RESEARCH REPORT

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Agricultural Research Service

The North Central Soil ConservationResearch Laboratory

Preface

By A.A. Jaradat

The Lab's present and future, as was its past, are critical to Minnesota, its farming communities and to farming communities throughout the upper Midwest. There is a long and productive history of collaborative research involving our major stakeholders: the farmers, the Barnes-Aastad Association, the State, the University of Minnesota, and private agricultural interests.

During the last 40 years, scientists at the Lab, addressed problems faced by Midwest farmers in order to conserve valuable soil resources for crop production. Most recently, however, the Lab is developing farming systems in the Midwest that are environmentally, economically and socially sustainable. These cropping systems are based on proper land, crop and weed management practices to enhance the biological, chemical and physical properties of soils, and to reduce impact of farming on environmental quality.

The Lab conducts its research under four major themes. ***Land Management:*** to identify tillage and cropping practices that will minimize soil and water degradation as well as optimize soil carbon storage, microbial activity, and soil microclimate. Identify the importance of natural and mechanical forces in eroding soil; determine the value of adding organic carbon to soils for enhancing crop production; identify the potential of using fatty acid methyl ester (FAME) extraction as an indicator of soil quality; and identify soil elements that limit crop yield. ***Carbon Cycling:*** to identify and quantify impact of specific components of cool, wet soil environments that influence biochemical and microbial activity involved in decomposition of plant residues, re-cycling of carbon and nitrogen compounds, and storage of soil carbon; determine effect of various cropping systems on carbon dioxide flux from soil; evaluate the economic sustainability of integrating biofuel crops into corn-soybean rotations; and develop methods for quantifying soil carbon content. ***Crop and Weed Biology:*** relate microclimate to crop and weed development, and include relationships in user-friendly software; develop management strategies for consequences of adopting alternative and transgenic crops; provide information for management and genetic improvement for tolerance of traditional and new crops to temperature and water stresses; assess ability of temperature-sensitive polymer seed coatings to protect seeds in cold and wet soils; and supply basic knowledge of soil-plant-nitrogen interactions for improving fertilizer recommendation models. ***Sustainable Cropping Systems:*** determine the agronomic, economic and environmental risk/benefits of adopting and transitioning into alternative cropping systems including organic and minimum tillage production systems and the introduction of alternative crops; develop the technologies to facilitate the transfer of research results to customers, including on-farm research and involvement of farm managers in research planning; and develop decision aids that include economic analysis of various crop and resource management strategies.

During 2002, soil scientists carried out research on soil erosion, tillage-induced erosion and carbon loss, and soil fertility management. Crop scientists initiated research to delineate the underlying biological processes limiting corn growth during cold wet spring seasons, plant and soil biochemical processes related to carbon and nitrogen cycles to enhance soil quality and crop productivity, weed biology, control and dynamics, and evaluate cultural practices, cuphea as an alternative crop. Additional research being conducted at the ARS laboratory into more efficient nutrient use will have positive economic and environmental impact for producers at state, regional, national, and international levels. This research could lead to reduced fertilizer costs for growers and also reduce the environmental risks associated with crop fertilization.

The development and testing of new and alternative crops for the Midwest are important for the diversification and long term development of sustainable strategies for producers. Winter canola, annual medics and a South American Lupin species were introduced as potential alternative crops. The list of alternative crops is long and it will continue to change in response to environmental conditions, market forces and consumer preferences. Certain specialty crops can be used to improve the health of the soil by replacing nutrients used in crop production. Bioenergy and biomass crops, on the other hand, could have significant impacts on the agricultural sector in the Midwest in terms of quantities, prices and production location of traditional crops. Of course, these crops also can be expected to affect farm income.

The Lab embarked on a new endeavor to translate its mission into 21st Century language, where new tools are needed to generate new information and develop new management practices in order to preserve the productivity gains of the 20th century, provide strong protection for the environment and lay down firm bases for vigorous rural communities. **The new mission of the Lab is to** "*Develop agricultural systems in the Midwest that are environmentally, economically, and socially sustainable by providing knowledge and technologies for proper land, crop, and weed management to enhance the biological, chemical, and physical properties of soils, and to improve environmental quality.*"

In 2002, the ARS laboratory began important research into integrated farming systems. This interdisciplinary, long-term, research is aimed at developing agricultural systems research that protect the environment and, at the same time, enhance rural communities. This research effectively utilizes the short growing season in the upper Midwest, and should allow farmers to successfully improve the productivity, and expand production of traditional and new crops. Moreover, it will provide farmers with much needed information and skills on how to effectively rotate diverse crops with corn and soybeans.

