# Crop Rotation Tips

***Best Practices for Designing a More Effective Crop Rotation***

A Special Report

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Crop rotation has never been more critical. It not only affects short-term profits, but long-term sustainability. An effective rotation can: reduce weed and pest control and fertilizer costs; increase the amount of moisture that the soil will absorb; improve soil health and nutrient cycling; and boost the amount of residue that will be consumed by soil organisms.

This free report, written by Dwayne Beck, manager of the Dakota Lakes Research Farm, Pierre, S.D., and an internationally recognized expert on the subject, offers an in-depth look at the art and science of designing rotations.

In this report, you will discover the power of hybrid stacked rotations and learn about the pros and cons of everything from the simplest rotation to the most complex.

## Designing a more effective crop rotation

Determining what to grow as rotational crops and how they will be sequenced can be a complex process. There are, however, some general guidelines that can be extremely helpful in beginning the process. Consider this your Top 10 list. The order they appear does not denote their importance.

•Chemical fallow is not as effective at breaking weed, disease, and insect cycles as black fallow, cover crop, or production of a properly chosen crop.

•Rotations should be sequenced to make it easy to prevent volunteer plants of the previous crop from becoming a weed problem.

•Producers with livestock enterprises find it less difficult to introduce diversity into rotations.

•Use of forage or flexible forage/grain crops and cover crops enhance the ability to tailor rotational intensity.

•Livestock make using rotations with perennial sequences easy. It is probably not possible to be sustainable over long periods of time without using perennial plants in the system.

•Crops destined for direct human food use pose the highest risk and offer the highest potential returns.

•The desire to increase diversity and intensity needs to be balanced with profitability.

•Soil moisture storage is affected by surface residue amounts, inter-crop period, snow catch ability of stubble, rooting depth characteristics, soil characteristics, precipitation patterns, and other factors.

•Seedbed conditions at the desired seeding time can be controlled through use of crops with differing characteristics in regard to residue color, level, distribution, and architecture.

•Rotations that are not consistent in either crop sequence or crop interval guard against pest species shifts and minimize the probability of developing resistant, tolerant, or adapted pest species.

It is sometimes easier to discuss concepts if they are placed into categories of some sort. With this in mind, we have developed the following scheme to describe crop rotations. This classification is totally arbitrary and is meant to serve only as a tool to help understand rotation planning.

## Simple Rotations
Simple rotations are rotations with only one crop of each crop type used in a set sequence. This is the most common type.

**Examples:** Winter Wheat-Corn-Fallow; Wheat-Canola; Spring Wheat-Winter Wheat-Corn-Sunflower; Corn-Soybean; Winter Wheat-Corn-Pea

**Advantages:** It's simple. There are a limited number of crops to manage and market.

**Disadvantages:** Limited number of crop sequence/interval combinations. All corn is sequenced behind wheat or all winter wheat goes into spring wheat stubble. This style is consistent in both sequence and interval. Conditions for each crop are the same an all of the acreage.

## Simple Rotations with Perennial Sequences
You can diversify a simple rotation by adding a sequence of numerous years of a perennial crop.

**Examples:** Corn-Soybean-Corn-Soybean-Corn-Soybean-Alfalfa-Alfalfa- Alfalfa- Alfalfa and many others.

**Advantages:** Simple. Limited number of annual crops to manage and market. The perennial crop is an excellent place to spread manure. Perennial crops probably can produce more soil structure than annual crops. This is especially true when grass or grass mixtures are the perennial crop. Perennial crop sequence rotations are the only way to mimic natural nutrient cycles. Biomass crops and use of grazing systems have potential.

**Disadvantages:** It is difficult to manage a sufficient percentage of the farming enterprise as a perennial crop without grazing. Harvesting 40% of the farmland as forage is tough. Using less than 40%, perennial crop minimizes its impact.

**Marketing a perennial crop is an issue**.
For instance, if the producer could only harvest 400 acres of alfalfa in a timely manner with the machinery and labor resources available, he would be limited to having 300 acres of each corn and soybeans in the above rotation. If he expanded his corn and soybean acreage more than this, the rotational benefit of the alfalfa sequence would be negated on the extra acreage.

If he had 400 acres of alfalfa and 1000 acres each of each corn and soybeans (leaving the alfalfa for 4 years), alfalfa would be placed on any given field only one time in a 24-year period. He would in essence have six years of corn-soybean in a perennial sequence rotation and 14 years or corn soybeans in a simple rotation.

Perennial sequence rotations have substantial benefit when used on fields close to the farmstead or feedlot. A producer could allocate 1,000 acres in proximity to where the forage would be used to a perennial sequence rotation. His remaining acreage could be managed in a more diverse rotation that did not involve perennials.

