Chapter 4:
A Look at Crop Rotation and Soybean Production

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This chapter provides a brief overview on how rotations that include soybeans can increase long-term sustainability and resilience against climate variability. Crop rotation is a complex subject where biological factors, farm management resources, and market forces all interact in shaping its effectiveness (Fig. 4.1). A common rotation used for soybean production is soybeans followed by corn. If resistant pests are a concern consider using a stacked rotation. (corn, corn, soybeans, soybeans, wheat, wheat). The benefit of a stacked rotation is that the selection pressure is reduced by increasing the length of time between crops.

Figure 4.1. This image shows crops in a corn-soybean-wheat/red clover rotation. Crop rotation is an approach that diversifies income, spreads labor, breaks disease and weed cycles, and spreads climate risk across several crops. (Source: http://soilquality.org/practices/row_crop_rotations.html)

Introduction

A crop rotation is a long-term plan for whole farm planning. In a broad sense, sustainable and productive crop rotations should:

- Be profitable.
- Provide an acceptable level of risk in the face of climate and market variability.
- Provide adequate residue to protect the soil from erosion and to provide for soil quality.
- Provide sufficient diversity to prevent buildup of weeds, pests, and diseases.
- Match timing and amount of crop production requirements to resource availability (moisture, length of growing season, equipment, etc.).

We may not realize it, but the practice of good crop rotation is a foundational element in our nation and society. For example, the introduction of the "Norfolk Rotation" (Barley-Clover/ryegrass-Wheat-Turnips) by Sir Charles Townshend in England played a large role in nearly tripling England's agriculture output in the 1700s in a sustainable manner. This led the way into England's Industrial Revolution, which changed the world.

There are also negative examples of extractive agricultural systems that over-exploited their resource base, which led to ecological and societal collapse (e.g., ancient inhabitants of Easter Island over time apparently deforested their island leading to soil erosion and loss of productivity). The latter is an example we do not want to follow.

One way to consider sustainable production systems is to look at natural systems as a model to mimic. Natural systems tend to maximize resource capture and biomass production while minimizing nutrient loss; they keep the soil covered and protected from erosion; their diversity provides for resilience against pests and diseases as well as environmental stresses. As natural systems develop, they follow a "succession" process where one set of species modifies the environment to the benefit of the next set of species—each step, so to speak, prepares the way for the next. In a similar manner, a good rotation program should be productive, minimize nutrient loss, cover the soil, provide resilience against pests and stress, and each crop should prepare the way to the benefit of the next.

Designing a rotation

Rotations should be adaptable to local conditions and problems. There are many factors that must be considered when designing a rotation. Some of these are:

- Crop water use patterns (critical periods, rooting depths, and peak use periods) and total water use.
- Soil properties.
- Climate conditions.
- Pests.
- Costs, returns, and markets.
- Equipment availability.
- Labor availability.

Producers need to consider rotations as one tool for optimizing long-term profitability and reducing risk.

Rotation and diseases

Rotation is a very valuable tool for breaking disease cycles. For diseases that persist in the soil, rotating away from hosts is critical for decreasing the disease potential. Even if it doesn't provide complete control, rotation to non-host crops keeps the disease from increasing and it gives time for soil organisms an opportunity to decrease pest populations.

Table 4.1. Some soybean diseases of interest with their alternate hosts and reported lifetime in the soil.

Pathogen	Alternative Hosts	Lifetime in the Soil
Soybean Cyst Nematode (SCN)	hairy vetch, cowpea, dry bean, sweet clover	15 or more years
Phytophthora Root Rot	mone of economic importance	5+ years
White Mold	almost all broadleaves are susceptable, plants with more flower petals seem to be more susceptible (infection often starts on dropped flower petals)	3 to 5 years
Brown Stem Rot (*Note:* this disease is exacerbated by the presence of SCN)	none of economic importance	services on residue only
Charcoal Rot	wide host range, including corn	2+ years in dry soil; appears to be less persistent in wet soil

Diseases with a wide host range such as seedling damping off caused by *Pythium* spp. fungi and root rots caused by *Rhizoctonia solani* are more difficult to manage with rotation. These fungi attack so many different crops and persist long enough in the soil that they usually have to be managed by other means (e.g., using appropriate seed treatments, waiting until the soil is warmed up before planting, promoting good soil structure to increase drainage).