This participatory research is the key to successful and immediate technology transfer, both of which will be implemented as a part of the "New Mission." The goals of this initiative are to offer Barnes-Aastad and the farming community the opportunity to play a leadership role through research, education and demonstration in helping growers in the upper Midwest make the transition agronomically and economically to a more diverse cropping system, adoption of appropriate management technologies and introduction of alternative crops, and provide databases and understanding of the variable soil characteristics, biotic and abiotic pressures, and historic crop yield and quality attributes over a typical landscape as the foundation for the adoption and perfection of precision-agriculture technology in this region.

The Lab opened its doors to the public during the National Ag Week celebrations and during the Field Day at the Swan Lake farm. The objectives were to showcase the research activities that have been and are being conducted and to increase awareness of their relevance to the farming community and the public at large.

The Lab continued to host visiting national and international scientists and graduate students with research interests relevant to the Lab mission and objectives. The Lab will continue the current thrust and will emphasize collaborative research and training dealing with cropping systems, alternative crops, and soil health as components of the overall management and sustainability of soils and their productivity.

Finally, the "Soils" Lab is more than what the name implies. And this is why, after adopting a new mission, the Lab is in the process of acquiring a new name! The Lab is requesting members of the Barnes-Aastad Association and the community at large to come up with a new name for this research facility; a name that can reflect the new research direction and, at the same time, preserve the long and productive work on soil conservation.

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Chapter

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The Barnes-Aastad Association

When the USDA-Soils Lab was established back in the late 1950's, one of the major research needs was information addressing water runoff and soil erosion in western Minnesota and eastern North and South Dakota. The predominant soil type in this region was the Barnes-Aastad clay loam complex. So the early charge to the Soils Lab was to conduct field research on cropping systems that would reduce water runoff and soil erosion on Barnes-Aastad soils. This required land with a uniform 6% slope, Barnes soil, and access to a water source for applying simulated rain events on research plots.

A group of farm managers and business people organized themselves into the Barnes-Aastad Soil and Water Conservation Research Association and sold stock to raise funds to purchase 130 acres of land adjoining Swan Lake about 10 miles north east of Morris. This Swan Lake Research Farm is leased to the USDA-ARS Soils Lab for research purposes.

Each year the Barnes-Aastad Association sends a delegation to Washington D.C. each year to inform USDA-ARS of producer and society needs in rural America, and to lobby Congress to support federal funding of research to find solutions to these ever increasingly complex problems.

Over the years, the Barnes-Aastad Association has developed a strong relationship with important groups in Washington, D.C. Additions of scientists and bricks and mortar can be directly attributed to the efforts of the Barnes-Aastad Association.

Meet Our Scientists

David W. Archer, Agricultural Economist

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Economics and management of alternative cropping systems, and the development of decision aids to improve cropping systems management.

Frank Forcella, Research Agronomist

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Weed ecology, management, and modeling, with the goal of achieving "right-input" agriculture.

Russell W. Gesch, Plant Physiologist

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Identifying and characterizing biological factors in crops and management strategies for improving tolerance to environmental stress, and development of new/alternative crops.

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Accelerated domestication, evaluation and management of alternative crops to fit current and alternative cropping systems.

Jane M-F Johnson, Plant Biochemist

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Carbon and Nitrogen dynamics of plants and soils as related to Carbon sequestration and greenhouse gas emissions.

Alan E. Olness, Soil Scientist

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Soil chemistry, conservation of soil fertility, plant nutrition and complex plant nutritional relationships, and soil resource use efficiency.

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Tillage-induced Carbon Dioxide loss and developing improved soil and residue management practices to enhance carbon sequestration and and environmental quality.

Meet Our Collaborators

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Soil movement by tillage and effects on long-term soil sustainability.

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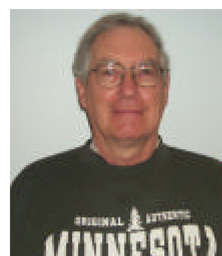


Agronomic effects of soil compaction caused by wheel traffic of farm machinery.

