: vary crops with deep roots with ones with shallow roots	 Alfalfa vs. Soybean
Competitive: vary crops that compete well with ones that don't	 Wheat vs. Flax
Legumes: vary legumes with non-legumes	 Soybeans vs. Corn
Season: vary cool season crops with warm season crops	 Field peas vs. Soybeans
Cultivars: vary cultivars to gain pest resistance and other benefits	 Cultivar 1 vs. Cultivar 2
Growth habit: vary crops with upright growth with low-growing crops	 Wheat vs. Red clover

Trait to vary	Examples
Species: the more diversity in a rotation, the better	 Oats vs. Barley
Row spacing: vary crops with different row widths	 Corn vs. Flax
Planting dates: vary crops with different planting dates	 Soybeans vs. Wheat
Harvest dates: vary crops with different harvest dates	 Alfalfa vs. Soybean
Crop height: vary tall crops with short crops	 Corn vs. Wheat
Life cycle: vary annuals with perennials	 Alfalfa vs. Corn
Adaptation to Mechanical Weed Control: vary crops that tolerate mechanical weed control	 Corn vs. Flax

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.

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

■ 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.

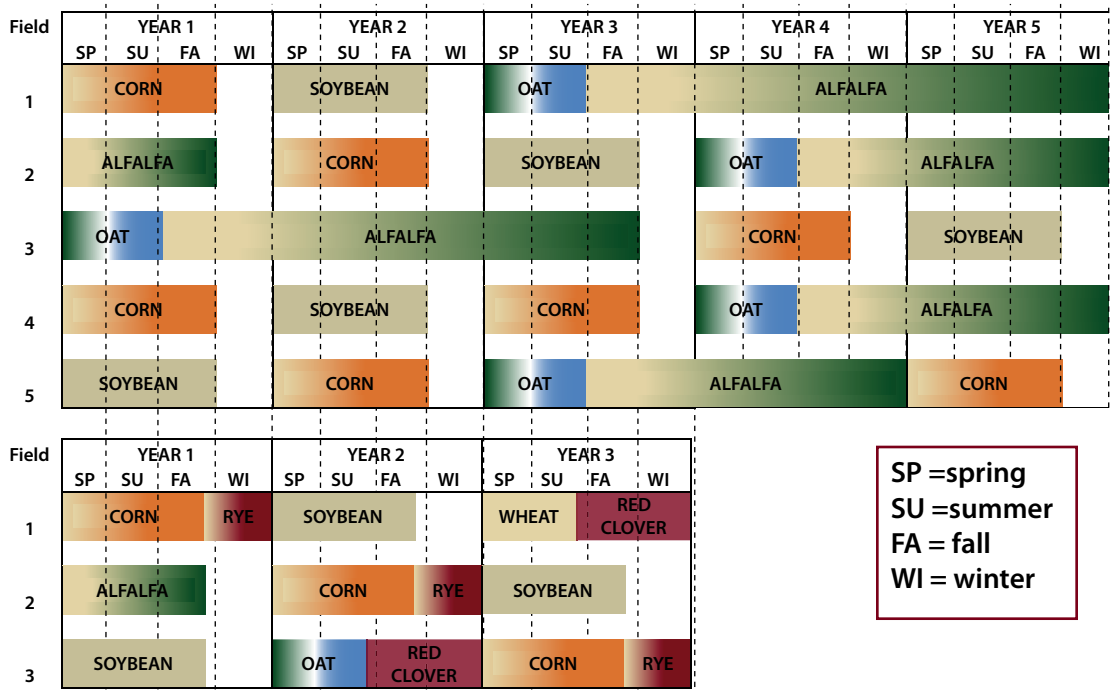


Figure 2-13. Multi-field rotations. *Here are two examples of farms, one with five fields and one with three fields. Notice how the different crops are spatially separate from field to field and not just temporally separate in a single field.*

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

Crop Rotation on Organic Farms. Sustainable Agriculture Research and Education. Mohler, C.L. and S.E. Johnson, editors. http://www.sare.org/publications/croprotation/croprotation.pdf

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

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