Rotation and weeds

Rotation can have large impacts on weed pressure. Rotation allows for the use of different herbicides which can help prevent buildup of resistant weed populations. This is particularly true in "stacked" rotations where the same or very similar crops are grown two years in a row and then skipped for four or more years (e.g., corn-corn-soybean-soybean-wheat-wheat), allowing for the use of herbicides with long residuals in the first year of each crop while maintaining a long period (four years) where the land is rotated to other crops (Beck, 2003).

Similarly, an advantage can be gained by rotation between warm- and cool-season crops where each cycle is held for two seasons (two warm-season crops followed by two cool-season crops) (Anderson, 2008). Holding the given pattern for two years disrupts weed lifecycles such that the weed seeds have to survive for three years before they get the opportunity to grow and multiply, leading to decreased weed populations (Fig. 4.2).

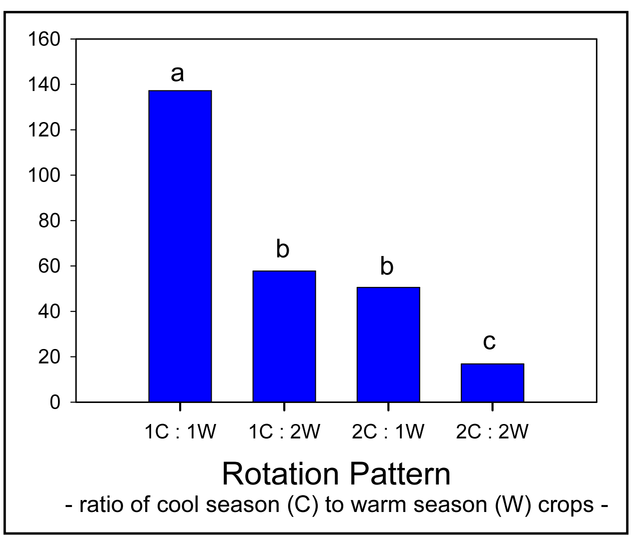

Figure 4.2. Average weed density after 10 years of different sequences of warm- and cool-season crops from three trials. The lowest weed density was found where the warm- and cool-season crops were each grown in two-year blocks (two years of cool-season crops followed by two years of warm-season crops, e.g., oats-wheat-corn-soybeans; or wheat-canola-sorghum-sunflower). (Modified from Anderson, 2008)

Rotation, residue, and nutrient availability

Soybeans return much less residue to the soil than corn or small grains. A 45 bu/acre soybean crop will generate about 2500 lbs/acre of residue, much of this being leaves which quickly decompose; whereas a 150 bu/acre corn crop will produce about 8400 lb/acre of residue and a 60 bu/acre wheat crop will produce about 3600 lb/acre of residue. Therefore, soybeans will provide less residue cover to protect the soil from erosion. This problem can be partially solved by following the soybean crop with a cover crop (Chapter 5).

Consistent with their relatively rapid decomposition and low residue levels, soybeans tend to release more N for the following crop than do grass crops. The SDSU soils lab allows a 40 lb/acre N credit for soybeans. This is a broad estimate and may vary based on growth and yield of the soybeans; for example, work in Nebraska has shown a N credit equivalent to 58 lb/acre of fertilizer N applied as either ammonium nitrate or urea-ammonium-nitrate (Varvel and Wilhelm, 2003).

Soybeans tend to tolerate high residue situations better than many other crops, perhaps because they are generally seeded following corn (Chapter 10) and their growing point is above ground during seedling growth. Hence they are not as affected by low soil temperatures. In any case, while soybean seedling growth tolerates high residue fairly well, they don't leave much residue behind them.

