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**SIoux FALLS CONVENTION CENTER
RUSSELL AND WEST AVE., SIOUX FALLS, SD
FEBRUARY 4-5, 2003**

February 4th

- 10:00 a.m.** Registration
- 1:00 p.m.**
- 1:00 p.m.** Opening Remarks – SDNTA
- 1:15 p.m.** Why and How to Use Cover Crops in a No Till System.
Rolf Derpsch, Ag Consultant, Paraguay, SA
- 2:15 p.m.** Permanent Cover Cropping System.
Steve Groff, Farmer, Lancaster, PA
- 3:15 p.m.** Break, exhibitors
- 4:00 p.m.** Cover Crops to Consider.
Dr. Shannon Osborne, USDA-ARS, Brookings, SD
- 4:30 p.m.** Dealing with White Mold in No Till Soybeans.
Dr. Tim Maloney, Ag Tech Consultant, WI
- 5:15 p.m.** Leveraging Biology: Discovering Efficiencies in Cropping Systems
Matt Hagny, Ag Consultant, Salina, KS
- 6:00 p.m.** Speaker Panel
Hors d'oeuvres, Cash Bar, Exhibits

February 5th

- 7:00 a.m.** Breakfast and Exhibits
- 7:15 a.m.** SD No-Till Assn. Annual Meeting, Meeting Room 3
- 8:30 a.m.** Opening Remarks
- 8:45 a.m.** Nutrient Efficiency In No Till Systems.
Dr. Paul Fixen, PPI, Brookings, SD
- 9:45 a.m.** Managing Salt Affected Soils
Jim Millar, NRCS, Redfield, SD
- 10:30 a.m.** Exhibitors, Break
- 11:00 a.m.** Forage and Grazing...No Till Profitable.
Wayne Berry, Williston State College, ND.
- 12:00 p.m.** Exhibits and Lunch
- 1:15 p.m.** Rotating Wheat for a Profit.
Kendall Peterson, Spink County Fertilizer, Northville, SD
- 2:00 p.m.** Panel of South Dakota Farmers
- 3:15 p.m.** Closing Statements
Dr. Dwayne Beck, Dakota Lakes Research Center, Pierre, SD

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OPENING REMARKS

South Dakota No-Till Association

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The South Dakota No-Till Association is proud to present the third in its series of biennial conferences designed to deepen our understanding of specific topics related to successful no-till systems. The 2003 No-till Under Cover program was designed to cover topics related to cover and forage crops; soil health and fertility; and wheat management in high yielding environments. We believe that the list of speakers represent the best expertise available on their specific topic. Much time and effort went into the planning of this event. We would like to thank our exhibitors whose contributions make it possible for us to obtain this caliber of program. We appreciate all of the time and effort Ruth Beck and Jason Miller put into organizing the conference. We must also recognize Catherine Valencsin for doing the web work and preparing the proceedings for publication. We hope that the attendees find the information of value to them and their operation.

The moisture saving attributes associated with no-till have allowed producers in the transition zone between the traditional corn and wheat belts to adopt rotations with intensities similar to those in the corn belt. Unfortunately many of these systems also have the low diversity characteristics common in that area. This has resulted in no-till systems that are less than optimum. It is the belief of the South Dakota No-Till Association that properly designed and managed no-till systems are far superior to tillage-based approaches in terms of both their environmental and economic characteristics. Information presented at this conference and in these proceedings should help in allowing each of us to better capture the true potential of the no-till approach.

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WHY AND HOW TO USE GREEN MANURE COVER CROPS IN A NO-TILL SYSTEM.

Experiences from Latin America.

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Reading the title of this paper some people may ask if the growing conditions in Latin America are not too different from the ones in the United States. When looking at the experiences in Latin America we of course can not “copy” what is done there. Farming is always site specific, but the principles of using cover crops are valid all over the world. The experiences from Latin America are especially interesting for no-till farmers, because they have played a key role in further developing and perfecting the no-tillage system. We should be aware that some cover crop species adapt to a very wide range of climatic and soil conditions. Several cover crop species used in South America are well adapted to the conditions of northern United States. We should also be aware that “no matter where you farm, there are cover crop species that meet your needs” (USDA-ARS, 2002).

While the US has the biggest area under no-tillage worldwide (about 22.4 million ha), the quality of this technology is often far from being satisfactory. According to CTIC (Dan Towery, personal communication 2002), only about 25% of no-tillage is practiced permanently, that means that most farmers use rotational tillage. On the other hand cover crops and crop rotations are generally missing in the system. In order to achieve maximum benefits of the no-tillage technology the system has to include these elements:

- permanent no-till (permanent soil cover),
- crop rotations and
- cover crops.

The use of green manure cover crops (GMCC) and crop rotation as well as permanent no-till are the key factors for the unprecedented growth of no-tillage especially in Brazil and Paraguay. Only those farmers that have understood the importance of these practices are obtaining the highest economic benefits from this system. While in some regions of the world farmers concentrate on avoiding tillage, Latin American farmers have understood that adequate production and management of crop residues are key issues in the no-tillage system. Cover crops do not cost but will pay. When practiced in monoculture or even in double cropping, i.e. when the same crop or crops are repeated on the same land each year, no-tillage is an imperfect and incomplete system, in which diseases, weeds and pests tend to increase and profits tend to decrease. Adaptive research in this area is the most important factor to make no-tillage work, that

is take advantage of all the benefits of the system, reduce weed pressure and increase economic returns!

Advanced no-till farmers in Latin America see it as good farming practice to use GMCC and crop rotations independently of the price situation of crops. Once farmers have discovered the benefits of these practices they don't want to miss them. Sorrenson (1984), among others, has clearly shown the economic advantages of using crop rotation and the right cover crops. While many people still think that when using GMCC you are adding costs without getting anything back, farmers especially in Brazil and Paraguay have learned that economics of no-tillage can be substantially increased with their use.

Research performed in Brazil has shown significant yield increases of some GMCC on cash crops. In the average of two years, the highest yield of soybeans (2670 kg/ha) could be achieved after black oats (*Avena strigosa*) as a green manure crop. This yield was 770 kg/ha higher than the average of all other treatments. It was also shown that black oats used as a green manure cover crop before soybeans can increase soybean yield by as much as 63% as compared to soybeans after wheat (Derpsch, et al., 1991). Phaseolus beans also produced the highest yield after black oats. Corn (without N) responded with the highest yields after white lupins (*Lupinus albus*) (6.410 kg/ha) and hairy vetch (*Vicia villosa*) (6320 kg/ha) as compared to yields of less than 4.100 kg/ha after wheat, oats and rye. Also after oilseed radish (*Raphanus sativus*) a high grain yield of corn (without N) was achieved (5.800 kg/ha). Higher crop gross margins could be achieved when using black oats as a cover crop before soybeans as compared to double cropping wheat and soybeans.

Good knowledge about green and dry matter production and profitability of green manure cover crops, how to fit them into different crop rotations and what residual fertilizer effect we can expect of each GMCC planted before the main cash crops is essential for dissemination of their use. A number of publications have contributed in filling this knowledge gap in Latin America (Sorrenson and Montoya, 1984; Monegat, 1991; Derpsch, 1991; Derpsch and Calegari, 1992; Calegari et al., 1992). Several publications on the use of cover crops have appeared in the US in the last decade, i. e., (Cover crops for clean water, W. L. Hargrove, Ed. 1991; Managing Cover Crops Profitably, SAN - SARE, 1998: www.sare.org). There is increasing information on cover crops also in web sites. A very recommended web site with comprehensive information on this topic is

- http://www.notill.org/cover_crops/cover_crops.htm In this site you find links to:
 - <http://www.sare.org/handbook/mccp2/index.htm> SARE handbook
 - <http://www.sare.org/handbook/mccp2/pests.htm> SARE, S.C. Pahtak
 - <http://www.barc.usda.gov/anri/sasl/covercrops.html> USDA-ARS
 - <http://www.ces.ncsu.edu/depts/hort/hil/hil-37.html> North Carolina State U.
 - <http://www.attra.org/attra-pub/covercrop.html> ATTRA Arkansas
 - <http://www.attra.org/attra-pub/nematode.html> ATTRA Arkansas

- <http://www.ianr.unl.edu/pubs/FieldCrops/g1146.htm#ccs>
(Univ. of Nebraska)
- <http://www.kbs.msu.edu/extension/covercrops/home.htm> (MSU, Michigan)
- http://www.gov.on.ca/OMAFRA/english/crops/facts/cover_crops01/covercrops.htm, Ontario, Canada

Many more sites can be found using normal search engines.

PRINCIPLES OF GREEN MANURE COVER CROPS (GMCC) AND CROP ROTATIONS

It is not possible to talk about green manure cover crops without talking about crop rotation. In a no-till system we can not talk about crop rotation without talking about cover crops. Maximum diversification of the system should always be a goal when applying no-tillage techniques. Mixtures of cover crops should be preferred over the use of a single species.

Green manure cover crops are the cornerstone of sustainable agriculture and should always be included in sound crop rotations. Green manure's and cover crops are used as synonyms in this paper. In a no-till system cover crops are incorporated biologically and not by tillage implements.

Green manure cover crops should:

- be of low cost (seeds)
- be easy to seed and manage
- provide good weed control and shading
- produce a positive residual fertilizer effect on following cash crops
- they should not compete in area, labor, time and space with cash crops

Monoculture, that means the continuous seeding of the same crop, in the same place during many years has only been possible in the case of rice. This crop has been cultivated as the only crop sometimes for centuries in highly populated areas in Asia. In general monoculture results in diminishing productivity per unit area, the maintenance of low productivity's, or in extreme cases the complete loss of production.

In general the following factors are responsible for this situation (Franke, 1976, 1980):

- Increase of specific diseases and pests
- Increase of specific weeds
- Reduced availability of nutrients due to changes in biological activity and physical degradation of the soil
- Reduced root development
- Accumulation of specific toxic substances that inhibit growth

The principles and fundamentals of crop rotation are:

- To alternate plant species
- with different rooting depth
- with different ability to absorb nutrients
- that are susceptible to diseases with those that are resistant

- taking into account positive & negative effects of one crop on the next
- that tend to mine with those that tend to increase soil fertility
- with different needs in terms of labor peaks, machines & implements, water, etc. (Arnon, 1972).

In a no-till system the use of crop rotation is much more important than in conventional tillage systems. Experience has shown, that tillage negates cover crops. Also cover crops are essential for producing the mulch needed in the no-tillage system. Cover crops have to be integrated in the agricultural system of each farm and show their beneficial effects. Cover crops, in combination with no-tillage and crop rotations ensure the sustainability of agricultural production. “But, rotation isn’t just a helter-skelter array of crops” (Rick Bieber, 2000). Without the knowledge of positive or negative residual effects of one species on the succeeding crop, any attempt of organizing a crop rotation is merely a theoretical model. Not only legumes are adequate green manure cover crops. Black oats for instance (*Avena strigosa* Schreb) are planted on 3,2 million ha in the States of Paraná and Rio Grande do Sul in Southern Brazil. They are planted on more than 300.000 ha in Paraguay.

DETERMINE HOW THE FARMING SYSTEM CAN ACCOMMODATE COVER CROPS

One of the biggest challenges is to fit green manure cover crops into your current crop rotation, or to develop new rotations that take full advantage of their benefits. Each farmer has to find the “window or niche” where a specific cover crop will fit to accomplish specific purposes. It has to be kept in mind, that in general cover crops function in the “off season” of crops but they may also be intercropped with cash crops. Remember that “no matter where you farm, there are cover crop species that meet your need. However, your success will depend on identifying the problem(s) that you want the cover crop to solve. Decide where and when you want to use the cover crop, and determine its fitness in the crop rotation. You may conclude that the main problem is soil erosion or low nitrogen or heavy weed pressure or all these”. (USDA-ARS, 2002).

In order to find those “windows or niches” research in Latin America has focused on:

- Screening adequate GMCC for different agro ecologic regions
- Studying the residual fertilizer effect of GMCC on following cash crops
- Showing the economics of cover crops.
- Without this basic and site specific information it will be difficult to determine which cover crop to use when.

FUNCTIONS OF GREEN MANURE COVER CROPS

Provide soil cover for:

- no-tillage
- increasing water infiltration into the soil
- reducing water evaporation
- reducing soil temperature
- protection against erosion

- reducing weed infestation
- accumulation of organic matter in the soil
- adding and recycling nutrients
- improve soil structure
- promotion of biological soil preparation

Adding of organic matter in the soil is often mentioned in the literature as one of the main objectives of cover crops, but this can in general and (especially in warmer climates) only be achieved in the no-tillage system.

BENEFITS OF GREEN MANURE COVER CROPS

Cover crops are a key element to make sustainable agriculture possible and have shown the following benefits in Latin America:

- Higher economic returns when appropriately chosen
- Reduce the need for herbicides and pesticides
- Improve yields of following cash crops
- Conserve soil moisture (when properly managed)
- Prevent soil erosion
- Enhance organic matter content of the soil
- Provide nitrogen
- Avoid leaching of nutrients and improve soil fertility
- Reduce fertilizer costs

POSSIBILITIES OF REDUCING WEEDS AND HERBICIDES COSTS WITH THE USE OF COVER CROPS IN NO-TILLAGE:

One of the most recent and fruitful lessons we have learned in the no-tillage system is that farmers should, if possible, never leave the land in fallow. In general fallow periods of only a few weeks will result in weed proliferation, seeding of weeds, reduction of soil cover, soil erosion as well as lixiviation (leaching) of nutrients. The old farmers rule is still true, “one years seeding means seven years weeding”. If instead of leaving the land in fallow, farmers seed any crop immediately or as soon as possible after harvest of the previous crop, they will reduce weed proliferation, avoid that weeds produce viable seeds, increase soil cover and the biomass returned to the soil, increase organic matter content of the soil, avoid soil erosion as well as washing out of nutrients, and improve biological conditions of the soil.

Research conducted by Kliewer et al., (2000) in Paraguay has shown, that crop rotation and short term GMCC can reduce the cost of herbicides drastically to US\$ 43,05/ha in the case of sunnhemp (52 days growth period) and to US\$ 39,27/ha in the case of sunflower (57 days growth period), as against costs of US\$ 105,10/ha when only herbicides and monoculture were used. Kliewer et al., (1998) also reported soybean yields after black oats of 2600 kg/ha without using any herbicides at all. Weed measurements 96 days after seeding soybeans showed 93 kg/ha of dry matter of weeds/ha after black oats, as against 7390 kg/ha after fallow. In the last case, soybeans yielded not more than

780 kg/ha. Using a rotation where long and short term GMCC or cash crops are seeded as soon as possible after harvesting the previous crop, or after rolling down GMCC with a knife roller, it was possible not to use herbicides in no-tillage for as much as three years in a row. In some cases, when farmers are using crop rotations, only eliminating weeds with a burndown herbicide before planting is necessary, without any herbicide application during the growing season at all.

MAIN COVER CROPS USED IN SOUTH AMERICA ESPECIALLY IN PARAGUAY AND BRAZIL

After initiating a more intense and systematic research with GMCC in the late 1970's, testing more than a 100 species and some varieties of these same species, a range of crops have been identified and are now available for the use by farmers especially in Brazil and Paraguay. Some of the winter cover crops are black oats (*Avena strigosa* Schreb), rye (*Secale cereale* L.), triticale (*Triticum-cereale*), oilseed radish (*Raphanus sativus* var. *Oleiferus* Metzger), white bitter lupins (*Lupinus albus* L.), blue bitter lupins (*Lupinus angustifolius* L.) common vetch (*Vicia sativa* L.), hairy vetch (*Vicia villosa* Roth), forage peas (*Pisum sativum* subspecies *arvense*), chick peas (*Lathyrus sativus* L.), serradela (*Ornithopus sativus* Brot.), sunflower (*Helianthus annuus* L.), ryegrass (*Lolium multiflorum* L.) etc. The most commonly used summer cover crops are millets (*Penisetum americanum* L., *Sorghum bicolor* L etc), foxtail or German millet (*Setaria italica* L.), sunnhemp (*Crotalaria juncea* L.), lab-lab (*Dolichos lablab* L.), pigeon pea (*Cajanus cajan* L.). Even plants that up to now have been considered to be noxious weeds like *Brachiaria plantaginea* are used in the Cerrados of North-Central Brazil as cover crops in no-tillage. The Cerrados have only one growing season. Here farmers and researchers have developed production systems where cover crops are established immediately after harvest of the main crop. If cover crops die in the dry season it is not a problem as long as they have produced enough biomass. In Southern Brazil and Paraguay conditions are such, that some cash or GMCC can be seeded at any time of the year if soil moisture is available.

CLIMATIC CONDITIONS IN EASTERN PARAGUAY (CLOSE TO THE BRAZILIAN BORDER)

The climate of Colonia Yguazú, 45 km from the city of Iguassu Falls, Brazil, is classified as Cfa by Koeppen

AVERAGE PRECIPITATION IN YGUAZÚ, EAST PARAGUAY, 1972 - 1999 = 1590 MM											
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
148	130	117	141	138	133	73	102	125	174	136	171
AVERAGE AIR TEMPERATURE IN YGUAZÚ, EAST PARAGUAY, 1972 - 1999 = 21,6°C											
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
26,1	25,6	24,7	21,6	18,4	16,5	17,8	17,9	19,2	22,1	23,8	25,4

MANAGING GREEN MANURE COVER CROPS

The knife roller to flatten and kill green manure cover crops and leave the plant residues on the soil surface is an essential tool for cover crop management. This implement is not terribly expensive and in many cases can be made locally or by the farmer himself. The implement can be pulled by medium sized tractors or by animal traction and has contributed a lot in reducing herbicide rates in the no-tillage system. The

knife roller has become an essential tool for managing GMCC in many countries of South America. Alternatively steel bars can be welded on top of the discs of disc harrows and the implement used for the same purpose. The use of machines that chop cover crops like a rotary mower is not recommended in warmer climates because residues decompose too rapidly.