Another option for obtaining a larger percentage of annual crop acres is to combine a more diverse type of rotation and a perennial sequence.

## Compound Rotations
Compound rotations are two or more simple rotations in sequence, which creates a longer, more diverse system.

**Example:** Spring Wheat-Winter Wheat-Corn-Soybean-Corn-Soybean. This results from a combination of the Corn-Soybean and Spring Wheat-Winter Wheat- Corn-Soybean rotations.

**Advantages:** There are still a limited number of crops to manage and market. This approach creates more than one sequence for some crop types. There is diversity in both sequence and crop environment for corn and wheat (not soybeans). Diversity exists in interval for all crops.

**Disadvantages:** There is a limited ability to spread workload since one-third of the acreage is in corn and one-third in soybeans.

## Complex Rotations

Rotations where crops within the same crop type vary are called complex rotations.

**Example:** Barley-Winter Wheat-Corn-Sunflower-Sorghum-Soybean or Barley-Canola-Wheat-Pea. This is similar to the example cited for compound rotations. Barley has been substituted for one of the wheat crops; sorghum for one corn; and sunflowers for one soybean.

**Advantages:** This type of approach is capable of creating a wide array of crop type/sequence combinations. If the crops are chosen wisely, there is substantial ability to spread workload. This approach is effective at combating species-specific pest problems such as cyst nematode in soybeans, blackleg in canola, or corn rootworm in corn. Pests such as white mold that have multiple hosts respond similarly to the way they behave in compound rotations.

**Disadvantages:** The larger number of crops requires substantial crop management and marketing skill.

## Stacked Rotations

One of the lesser-known crop rotations is a stacked rotation. This describes a rotation where crops, or crops within the same crop type, are grown in succession (normally twice) followed by a long break.

**Example:** Wheat-Wheat-Corn-Corn-Soybeans-Soybeans or Barley-Wheat-Pea-Canola.

**Advantages:** Stacked rotations attempt to keep pest populations diverse (confused) through diversity in the sequences and intervals used. Diversity is gained while keeping the number of crops smaller. They allow a mix of long and short residual herbicide programs. This approach can reduce costs and minimizes the chance of tolerance, resistance, and biotype changes.

**Disadvantages:** Not well tested. Some crop sequences may not be ideal. Fewer crops mean less workload spreading.

**Meant to mimic nature**

Stacked rotation concepts should not be unfamiliar; they are the way plants sequence in nature. A species predominates a space for a period of time and is succeeded by another species. Eventually (after many such successions), the original species will again occupy the space. The time frame for these "rotations" is much longer than the one usually considered in annual crop production, but the principles are the same.

Humans tend to operate in a different time frame than other species. Days, hours and years have a totally different meaning to a bacteria or fungi than they do to a tree. Some species have very fast growth curves, once they are given the opportunity, while others take a long time to build population. Each species has a "survival strategy" designed to increase the chances that it will continue to exist. Humans learned to build shelters, grow food, etc. because we were not the best adapted species at enduring the elements and hunting or gathering.

Many annual weeds produce huge numbers of seeds, increasing the probability that at least one will survive. Other weeds have seeds that contain a range in dormancy allowing them to fit into environments where all years are not good years. Many disease organisms produce resting bodies that require favorable conditions to exist before they attempt to grow.

The universal survival strategy for all species is genetic diversity. This allows some of them to survive in conditions that eliminate the rest of the population. Some of the offspring of these survivors have this same survival advantage. Consequently, individuals with this trait will increase as long as the conditions that favor them continue.

They may not have an advantage if conditions change. The main reason agriculture faces issues with resistant weed and insect biotypes is that cropping programs create conditions that favored specific individuals amongst the population and keep these conditions in place long enough, frequently enough, and/or predictably enough to allow that biotype to become the predominate population.

The concept behind stacked rotations (as with some of the other types of rotations as well) is to keep both crop sequence and crop interval diverse. Part of the strategy recognizes the fact that rotations containing only one crop sequence or one interval will eventually select for a species (or a biotype within a species) that suits the particular conditions.

In the case of a species biotype, the population will continue to grow and purify as long as the specific conditions remain the same.

In the Corn Belt and in irrigated areas on the Plains, it is common for many growers to produce corn on the same land every year. When this is done, the corn rootworm beetle (there are different species with similar habits) feeds on the corn silks and lays eggs at the base of the corn plant. Most of these eggs hatch the next spring.

If corn or other suitable hosts are present, the larvae feed on the corn roots and cause significant losses. This required use of insecticides on land devoted to continuous corn production.

When corn was seeded following soybeans, this insect was initially not a problem. Interestingly enough, following a long history of corn-soybean rotation in parts of the Corn Belt, corn rootworm beetles have devised two known survival strategies. In western areas an extended diapause biotype has become common and in some cases, predominate.