Chapter

2

Land Management

Soil and water are two of the most important natural resources we have. The way we handle crop residues after harvest, and the kind of tillage we use can have an important impact on the quality of both soil and water.

The objectives of the Land Management Project are to: Identify tillage and cropping practices that will minimize soil and water degradation as well as optimize soil carbon storage, microbial activity, and soil microclimate. Identify the importance of natural and mechanical forces in eroding soil. Determine the value of adding organic carbon to soils for enhancing crop production. Identify the potential of using fatty acid methyl ester (FAME) extraction as an indicator of soil quality. Identify soil elements that limit crop yield.

Insights into Soil Management

By Alan Olness

Many landscapes appear to be rather uniform. However, a new approach to evaluating soils revealed huge differences between soils over very small (less than 100 yards) distances in the field. During 1999, we sampled four soils from the Northern Great Plains in North Dakota, South Dakota, and Minnesota. Our

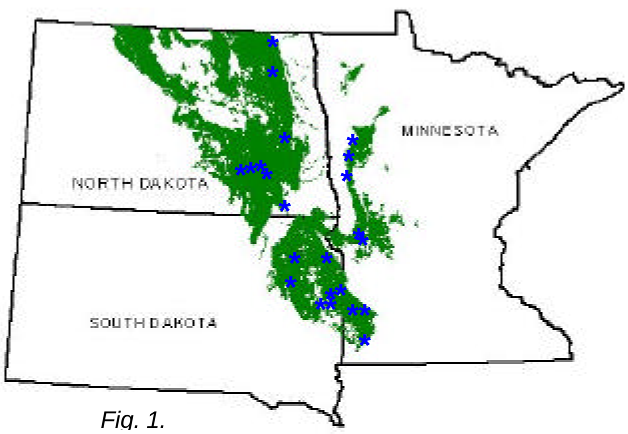


Fig. 1.

sites ranged from the Canadian border to the southern border of Minnesota (Fig. 1).

The four soils chosen were the Barnes loam, Buse loam, Langhei loam, and the Svea loam. The Svea soil was sampled only in South Dakota. These four soils usually exist next to each other in the field (Fig. 2).

The Barnes loam is located on or near the crest of the knolls and the Buse loam is usually located immediately next to Barnes soil. The Langhei is usually located on the steeper slopes and the Svea soils are usually located at the base of the slope. The Barnes

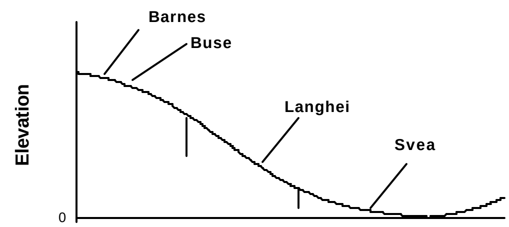


Fig. 2.

and Svea soils usually have neutral or near neutral surface horizons or top-soils; that is, they have a pH of about 7. The Buse and Langhei soils have free calcium carbonate at the surface; so, their pH values usually range from about 7.5 to 8.0 or more. In appearance, the Barnes, Buse, and Svea soils are similar but the Langhei soil has a much lighter color (Fig. 3).

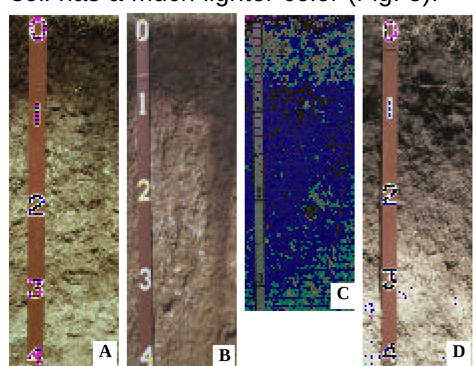


Fig. 3.


Fig. 4.

These soils are generally rich in organic carbon (the Langhei soil has less than the others), total bicarbonate extractable P and available K. So, it

Fig. 5.

isn't surprising that these soils receive uniform management (Figs 4 and 5). But should they?

When we apply resin extraction methods to surface samples from these soils, we find very different phosphate extraction relationships from these soils (Figs. 6, 7, 8, and 9). The Langhei soils seem to be particularly difficult; they have ample amounts of total P but little readily available extractable P. The Buse soils seem to have much less readily extractable sulfur and it would appear that they might respond to sulfur fertilizer additions.