Dimensions of a knife roller: The Knife Roller consists of a hollow steel cylinder, 6mm thick, approx. 115 - 200 cm wide and 60 -70 cm in diameter. Ends are welded to be filled with water if needed. Approx. 8 - 12 blunt knives are placed every 19 cm. The knives are about 7 - 10 cm high and are placed parallel to the cylinder at an angle of 45° or 90°. Weight of each 200 cm cylinder is approx. 400 kg empty and 800 kg full of water. Three cylinders are often placed in such a way that two run in front and one in back allowing for greater working width. Cylinders are mounted on a frame to allow hydraulic lifting.

Pictures of a knife roller can be seen in www.rolf-derpsch.com under "news".

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A PERMANENT COVER CROPPING SYSTEM

Steve Groff

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I started no-tilling in the early '80s on about 15 corn acres because we had some erosion problems and I didn't like having to fill in gullies before harvesting corn and I felt that wasn't right. In 1991 I began using a rye cover crop as another soil-conservation measure. In 1994 we started no-tilling tomatoes and in 3 years, all of our 175 acres of 15 different crops were no-tilled. This "Permanent Cover Cropping System" is done successfully by using cover crops, intensive crop rotation, and long-term no-tillage. I can't say enough how these 3 components are the foundation to make this system work. No-till is not the "magic bullet". It is an equal partner with cover crops and rotation. I use this system for 3 reasons:

- Increase profits
- Enhance soil quality
- Reduce pesticides.

INCREASE PROFITS

The economics of this system are positive. Total savings when no-till transplanting tomatoes amounts to \$675 per acre. Nearly \$500 of the cost reduction is from material, labor, and time savings when eliminating the use of plastic mulch. Bear in mind that plastic mulch would still be needed for early-season tomatoes, but I'm experimenting with the use of row covers to get the earlier plantings off to a good start. A saving in tillage is \$50/A and \$125/A for pesticides (average of the last 5 years). Increased costs are \$50/A for establishment and seed of a cover crop, and \$10/A for controlling the cover crop. It's hard to put a dollar value on the other benefits cover crops give such as erosion control, better soil quality, and increased organic matter, but it has to be factored in at least indirectly. On my farm I've been able to grow my own cover crop seed and use a rolling stalk chopper to control the covers. This allows me to further reduce expenses. Our yields have increased the last several years and this adds to the profit.

ENHANCE SOIL QUALITY

Soil erosion is the most detrimental aspect of agriculture. We can't turn our backs on soil erosion and call ourselves sustainable! No-till has some very attractive attributes especially when combined with cover crops and crop rotation. SOIL IS MEANT TO BE

COVERED! Soil erosion on Cedar Meadow farm has been cut from 14 tons per acre per year to almost nothing. With the ground covered by plant residues and not loosened by vigorous tillage, the soil stays rather than getting washed away during heavy rainfall. With an average soil loss in Lancaster County of 9 tons per acre per year on the typical farm, you begin to realize the importance of keeping this valuable soil resource in place. The combination of cover crops and no-tilling does more than cut erosion -- it improves soil tilth, increases organic matter levels, enhances water infiltration and lessens pest problems. Organic Matter has gone from 2.7% to 4.3%. Soil aggregate stability in fields tilled recently (less than 10 years) is 16% and fields that have not been tilled for over 10 years is 67%. Soil microbial biomass has tripled. These results are proof to me that this system is working. Yields have increased 10% over the last several years.

REDUCED PESTICIDES

A good thick mulch helps control weeds and has really cut down on my herbicide bill. It's very important to have a consistent cover crop to make this work. Total pesticide use on tomatoes has dropped from \$200/A to \$75/A. This is mainly due to fewer fungicides for early blight and insecticides for Colorado Potato Beetle. Consistent with what Dr. Aref Abdul-Baki (USDA Researcher) and Dr. Ron Morse have found, as well as others who have tried no-till tomatoes, the onset of early blight has been delayed. Penn State has a weather station (FAST system) near Cedar Meadow Farm that forecasts favorable early blight susceptibility. The last 4 years I was able to wait 3-7 weeks to spray after the FAST system recommended a protective fungicide. We've experienced 4 years of extremely different weather conditions -wet, dry, and near normal. In every year, early blight has been delayed with this system. I've also noticed healthier plants even to the end of the season. I've planted a cumulative total of 150 acres of no-till tomatoes the past 8 years and have yet to spray for Colorado Potato Beetles! I haven't used Admire at transplanting. A good thick mulch helps control weeds as well and has really cut down on my herbicide bill. It's very important to have a consistent cover crop to make this work. Herbicide use for corn and beans has dropped from \$25/A to \$18/A. Total pesticide usage on the whole farm has decreased 50%. Beneficial insects have increased.

HOW THE SYSTEM WORKS

The foundation of this system is the establishment of a cover crop in the fall. My favorite for transplanted vegetables right now is a mix of hairy vetch (25 lbs.) and rye (30 lbs.). I have successfully no-tilled vegetables into corn and soybean residue with excellent results, however more herbicides, fungicides and fertilizers are needed to control weeds and diseases. I credit rye/vetch giving #50lb. of N and straight vetch #75lb. of N. Vetch seed is expensive so I grow my own with rye. I have seed to sell.

I wanted to control covers mechanically and in a way that flattens them near the soil to help their decomposition. I ended up buying a 10-foot Buffalo Rolling Stalk Chopper in 1996. It's designed to flatten and chop cornstalks, on a scale between a flail mower and a disk. The machine has two rows of rollers, four in front and four in back,

with eight 23-inch blades per roller. The turning rollers crimp up the cover and push it right down. It can be run at 8-10 miles per hour, so it's fast and economical. I added parallel linkage so each roller floats independently.

The versatile machine has been used on nearly 1000 acres in 7 years. I roll the covers with it, and get good control of hairy vetch and rye if it has flowered. Vetch that hasn't bloomed yet will give some re-growth and needs a low rate of post emergent spray. It is important to roll the cover before wind blows it in various directions so it is laid parallel to the direction of planting. I always roll soon after the rye is 4 feet tall, which is around May 10th unless the cover is thin, and will not blow down. If I need to plant before the cover is 2 ft tall I will spray with Roundup 3 days before planting instead of rolling. A cover that is rolled before or during flowering will re-grow somewhat and then I spray with 3 ounces of Sencor and 1/2 ounce of Matrix at least 10 days after transplanting tomatoes. Occasionally I will need to do a follow-up spot spray with this same rate. If grasses break through Poast is used to control them. I've successfully eliminated all herbicides when I have a good thick mulch cover and it is fully matured when rolled. This system does have potential for organic growers when a heavy cover is achieved. After harvest, I use the rolling stalk chopper to roll the plant residues and then immediately plant another cover crop.

I've customized an RJ Equipment carousel no-till transplanter for no-till transplanting of tomatoes into killed cover crops. This transplanter has a spring-loaded 20-inch, turbo coulter, followed by a double disk opener and a short shoe to place the transplant in. Angled press wheels tuck the soil firmly around the plant. The package leaves virtually no soil showing after the crop is planted, giving good full coverage mulch for the whole season. RJ Equipment is now manufacturing no-till transplanters on custom order basis. Phone: 519-676-4110

Fertilizer management evolves, as you have become more committed to the use of no-till, cover crops and the overall concept of sustainable ag. Any synthetic N I use is mainly ammonium sulfate. I need the sulfur it supplies, as well as its low volatility. I sidedress by broadcasting 40 - 80 lbs. of dry N (depending on contribution of cover) just after the first flowers appear. I've found that you need to get N on earlier with the no-till system. I credit my higher organic matter soils of giving me 25lb of N or so from release of additional N and do some foliar feeding as well.

Soil Compaction is to be avoided at all costs! However, once you've no-tilled for several years the soil becomes noticeably less susceptible to compaction. Cover crops are key to this in building soil structure. I'm real fussy about when lime and manure trucks can get on my fields. If you ever need to alleviate compaction, do so with as little surface disturbance as possible. I just purchased a customized 2 shank Unverferth ripper/stripper to go through my field driveways after harvest. This tool has a 3/4" narrow shank that penetrates 12 inches deep and has a 2-inch wide wavy coulter on either side of the shank. This keeps soil from being thrown away from the shank and chops it up a bit. A 12-inch wide rolling basket follows to further break up clods. I am able to plant behind this without needing to disk.

Controlling perennial weeds can be a challenge in no-till but I have found that with intensive crop rotation and occasional spot spraying, weeds can be managed effectively. Perennial weeds are not a problem on our farm.

In wet years, you might notice more slugs, but they haven't chewed our fresh-market tomatoes unless the crop is in contact with the soil. I am concerned though with the potential of slug damage and have begun to collaborate with researchers in establishing biological and chemical controls of this pest. Aphid pressure has remained the same.

FIELD DAYS

We have held an annual field day at Cedar Meadow Farm since 1994. In 2001, 475 people attended to view the "Permanent Cover Cropping System" as well as see various agri-businesses and equipment dealers demonstrate their machinery. Penn State University, NRCS, Rodale Institute, and University of Maryland are testing the soils and observing the changes that are taking place with this system.

VIDEOS AND WEB SITE

We have produced 2 videos titled, "No-Till Vegetables; A Sustainable Way to Increase Profits, Save Soil, and Reduce Pesticides", which covers the basics of sustainable no-till vegetable production. "Cedar Meadow Farm, A Model for Clean Water and Healthy Soil" shows how are farm handled hurricane Floyd which dumped over 8 inches of rain in 12 hours. Cost is \$21.95 each plus \$3.00 S/H. To order call (717) 284-5152, e-mail: sgroff@epix.net, or web site: www.cedarmeadowfarm.com.

These examples of the use of cover crops, crop rotation, and long-term no-till are what sustainable agriculture is all about. Don't try and adopt exactly what I have done. You need to adapt these principles to your operation in accordance to the resources, equipment, and experience you've attained. Start small. Learn as you go. Network with researchers, extension agents, and other growers who have been successful. Go to field days or research tours. At the very least, think of one idea you can implement on your farm to make it more environmentally friendly, yet still maintain profitability.

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COVER CROPS TO CONSIDER

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INTRODUCTION

A sustainable agricultural system is one that, over the long term: enhances environmental quality and the resource base on which agriculture depends; provides for basic human food and fiber needs; is economically viable; and enhances the quality of life for farmers and society as a whole (White et al., 1994). Increased diversity of crops grown in rotation and no-till farming practices are important components of sustainable agriculture systems. Improved yield under rotation is related to both soil and crop parameters. Crop rotations that included legumes increased soil nitrogen levels (Peterson and Varvel, 1989; Raimbault and Vyn, 1991). Crop rotation also improved soil structural stability (Raimbault and Vyn, 1991), increased crop water use efficiency (Varvel, 1994), improved crop mineral nutrient uptake (Riedell et al., 1998), and increased soil organic matter levels (Campbell and Zentner, 1993).

Many of the advantages of no-till crop production are derived from the residue mulch that remains on the soil surface after grain harvest. The residue mulch protects the soil from wind and water erosion but also delays soil warming in the spring (Swan et al., 1996). Cooler soil temperatures translate into slower seed germination, reduced uptake of non-mobile soil nutrients, and less vigorous early crop growth (Barber, 1984; Griffith and Wollenhaupt, 1994). Under no-till conditions, Drury et al. (1999) found that fall-seeded cover crops (red clover) planted after wheat harvest allowed the following corn crop to have emergence and yield equal to that of a corn crop following wheat under tilled conditions. Meisinger et al. (1991) outlined the importance of cover crops in improving environmental quality. Cover crops scavenge nitrogen from the soil profile and prevent it from moving below the root zone during periods of time when the soil water is being recharged. Under tilled conditions, cover crops also help protect the soil from water and wind erosion. Hatfield and Keeney (1994) outlined some of the knowledge gaps in cover crop use that need to be addressed through research including; cover crop systems for climates with short growing seasons and/or low water availability, and the benefits of fixed nitrogen from legume cover crops. As different cover crop species have differing characteristics, the hypothesis is that certain cover crop species will be more suited for inclusion in complex crop rotations under no-till soil management in the northern Great Plains than other species.

APPROACH

A field experiment was conducted in which different species of grasses and legumes (planted into spring wheat stubble) were evaluated as cover crops in crop rotational system (soybean/spring wheat-cover crop/corn) under no-tillage soil management. The experiment is located near Brookings, South Dakota on a silty clay loam at the USDA, ARS, Northern Grain Insects Research Laboratory on two separate experimental sites. Cover crop (including 14 different species), a fallow (no cover crop) and conventional tillage treatments were replicated four times within the experimental area. Cover crops evaluated include: Crimson clover, alsike clover, red cover, sweet clover, annual ryegrass, winter ryegrass, hairy vetch, Carneval field pea, Austrian winter pea, slender wheat grass, non-dormant alfalfa, sudangrass, buckwheat and barley. All cover crops were planted in early August (following spring wheat harvest) at recommended seeding rates. The following spring all plots were planted to corn. Corn phase of the rotation was planted on 29 May, 2001 and 6 June 2002.

Soil samples were collected prior to the first cover crop planting. The 0-60 cm samples will be separated into 0 - 15, 15 - 30 and 30 - 60 cm increments before initial soil physical and chemical conditions are measured. During the course of the experiment, data collection included growing environment (soil temperature, soil moisture, rainfall, and air temperature, soil physical properties (soil bearing strength, bulk density, water content at planting, and vane shear strength), total cover crop growth, soil nitrogen mineralization, cash corn emergence and growth (stand counts, phenological development staging, and leaf area index), and final corn grain yield and quality (protein and oil content).

RESULTS AND CONCLUSIONS

There are numerous species of grasses and legumes that can be utilized as cover crop. The species that best fit each individual situation is dependant on a number of factors. As stated previously this research project evaluated 14 different species, as well as a no cover crop (fallow), and conventional tillage treatments. For the purpose of this presentation and report only a few species will be discussed. These species were selected due to their significant effect on measured parameters.

One of the biggest concerns with no-till production practices is stand establishment due to unfavorable environmental conditions at the time of planting. Soil temperature measurements collected the day prior to planting (28, May, 2001 and 5, June, 2002) illustrated the dramatic difference in soil temperature for conventional tilled plots versus plot that did not receive tillage (Figure 1). The lowest soil temperature for the 2001 season was the no cover crop treatment and the red clover, while in contrast for 2002, the hairy vetch had the lowest soil temperature compared to the other cover crop treatments and no cover crop treatment. These differences were possibly due to the large differences in biomass production for the red clover and hairy vetch. The photos illustrate the large differences in growth the two years. Hairy vetch biomass production was quite low in 2001 compared to 2002, while red clover biomass production was quite high for 2001 compared to 2002 (Figure 1). This variation accounted for a significant

difference in ground cover between the two species each year contributing to the difference in soil temperature.

Stand counts were performed to evaluate the effect of soil temperature on stand establishment. Initial stand counts performed eight days after planting revealed that emergence for the hairy vetch and no cover crop was significantly lower compared to the other treatments, while the conventional tillage and slender wheatgrass had the highest initial emergence (Figure 2). Count performed on later dates (11 to 13 days after planting) found that stand establishment evened out for all treatments except for the hairy vetch which remained significantly lower (approximately 5,000 fewer plants per acre).

Another concern with no-till production in an area with limited growing degree days is the ability to plant crops in a timely manner to utilize as much of the growing season as possible. No-till production in this area can delay crop planting due to moist soil conditions in the spring. Cover crops that survive the winter have the ability to utilize this excess moisture and increase soil strength to ensure an earlier planting date. Soil strength is defined as a measure of the soil's capacity to withstand stresses without giving way to those stresses by collapsing or becoming deformed. Soil bearing strength and the depth of soil failure was measured to evaluate the effect different species have on soil trafficability. Measurements collected prior to corn planting found that plots with a hairy vetch cover had a significantly higher bearing strength compared to all other treatments, with conventional tillage and no cover crop treatments having the lowest bearing strength (Figure 3). This can be attributed to the above ground biomass growth characteristics and the root system. While the hairy vetch did not have the highest spring or fall biomass production, the manner in which the hairy vetch grows should assist in increasing the soil strength. Winter rye had a significantly higher biomass production in the fall and spring compared to the hairy vetch, but the structure of the winter rye is dramatically different (Figure 4). The hairy vetch grows in a manner that it is inter-twined making a thick mat that covers the ground, while the winter rye exhibits a vertical growth. While the bearing strength was not significantly different for the conventional tillage compared to the no cover crops and the other cover crop treatments the depth of soil failure was significantly deeper, indicating that once force is applied to the soil such as tractor wheels that exceed the bearing strength the soil will fail or sink to a depth of eight inches compared to the hairy vetch that would only sink to a depth of five inches after considerably more pressure is applied (Figure 3). In general terms this indicates that plots with a hairy vetch cover crop would be able to handle heavier wheel traffic without causing significant compaction.

Corn grain yield was significantly affected by cover crop treatment for the 2001 growing season the no cover crop, red clover and winter rye had the highest yield compared to the conventional tillage and slender wheatgrass, with hairy vetch resulting in the lowest yield. While for the 2002 growing season the no cover crop, hairy vetch, slender wheatgrass and red clover had the highest yield compared to the conventional tillage and winter rye. This experiment illustrated the ability of cover crops to utilize

excess soil moisture and increase soil strength compared to conventional tillage or no cover crop, without adversely affecting yield.