The majority of the eggs laid by this biotype do not hatch the next spring (when soybeans are seeded) waiting instead for corn to predictably return the second year. In reality, eggs laid by some individuals always had a higher proportion with this tendency. They now predominate the population because the persistent and widespread use of the corn-soybean rotation was consistent in the interval between successive corn crops. This gave this biotype competitive advantage.

The second example comes from more eastern areas. This adaptation involves the gravid females migrating to soybean fields to lay their eggs. When these hatch the next spring, corn will most likely be there. In this case the biotype was given an advantage because the corn soybean rotation is consistent in sequence. A similar adaptation would probably occur if all corn in an area was seeded following wheat.

In the stacked Wheat-Wheat-Corn-Corn-Soybean-Soybean example, the sequence for corn and the interval between corn crops is unpredictable in the time frame of an insect. (It looks very predictable to humans). Just as importantly, some of the population with normal habits (feeding on corn, laying eggs in corn, eggs hatching the next spring) has been kept alive due to the corn-corn stack. This will dilute the population of those with aberrant behavior.

Examples can just as easily be found using weeds or diseases. The important point to remember is that these shifts in characteristics do not always occur quickly. Species with only one generation per year may take a decade or two for a biotype with suitable survival strategy to develop into predominance.

During this period the producer becomes convinced that he has developed the ultimate crop rotation, found the perfect chemical, etc. for his operation (it has worked for seven years in a row). Then almost without warning the system fails. Everyone with resistant weed biotypes has witnessed this phenomenon.

**How stacked rotations break pest cycles**

The second part of the stacked rotation concept is to have a long break in the rotation. To provide maximum protection against pests with short cycles, one of the intervals must be sufficiently long to allow populations of certain diseases or weeds to drop to low levels.

Careful study of growth and decay curves demonstrates that "first year" crops on a given piece of land experience few crop specific pest problems. If the crop is planted a second time in succession on this "virgin" site, it often does nearly as well or maybe occasionally even better. It is only during the third year (or more) that problems begin to appear. These problems often grow very quickly once they establish.

The reason this happens is that growth and decay curves for biological systems follow geometric or logarithmic patterns. (Examples: 2, 4, 8, 16, 32, 64 or 1, 10, 100, 1000). Since decay works the same as growth in reverse, a short break is not sufficient to decrease some problems to economic thresholds.

This is especially true if they have survival mechanisms like seed dormancy. The power behind a perennial sequence is the long break. The theory behind stacked rotations is to provide a long break somewhere in the system.

In the "old days" it was common to have a perennial sequence followed by several years of the same crop. That is why homesteaders were initially so successful when they began farming (and the fact that they had a huge no-till history preceding them).

In Argentina, it was common until recently to rotate seven years of pasture with seven years of cropping. On rented land this may be seven years (or less if disease strikes) of continuous soybeans.

Plants develop associated positive biology just as they develop associated negative biology. These associated species can sometimes benefit crops when they are planted in the same field in subsequent years.

The most commonly cited example includes VAM, the mycorrhyzal fungi that help crops like corn and sunflowers obtain moisture and nutrients from the soil. It is thought that these organisms might be the reason for corn on corn and sunflower on corn sequences performing better than expected.

Another example is the N-fixing rhizobia bacteria associated with legume crops. Soybeans grown following soybeans are capable of fixing more nitrogen because higher rhizobia populations exist in the soil. The soil is also lower in mineral N sources since the previous year's legume crop scavenged these prior to beginning the fixation process.

Part of the theory of stacked rotations involves taking advantage of these positive associations before negative associations can build to harmful levels.

There probably are positive associations involving predatory insects as well, but this has not been thoroughly studied.

Recently, an agronomist gave what he thought was a negative example of a producer's rotational planning. He stated that the gentleman would seed a particular field to wheat every year until jointed goatgrass pressure became sufficient to preclude wheat.

He would then seed it continuously to sorghum until shattercane overwhelmed him. At that point he would seed sunflowers in successive years until white mold became a major problem. At that point he began again with the wheat program.

The producer was at least responding to the natural cycles in his field. It might be better if he anticipated these occurring so that the switch could be made in advance. However, he probably was doing a better job than someone who blindly planted a corn-soybean, wheat-canola-wheat-pea, or wheat-corn-soybean rotation and was surprised when he had to keep changing technology to deal with "new" problems.

**Stacked rotations offer more herbicide options**
Still another concept in stacked rotations involves allowing the use of more diverse herbicide programs, specifically those utilizing long-residual compounds. Relatively high rates of atrazine can be used in the first year corn (or sorghum or millet) of a stack since another tolerant crop will follow. This provides the time necessary for the herbicide to degrade before sensitive crops are grown.