A few years ago we noted that some varieties of soybean and hybrids of corn seemed to respond to greater magnesium:(magnesium + calcium) ratios in the soil. This led us to test the idea that magnesium fertilizer might be a possible fertilizer for some varieties of soybean. We tested this idea at the Barnes-Aasted Research Farm last year and, indeed, we got a small response to a very small application of magnesium placed over the row (Fig. 10). This wouldn't have been predicted from the usual soil testing methods because these soils are rich in magnesium.

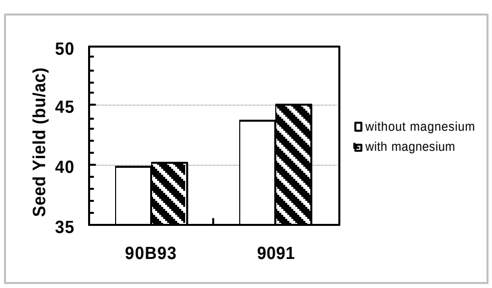
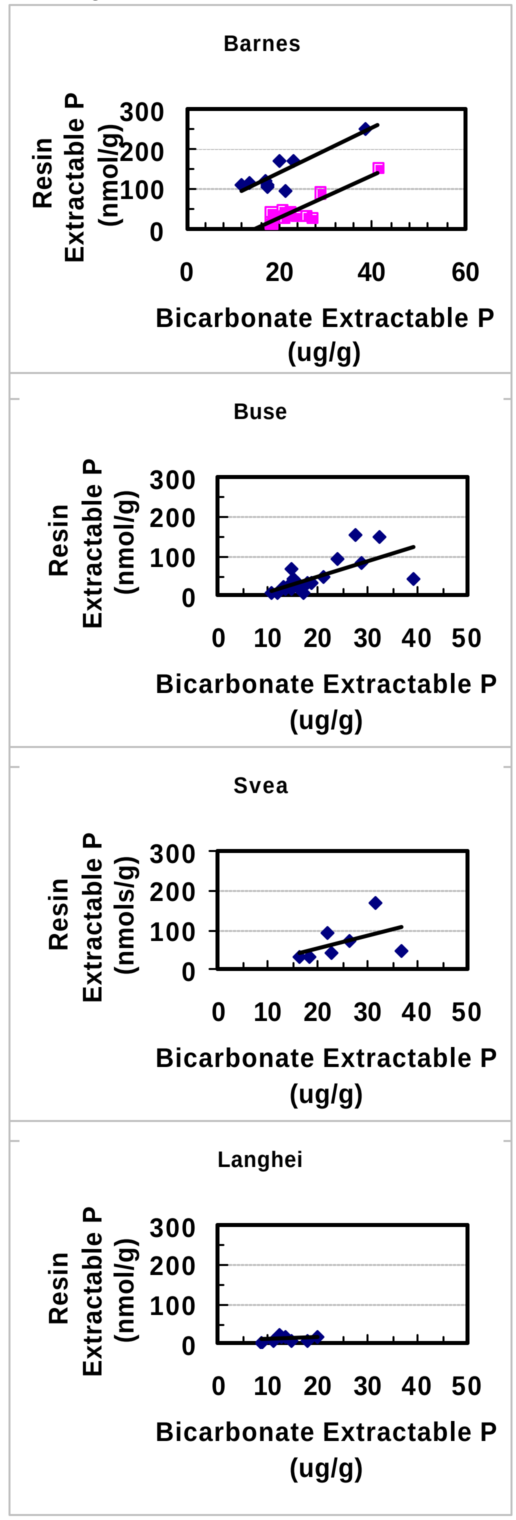


Fig. 10.



Figs. 6,7,8 and 9.

Chapter 3

Soil Carbon Cycling

Building soil organic matter is a very complex process, and is affected by crop, management and climate variables; the benefits of which include less carbon dioxide loss to the atmosphere as a greenhouse gas, and more stable soil structure to reduce erosion.

The objectives of this research project are to: identify and quantify impact of specific components of cool, wet soil environments that influence biochemical and microbial activity involved in decomposition of plant residues, re-cycle carbon and nitrogen compounds, and storage of soil carbon. Determine effect of various cropping systems on carbon dioxide flux from soil. Evaluate the economic sustainability of integrating biofuel crops into corn-soybean rotations. Develop methods for quantifying soil carbon content.