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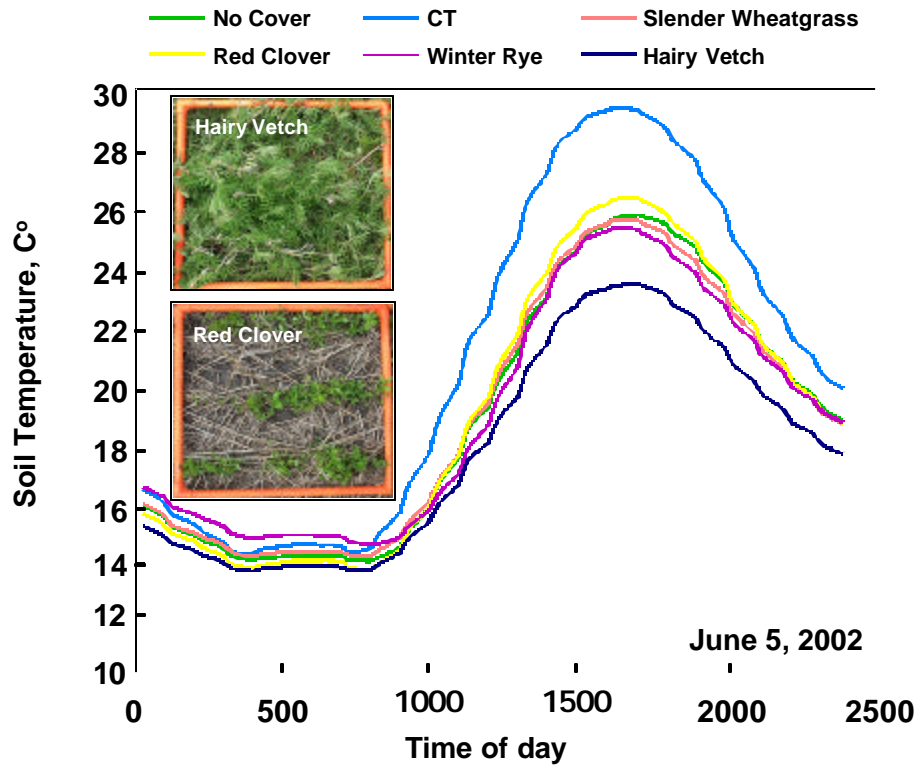
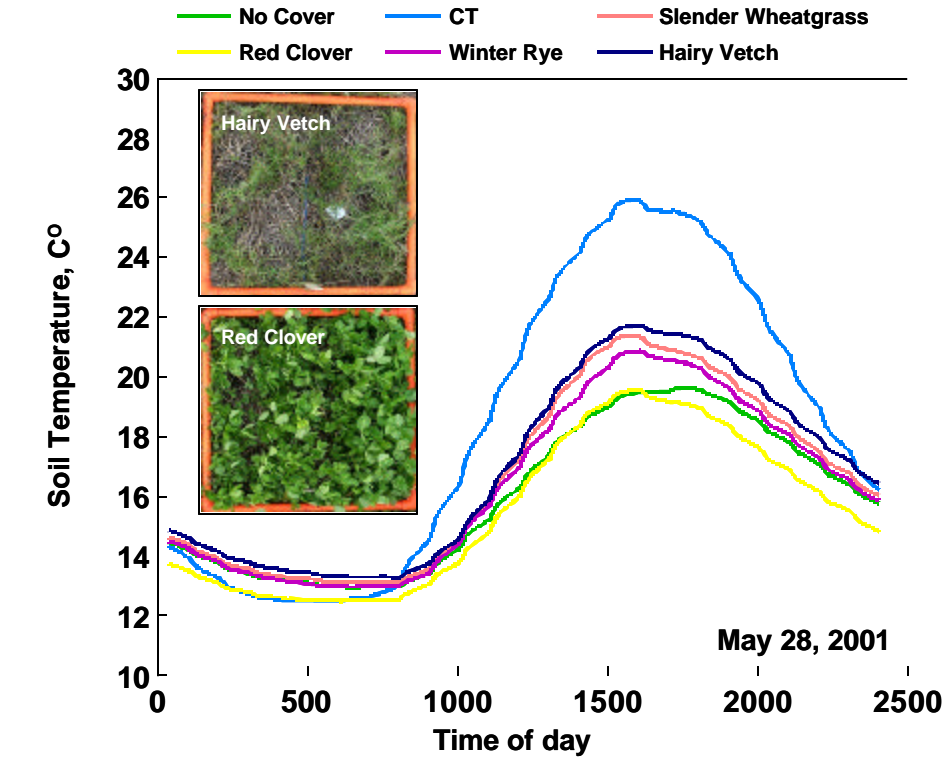


Figure 1. Soil temperature at 3 inches the day prior to corn planting, by treatment for the 2001 and 2002 experiment.

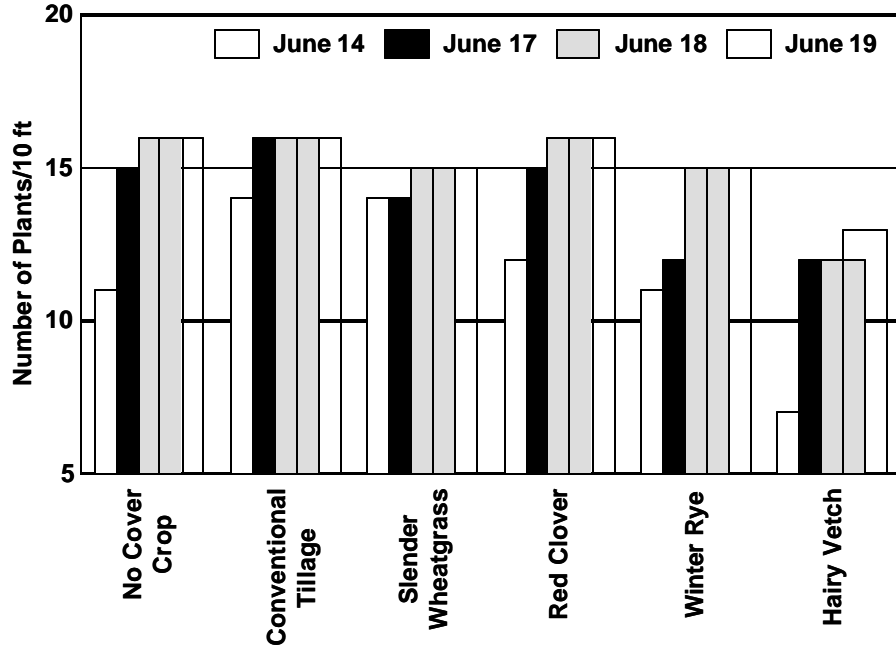


Figure 2. Stand establishment counts, number of plants emerged in to feet of row, by treatment for the 2002 experiment.

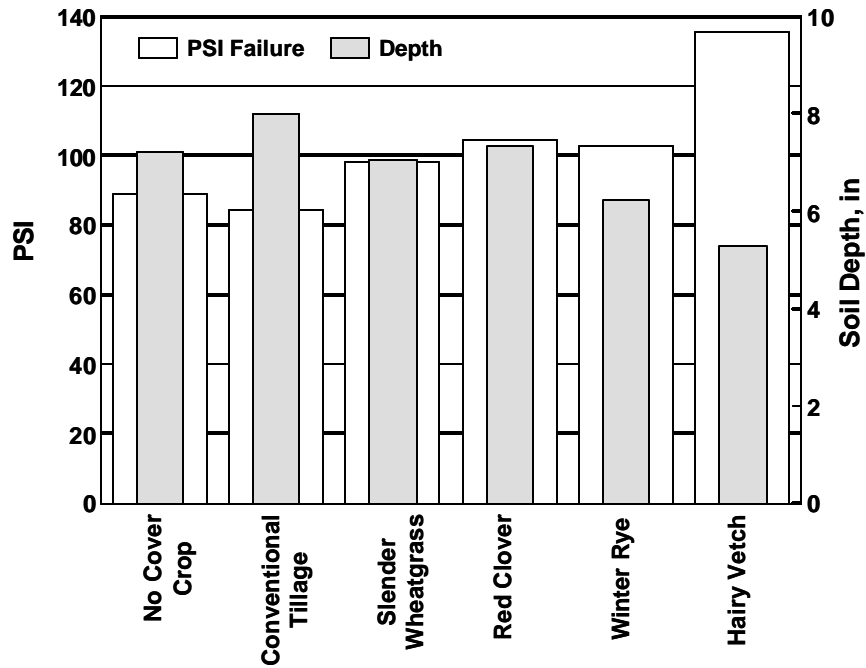


Figure 3. Soil bearing strength measured in pounds per square inch of pressure and the depth of soil failure, by treatment for the 2002 experiment.

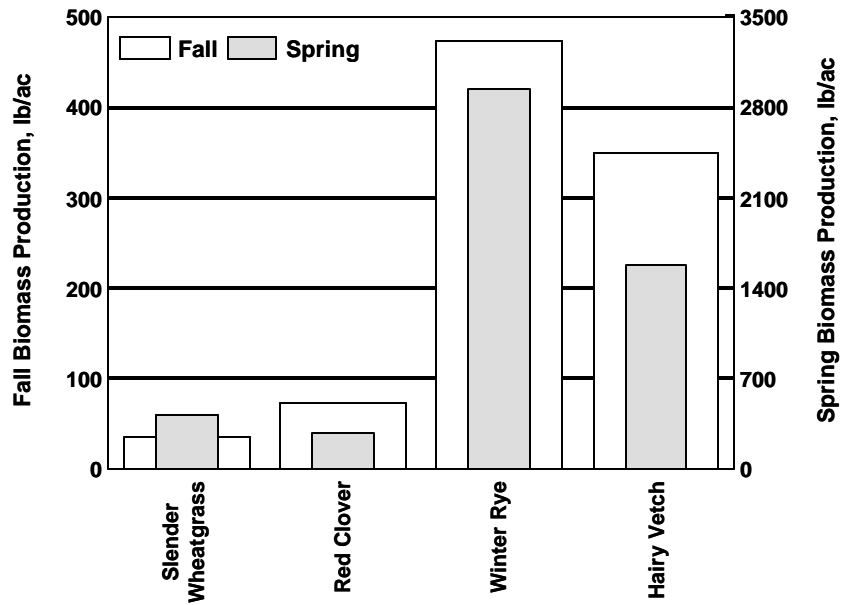


Figure 4. Individual cover crop biomass production; fall biomass growth from planting until killing frost; spring biomass growth from early spring until herbicide burndown approximately two weeks before planting for the 2002 experiment.

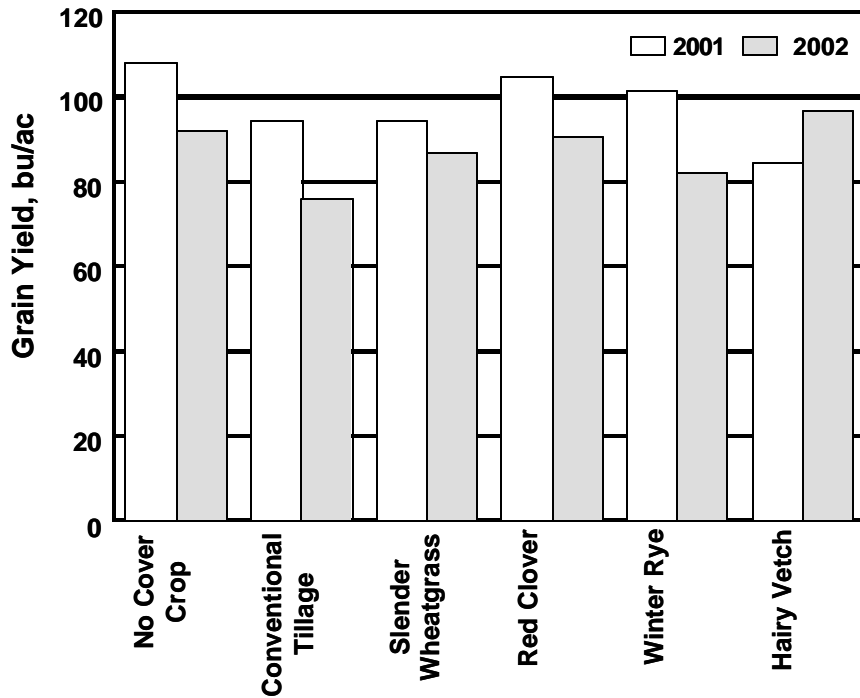


Figure 5. Corn yield following cover crop growth for each treatment for the 2001 and 2002 growing seasons.

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UNCONVENTIONAL APPROACHES TO COMBAT SOYBEAN DISEASES

T.S. Maloney, PhD ^{1/} and C.R. Grau ^{2/}

INTRODUCTION

White mold (*Sclerotinia sclerotiorum*) is a disease frequently found in high yield potential soybeans [*Glycine max* (L.) Merr.]. Soybean producers who adopt management techniques to maximize yield are often penalized by this disease. Several factors responsible for the onset of white mold relate to how we manage soybean canopy closure. A dense canopy provides an environment that enhances white mold pathogen development. Canopy is influenced by plant health, narrow row spacings, high plant populations, high fertility, early planting dates, and sometimes herbicide tolerant varieties that do not succumb to postemergent herbicide “setback” by burning canopy foliage. Essentially, all practices that promote rapid and aggressive soybean plant growth will encourage rapid canopy closure.

The number one defense to combat a soybean disease is through genetic resistance. Choosing varieties with good levels of resistance should be the foundation of a white mold management plan. Afterward, management practices can be modified to further enhance the level of resistance in the variety selected to suppress white mold. Modifications can include altering plant canopy through practices such as wider row spacings, reduced seeding rates, and delaying planting dates. The main drawback with each of these modifications is the potential negative effect each has on soybean yield. What then can be done to maintain high yield practices while minimizing white mold?

It is common knowledge that crop rotations have the ability to increase yield, minimize inputs, reduce the cost of external inputs, and promote crop health through breaks in insect and pathogen cycles. The phenomenon of “rotation effect” has been coined to describe a chain of events or effects that promotes better health and yield by a crop due in part to the crop that was grown previously. Interruption of disease and insect cycles positively influences the “rotation effect”. Corn [*Zea mays* (L.)] usually performs better following soybeans than when corn follows corn. Similarly, soybeans perform better the longer the frequency between the current crop and previous crop of soybean. A typical corn-soybean rotation may work well with corn, but may not be a “long” enough interval to prevent soybean crops from susceptibility to soybean diseases, like white mold and brown stem rot (*Phialophora gregata*).

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OBJECTIVES

Previous research conducted by the University of Wisconsin demonstrated the disease-controlling advantages of small grains in a corn-soybean rotation. Sclerotinia sclerotia density declined each year a non-host crop was planted. Two or more years of corn, small grains or other non-host crops also lowered white mold severity in soybean. Growing two years of corn then following with soybeans is an improved soybean rotation system, but many producers would prefer to eliminate the need for corn insecticides and the expense of additional nitrogen for corn when corn follows corn. Substituting a small grain like wheat [*Triticum vulgare* (L.)] or oats [*Avena sativa* (L.)] for one year of corn will eliminate the need for a corn insecticide, but most producers find that there is an economic disadvantage to raising wheat or oat. This situation led us to consider some “unconventional” management systems which incorporate small grains in the rotation without sacrificing the production year to a less profitable cash crop.

The first objective of this study was to find a reliable method to reduce the incidence of white mold even with susceptible soybean varieties. The second objective was to seed small grains ahead of soybeans in an attempt to promote formation of a closed crop canopy to encourage germination of sclerotia ahead of soybean flowering. A third objective was to use small grains as a cover crop to promote better soybean canopy health.

MATERIALS AND METHODS

Phase One of this study conducted for two years (1998-1999) compared two treatments: 1) oat cover crop followed by soybean and 2) no cover crop followed by soybean. The trial conducted near Whitewater, WI, on a Milford clay loam was planted using four replicates in 1998 and six replicates in 1999. All cover crops and soybeans in this study were planted using large-plots (20 feet x 500 feet). Belle oats were no-til planted with a John Deere 750 no-til grain drill (Deere and Co., E. Moline, IL) at 2.0 bu/acre on 7.5" row spacings and a 0.75" depth on a Milford clay loam soil on April 15, 1998 and March 27, 1999. Jung 8221RR (Jung Seed Genetics, Randolph, WI) soybeans were no-til seeded May 04, 1998 and May 10, 1999 into the live-oat plots plus equal-sized no-oat plots at 225,000 seeds per acre on 7.5" row spacings and 1.0 inch depth. Oats were chemically killed with a mixture of 1.0 qt/acre Roundup Ultra (glyphosate, a product of Monsanto, St. Louis, MO) plus 2.0 oz/acre Pursuit (imazethapyr, a product of BASF, Research Triangle Park, NC) when soybeans reached V2 growth stage (June 10, 1998 and June 05, 1999). The no cover crop plots also received the same herbicide treatment on the same date. Data collected included grain yield and moisture, plant height, lodging, stand density, white mold and brown stem rot incidence. Apothecia counts (per meter²) were made June 10, July 01 and August 01, 1998 and June 01, June 05, July 01, August 01, 11, 16 and 23, 1999. Plots were harvested September 29, 1998 and September 17 1999 using an International Harvester 1660 combine (Case Corp., Racine, WI) with 20.0 foot 1020 grain platform and AgLeader PF2000 yield monitor (AgLeader Technology, Ames, IA). A Parker Model 150 weigh wagon (Parker Industries, Jefferson, IA) was used for individual plot weights.