This is an area that needs some thought and work in terms of using cover crops, especially in erosion-prone areas, to help minimize soil loss and maintain soil structure. If current climate projections hold true, then more of our rain will come in intense storms (Seeley, 2012) and the value of using cover crops to maintain soil cover and limit erosion will become increasingly important.

Soybeans tend to remove more K than corn or small grains (Table 4.2). A typical 45 bu/acre soybean crop will remove 62 lbs/acre of K_2O; a 150 bu/acre corn crop will remove about 40 lb K_2O/acre; and an 80 bu/acre wheat crop will remove about 24 lb/acre of K_2O. This is not a critical difference in the short run, but over the years it means that soybean cultivation will tend to draw down soil K a little faster than other grain crops would.

Table 4.2. Pounds of nutrient removed in the harvested crop. (Modified from Clay et al., 2012)

Crop	Unit of Yield	lbs Nutrient Removed				
		N	P_2O_5	K_2O	Mg	S
Alfalfa	ton	51	12	49	5.4	5.4
Canola	bu	1.9	1.2	2	---	0.34
Corn grain	bu	0.9	0.38	0.27	0.09	0.08
Fescue	ton	37	12	54	3.7	5.7
Red clover	ton	45	12	42	7	3
Rye grain	bu	1.4	0.46	0.31	0.1	0.1
Soybean grain	bu	3.8	0.84	1.3	0.21	0.18
Switchgrass	ton	22	12	58	---	---
Wheat grain	bu	1.5	0.6	0.34	0.15	0.1

The other point regarding rotations and nutrient availability has to do with cover crops and green manures. This is an area that needs further research, but it appears that sometimes cover crops or green manures may increase P availability (Sexton et al., 2009), perhaps by bringing P up from deeper in the soil profile and concentrating it near the surface or by contributing to improved soil structure and root exploration of the profile. Managing the rotation to maintain sufficient residue to protect the soil will build soil quality over time and in the long term, help improve nutrient availability.

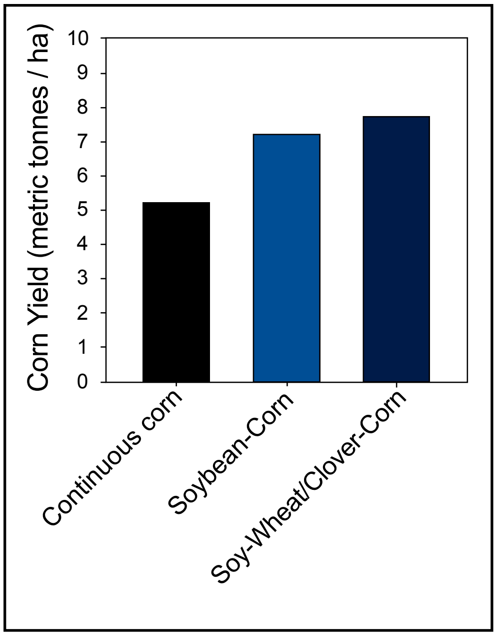

Figure 4.3. Average corn yields, at the end of six years, in three rotational sequences. (Katsvairo and Cox, 2000). Even after just two cycles, yield differences were apparent. Data shown are averages across three tillage regimes from the final year of the study. These plots received 163 kg/ha of N.

Impacts on yield in a corn-soybean system

It is well known that continuous corn production tends to result in a yield drag. Studies in South Dakota, Minnesota, Wisconsin, and Nebraska show a 10 to 22% yield benefit for corn grown in rotation with soybeans versus continuous corn systems (Porter et al., 1997; Reidell et al., 2009; Stanger and Lauer, 2008; Wilhelm and Wortmann, 2004) (Fig. 4.3). In turn, soybeans also yield on the order of 8% to 10% greater yield when grown in rotation with corn than continuous soybean (Porter, 1997; Pederson and Lauer, 2004; Wilhelm and Wortmann, 2004). So both corn and soybeans benefit from the presence of the other crop.