Similarly, products like Command or Scepter can be used in first year soybeans in areas where these products could not be used in other rotations.

The following is a typical herbicide program for a Spring Wheat-Winter Wheat (double crop forage sorghum-Corn-Corn-Soybean-Soybean rotation starting following the second crop soybean harvest): Year one -- Spring Wheat, no burndown followed by Bronate (Buctril M). Year two -- Winter wheat would have a burndown between spring wheat harvest and winter wheat seeding.

No herbicide is normally required in the winter wheat. Two pounds of atrazine would be applied either to the double crop forage sorghum or after it is harvested in the fall. This is dependent on the weeds present. The first year corn usually does not need a burndown, but normally receives an early post-emergence application of bromoxynil and perhaps a grass herbicide. Second year corn receives a traditional program. A GMO, such as Liberty-Link or Roundup Ready, could be used.

First year soybeans receive a long residual program like Scepter plus Command. Second year soybeans are Roundup Ready. With this program, we have used ALS chemistry once in six years, triazines once in six years, Roundup Ready once or twice in six years (and perhaps a burndown between wheat crops also but this could be paraquat). The Roundup is applied at different times with different companion herbicides.

It is obvious that weeds (viewed from their perspective of time) will find it difficult to develop resistance or tolerance to any of the modes of action employed.

## Hybrid Stacked Rotations
The idea in a hybrid stacked rotation is to use stacks for the species where it provides the most advantage while avoiding it for other species.

This may be the most powerful rotation type. The key with this and other rotations to understand how natural cycles work and uses sequences and intervals to create the type of environments that favor the crops while preventing problems.

**Examples:** Canola-Winter Wheat-Soybean-Corn-Corn and Spring. Wheat-Winter Wheat-Pea-Corn-Millet-Sunflower.

**Advantages:** Depending on the rotation, either a large or smaller number of crops can be used. It provides many of the advantages of the stacked rotations but can be designed to avoid some potential problems. The spring cereal to winter cereal stack is especially powerful in areas where winter hardiness is an issue.

**Disadvantages:** There are few disadvantages, if the rotations are well designed.

The power of this approach can be demonstrated best by using the examples given. The Sprint Wheat-Winter Wheat-Pea-Corn-Millet-Sunflower rotation is designed for cool and dry areas. The two cereals in a row follow a four-year break for cereal.

This builds deep soil moisture and surface residue. Winter hardiness of the winter wheat is less of a concern than with other sequences. Peas and other large-seeded, cool-season legumes perform well in heavy residues. They turn this cool environment to their advantage and transform it into a warm environment for the subsequent corn crop. Peas make this transformation without using the deep moisture needed for the corn.

Atrazine can be safely used in the corn year because millet (or corn or forage sorghum) tolerates atrazine. Millet is a low intensity crop that again allows excess moisture to recharge the subsoil. Sunflower is now seeded into a nice environment that has deep moisture most years. Any volunteer millet can be easily controlled. Broadleaf weeds should have been controlled easily in the corn and millet crops.

The warm and dry environment left by the sunflowers allows early seeding of the spring cereal crop. Cereal herbicides with longer residual can be used in the spring cereal going to winter wheat than if a broadleaf were to be used the next year.

If a producer feels it would be too risky to try to grow spring wheat after sunflower, he can use a less intense broadleaf (flax for instance) or include a green fallow year following the sunflowers.

## Final Tips: No Best Rotation

This summary is meant to be an overview of some rotations strategies that will allow producers and those working with them to better understand the "art" of rotation planning.

However, there is no "best" rotation. No one can design a rotation that will work every year under every circumstance. It is a probability game. There are bad rotations that work well for a while. There are good rotations that fail at times due to weather or other uncontrollable factors. Poor gamblers make money at times; good gamblers lose money at times.

Rotations can be designed that work well in dry years but they fail to take advantage of good years. Or even worse, they fail badly in good to wetter than normal years.

Producers with more risk tolerance (financially and psychologically) will be more comfortable with riskier rotations. Properly designed "risky" rotations can make more money in the long-run but can result in substantial losses over the short-term.

The best approach to spreading risks is to use more than one rotation (preferably sequentially to make an even longer complex rotation).

Rotations used may differ depending on the soils involved. In other words, some of your land may require a different rotational approach than other land you farm. Some of the reasons for this include inherent soil characteristics, past history, weed spectrum, distance from the farmstead, landlord, etc.

Most farmers are good at designing rotations once they start trying.

The rotations used may have to change as market, soil, climate and enterprise conditions change. That is to be expected. When designing a rotation, be thinking of ways you could change it. Don't be afraid to ask for advice, but accept no recipes from others. Do your own cooking.

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