Phase Two of this study conducted for one year (2000) compared four treatments: 1) winter wheat cover crop followed by soybean, 2) oat cover crop followed by soybean, 3) barley [*Hordeum vulgare* (L.)] cover crop followed by soybean, 4) no cover crop followed by soybean. The trials were conducted at three southern Wisconsin locations near Milton on a St. Charles silt loam, near Janesville on a Plano silt loam, and near Whitewater on a Kidder sandy loam. For 2000, we further expanded our cover crop comparisons to include two soybean varieties. These varieties consisted of one with average susceptibility to white mold (WM-) and one with above average tolerance to white mold (WM+). Soybean varieties planted at Whitewater (May 05, 2000) and Janesville (April 30, 2000) were Dairyland DSR218 (WM+) (Dairyland Seed Co., West Bend, WI) and Dekalb CX232 (WM-) (Dekalb Seed Division of Monsanto, St. Louis, MO), non-Roundup Ready. Asgrow AG2001 (WM+) (Asgrow Seed Division of Monsanto, St. Louis, MO) and Spangler 249RR (WM-) (Spangler Seedtech, Jefferson, WI) were planted at Milton (April 28, 2000), both Roundup Ready. Soybean plots were no-til seeded at 225,000 seeds per acre at a 1.0 inch depth. The experiment was established in large 20 foot x 1000 foot on-farm plots in a randomized complete block arrangement of treatments with two replicates.

Winter wheat cover crop plots were planted October 01, 1999 at all three locations at 2.0 bu/acre and a 0.75 inch depth. Spring oat and spring barley cover crop plots were seeded April 07, 2000 at Milton and Janesville and April 14, 2000 at Whitewater. Oat and barley plots were no-til seeded at Milton and Janesville and conventionally at Whitewater at 2.0 bu/acre at a 0.75 inch depth. Winter wheat plots all received 1.0 qt/acre Roundup Ultra as a burndown either three days before planting soybeans at Whitewater (May 02, 2000) or after planting at Milton and Janesville (May 02, 2000). Oat and barley cover crop plots received 8 oz/acre Select (clethodim) herbicide to kill small grains (June 03 at Whitewater and Janesville and June 04 at Milton). All plots at Whitewater and Janesville received 4 oz/acre Pursuit (June 03, 2000). Milton plots received 1.5 qts/acre Roundup Ultra on June 17, 2000.

Soybean plots were harvested Sept 25, 28 and 30, 2000 at Milton, Janesville and Whitewater, respectively, using an International Harvester 1460 combine with 16.5 foot 1020 grain platform. Yields were determined using an AgLeader PF3000 yield monitor with GPS and a Parker Model 150 weigh wagon.

Data collected included grain yield and moisture, plant height, lodging and density, aphid and bean leaf beetle density and relative injury, virus-like plant symptoms, percent green stem, white mold and brown stem rot incidence. Apothecia counts (per meter²) were conducted in each cover crop plot every five days from April 01 to August 31, 2000.

RESULTS AND DISCUSSION

1998 DISEASE AND YIELD DATA

Growing conditions in 1998 were generally good to excellent for soybeans. Rainfall was generally adequate at Whitewater, but not excessive. Apothecia counts from oat + soybean cover crop plots had much higher apothecia numbers in June than either of the later dates or for any of the soybean only plots, Table 1. Canopy was quite dense in these small grain plots on June 10. Chemical control of these oat strips was applied after apothecia measurements on June 10. The dramatic decrease in apothecia density by July 01 in these oat plots and the low counts in the soybean only (no cover crop) plots indicates that oat plots may have provided an early environment favorable to “spending off” apothecia.

TABLE 1. APOTHECIA COUNTS / METER² AT THREE SAMPLING DATES. WHITEWATER, WI. 1998

Cover crop	June 10	July 01	August 01
Oat/soybean	3.8	0.5	0.1
Soybean	0.3	0.1	0.5
LSD(P=0.10)	1.5	0.3	0.1

The encouragement of early apothecia production in oat plots resulted in lower white mold incidence, Table 2, in these plots, whereas in soybean only plots white mold incidence was higher. Soybean grain yield in oat/cover crop treatments yielded 73.8 bu/acre versus 69.2 bu/acre for the no cover crop treatment (LSD P=0.10 = 2.5 bu/acre).

TABLE 2. WHITE MOLD INCIDENCE (%) AT THREE SAMPLING DATES. WHITEWATER, WI. 1998

Cover crop	August 01	September 01	September 28
Oat/soybean	0.1	0.4	0.4
Soybean	1.1	2.0	2.0
LSD(P=0.10)	1.0	1.5	1.5

1999 DISEASE AND YIELD DATA

Growing conditions at Whitewater for 1999 were very different from 1998. After June 17 very little measurable rain was received until late August. Soil conditions were deficient for moisture. However, there were many days in July and August with a heavy dew on soybean plants each morning. This provided a “perfect” environment for germination of sclerotia, hence the increase in white mold incidence. Apothecia counts were expanded to six sampling dates. As in 1998, the oat cover crop plots had much higher apothecia numbers earlier in the season compared to soybean plots with no cover crop, Table 3. Oat plots had high early season apothecia numbers which dropped dramatically after chemical control of oats. No apothecia were detected in these plots

after July 01. Apothecia were not present at early season sampling dates in soybean only, no cover crop plots, but as soybean canopy closed, apothecia densities rose quickly and never diminished. No foliar symptoms of white mold were detected in oat/soybean plots,

TABLE 3. APOTHECIA COUNTS / METER² AT SIX SAMPLING DATES. WHITEWATER, WI. 1999.

Cover crop	June 05	July 01	Aug 01	Aug 11	Aug 16	Aug 23
Oat/soybean	3.1	0.1	0.0	0.0	0.0	0.0
Soybean	0.0	0.0	0.2	2.2	1.4	1.6
LSD(P=0.10)	0.5	NS	NS	0.7	1.2	0.3

while soybean plants in the soybean/no cover plots had a significant infection at the first date and increased with each subsequent reading, Table 4. There was no significant soybean grain yield difference between oat cover crop or soybean only plots (57.2 bu/acre vs. 56.5 bu/acre)(LSD P=0.10 = NS).

TABLE 4. WHITE MOLD INCIDENCE (%) AT FOUR SAMPLING DATES. WHITEWATER, WI. 1999

Cover crop	August 01	August 16	September 02	September 16
Oat/soybean	0.0	0.0	0.0	0.0
Soybean	3.7	6.0	7.5	10.0
LSD(P=0.10)	1.2	1.5	0.9	1.2

2000 DISEASE AND YIELD DATA

The weather was generally more favorable for soybean growth in 2000, compared to 1999, at these southern Wisconsin locations. Moisture was more plentiful, however, rainfall came in large amounts over brief periods of time. Several times during the season soil would be very dry then recharged by a single large rainfall only to dry up again later. Other factors became of interest, namely from bean leaf beetles and soybean aphids each having some potential effect on yield. Table 5 illustrates eleven of those sampling dates and the density of apothecia for each cover crop averaged across all three locations. Once again, our small grain cover crop plots enhanced sclerotia germination earlier in the season well ahead of soybean flowering. Soybean only plots delayed apothecia production until July at the same time that soybeans began to flower. Apothecia remained in soybean only plots through August.

TABLE 5. APOTHECIA COUNTS / METER² AT ELEVEN SAMPLING DATES. MEANS FROM JANESVILLE, MILTON AND WHITEWATER, WI 2000.

Date	Cover crop				LSD(P=0.10)
	Wheat/SB	Oat/SB	Barley/SB	Soybean	
April 15	0.0	0.0	0.0	0.0	NS
April 20	1.3	0.0	0.0	0.0	0.5
May 02	1.7	1.7	1.3	0.0	0.3
May 17	1.7	1.7	1.7	0.7	0.7
June 02	0.0	1.0	1.0	0.0	0.5
June 17	0.0	0.0	0.0	0.0	NS
July 02	0.0	0.0	0.0	0.7	0.2
July 17	0.0	0.0	0.0	1.3	0.6
August 01	0.0	0.0	0.0	1.0	0.3
August 16	0.0	0.0	0.0	1.0	0.4
August 31	0.0	0.0	0.0	1.7	0.8

Tables 6, 7 and 8 illustrate incidence of white mold at each of the three locations at four sampling dates. White mold incidence follows the trends detected from 1998 and 1999.

TABLE 6. WHITE MOLD INCIDENCE (%) AT FOUR SAMPLING DATES. JANESVILLE, WI 2000

Cover crop	August 01	August 16	September 02	September 16
Wheat/soybean	0.0	0.0	1.5	5.3
Oat/soybean	0.0	0.0	0.0	0.0
Barley/soybean	0.0	0.0	0.0	0.0
Soybean	0.5	2.0	3.5	6.0
LSD(P=0.10)	NS	NS	2.1	1.8

TABLE 7. WHITE MOLD INCIDENCE (%) AT FOUR SAMPLING DATES. MILTON, WI 2000

Cover crop	August 01	August 16	September 02	September 16
Wheat/soybean	0.0	0.0	0.0	1.0
Oat/soybean	0.0	0.0	0.0	1.0
Barley/soybean	0.0	0.0	0.0	1.0
Soybean	0.0	0.0	0.0	1.0
LSD(P=0.10)	NS	NS	NS	NS

TABLE 8. WHITE MOLD INCIDENCE (%) AT FOUR SAMPLING DATES. WHITEWATER, WI 2000

Cover crop	August 01	August 16	September 02	September 16
Wheat/soybean	0.0	0.0	0.5	2.0
Oat/soybean	0.0	0.0	0.0	0.3
Barley/soybean	0.0	0.0	0.0	0.3
Soybean	0.0	2.0	3.5	6.8
LSD(P=0.10)	NS	0.7	0.7	0.9

White mold was not the only disease observed in 2000. The conditions were “perfect” for brown stem rot expression. Table 9 illustrates the effect brown stem rot had on Milton plots, severely reducing yield at that site. The Milton location has a long history of a corn-soybean rotation (30+ years). However, cover crop did not influence brown stem rot severity. Soybean variety did respond to brown stem rot incidence (AG2001 averaged 36.9 bu/acre whereas SP249RR averaged 43.3 bu/acre, LSD P=0.10 = 2.1 bu/acre).

TABLE 9. BROWN STEM ROT INCIDENCE AT FOUR SAMPLING DATES. MILTON, WI 2000

Cover crop	August 01	August 16	September 02	September 16
Wheat/soybean	3.8	20.5	47.5	71.3
Oat/soybean	2.5	20.8	45.0	68.8
Barley/soybean	1.3	15.8	38.8	67.5
Soybean	5.0	21.3	43.8	63.8
LSD(P=0.10)	NS	NS	NS	3.0

Grain yields of soybean in 2000 for soybeans seeded in barley cover crop plots were generally lowest for all treatments, Table 10. Soybean yields in oat cover crop plots yielded similar to soybean with no cover crop. The surprising winner were soybeans seeded into winter wheat plots. Soybean yields from winter wheat plots were 10.3 to 13.4

bu/acre higher than no cover crop plots and 10.6 to 14.3 bu/acre higher than oat cover crop plots, except at Milton where there were no differences between cover crop treatment.

TABLE 10. GRAIN YIELD (BU/ACRE) OF SOYBEAN PLOTS FOLLOWING FOUR COVER CROP TREATMENTS AT JANESVILLE, MILTON AND WHITEWATER, 2000.

Cover crop	Janesville	Milton	Whitewater
Wheat/soybean	70.8	40.0	74.9
Oat/soybean	60.2	39.5	60.6
Barley/soybean	53.5	40.0	57.4
Soybean	57.4	40.9	64.6
LSD(P=0.10)	3.2	NS	2.9

2000 APHID, BEAN LEAF BEETLE, VIRUS-LIKE SYMPTOM MEASUREMENTS AND OBSERVATIONS

An interesting effect detected in 2000 was the effect of cover crop on aphids, bean leaf beetles and virus-like symptoms. During apothecia counts a rating was also made for aphid density (scale of 1 to 9, with 9 indicating very heavy infestation), bean leaf beetle density (similar 1 to 9 scale) and percent pod feeding injury as well as percent virus-like symptoms and green stem. Across all three locations, aphid density and infestation was greatest on soybean only plots, followed by wheat, and least on oat and barley cover crop plots. Aphids preferred a drier, less moist canopy.

Bean leaf beetles were in our plots as early as mid-May feeding on soybean cotyledons. Generally a greater density of feeding occurred in soybean only plots. Wheat, oat and barley plots were similar in beetle injury, much less than soybean only plots.

Another observation was made for virus-like plant leaf symptoms (i.e. puckered leaves, mosaic patterns, etc.). Virus symptoms on soybean plants occurred at a level of 10-15% for oat cover, 15-20% for barley cover, 20-25% for wheat cover and greater than 30% for soybean only plots. At harvest green stem percent infected plants showed similar trends where soybean only plots had the highest incidence of green stem (3-5%).

CONCLUSIONS

Phase One and Two data demonstrates that an early spring-seeded small grain used as a cover crop will encourage an environment favorable to sclerotia germination and apothecia production. The cover crop plot data from three years at Whitewater demonstrates a “flush” of apothecia between June 01 and July 01, well ahead of soybean flowering, Figure 1. Soybean plots without a cover crop delayed canopy closure until July when soybeans began flowering and at a time when they are most susceptible to white mold infection. Figure 2 shows data from our three 2000 locations from April to September following a similar trend to Figure 1. After only one year of data, winter wheat also appears to flush out apothecia, but earlier in the season than oats or barley.

Environmental conditions in 1998, 1999 and 2000 may not have seemed favorable for white mold establishment, but apothecia numbers show that conditions were present for white mold to occur. White mold did occur but not at very high levels. White mold was reduced in plots where a cover crop was grown. Yield increases due to cover crop may be part of an overall rotation effect providing relief from both apothecia production, of pathogens and possibly due to a health aspect to the plant as a growth hormone effect. Additionally, a dense growth may provide some relief from aphids and reduction other insects. We have winter wheat seeded again at three locations for 2001 research plots. We plan to use oats as a spring cover crop, but will probably drop the barley cover crop treatment.

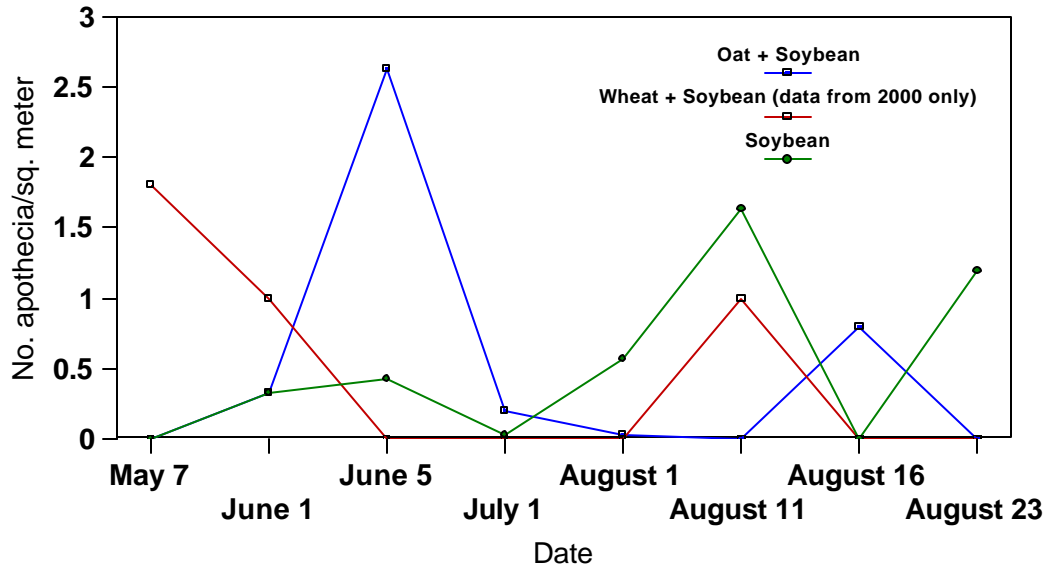


Figure 1. Apothecia developing in Small Grain + Soybean or Soybean only plots during 1998, 1999, and 2000 growing seasons. 3-year means. Whitewater, WI.

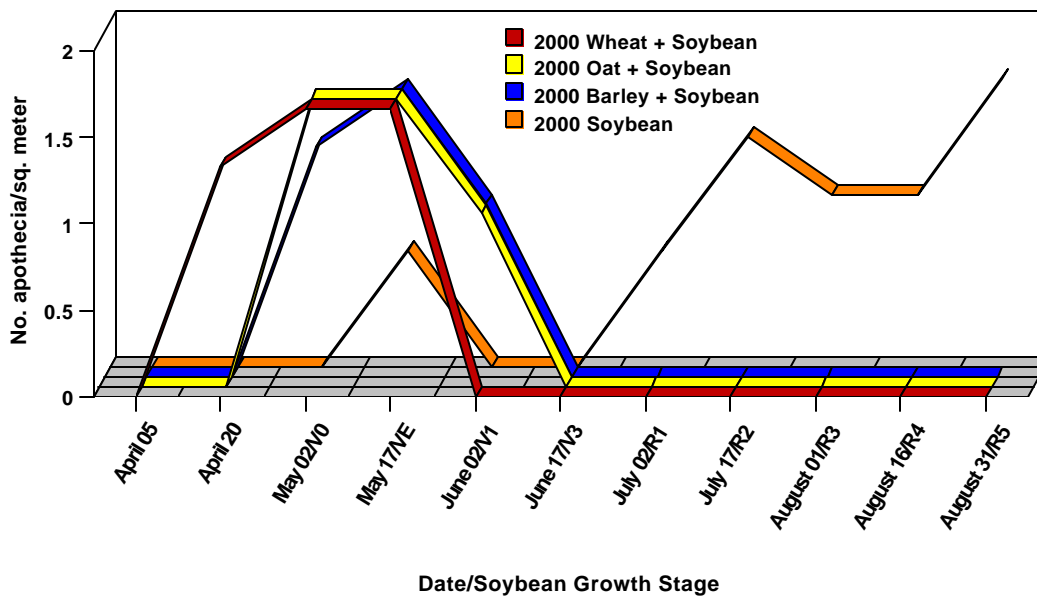


Figure 2. Apothecia developing in Small Grain + Soybean or Soybean only plots at Janesville, Milton and Whitewater, WI. April 05 to August 31, 2000. Three-location means.