The two crops show a trend for better root growth lower in the profile when they are grown in rotation (Nickel et al., 1995). A 15-year study done in Wisconsin comparing corn-soybean rotation to continuous corn, amongst other rotations including oats and alfalfa, found that the corn-soybean rotation was the more profitable and less risky over time than was the continuous corn system. In their study, it was also more profitable than rotations including oats and alfalfa; however, that would, of course, be influenced by whether or not the farm was engaged in livestock production.

While a corn-soybean rotation has been shown to be superior to continuous corn over time, it is still not a very diverse system. Crookston et al. (1991) conducted a nine-year study looking at corn and soybean yields in southwestern Minnesota and concluded, even in this relatively humid area, that “a superior cropping sequence … would include at least three crops and possibly more.”

As we look to the future and contemplate increasing development of pest resistance to chemical controls, and the likelihood of more variable weather conditions, it seems prudent over time to develop or maintain a diverse crop rotation.

Rotations and water use

Rotations can be used to manage water excesses and shortages. The relationship between water and rotations is especially important given the wide range of climate conditions observed over the past several years. Rotations provide protection from summer droughts by distributing the critical water use periods across the growing season. Research shows that corn, wheat, and soybeans use different amounts of water and have different critical periods. Wheat partially avoids this problem by flowering and completing its lifecycle earlier in the growing season than either corn or soybeans (Fig. 4.4).

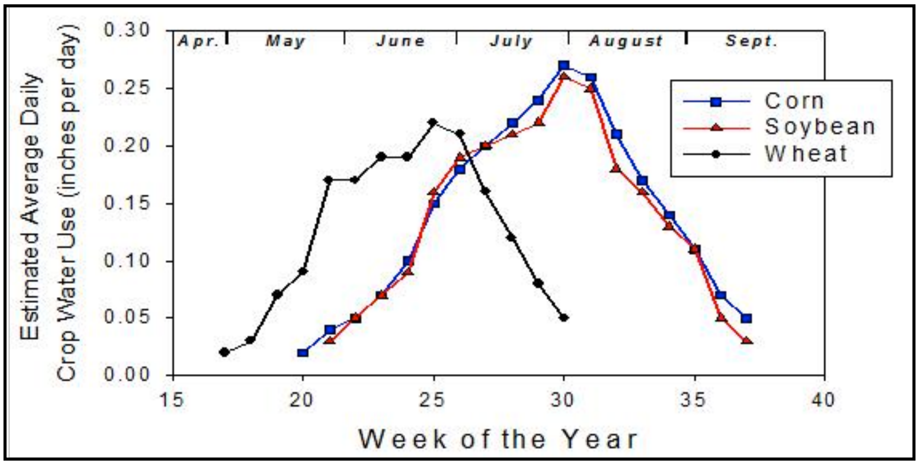

Figure 4.4. Estimated crop water use spring wheat, corn, and soybeans grown over a season at Huron, S.D. Based on data from http://www.extension.umn.edu/distribution/cropsystems/components/DC1322a.pdf and http://climate.sdstate.edu/archives/data/tempnormals.shtm. Note how wheat water use is shifted earlier in the season so that it avoids drought stress.

Soybean flowering is spread over several weeks so that it can better avoid the effect of drought stress on seed set. A worksheet for calculating agricultural intensity for different rotations is available at http://www.dakotalakes.com/Publications/Div_Int_FS_pg6.pdf.

This calculator can be used to determine water harvesting from different regions and from crops in a rotation. Along with timing of water use, another factor to consider in looking at rotations is rooting depth of the crop in question. Crops with deep extensive root systems that grow late into the season (e.g., sunflower and alfalfa) are less likely to leave behind reserve moisture than are crops with shallower root systems that mature relatively early in the season (e.g., peas, flax, and lentils).

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