Plants, Soil Carbon and Climate Change

By Jane Johnson

The evidence for climate change continues to mount. Carbon dioxide, nitrous oxide and methane are the major greenhouse gases from agricultural production (crop and animal). Climate change can have a profound impact upon agriculture. Research addresses strategies for agriculture to reduce net greenhouse gas emissions. Research is also being conduced to address with how a changing climate may impact plant growth and development.

The problems

Carbon dioxide released from burning fossil carbon (coal, petroleum), tilling prairie, forestlands, or farmland, and burning of forests have all contributed to the increased amount of carbon dioxide currently in the atmosphere by converting stable non-gaseous forms of carbon into carbon dioxide. Methane has a warming potential of 21 compared to carbon dioxide and is a concern primarily in animal production systems. Nitrous oxide is present at concentrations dramatically less than carbon dioxide, but every nitrous oxide has 270 to 310 times the warming potential of carbon dioxide. Agricultural land is a major contributor of nitrous oxide in the environment via chemical and biological conversion of nitrogen fertilization. Crop rotation and other management decisions change the rate of emission for nitrous oxide and carbon dioxide.

Search for Solutions: GRACEnet effort

By Jane Johnson, Don Reicosky, Dave Archer, Nancy Barbour, Chris Wente and Jim Eklund

How can United States' agriculture reduce greenhouse gases? The USDA-ARS-NCSCRL, Morris, MN, along with more than twenty other ARS laboratories are trying to answer this question. These laboratories are coordinating their efforts through GRACEnet program. GRACEnet stands for Greenhouse Gas Reduction through Agriculture Carbon Enhancement Network. These locations span both crop and grazing land. The goal is to identify management systems, which store carbon, while reducing greenhouse gas emission (carbon dioxide, nitrous oxide, and methane). Both environmental and economic implications of the management systems will be addressed.

GRACEnet compares four management scenarios. The first is **Business as Usual,** which refers to management practices typical of an area. The second is **Maximum Carbon Sequestration,** which refers to economically and technically feasible practices for storing carbon in soil. The third is **Optimize Greenhouse Gas Benefits**, which refers to practices that minimize greenhouse gas emission (carbon dioxide, methane and nitrous oxide) including livestock operations. The final is **Optimize Environmental Benefits**, which refers to practices that attempt to improve the environmental friendliness of agricultural systems.

One of the challenges in comparing these farming approaches is the development of common protocols for sampling and measurement to produce comparable data among treatments and locations. In addition, a common data management strategy is under development to assure ease of collating information from the different locations. Communication among the locations has been established with workshops, training and conference calls.

Nitrous oxide contributes to global warming and the depletion of the stratospheric ozone layer. The effects of farming practices on soil have been identified as a major source of nitrous oxide in the atmosphere.

Therefore, quantifying emissions is important for future policy decisions in agriculture. Several members of our laboratory will be attending a training workshop on measuring nitrous oxide from soil. In the summer of 2003, nitrous oxide and carbon dioxide emissions will be quantified on plots, which reflect the various farming scenarios.

Several projects related to GRACEnet are in progress at our laboratory: 1) comparing gas emission (carbon dioxide and nitrous oxide), soil quality, productivity and economics on the plots comparing conventional and

organic farming systems with different fertilizer and tillage management; 2) investigating tillage erosion and spatial variation on carbon loss across an eroded landscape; 3) investigating the effects of strip tillage on a corn-soybean rotation; 4) identifying crop rotations for maximum soil carbon input and above ground biomass for biofuel needs; 5) determining the value of adding carbon to soil for enhancing crop production; 6) and participating in a multi-location effort studying the implications of using corn stover as a biofuel.

Answering the question of how United States' agriculture can play a role in reducing greenhouse gases is challenging but very important. The formation of GRACEnet, utilizing multiple locations is a vital step in providing sound information for prudent policy decisions.

Implications of Using Cornstalks for Production of Ethanol

By Jane Johnson and Don Reicosky

The goal of biofuel development is to provide a renewable and sustainable fuel supply that is environmentally sound. This reduces dependence on foreign oil supplies while reducing the amount of fossil fuels burned. When fossil fuels are burned, old, stable carbon is released into the atmosphere as carbon dioxide, which would otherwise remain stored. Carbon dioxide is fixed through photosynthesis by the crops used for biofuel. When the biofuel is used, carbon dioxide is released. Thus, the carbon cycle in a managed agricultural system adds little or no net carbon dioxide to the atmosphere.