Winter wheat may prove to be the “easiest” treatment because it can be fall-seeded and then burned off during normal preplant soybean weed control. Oats prove to be more of a challenge because timing of chemical control has always been difficult due to rain at that time. Plus, oats can create a greater opportunity to compete directly with the soybeans if not controlled on time. We hope that 2001 will provide us additional data to promote seeding of small grains as an alternative, albeit unconventional, method to manage soybean diseases such as white mold. Additional benefits of seeding a small grain crop prior to soybean would be control of soil erosion and weed suppression.

LITERATURE CITED

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Soybean Plant Health Website: <http://www.plantpath.wisc.edu/soyhealth/index.htm>
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LEVERAGING BIOLOGY: DISCOVERING EFFICIENCIES IN CROPPING SYSTEMS

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In the Big Picture perspective, all we're trying to do out in those fields of crops is to 'leverage' the biology to our benefit—to extract a little more than we put in (hopefully a whole lot more, but this is often not the case unfortunately). After all, the crops we grow are merely slightly altered forms of wild plants—selected over the millennia to be more 'user-friendly' than their wild cousins, often with traits such as larger seeds for easier harvesting or processing, less dormancy, more responsiveness to fertilizers, etc. But in the search for greater efficiencies, crop genetics are only one piece of the puzzle.

Think of your fields as ecosystems—you can't sterilize the whole thing and have only the crop out there. Nature isn't easily confined or excluded. Life is quite resilient—the biology just can't be kept out without extreme measures. Think about your shower curtain or bathroom tile—no matter what you scrub it with, the mildew and other living 'gunk' show up again in a few weeks. Or how about hospitals—supposedly nice and sterile, right? Not so—a high percentage of nasty infections and diseases are transmitted during hospital stays and medical procedures, despite the advances of modern medicine. So a person can hardly expect to have complete control over big fields of crops, in the great outdoors—at least not without massive technology, deployed at a staggering cost.

Instead of focusing on wiping out the population of pesky organisms, we should instead be looking to avoid the confrontation, or at getting the suppression some other way. 'Brute force' technology generally fails to subdue biology—the technology is very costly, plus, the target often evades the control measure (particularly if used repeatedly), and the side-effects are sometimes unanticipated and unpleasant. So we need to look for ways to manipulate the system to get what we want—to find those places where we can exert small pressures and produce big changes, to leverage biology in our favor. Give me a lever and a place to stand, and I will move the world. Or at least nudge it. Really, what we want to do is mostly observing, with very little intervening—a good system will run fine by itself much of the time.

HIRED GUNS

While some 'rules' undergird the whole shebang, most of the practical pieces must be learned in dribs and drabs—the effects are often rather specific to a location and the

circumstances involved, and not all that predictable (at least with our current knowledge). What is predictable: for much of what you could want done, biology provides a way, although sometimes the pace is too slow for us.

One of the most visible ways of leveraging biology is using beneficial organisms to control harmful ones—essentially nurture your allies and let them fight your wars for you. We've heard about the importance of "beneficials" for years, and how some farmers purchase and release beneficials in their fields to boost numbers—i.e., biocontrol. The problem was in having to purchase and release them. Why not ensure that their numbers were high from the start? This is what can occur in a well-managed no-till system. Keeping crop residues on the surface holds moisture and creates an environment suitable for these beneficial organisms, ensuring their population builds early and stays strong. Lady beetles and lacewings are often given most of the credit, but spiders actually do much of the work when it comes to controlling damaging insects and aphids. In cotton, for example, spiders are very important for controlling fleahoppers (*Pseudatomoscelis seriatus*). For years, I had noticed fleahoppers damaging some early squares (buds) in our no-till cotton fields, but often the levels never became all that serious, even if no control measures were taken. I always wondered what was doing the control for us, until I realized much of it came from spiders capturing the fleahopper nymphs (there may be other control mechanisms also—the point is that fleahoppers rarely reach damaging levels in well-managed no-till cotton).

Establishing a good beneficial population early involves providing habitat and a food source for them, by keeping residue on the surface (or, better yet, a growing crop) and not spraying insecticides. Spiders and lady beetles will feed on a wide range of other organisms, and can establish populations long before damaging insects ever show up—but these beneficials can't prosper in the barren wasteland of a tilled field. However, a winter cover crop killed just before cotton emergence (or even early post-emerge)¹ really builds the spider and lady beetle population early, which will typically control thrips, aphids, and bollworms (having some milo and corn in the vicinity really helps, too, as the bollworm [a.k.a. earworm] moths prefer to lay eggs in those crops). Consequently, in well-managed no-till cotton in Kansas we have virtually eliminated post-emerge insecticide use—without Bt varieties.

Similar measures keep European and southwestern corn borers at bay—a good supply of lady beetles will devour most of the eggs and larvae, although it is strictly a 'numbers game.' Some areas of the northern U.S. Plains tend to have consistently higher numbers of corn borer, prompting the question of which biological suppression Beck has speculated that bats (the flying mammals, not the baseball stick) may well do the trick, consuming a number of corn borer moths each night before the moths lay their eggs. So perhaps we should be building bat habitat in our fields. Other insect problems can also be avoided with good management. Corn rootworm can be handled by rotation, so long mechanisms might be available. Of course there's Bt, a human-engineered utilization of

¹ The cover crop often adds yield, too—many times the best cotton comes from fields where wheat cover is killed about the time of cotton planting.

biology.² But we'd like something on a more affordable and renewable level. Dwayne as the rotation isn't too short or predictable (see issue #1 on stacking)—this is basically deprivation of a host. Chinchbugs in milo aren't as bad in no-till, although I'm not sure why (I've been told it is due to a fungus). Greenbugs and other aphids in corn and milo are generally reduced in no-till, as has been documented by some researchers.

Sure, we haven't got all the pests under control yet, and sometimes we get 'ambushed' by something (such as snails in South Australia). We still fight grasshoppers—we haven't found much for ways to marshal their natural enemies against them yet, although they don't seem any worse in no-till than anywhere else (in fact, just the opposite seems to occur—the grasshopper populations seem to move in from the grasslands and brome waterways). Sunflower headmoth defies biocontrol, at least thus far. Often it is simply insufficient knowledge.

A JUNGLE OUT THERE

What about weeds? They do seem to 'disappear' when left on the soil surface, which is well documented (see Randy Anderson's data in issue #1, or Leon Wrage, an SDSU weed specialist). Some of this is biology (predation), and some is just pure weathering and chemical degradation. Leaving the weed seeds on the soil surface maximizes these mechanisms. Temperature fluctuations and sunlight are strongest on the surface, as well as the most feeding by ants, beetles, crickets, etc. And the same microbial and fungal feeding that degrades stubble also works to destroy weed seeds. The greatest amount of biology is almost always in the duff layer on the surface and the half-inch of soil underneath, which is also true of nearly all other ecosystems on land—the interface of a substrate, minerals, gases, and sunlight. Generally, most of these decay processes are accelerated under crop canopy conditions (by keeping the humidity higher). These processes seem to go along just fine by themselves, especially after a few years of no-till (indeed, sometimes our crop residues decay a little more quickly than we'd like). Weed seeds are further disadvantaged by just lying loosely on top—a poor place to germinate, except in very damp environments.

Another component of biological control of weeds is competition from your crop. Sunlight and nutrients are limited in supply, not to mention pure physical space to grow. What is it you don't like about weeds? Obviously, they take something away from your crop's growth and yield. Turning this around helps level the playing field—so make the crop as competitive as possible. Proper seed and fertilizer placement help 'build' a vigorous crop, as does selecting quality seed (usually larger seeds with high germination) with genetics to grow quickly. Thicker stands and narrower rows will help, too. Anderson showed that using a tall variety in narrower rows with N placement reduced

² In the wild, the bacterium *Bacillus thuringiensis* produces substances toxic to Lepidopteran (moth and butterfly) larvae, such as corn borer. Researchers successfully moved the genetic snippet for producing this protein into several corn genomes, causing the resulting "Bt" corn plants to produce those toxins in some of their tissues. In the wild, such shuffling of genetic material between species is known to occur when mediated by viruses—genetic 'engineering' is an ancient occurrence.

weed seed production by 40 to 45% in wheat. Of course, rotations are key to effective biological control, as crops will be competitive at different times of the year.

Beyond competition for resources, weeds may even actively suppress crop growth with ‘chemical warfare’—emitting compounds to limit the growth or even kill neighboring plants (the first herbicides were used by Nature!). Sometimes this works the other way as well, and a crop will do a decent job of actively suppressing one or more weed species. This chemical warfare, or allelopathy, is only beginning to be understood yet is another biological tool to be used to our advantage, if only we would.

One striking example of the failure to make use of competition is the “ecofallow” program in western Kansas, which is basically a wheat >>milo (or corn) >>summerfallow rotation. After a few cycles, windmillgrass (*Chloris verticillata*), prairie cupgrass (*Eriochloa contracta*), and other “go-back” grasses dominate the system, resulting in the desire to ‘solve’ the problem with tillage—using v-blades, undercutters, plains plows, or whatever you want to call them. The interesting thing is that these grasses do not ‘blow up’ or become prevalent in other systems—only in that rotation. These grasses share a few tough management characteristics, such as tolerance to low rates of glyphosate, but also are weak in that they don’t produce much seed and are not terribly aggressive in their growth habits. Why did they come to dominate? The system gave them an opportunity. The herbicides used (low rates of glyphosate + growth regulators in the wheat stubble and again in the summerfallow, atrazine + acetamides in the milo) were not particularly good on the windmillgrass, etc., and in fact helped them by removing competition from other weed species susceptible to those herbicides (pigweeds, kochia, foxtails). Of course, the crop competition was zero in the summerfallow year, only moderate in the wheat year (with a long summer for the windmillgrass to recover), and not overly wonderful in the wide-row (30 to 40-inch) milo either. Soon, the thing fell apart—Nature had found the Achilles’ heel of this cropping system.³

While many now consider the v-blade an integral part of their management of that system, it need not be so. Many producers have cleaned up problem fields of those grasses with good rotations and proper herbicide selection, relying on more ‘fop’ and ‘dim’ herbicides and higher rates of glyphosate. But the death-knell to those weeds is a dense canopy above them during the summer—they cannot tolerate being shaded. Putting a vigorous broadleaf summer crop into the rotation fixes the problem with biology, and has many other desirable attributes as well. I have clients who have nearly eliminated windmillgrass and cupgrass in some fields by using narrow-row soybeans and well-chosen herbicides, without any mechanical tillage devices whatsoever. Despite a constant supply of windmillgrass blowing in from borders and adjacent pastures, we see no windmillgrass problems developing. Summer broadleaf crops other than soybeans

³ The ecofallow program also caused shifts in annual grass biotypes and species toward those more tolerant of acetamides, since this was almost the only major pressure being applied to some of the summer grasses. In some regions, nutsedge also became predominant under ecofallow or similar systems that provided the opportunity. As Beck observes, “Mother Nature is an *opportunist*—she’s not a bitch.”

appear to address the problem similarly, in varying degrees, depending on their canopy and growth characteristics.

Rotations, competition, and weed seed disappearance have dramatic impacts on weed populations in no-till fields. However, herbicides still pick up the slack, partly because we do not sufficiently exploit these other control measures, and partly because we have bred crops to have fewer defensive traits while going for bigger yield potential. The most economical system will make judicious use of all these means.

UNHEALTHY LIVING

What about crop diseases? Diseases aren't quite as obvious as insects and weeds, and may not receive as much attention. But they're still in the realm of biology, and of biological controls.

Disease-causing organisms all have resting (dormant) stages, called spores, conidia, apothecia, perithecia, sclerotia, etc. depending on the structure produced. These can survive for some time until coming into contact with a new host. Interfering with disease infection and/or progression in plants can involve several mechanisms, such as reducing the levels of these resting stages in the environment (soil or air), disrupting their 'sensing' of the proper host, or enhancing the plant's defense mechanisms.

Reducing inoculum load may involve longer intervals of non-host plants, or other ways of increasing attrition of the resting structures—time, chemical weathering, and biological predation are your allies. Having a crop growing in the field often creates conditions that either accelerate the death of these enemies, or that actually fake them out of dormancy (only to find themselves trying to infect a non-host species, or one that isn't the cash crop).

This is perfectly illustrated by a recent study of white mold (*Sclerotinia sclerotiorum*) levels in soybeans as affected by cover crops, conducted by Craig Grau of Univ. Wisconsin. White mold is a scourge of the Northern Plains, especially in areas with 'tight' rotations of susceptible or carrier plants, such as soybeans, canola, and sunflowers. It is worst in humid conditions, and during the late '90s caused much of the Corn Belt to revert to wide-row soybeans and other yield-limiting management strategies, such as planting semi-resistant varieties—all in an attempt to avoid disastrous levels of white mold. Looking for a better way, Grau suspected a biological solution might work. In a no-till corn >>soybean rotation, Grau compared cover crops of winter wheat, spring oats, and spring barley (all non-hosts) grown ahead of soybeans, versus check strips of no cover crop. Over multiple years and locations, Grau found that white mold incidence in the soybeans was significantly reduced by all three cover crops, and that the white mold resting structures had indeed broken dormancy in all of the cover crop strips, but not in the check strips.^{4,5}

⁴ Long-term use of cover crops to prematurely break the dormancy of white mold sclerotia may result in shifts of that species toward more precise germination requirements, i.e., *Sclerotinia sclerotiorum* might begin to break dormancy only when sensing compounds exuded by soybean roots, but not winter small

The game gets more complicated when we realize that disease-causing species change their characteristics in response to their environment. Just like some human pathogens have evolved resistance to all known anti-microbials, so does the population of any given crop pest adapt to the control measures used, including adapting to rotations. For instance, *Bipolaris sorokiniana* is a soil-borne fungus causing common root rot in both wheat and barley. Five years of monoculture wheat will cause the population of *B. sorokiniana* to change from being weakly virulent to wheat to becoming highly virulent to wheat, as demonstrated by R.L. Connors and T.G. Atkinson.⁶ The opposite occurred with five years of continuous barley: the *B. sorokiniana* increased in virulence to barley but decreased in its ability to colonize wheat. Other studies support the findings of short rotations (or monocultures) causing increases in both inoculum levels and disease aggressiveness for most pathogens.⁷ Planting non-host crops reduces inoculum levels, but may not alter that pathogen's adaptedness to the host crop, whereas planting crops that are weak hosts or alternate hosts may increase inoculum by allowing the pathogen to reproduce, but may actually reduce the pathogen's aggressiveness in relation to the primary host crop.

UNDERGROUND WORLD

The roots of your crops grow in a unique world—an ecosystem largely unseen and unexplored by humans. Which vascular plants (crops and weeds) are allowed to grow in your fields will radically alter that ecosystem every year.⁸ Every plant has a 'signature' of root exudates (substances leaking from roots), and these exudates may attract or discourage certain species among the diversity of bacteria, fungi, nematodes, and other organisms in the soil. Those species often vie for root exudates as food sources, to the extent of bacteria that produce antibiotics (to kill the competition) and plant growth stimulants to increase root growth.⁹ In turn, some of those species will be food for still other species. Other organisms are free-living, adding to the richness of the soil ecosystem. Many of the species found in the soil ecology help the vascular plants, directly or indirectly—by creating or liberating nutrients, discouraging harmful

grains. Cover crops may be highly effective in the short-term however, and would maintain some effectiveness regardless, to the extent that predation and decomposition would be higher under a canopy of cover crop. A number of fungi are known to attack or inhibit *S. sclerotiorum* in the soil, including *Coniothyrium minitans* (which is actually marketed as a biocontrol product), *Sporidesmium sclerotivorum*, *Trichoderma spp.*, and several others.

⁵ Yields of soybean were highest following the cover crop winter wheat. Whether winter wheat is the ideal cover crop ahead of soybeans remains open to debate—observations in S. Dakota and Kansas indicate allelopathic effects on the soybeans, which do not seem to occur when winter rye or oats are used instead of wheat. In Grau's conditions (high moisture, high disease), the additional growth of the fall-seeded winter wheat (compared with spring-seeded oats or barley) likely overwhelmed all other factors.

⁶ R.L. Connors & T.G. Atkinson, 1989, Influence of continuous cropping on severity of common root rot in wheat and barley, *Can. J. of Plant Pathology* 11: 127-132.

⁷ Some exceptions occur, such as is commonly reported with take-all in wheat—these soil ecologies are termed "suppressive," and are thought to be caused by a resurgence of the 'enemies' or antagonists of the pathogen in question. There is some debate as to whether this is dependent on one or two species, or on entire ecological shifts. In any event, suppressive soil ecologies deriving from monocultures tend to only be effective at controlling a few pests, and do not develop equally in all soils and climates.

⁸ Not only which crop is grown, but which *variety*, significantly affects the soil ecosystem.

⁹ Jill Clapperton, *Creating Healthy Productive Soils*, from Alberta Reduced Tillage (ARTI) website.

organisms, or just by occupying a niche (a robust ecosystem has great diversity, which discourages both invasion and erratic population swings by the various species).

Soil ecosystems are slow to reveal their secrets. Many of the “rotational effects” we observe are likely caused by shifts in the soil community, as they are not explainable by moisture levels, nutrient cycling, or known diseases—a conclusion reached by many independent researchers worldwide.

Choices of crop sequencing are really one of the ultimate tools available for leveraging biology in the producer’s favor. The consequences of getting it right are big. For instance, in ’02 at Dakota Lakes Research Farm in the w.wht >>corn >>broadleaf rotation, winter wheat yields varied from 8 bu/a to 56 bu/a depending on the preceding b-leaf crop. It was a dry year (understatement), so the wheat after soybeans making only 8 bu/a isn’t so surprising. The shocker is the wheat making 56 bu/a after field peas, but only 28 bu/a after canola and 28 after chickpea. According to Beck, wheat after field peas is always some of the best. Moisture, organic N, and mycorrhizal levels may explain some of the differences, but mostly we just don’t know why.

In another example, Randy Anderson’s long-term work at Akron, CO shows an increase in wheat yields of 46% by having corn in the rotation (w.wht >>corn >>fallow versus w.wht >>proso >>fallow). On the other hand, including sunflower in the rotation decreased wheat yields significantly, even with a year of fallow after the flowers, although the loss was reduced (but not eliminated) if a year of corn was included ahead of the flowers.

Underworld inhabitants also have many desirable effects on soil physical characteristics. Want to loosen and aerate the soil? Earthworms can handle that for you, as can plant roots. Redistribute nutrients? Earthworms again. Help plant roots absorb nutrients and water? Mycorrhizal fungi to the rescue. And all of these helpers work best in continuous no-till.

BUILDING A BETTER SYSTEM

All of this is just leveraging biology in our favor (or not). The secret is in figuring out how to let nature solve your problems for you. Fields are ecosystems, and they may either be on life-support or be quite robust. Sometimes we don’t even know how close they may be to crumbling. The nature of epidemics is such that we have been notoriously poor at predicting and preventing them.

The take-home message is that, in the biological world, brute force generally fails. The target almost always finds ways around the pressure, i.e., the pressure forces the target to change. Even if this weren’t the case, the technology is usually expensive. Biological solutions often can be ‘persuaded’ to work for less cost, and they are ‘on the job’ when and where they are needed—much more so than applied inputs.

None of this is intended to be an “avoid technology” message—technology is wonderful, especially when it is used for those problems at which it excels. However, it seems that we have gotten sloppy in thinking technology will bail us out of every jam, or that every new technology must be the most economical way to doing something. The electronic era certainly didn’t spell the end of paper (as some predicted)—we use more than ever—nor will slick new technologies allow you to utterly control everything in your fields and forget about the underlying biological and ecological principles. Your fields will always be a messy tangle of wild biology. Embrace it. Learn to exploit it. This time at least, the future belongs to those with a bit more subtle understanding and finesse.

Editors’ Note: To learn more on “leveraging biology,” catch our blockbuster array of speakers for the No-Till on the Plains’ 2003 Winter Conference in Salina, including venerable no-till researchers Dwayne Beck and Rolf Derpsch. Another featured speaker will be Jill Clapperton, soil ecologist at Lethbridge, Alberta, who will heighten our awareness of fundamental biological happenings in the root zone.

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NUTRIENT EFFICIENCY IN NO-TILL SYSTEMS

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Dr. Fixen is Senior Vice President of the Potash & Phosphate Institute and is located in Brookings, South Dakota. In this position he coordinates the Institute's activities in North America and directs its research program in the U.S. and Canada.

Dr. Fixen grew up on a farm in southwestern Minnesota and received his Ph.D. at Colorado State University. Prior to joining the Potash & Phosphate Institute, he spent nine years in research and teaching in soil fertility at the University of Wisconsin and South Dakota State University. In these positions he authored or co-authored over 150 articles related to soil fertility including several book chapters.

Dr. Fixen has served on many scientific committees and has been active on several boards, including those of the Certified Crop Adviser (CCA) program. He has served as an associate editor for the Soil Science Society of America Journal, as Chair of the Fertilizer Management and Technology Division of the Soil Science Society of America, as President of the North Central Branch of the American Society of Agronomy, and currently serves on the editorial board of the new international Precision Agriculture journal. He is a Fellow in the American Society of Agronomy and the Soil Science Society of America.

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MANAGING SALT AFFECTED SOILS

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The abundance of precipitation in the 1990's has increased the number and extent of salt affected soils in South Dakota. Many of these salt affected soils started in the middle 1990's as small isolated areas that had limited crop yield. As the wetness continued the salt areas grew larger and would support only foxtail barley or kochia vegetation. By the late 1990's many areas have accumulated enough salt on the surface to inhibit kochia survival and ensure barren ground. Before we can attempt to manage these salt affected areas we must first understand that there are different types of salts present in South Dakota soils.

CHARACTERIZATION OF SALINE AND SODIC SOILS

Salt affected soils can be categorized into three groups depending on the total soluble salts and the amount of sodium salts. Table 1 summarizes the different salt affected soils as: saline, sodic, and saline-sodic. Electrical Conductivity (EC), the ability of a soil solution to carry an electrical current, is used to measure soluble salts. The higher the EC value the higher the soluble salt content in the soil. Sodium Adsorption Ratio (SAR) is a measure of the amount of sodium present in comparison to calcium and magnesium. To calculate the SAR you must add the calcium and magnesium together and then divide by two. Next take the square root of the number. Finally, divide the sodium value by the square root number you just calculated. The calcium, magnesium, and sodium concentrations are in milliequivalents /liter. Soils with high sodium concentration typically are not a problem if the soil also has a very high concentration of calcium and magnesium. Soils high in sodium will be a problem if the calcium and magnesium concentrations are low. The pH is a measure of how acid (low pH) or alkaline (high pH) your soil is. Soils that have a high sodium concentration typically have a high pH. It is very important that we understand the difference in these soils as the management is dependent on the type of salt affected soil we are dealing with.

<u>Classification</u>	<u>Electrical Conductivity (mmhos/cm)</u>	<u>Sodium Adsorption Ratio (SAR)</u>	<u>pH</u>
Saline	>4.0	<13	<8.5
Sodic	<4.0	>13	>8.5
Saline-Sodic	>4.0	>13	<8.5

SALINE SOILS

All soils contain some water-soluble salts, but when these salts occur near the surface and start to impede germination or plant growth they are referred to as saline soils (U S Lab Staff, 1954). The high salt content in the soil has an adverse affect on vegetative growth because of three main reasons. They are 1) salts can prevent soil water uptake into the plant because of the osmotic effect; 2) specific ion toxicity, which can disrupt the nutritional processes of the plant; and 3) salts can alter the soil structure and permeability (Brown et al., 1982). Plants vary in their tolerance to salts. South Dakota State University Extension Fact Sheet 903 shows the yield reduction of various crops and grasses due to salinity. Many plants are most sensitive to high salinity levels during germination or at the early seedling stage than as mature plants. The most tolerant crop is barley, while tall wheatgrass is one of the most tolerant grasses.

Electrical conductivity is the common method of measuring the salinity in the soil. The following table indicates the different salinity levels.

<u>EC</u> <u>(mmhos/cm)</u>	<u>Salt</u> <u>Rank</u>	<u>Interpretation</u>
0 – 2	Low	Very little injury to plants.
2 – 4	Moderate	Sensitive plants may suffer
4 – 8	High	Non-salt tolerant plants will suffer
8 – 16	Excessive	Only salt-tolerant vegetation will grow
16 +	Very Excessive	Very few plants will grow

Most saline soils develop a white surface crust. There are typically two different types or formation of saline soils (saline seep or capillary seeps). All saline areas are a result of water movement. As water moves through the soil, soluble salts will be dissolved and increase in concentration in the water. When the water reaches an exposed surface the water evaporates and the salts are left behind to accumulate on the soil surface. It is common for South Dakota soils to have some salts present in the soil profile. That typically does not cause a concern, until the salts are elevated to close to the surface. South Dakota soils tend to have a large amount of salts present in the soil profile because of the lack of adequate rainfall to leach the salts down through the profile and because the soils in eastern South Dakota are fairly young (less than 10,000 years). The majority of these saline areas are located in cropland or poorly managed rangeland. In well managed rangeland, the native vegetation is so efficient at utilizing water that saline soils can not develop. The wetness that South Dakota experienced in the 1990's is nothing new. Studies have shown that South Dakota has had five periods of above average precipitation since the 1650's (Johnson et al., 2000). The four previous wet periods in South Dakota all occurred prior to settlement and thus under native vegetation. The excess precipitation in the 1990's provided the environment to increase the saline soils in cropped fields. There were many areas in fields that did not get cropped in the 1990's because of the wetness at planting time. Later in the year, when it was drier, these nonplanted areas were sprayed

(compliments of 90 foot spray booms) resulting in no vegetation present to utilize this excess precipitation. A combination of a water table close to the surface and no vegetation was a perfect combination for capillary saline soil development. Summer fallow practices farther west were not utilizing enough moisture, resulting in water movement out of the root zone, prime conditions for saline seep development.

SALINE SEEPS

Factors in saline seep formation are the geology of the area, high precipitation, and farming practices that allow water to move out of the root zone into the subsoil (Figure 1). As the excess water continues to drain downward the water will dissolve and accumulate salts. At some point in the subsoil the water will reach a layer of very slowly permeability and accumulate above this layer, forming a perched water table. Over time the perched water will move laterally until the water reaches the soil surface. The water will evaporate, leaving the salts behind to accumulate and form the saline seep (Brown, et. al., 1983). Saline seeps are more common in western South Dakota because of the practice of summer fallow and the majority of the subsoil consists of bedded shale material, which has a very low permeability. The excess water from the summer fallow practice moves out of the rooting zone until it contacts the bedded shale material. In areas where the bedded shale is close to the surface, which often happens, the area will eventually become saline as the water evaporates. The saline seeps in eastern South Dakota are associated with those areas where the glaciated material has variable substratum. In these areas, it is common to have thin layers of sands above finer textured material or thin layers of slowly permeable clay in the subsoil.

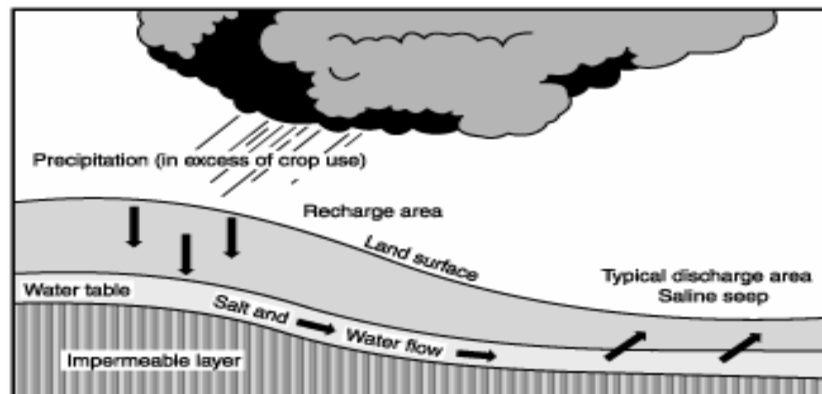


Figure 1. A generalized diagram of a saline seep.

CAPILLARY SEEPS

Capillary seeps are a result of a shallow water table. In capillary flow, water moves from where the soil is saturated, or nearly so, to drier soil independent of gravity. A high water table and a salinity problem can go hand in hand. When a water table gets close enough to the surface, the soil can act as a sponge and pull water up through the soil to the surface (capillary action). Because of capillary action, soils high in clay can pull a water table up 4 to 5 feet while sandy soils, with the larger pore spaces, can only pull the water table about 2 feet (Figure 2) (Franzen et al., 1994). It is not that uncommon for the majority of South Dakota soils to pull the water table up 3 to 4 feet. The salts are left

behind as the water evaporates from the soil surface. This is especially a problem in areas that do not have actively growing vegetation. Without vegetation there is no utilization of the excess water or any cover to prevent the water from being evaporated on the surface.

The majority of the saline soils that have developed during the 1990's in eastern South Dakota are located on the edge of wetlands, along road ditches, field ditches or drainageways. Figure 3 shows how the water high in soluble salts moves away from the water source. The soil evaporation rate is higher along the edge of the wetland and thus

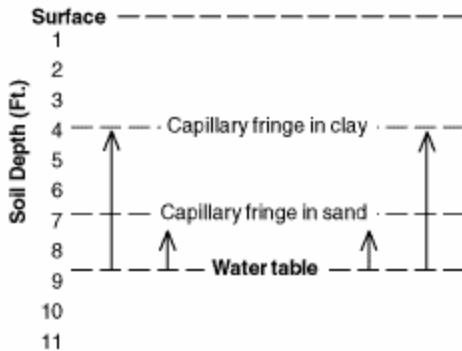


Figure 2. Capillary rise from a 9 foot water table depends on soil texture.

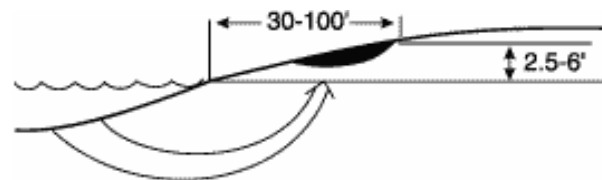


Figure 3. Saline soil development adjacent to pothole, road ditch, or field ditches.

as the water is moved toward the surface the salts are deposited along the edge of the wetland. The EC values of less than 1 mmhos/cm are common inside the wetland, while EC values greater than 10 mmhos/cm are not that uncommon on the wetland edge. In fact, the EC value is generally less than 1 mmhos/cm down to a depth of five feet inside the wetland. These saline areas will continue to occur until it reaches a landscape break. Wetlands that are surrounded by a steep landscape (> 6 % slope) typically will have only a narrow saline areas around the edge of the wetland. The largest saline areas in eastern South Dakota are found on flat land adjacent to wetlands, drainageways, etc. The saline area continues to grow out away from the original source and thus large acres can be consumed by the saline development. The narrow vs. extended saline areas are due to the rise above the wetland. If landscape is a steep short rise it deters the capillary water movement. If it is a low gentle rise, the capillary water movement will extend a greater distance from the wetland.

SALINE SOIL MANAGEMENT

Saline soils can not be reclaimed without first controlling the source of the soluble salts (i.e. water table). The only blessing of the dry conditions in 2002 was that the water tables have definitely been lowered and thus we can start to reclaim these saline areas. First and foremost there are no chemical amendments that will reclaim these saline areas. The application of gypsum and lime on saline soils is like peeing in the ocean, it may make you feel better, but it just adds more salt to the ocean. The salts that have been deposited in these saline areas are very soluble and move quite readily with water, as

evident in how quick these saline areas formed. Now that the water table has dropped any snowmelt or rainfall will start to move the salts back down into the subsoil. This will require some time, as a large amount of salts have been deposited on the soil surface. Think about it, the evaporation rate in South Dakota is close to 40 inches per year. It will take time to move that much salt back into the subsoil. Tillage of saline areas will make the site look better (white to black) but typically will increase the surface salt concentration. A number of hot windy days and your black area is back to white. This is again caused by the evaporation of the water and leaving the soluble salts behind.

The following practices can aid in reclaiming saline soils: 1) intensify cropping rotation or plant salt tolerant crops; 2) drainage or tiling; 3) organic matter application; 4) perennial vegetation/CRP. Intensive cropping can reduce or eliminate water movement out of the root zone, which is eventually carried to the seep area. Eliminating fallow or growing crops that use more water, such as alfalfa are strongly recommended on the recharge area. The most salt tolerant crop available for these saline areas is barley followed by rye. Any drainage or tiling that can intersect the saline water flow to the surface can help with these saline areas. The major problems with drainage or tiling are the possibility of a wetland violation, cost of drainage/tiling, and trying to find an outlet area. Inadequate drainage can lead to a salinity problem not only around the rim of the wetland, but of the entire wetland itself. A shallow surface ditch out of a wetland will not lower the water table enough to prevent the formation of a saline soils around the edge of the wetland, but it will lower the water table enough in that the entire wetland can become salted out. Any type of organic matter application will increase the productivity of the saline area. The organic matter can help the soil tilth and also provide a barrier on the soil surface to prevent evaporation from the soil surface. Any method that eliminates evaporation reduces capillary rise of salt towards the saline area. Perennial vegetation or a deep-rooted crop (alfalfa) is the quickest and most effective method of reclaiming saline seeps. After vegetation is established in the upslope recharge area, it will intercept the saline water flow and prevent additional salt accumulation. The United States Department of Agriculture administers the Continues Conservation Reserve Program (CRP), which enables a producer to enroll these saline areas into the CRP program, for a yearly payment for 10 years. The contract requires establishment of permanent salt tolerant vegetation on the saline area and permanent vegetation on the adjacent recharge area. The CRP program will allow 10 acres of recharge area for every acre of saline area with a maximum contract of fifty acres. There is 50 percent cost share on seed cost, seedbed preparation, and seeding operation. Dormant seeding of these saline areas with western wheatgrass or tall wheatgrass has been successful. Research has shown that a one-inch spring rain can reduce salt concentration by 50 percent in the top inch or two of the soil. This gives the seed an opportunity to germinate prior to salts moving back to the surface (Franzen et al., 1994).

SODIC SOILS

Sodic soils are low in total salts (EC), but are high in exchangeable sodium (SAR). As mentioned in Table 1, a sodic soil should have a SAR value greater than 13. This number is not absolute because the type of clay and the soil organic matter content

influence the value. As mentioned earlier, sodic soils are high in sodium concentration in relation to calcium and magnesium. The sodium will replace the calcium and magnesium on the clay particles, which causes the soil to become dispersed, and destroys the soil structure. When the soils become dispersed, clay particles will move down in the soil profile to form a layer of clay, enriched with sodium salts. All sodic soils will have a dense clayey layer within 18 inches of the surface and thus are commonly referred to as claypan soil, gumbo, or slickspots. These soils are very hard when dry, sticky when wet, and nearly impervious to roots, water, and air. Sodic soils typically have a very high pH (> than 8.5), but it is not that uncommon in eastern South Dakota for the sodic soils to have a pH down to 7.8. Because of these high pH values these sodic soils are typically referred to as black alkali soils. These soils are usually located on a level or nearly level landscape. Sodic soils normally are intermingled with non-sodic soils and often occur in very slight depressions on the landscape. Sodic soils are usually naturally occurring, and usually not caused by man's influence.