The United States Department of Energy (DOE) and private enterprise are developing a fermentation process for producing ethanol from materials, which are high in cellulose (corn stocks) rather than starch (corn grain). There are many high cellulose biomass sources (wood crops, lumber waste, forage crops, industrial and municipal wastes, animal manure and other crop residues). Corn residue production is very large and considered a reliable source of cellulose material.

It is important to consider both evaluating the economics and environmental impacts of ethanol production from corn stalks. In 1999, a joint effort between DOE and the United States Department of Agriculture-Agricultural Research Service (USDA-ARS) was launched to

study the erosion, soil quality and productivity issues related to removing corn stalks for ethanol production. This group met in February 2003 to review progress and to identify those research areas that still need to be addressed.

There are six USDA-ARS locations across the corn-growing regions of the United States involved in this research including the North Central Soil Conservation Research laboratory (Soils lab) at Morris, MN. Each laboratory is utilizing its unique strengths to address various aspects of this large issue.

The laboratory in Morris has the unique distinction of working with the material, which is left after the corn stalks have been fermented. It is important to have a disposal plan for this fermentation by-product. The under-lying assumptions is that corn residue is valuable for erosion control and maintaining soil organic material. Removal of corn residue could result increased erosion and accelerated loss of soil organic matter due to decreased residue inputs. The hypothesis was that if the by-product of fermentation was returned to the field, it could offset some of the potential negative effects of removing the corn residue. Experiments have been conducted to study the effects of the by-product on biological, chemical and physical aspects of incorporating the high lignin-containing by-product to soils with different levels of organic matter.

2.2 % Tot. C	3.1 % Tot. C
2.1 % Org. C	0.4 % Org. C
0.2 % Tot. N	0.07% Tot. N
pH 7.8	pH 8.3
non-eroded soil	eroded soil

Core studies were done to the very limited availability of the fermentation by-product. The impact of the by-product was compared adding nothing or adding corn stover. In 2001, the amount of corn stover used was equivalent to the amount remaining at low yield (70 bu/acre) and in a similar study in 2002 at high yield (160 bu/acre) rate was used. The data from 2002 is still being analyzed.

Decomposition is measured by the amount of carbon dioxide released. The by-product because of its high

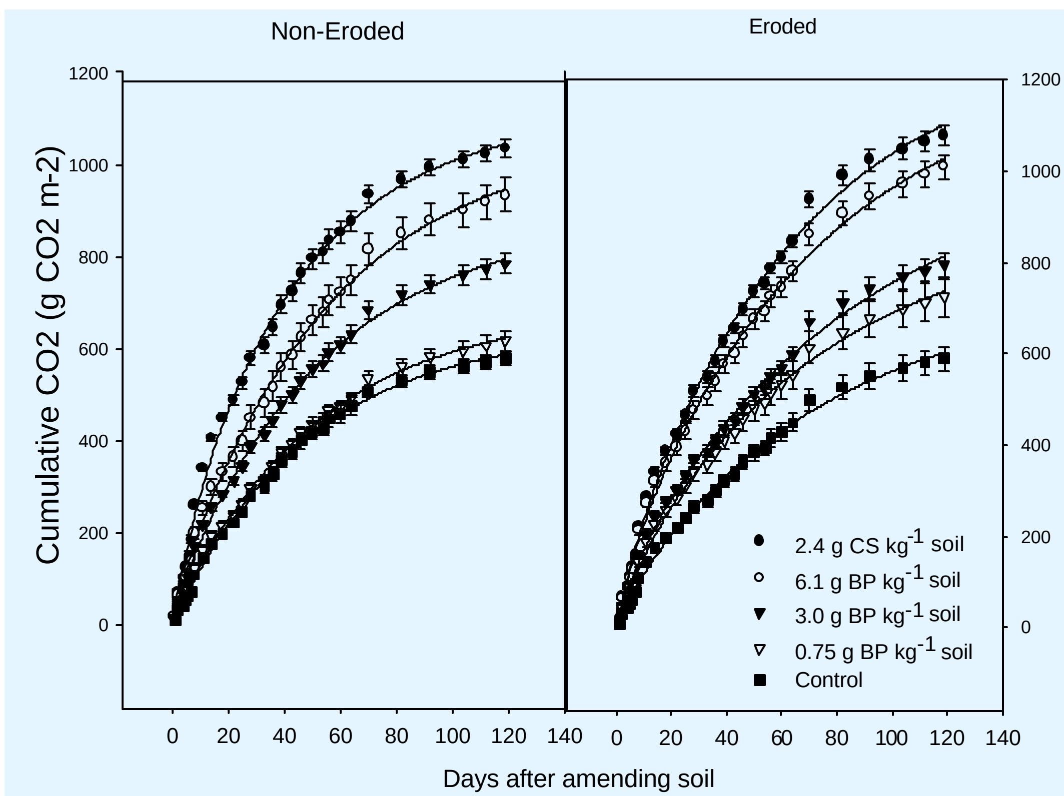
lignin concentration decomposes more slowly than corn stover. Based on the 2001 study, after 118 days, less than 20% of the by-product had decomposed but about 50% of the corn stover had decomposed. Therefore, the by-product can provide a source of slowly decomposing material.

Humic acid is one measurement of soil organic matter. There was some evidence on the severely eroded soil that addition of the by-product could increase humic acid. The amount of humic acid extracted form soil treated with corn stover was about the same as the amount extracted on soil treated

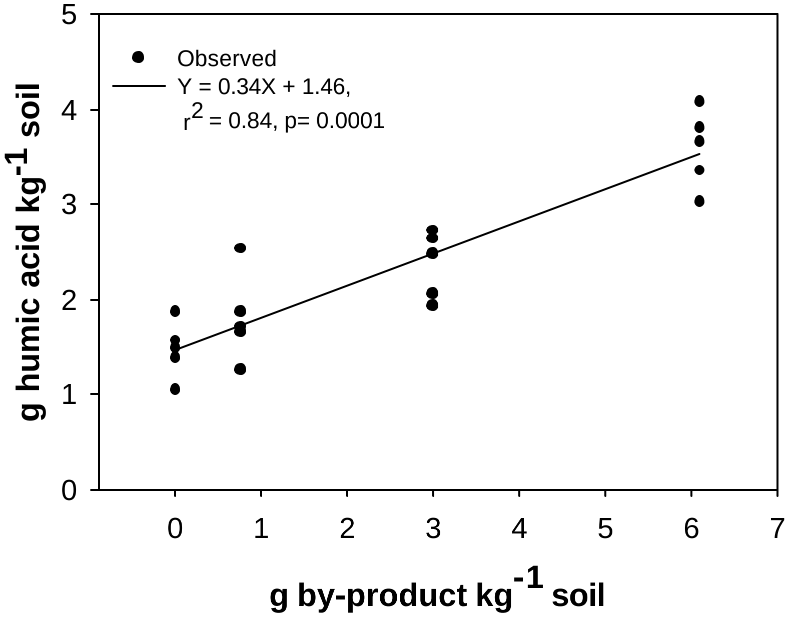
at the lowest rate of by-product. In addition, the number of stable aggregates increased with increasing by-product application on the severely eroded soil. Corn stover had stable aggregates between the two highest by-product treatments.

Studies at the Morris laboratory suggest this by-product has merit as a soil amendment by adding slowly decomposing organic material. This material may also reduce soil erodibility by increasing the stable aggregates. The draw back is that after fermentation the material has a very high water content, which making it expense to transport. An alternative use for the by-product would be to use it for the production of electricity.

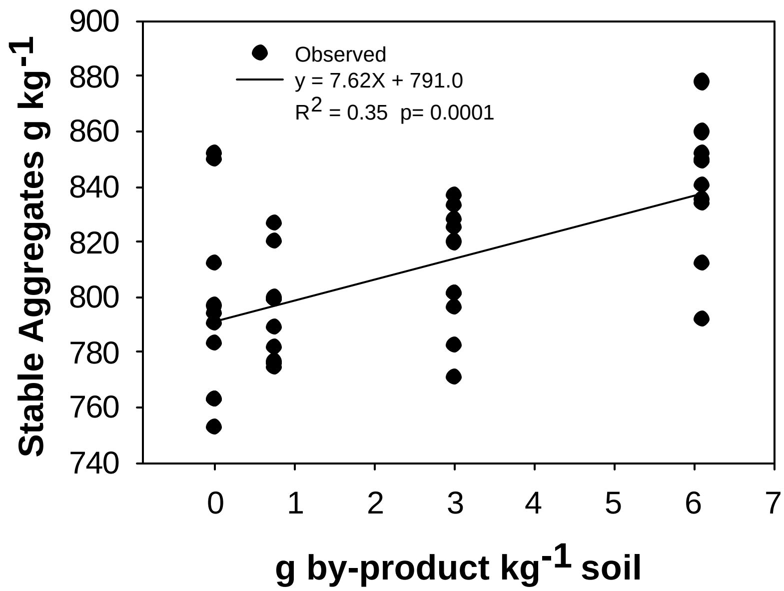
As the biofuel industry expands to include crop residues, research by USDA-ARS at the Morris laboratory and others will help ensure that harvest of those residues is done in a manner that prevents soil erosion and preserves soil organic matter; thus, maintaining long-term soil productivity and environmental quality.