Using the Natural Resources Conservation Service (NRCS) soil survey publications can help to identify sodic soils. The NRCS has produced soil survey maps will indicate the presence or absence of sodic soils. There are very few sodic soils in the eastern third of South Dakota, with the majority of the sodic soils located in the James River Valley or the northwestern area of South Dakota (Figure 4). The NRCS recognizes three different types of sodic soils, based on the depth to the claypan, ranging from 0 to 6 inches, 6 to 12 inches or 12 to 18 inches. The sodic soils with the dense claypan layer within 6 inches are better suited to grass than crop production. These soils have a high SAR value near the surface and are virtually impervious. Farming this soil would be like farming the interstate highways. The sodic soil with the claypan layer at 6 to 12 inches typically does not have a high SAR value within in the top two feet, as the sodium is slowly starting to move through the profile. These soils can be farmed and will be productive under certain conditions. These certain conditions consisting of a normal to dry spring so the crop can be planted and timely rains throughout the growing season as the rooting depth is limited on this soil. One heavy rain will drown out the crop because of the slow permeability and any prolonged dry period will be detrimental on the limited rooted crop. Both types of sodic soils with claypan within 12 inches of the surface tend to crust relatively easy, because of the low organic matter content and the clay dispersion. The sodic soils with a fractured claypan layer at 12 to 18 inches is the most productive sodic soil, nearly as claypan layer at 12 to 18 inches is the most productive sodic soil, nearly as productive as non-sodic soils high in clay. The sodium has leached below the rooting depth and the once impervious claypan layer is partially fractured and thus roots, water, and air are able to pass through the profile. These soils only show decreased productivity during abnormally wet period (slow to dry) or abnormally dry periods.

SOUTH DAKOTA CLAY PAN SOILS

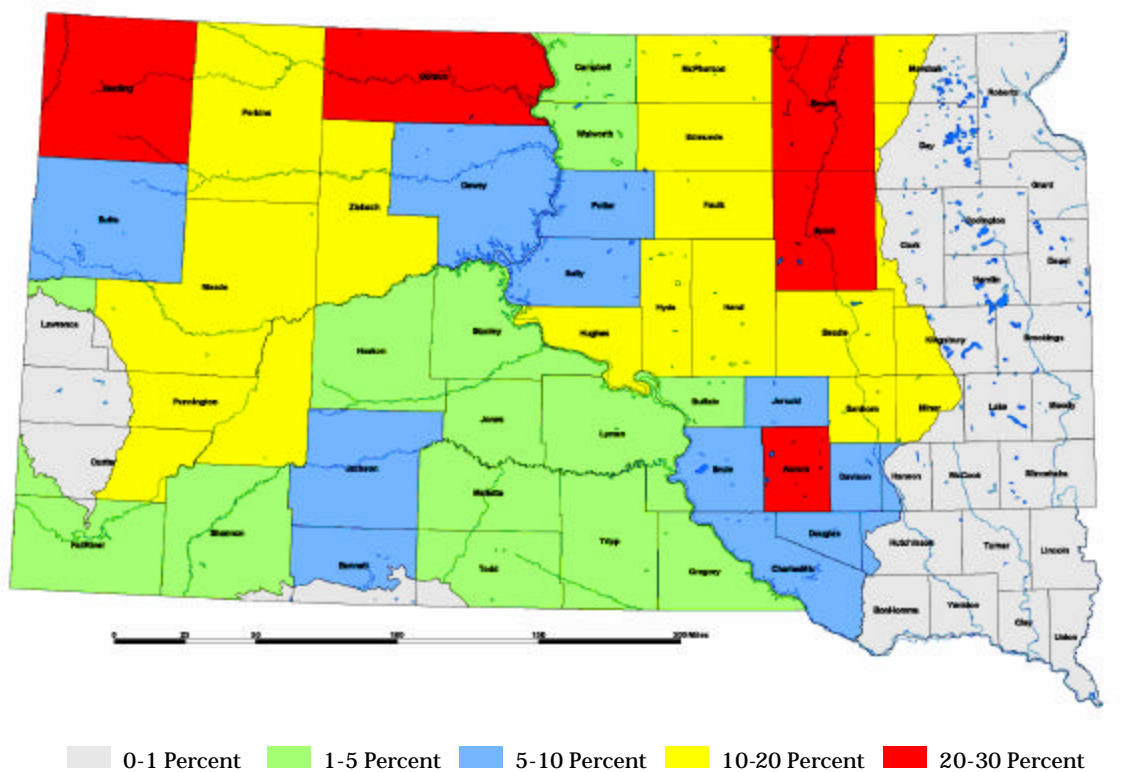


Figure 4. Percentage of sodic (claypan) soils for each county in South Dakota

Source: Counties, lakes and rivers-SD Dept. of Transportation; Claypan soils from soil surveys-NRCS-USDA; Projection Universe Traverse Mercator, Zone 14, NAD 83 Map produced by Brookings Field Support Office NRCS-USDA, January 2002

Vegetative growth is limited because of the shallow rooting depth in claypan soils and the high pH. Most roots are restricted to the topsoil above the claypan. This dense claypan also restricts water, nutrients, and air movement. The effect of sodic soils on crop growth is most noticeable in dry years. The high pH of the sodic soils reduces the availability of some plant nutrients, such as phosphorus, iron, and zinc.

RECLAIMING SODIC SOILS

Sodic soils are usually the most expensive type of soil to reclaim. Sodic soils can be reclaimed by adding chemical amendments, adding organic matter, or deep tillage (Seelig and Richardson, 1991). The purpose of applying chemical amendments is to supply calcium in the soil water for the replacement of the absorbed sodium on the clay particles. The major chemical amendments are gypsum (CaSO_4), lime (CaCO_3), elemental sulfur, and sulfuric acid. Gypsum is the most common amendment and also adds sulfur to the soil. Lime is only beneficial if the pH is below 7.5. The elemental sulfur or sulfuric acid will be beneficial for sodic soils that are calcareous (high in calcium carbonate). The sulfur will react with the calcium carbonate to form gypsum. The finer textured soils (clay soils) require more amendments and a longer time period to reclaim than coarse textured soils (sandy soils). Application of elemental sulfur is a slower process, as microbial

activity is required to oxidize the sulfur. These chemical amendments are only beneficial on sodic soils and not saline soils. Applications of amendments may be largely ineffective unless the soil is periodically leached so the sodium can be moved deeper in the soil profile. Reclaiming sodic soils is slow because the poor soil structure is slow to improve.

Adding organic matter is always beneficial when working with sodic soils. Decomposing organic matter helps stabilize calcium as well as providing channels in the soil to conduct water, and to help reduce evaporative losses. The organic matter also helps to lower the soil pH, which decreases the exchangeable sodium near the surface. The organic matter stimulates microbial activity, which promotes aggregate stability of the soil particles.

To be effective deep tillage should reach below the sodic subsoil and mix several inches of the underlying material with the subsoil and topsoil. Many of the sodic soils contain natural gypsum below the claypan layer and thus deep tillage may bring the gypsum to the surface to react with the sodium. Depending on the soil, tillage to a depth of 15 to 36 inches may be needed. On-site investigation is needed to confirm the feasibility of deep tillage in a particular area. Any reclamation of sodic soils is a long-term endeavor. Complete reclamation may never be achieved.

IRRIGATION AND SALT PROBLEMS

All water from sources other than precipitation contains some salts. Application of irrigation water will increase the soil salinity. This is not a problem with good quality water (i.e. Missouri River) or if the soils are coarse textured. The biggest problem exists when poor water quality (high in total salts or sodium salts) is applied to finer textured soils. These soils have slow permeability and thus the salts can not be leached out of the soil profile and become concentrated at the surface. Table 3 indicates the severity of poor water quality on heavier soils. This center pivot has not had any water applied since 1981. The irrigation water was so high in sodium that the quarter of land was virtually ruined.

<u>Sample</u>	<u>Depth (in)</u>	<u>EC</u>	<u>SAR</u>
Outside the Center Pivot	0-2	0.4	1
	2-6	0.4	1
	6-12	0.3	1
Inside the Center Pivot	0-2	1.0	6
	2-6	1.2	8
	6-12	1.8	18

Make sure you know the quality of the water you are applying, especially on heavier soils. Please refer to the following publication for additional information on water quality and irrigation: Irrigation: Your Water, Your Soils, and their Compatibility.

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FORAGE AND GRAZING... NO-TILL PROFITABLE

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The need to change is a prediction of the future, not a judgment of the past. I copied this off the wall of a successful man's office.

Yes, we can change and shift our paradigms and attend meetings and read and visit and do research and demonstrations and.....

Wonder-what will this change cause or do for or to me. Success comes in many forms. The great Wayne Gretzky has a success formula: "I skate to where the puck will be, not where it is now." How do we become profitable? We plan our profits against our goal. How important is the goal? All important! Once while working with a farm family, they told me their goal was to "get out of debt". I told them I could do that—sell the cows—sell the machinery and sell the land—and then they stopped me. "But we still want to farm." So, the goal was manageable debt and some profits, not no debt and no farm. As world class no-tillers, Duane Beck tells me you can grow anything. So, what is the problem? I see two problems (1) does the different crop meet your personal goal, and (2) does the new crop provide profitability? An aside. It has been said that to learn something new—read an old book. Here are 3 old books of value:

1. Malabar Farm by Louis Bromfield
2. Grass Productivity by Andre Voisin
ISBN: 0-933280-64-5
3. Plowman's Folly by Edward H. Faulkner
ISBN: 0-933280-43-2

Here is a new book of value:

1. Holistic Management by Allan Savory
ISBN: 1-55963-488-x

The folks in New Zealand read the old books-revolutionized their cropping and grazing and we copied their system of "intensive grazing" for our grass-based dairies. Another book of value to cropping is:

1. The One Straw Revolution by Masanobu Fukuoka
ISBN: 0-87857-220-1

First things first. Here is the holistic management model (simplified) as developed by Alan Savory.

In order you need these steps.

Step 1: Identify the people, resource base, and money currently available.

Step 2: The people create and write out their holistic goal. Note a singular goal with 3 Statements:

1. Quality of life
2. Production that provides quality of life*
3. Future resource base description:
(land, technology, advisors/researchers, customers, neighbors)

*A crops farm-statement would include profits from the production and marketing of agronomics crops. See how profit is planned...more later.

Step 3: Test decisions against the goal. Does this action move us toward or away from our goal?

We look at the triple bottom line: biological, sociological, and economic sustainability. Holistic managers use seven testing questions to arrive at the triple bottom line. Society and culture is always relevant in rural communities. Neighbors all watch and evaluate their neighbors. Remember the "I farm ugly" jingle and caps? Will my neighbors accept my new enterprise?

Using this model we have seeded most of our tillable land to permanent forage for grazing. Our wealth-generating question is: "What today is impossible to do, but if we were able to do it, it would fundamentally change the way we do business? Winter feed costs often are the difference between profit and loss with cattle. I have looked at many ideas used in Canada. (We have 2 children, a son-in-law from Sask and a daughter-in-law from Manitoba. How about that contribution to NAFTA?)

Our cowherd has bulls turned out on August 4 and calves start on May 15. Most of the winter these cows are hardly P.G. so nutrition requirements are easy to meet. The goal is to graze as long as possible using standing stock piled forage. Swathed feed that is grazed in the windrow, and finally bales grazed on the land. Yes, we are working in drought proofing just like no-tillers. Keep the soil covered etc. But, our moisture is not always predictable so yearlings are the shock absorber. They can be moved and sold easier than cows. (Multiple cropping or enterprises.)

How do you measure dollar return from grazing enterprises? Here is an example of tillable land seeded to Indian head black lentils (20 lbs. @ 30 cents, seed cost of \$6 acre). Inoculate, weed control and test phosphorous. Seeding was early May and grazing in August.

VALUE OF GRAZING?

100 acres for 130 cows for 2 months. 130 cows @ \$15 per AUM x 2 months=\$3900.

\$3900/100=\$39 per acre gross as pasture rent.

Or, what really happened?

130 cows x 60 days/100 acres=78 ADA

ADA is animal days per acre. So each acre supported 78 cow/calf pairs for one day. The calves gained at least 2.5 lbs per day.

78 ADA x 2.5 ADG=195 lbs beef per acre

Sell calves for \$80 cwt

195 x .80=\$146.25 acre

This ignores the cow condition. They were in excellent shape from green grazing. Also, how much nitrogen was fixed? 20 up to 50 lbs per acre @ .25 is worth \$5 to \$12.50 per acre. Note: This is in 12-inch moisture world.

The swath-grazing example: 84-bushel oats, cut at beginning of kernel development. 100 acres, 180 cows for 70 days.

180 x 70/100=126 ADA

Value @ \$1 per day...\$126/ acre. Neighbors evaluation: "Now all his shit is in windrows."

The ultimate no-till system: cows on grass. Would you believe that is the title of an article by Russell J. Lorenz in the November 1983 North Dakota Stockman Magazine. Russ Lorenz and George Rogler had 79 years of research combined between them in 1973. This table is for their fertilized work on crested wheat grass.

Ten year average	No Nitrogen	40 Pounds	80 Pounds	Alfalfa Crested Wheatgrass
Pounds of beef per acre	100.7	168.8	176.3	135.4
Daily gain per animal	2.66	2.63	2.53	2.82
Acres required per animal	0.97	0.62	0.50	0.88

We graze lots of crested wheat grass. My students know that my special list in life begins with: number 1-wet toilet paper, number 2-crested wheat grass, and number 3-could be you. We bought a farm of crested wheat (next door). I traveled to Wisconsin to a dairy grazing conference. The lesson they taught was: "Bite the grass so it grows sideways not up to form the seed head." So-o-o—we fenced 40-acre paddocks and grazed up to 400 steers or 350 cows at one time. They moved often.

Grazing and grass growth go together:

	Fast Growth	Slow Growth
Re-growth	3 days	10-15 days
Recovery	30 days	60-90 days

Re-growth and the second bite of green growth will damage the plant. So, get on and get off. Recovery is when the plant has enough time to re-grow and start the process of storing energy below ground.

A soil building note: Louis Brumfield in Malabar Farm stated the fastest way to rebuild worn out farm ground was to plant grass and pulse graze with dairy heifers. Gene Goven of Turtle Lake, ND had a plan to on purpose set his combine to throw over some extra grain. He then grazes and regrazes the fall growth. Surprise-surprise- the fields that were grazed-regrow-grazed-regrow until freeze up had faster and more total increase of organic matter than fields where sweet clover was plowed down. Great things happen at the mycorrhize level if we allow or create the condition by management. Oh yes, profits. Gene found that in good years and poor years, the value of this grazing equaled one-half the value of his crop.

Back to the crested wheat. We have produced and harvested 30 up to 85 ADAs per acre. Lots of beef.

Another Canadian copycat by us, alfalfa and meadow brome grass seeded on tilled ground. The learning curve of not bloating and killing the stock is less steep than with pure stands of alfalfa. Yearling steers can be stocked at 1 head per acre for 60 to 80 days. They gain over 2 lbs per day. This produces 120 to 160 lbs of beef per acre. (Conservative). This same ground produced an average of 25 bushels of spring wheat.

What is the value of gain on stocker yearlings?

Sale	850 lbs @ \$.80=	\$680
Purchase	450 lbs @ \$.95=	\$428
Gain	400 lbs	\$252

$\$252/400=.63$ value of gain

How about the good year?

Sale	850 lbs @.80=\$680
Purchase	450 lbs @.75=\$338
Gain	400 lbs \$342

$\$342/400=.855$ value of gain

So those steers grossed \$75 to over \$100 per acre. The exceptional year of the cattle cycle was over \$125 per acre. Why do I need or want a combine?

THE PRINCIPLES:

1. Plan grazing based on forage plant re-growth (not the calendar)
2. Keep soil surface covered and avoid bare ground
3. Fancy cattle may look good, but not be most profitable (we do graze next to the highway)
4. Fertilizer "N" can be a major wealth generator
5. Have a diverse selection of forages to spread and extend the grazing season
6. Remember: Plants like to put down roots and grow in one place while animals like to walk around and graze. Your job is to allow these natural instincts to coincide.

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ROTATING WHEAT FOR A PROFIT

Kendall Peterson

Spink County Fertilizer
PO Box 109
Northville, SD 57465
(605) 887-3422

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PROFITABLE NO-TILL SYSTEMS DESIGNED FOR PRODUCERS IN THE NORTH AMERICAN GREAT PLAINS AND PRAIRIES

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[Dakota Lakes Research Farm](#)
South Dakota State University

In an effort to save trees (and time) we have chosen to limit our remarks in these proceedings to some brief comments. The in-depth information that normally would be included is more easily and comprehensively accessed from our home page (www.dakotalakes.com). It is hoped that this approach will allow the user to tailor the information for their specific needs. “No-till Guidelines for the Arid and Semi-arid Prairies” is recommended for beginners and experienced producers alike.

The title of this presentation “Profitable No-till Systems Designed for Producers in the North American Great Plains and Prairies” was purposely chosen rather than a title such as “Conservation Farming on the North American Great Plains and Prairies”. On the surface there does not appear to be a great deal of difference between these titles. The geographic region of interest is the same. Both imply that farming practices are to be discussed. However one title uses the words “Conservation Farming”. This refers to soil and water conservation. In reality, this needs to be done in order for agriculture to be a renewable industry rather than (as it predominately is now) an extractive industry such as mining, petroleum, etc. Conserving soil and water resources should be a primary goal for every producer. However, the present economic system does not directly reward a farmer for conserving the soil and water with which he works. In fact with numerous “conservation farming” techniques the opposite occurs. The producer is often faced with the decision whether to conserve the resource or maximize profit. If he doesn’t do the latter, someone else will be farming his land in the future; mining the soil that he conserved. For this reason, conservation cannot be the only goal. Maximizing short-term profitability also cannot be the only goal if a producer hopes to remain (or have his family remain) on the land he farms.

The Dakota Lakes Research Farm has both a research and a production enterprise. The production enterprise must produce sufficient profits to fund a majority of the operational expenses of the research enterprise. For this reason, the first priority of the production enterprise is to be profitable.

This dual enterprise structure was established in 1983 in an attempt to provide an independent source of funding that was less prone to influence by special interests and politics. This required substantial change in what was then a conventional tillage based research operation. Substantial expansion in the amount of land managed was required to provide a sufficient base to operate both a production and a research enterprise. If conventional farming practices were to be used on both the production and research

enterprises a large investment in machinery and manpower would be required. This did not appear to be a prudent course. Consequently, it was decided that the production enterprise would be designed to utilize the manpower available and require only minimal investment in new machinery. The plan was to accomplish this through the use of diverse crop rotations. Weak-link analysis indicated that moisture would be a limiting factor for many of the potential rotational crops. Consequently, a key component of this plan was adoption of moisture conserving practices to allow growing of high water use crops in a region where their production was marginal with conventional tillage.

A holistic or systems approach was taken. This meant that component and technique choices were based on evaluation of how that choice would impact other components in the system. It was evident that (in 1983) there was not an adequate amount of knowledge available on the type of farming system needed for this situation. This meant that many of the component choices required to build the system could not be based directly on research data or producer's experience as is commonly done in agriculture. Consequently, many choices were based on fundamental agronomic principles using natural cycles and native vegetation as a guide. Research projects were initiated concurrently to better define components and techniques for areas where knowledge was lacking.

The present operation at the Dakota Lakes Research Farm is substantially different than what was begun in 1983. Only part of this difference is due to technological changes that have occurred in the last 17 years. A majority of the difference stems from developing a better understanding of what happens when crops are grown in a manner which places heavy emphasis on developing a healthy and biologically active soil ecology and uses cultural practices (rotation, sanitation, competition) as the primary methods of pest control.

An example of this philosophy sees weed problems as a symptom that the farming system does not contain sufficient diversity (the weed is Mother Nature's way of trying to add diversity). With conventional thinking attempts would be made to control this weed with herbicides or tillage. The systems approach adds a crop to provide the diversity that was lacking. With this philosophy, attempts are made at preventing problems by addressing the cause rather than merely treating the symptoms as they appear.

Many of the farmer practitioners of this technique refer to accepting this approach as having a "brain transplant" since it requires developing new skills and a different attitude. Most important among these is the need to realize that to be sustainable and profitable on a long-term basis the farming system must be designed such that natural cycles and principles become an ally rather than an enemy. Inputs such as fertilizers or pesticides then become methods to augment or initiate natural cycles rather than being tools designed to stop processes that are natural.

Tillage selection is a primary example of this different approach. In natural systems, tillage is a catastrophic event (associated with glaciers, erosion, volcanoes, etc.) that occurs only rarely. Both macro and micro fauna are profoundly impacted. Soil dwelling species are disrupted to an even greater degree than those that can migrate to more suitable habitat. With frequent and repeated tillage, the soil ecology becomes predominated by species that require tillage in order for residue and nutrient cycling to occur. Since tillage generally occurs prior to plant growth being initiated, nutrients have been placed in a mobile form before they are needed, making them vulnerable to loss. If tillage is not performed, lack of aeration (caused by the poor soil structure that results from repeated tillage) causes nutrient cycling and crop growth problems. In undisturbed natural systems, nutrients and residues are cycled by a complex web of macro (grazing animals, earthworms, mites, spring tails, etc.) and micro (fungi, VAM, bacteria) fauna. In this system, residues are maintained to protect the soil until new plant growth occurs. Canopy conditions created by this new growth allow residue decomposition rates to accelerate. This residue decomposition releases nutrients for use by the subsequent crop when they are needed. If this system were not properly balanced, the prairies of North America would either be deserts or hay stacks. In farming systems designed to mimic undisturbed natural systems, fertilizers are utilized to replace nutrients exported from the system and are applied in a manner to provide an early competitive advantage to the crop that is to be harvested.

This complex web does not reappear quickly when a soil that has been tilled for a number of years is managed without tillage. The soil structure and organic matter lost during the tillage period does not reappear quickly either. For this reason, initiating low-disturbance techniques requires careful planning in regard to how the transition can be made without sacrificing short-term profitability. Many of the struggles and failures associated with producers adopting low disturbance methods trace to inadequately addressing this issue.

Similar analysis can be performed in relation to the impact tillage choice will have on weed pressure, insects, diseases, etc. Nutrient and residue cycling was chosen to provide an example of the thought processes involved.

The Dakota Lakes Research Farm did not initially choose to use reduced tillage techniques because of the soil and water conservation benefits; or due to the fact that soil health and nutrient cycling would be improved; or for wildlife benefits; or for carbon sequestration potential; or any of the other benefits brought to light in the last 10 to 15 years. The decision was made on the basis of the potentially improved profitability that the moisture conservation and workload spreading characteristics provided. The ultra-low disturbance, diverse crop rotations system that has evolved also owes much to the desire to maximize the utilization efficiency of manpower and machinery resources. It has also resulted in lower pesticide use and higher yield levels than anticipated. It is believed that much of this is due to a better understanding of the use of natural cycles. It is also quite possible that soil health and soil ecology play a much greater role than has been realized in the past.

It is almost certain that no producer will utilize exactly the same system components used at the Dakota Lakes Research Farm. Their physical (soil, climate, etc.) and fiscal (machinery, capital, manpower) resources differ from ours. Their choice of components should reflect these differences. The fact that the basic laws of nature function the same independent of these differences does indicate that the “SYSTEMS” approach successfully used at the Dakota Lakes Research Farm (and more importantly by producers in other parts of the world) may provide insight in potential approaches to be used in developing improved farming systems.

CUSTOMIZING THE “SYSTEM”

The Dakota Lakes Research Farm enterprise presents a good example of how basic principles are used to create systems suited to differing physical resources. At the present time, the operation manages slightly over 1,200 acres of land. Some of this land is classed as a short-grass prairie due to the fact that it has shallow, clay, soils that limit available water holding capacity. Some of the land is short-grass prairie because of sandy soils that limit available water holding capacity. Some land is classed as mixed-grass prairie because the soils have good water holding characteristics. Some of the land is irrigated. This removes water availability as a primary constraint. Some land is close to the headquarters. Other land is as much as 40 miles away and requires moving machinery through the city and across the Missouri River Bridge in order to reach it. Some of this land has over 10 years of no-till history; some has just been acquired. Some has a history of over 50 years of wheat-fallow management with tillage; some has never been tilled (it was brought into production from native sod without tillage). Some land is owned; some land is rented. Differences in addition to these exist as well. It would be unwise to attempt to manage each of these situations with the same components. They are, however, all managed using the same approach to create a system designed to optimize the contribution that property makes to the operation. This approach is based on the application of fundamental agronomic and biological principles. These principles do not change.

One of these basic principles is that water utilization intensity must be proper. In other words the water use must match the water available. If the system is not sufficiently intense problems such as water logging, saline seep formation, nutrient loss, traffic ability problems, etc. are common. If the system is too intense, poor yields due to water stress or stand establishment problems are likely. Under irrigated conditions at Dakota Lakes the intensity of water use is limited only by the amount of growing season and heat received in the summer and by the availability of capital, manpower, and equipment to pump water from the Missouri River when it is needed. The choice to limit intensity under irrigation therefore is based on fiscal (manpower, equipment costs, energy) resources. On the dryland portion of the operation, intensity of water use is controlled by physical resources (soil type, rainfall, climate, etc.). In both cases, improper intensity results in management problems and less than optimum profitability. No-till management allows (requires) more water use by the crop (transpiration) since less water will be wasted by the direct and indirect impacts of tillage (evaporation and runoff).

Another basic principle is that diversity must be adequate (appropriate). As mentioned before, lack of diversity provides an opportunity for weed and disease organisms to build to harmful levels. The cost of controlling these opportunistic species and the capability to do so needs to be evaluated in each situation as it compares to what can be accomplished by using more diverse crop rotations. Under irrigated conditions at the Dakota Lakes Research Farm, corn (field and popcorn) and beans (edible and soybean) are the crops capable of returning the most increase in yields from the fixed costs associated with the irrigation development. If all acres were devoted only to these crops much of this increase would be offset by increased variable costs (pesticides), reduced efficiency in use of fixed machinery resources, and reduced yields. In addition, energy costs would rise on both a per acre and per unit of production basis. Some of this is caused by lower yields but most is due to a reduction in electricity price if the supplier is allowed to control (turn off) the irrigation pumps during periods of peak electrical demand. By devoting part of the acreage to rotational crops which do not share the same peak water use characteristics as corn and beans this can be done without limiting the ability to supply all crops with their full water needs. Consequently, on the irrigated portion of the operation, adding diversity has more impact in reducing variable costs than on reducing fixed costs although both are benefited. Conversely, on the dryland portion of the operation adding diversity provides the most benefit to reducing fixed costs (land, family labor, and machinery) per unit of production (not necessarily per acre). Variable costs are also reduced dramatically (especially pesticide inputs) once the system is in place and working properly. This may not be true during transition periods. Seed and fertilizer costs change very little on a per unit of production basis.

The bottom line of this approach is to view each farming operation as unique. The goal is to optimize the utilization of the resources (land, labor, capital, and machinery) available to that operation in a profitable and environmentally compatible manner. This requires devising a unique system for each operation, owner, parcel of land (and even portions of a piece of property), etc. rather than attempting to devise a farming recipe that fits all fields of all producers in all situations.

COMMON CHARACTERISTICS

This is not meant to imply that there are no common characteristics amongst the most successful no-till systems being used at Dakota Lakes and by real producers throughout the plains and prairies. Foremost among these is the inclusion of three or four crop types (cool-season grass, cool-season broadleaf, warm-season grass, and warm-season broadleaf) in the rotations used. Where cool-season crops are traditionally grown, addition of the warm-season grass component provides more benefit (adds more diversity) than adding a warm-season broadleaf because of the commonality of some diseases (such as white mold) and herbicide programs among warm and cool-season broadleaf crops. Rotations that are not consistent in terms of either interval or sequence provide the best protection against species shifts and biotype resistance. In other words rotations such as wheat-canola or wheat-canola-wheat-pea are consistent in both interval

and sequence. Wheat always occurs in alternate years and always follows a cool-season broadleaf. Rotations such as s.wheat-w.wheat-pea-corn-millet-sunflower are not consistent in either interval or sequence. Rotations should have crop type to crop type intervals of a minimum of two years somewhere in the rotation. Extended perennial phases (grass seed, alfalfa) minimize agronomic problems associated with the low diversity rotations in the annual cropping portion of the rotation. This approach is useful in some situations but does not normally lead to optimization of machinery and labor resources. Perennial sequences are an excellent way to “jump start” the system. Another trend that is obvious especially in the Dakotas, Kansas, Nebraska, and Colorado is a move to the use of lower disturbance techniques as rotations improve. This trend is stymied at times by limited choices in seeders that have the capability to properly place fertilizer while accurately seeding with low-disturbance. Dormant seeding of spring cereals (especially wheat) has become a predominant practice for many producers. This technique shifts workload from the busiest time of the year to a less busy time. When this is properly done, benefits for many operations far outweigh the risks. Dormant seeding of canola is not as well proven and consequently is not as widely employed. Producers in higher rainfall areas and those with irrigation are beginning to utilize cover crops as a means of adding diversity and intensity to their systems.

WRAPPING IT UP

Soil and water conservation are a consequence or side benefit of utilizing properly designed no-till systems. Sustainable profitability must be the primary goal in order to assure that conservation continues long-term. The best systems attempt to mimic native vegetation in terms of intensity (water use) and employ as much diversity as needed to optimize the system. Each resource (land, machinery, labor, etc.) is managed to optimize its contribution to the operation without overtaxing its capability. More in depth information on these subjects can be found at the dakotalakes.com web site and related pages. Of specific interest would be “No-Till Guidelines for the Arid and Semi-arid Prairies”.

AN EMPHASIS ON ROTATIONS

Determining what to grow as rotational crop(s) 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 to be Beck's TOP 10 LIST. The order they appear does not denote their importance.

1. Reduced and no-till systems favor the inclusion of alternative crops. Tilled systems may not.
2. A two season interval between growing a given crop or crop type is preferred. Some broadleaf crops require more time.
3. Chemical fallow is not as effective at breaking weed, disease, and insect cycles as are black fallow, green fallow, or production of a properly chosen crop.
4. Rotations should be sequenced to make it easy to prevent volunteer plants of the previous crop from becoming a weed problem.
5. Producers with livestock enterprises find it less difficult to introduce diversity into rotations.
 - a. Use of forage or flexible forage/grain crops and green fallow enhance the ability to tailor rotational intensity.
6. Crops destined for direct human food use pose the highest risk and offer the highest potential returns.
7. The desire to increase diversity and intensity needs to be balanced with profitability.
8. 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.
9. 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.
10. 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

CLASSIFICATION OF ROTATION TYPES

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

SIMPLE ROTATIONS: 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;
S. Wheat-W. Wheat-Corn-Sunflower; Corn-Soybean; Winter Wheat-Corn-Pea

ADVANTAGES: Simple-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. In other words this style is consistent in both sequence and interval. Conditions for each crop are the same on all of the acreage.

SIMPLE ROTATIONS WITH PERENNIAL SEQUENCES: Simple rotations that are diversified by adding a sequence of numerous years of a perennial crop.

EXAMPLES: C-Sb-C-Sb-C-Sb-Alf-Alf-Alf-Alf 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. 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 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 6 years of corn-soybean in a perennial sequence rotation and 14 years of 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: Combination of two or more simple rotations in sequence to create a longer more diverse system.

EXAMPLE: S. Wheat-W. Wheat-Corn-Soybean-Corn-Soybean.

This results from a combination of the Corn-Soybean and S. Wheat-W. 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 1/3 of the acreage is in corn and 1/3 in soybeans.

COMPLEX ROTATIONS: Rotations where crops within the same crop type vary.

EXAMPLE: Barley-W.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.

ADVANTAGE: This type of approach is capable of creating a wide array of crop type x 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.

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

STACKED ROTATIONS: One of the less well-known approaches is one we call stacked rotations. This includes rotations 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-Sb-Sb; Barley-Wheat-Pea-Canola

STACKED ROTATION CONCEPTS: This should not be an unfamiliar concept because it is the way that 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, frequent 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.

It is probably best to provide a few examples. In the Corn Belt and in irrigated areas on the plains in the US, it was at one time common for many growers to produce corn on the same land every year. When this was done, an insect known as the corn rootworm beetle (there are different species with similar habits) would feed on the corn silks and lay eggs at the base of the corn plant. Most of these eggs would hatch the next spring. If corn or other suitable hosts were present, the larvae would 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 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 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.

The examples given dealt with insects. 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 7 years in a row). Then almost without warning the system fails. Everyone with resistant weed biotypes has witnessed this phenomenon.

The second part of the stacked concept is to have a long break (crop to crop interval) in the rotation. From a diversity standpoint it is better to have a mixture of intervals. To provide maximum protection against pest 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 does as well or maybe 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 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 sufficiently. 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. When the homesteaders came, that is why they were initially so successful (and the fact that they had a huge no-till history preceding them). In Argentina, it is still common to rotate 7 years of pasture with 7 years of cropping. On rented land this may be 7 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 mycorrhizal 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 N because higher rhizobia populations exist in the soil. The soil is also lower in mineral nitrogen sources since the previous years 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.

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. A typical herbicide program at Dakota Lakes for a S.Wheat-W.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 dicamba. Second year corn receives a traditional program. A GMO like Liberty-Link or Clearfield could be used. We do not use Roundup-ready in this slot at Dakota Lakes. 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 6 years, triazines once in 6 years, Roundup Ready once in 6 years (and perhaps a burndown between wheat crops also but this could be paraquat). 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.

It would be possible to fill several more pages with stacked rotation concepts. I believe most readers will be able to develop these themselves once they begin to think about it. We will conclude with a final example. Recently, I saw an agronomist give 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. My response was that 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.

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. Less crops means less workload spreading.

ROTATIONS UTILIZING BOTH STACKED AND NORMAL SEQUENCES: This approach is a hybrid between stacked rotations and the other types. The idea 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 rotation planning to understand how natural cycles work and uses sequences and intervals to create the type of environments that favor the crops while preventing problems.

EXAMPLE: Canola-W.Wheat-Soybean-Corn-Corn and S.Wheat-W.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 SW-WW-Pea-Corn-Millet-Sunflower rotation is designed for cool and dry areas. The two cereals in a row follow a 4-year break for cereal. This builds deep soil moisture and surface residue. Winter hardiness of the WW 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.

It is hoped that the above discussion has been helpful. It 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.

THE FOLLOWING ARE SOME STATEMENTS CONCERNING ROTATIONS:

- I have no better chance of designing the best rotation for you than I have of choosing the best spouse for you. There are things in life that you have to do on your own. I can point out some factors you should consider when choosing a rotation.
- 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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