CS=corn stover, BP=by-product of corn stover fermentation



Observed
Y = 0.34X + 1.46,
r2 = 0.84, p= 0.0001
g humic acid kg-1 soil
g by-product kg-1 soil
0
1
2
3
4
5
6
7



Observed
y = 7.62X + 791.0
R2 = 0.35 p= 0.0001
Stable Aggregates g kg-1
g by-product kg-1 soil
740
760
780
800
820
840
860
880
900

Carbon Cycling

By Jane Johnson and Nancy Barbour

It is important to understand the carbon cycle through photosynthesis and respiration. Simply photosynthesis uses the light energy to convert carbon dioxide and water into sugar. Respiration collective refers to the processes that convert sugar back into carbon dioxide and water so the energy stored in the sugar can be used. Green plants are the most recognized organisms that are capable of photosynthesis. All living organisms including plants respire. When fungi and bacteria consume material, it is referred to as decomposition.

How quickly plant material decomposes is dependent upon the composition of the material. The compounds that decompose the easiest and fastest are proteins, starch, and sugars. Cellulose and hemicellulose are made up of sugars, but because of the way those sugars are linked together many organics are unable to break them apart so they simply pass through (for humans this is fiber). Plants also have lignin, wood is primarily lignin – it's tough and hard to decompose. If you are concerned with digestibility (e.g. cattle forage), then plants would be selected for less lignin, but if you what material that will decompose slowly, then you would want more lignin.

In the biochemistry laboratory at NCSRL the composition of common crops, alternative and biofuel crops are being researched, comparing species and plant part (leaves, stems and roots). The relationship between the composition and decomposition is being compared. The information will be helpful in predicted how long plant material will store the photosynthetically fixed carbon before it is returned to the atmosphere by respiration.

Bt vs non-Bt Corn

By Jane Johnson

Casual field observation suggested that the residue of Bt corn does not breakdown as quickly as corn residue form non-BT varieties. Therefore, a simple laboratory experiment was conducted to verify and understand this observation by a college intern Nancy Ruther. Corn from two hybrids, which differed only in the presence of the Bt gene were collected from the Swan Lake research farm (courtesy of Dr. Alan Olness and Jana Rinke). The plant material was dried and finely ground. Some of the material was analyzed for starch, cellulose, and lignin. The Bt corn had slightly more starch but less cellulose and lignin compared to the non-Bt corn. A small amount of material was mixed with soil and incubated under conditions near ideal for decomposition. The release of carbon dioxide was used as a measure of decomposition. The Bt treated corn released more carbon dioxide compared to the non-Bt corn; meaning more had decomposed compared to the non-Bt corn. This does not rule out the possibility that the corn stock of Bt corn breakdown was slower in the field, as the experiment used very finely ground material. The experiment showed that once the material is macerated it will decompose as quickly as non-Bt corn. Separate experimentation is needed to determine how Bt and non-Bt corn is broken down into smaller piece by insects and other small organisms.

Wheat and Switchgrass Response to Temperature

By Jane Johnson, Russ Gesch and Nancy Barbour

One aspect of climate change is increased global temperature. It is predicted that average global temperature could rise 2.5 to 6°C (5 to 12ºF). Increases in growing season temperature can reduce yields. Temperature can alter plant growth and development, changing how crops partition photosynthates among shoots, roots and reproductive parts.

A growth chamber experiment was conducted to determine the effect of hot temperatures on wheat and switchgrass. Two temperature ranges were used 33ºC day /27ºC night (91.4/80.6ºF) and 24/18ºC (75.2/64.4 ºF). It was hypothesized that hotter than optimum temperature would increase photosynthesis and respiration, but decrease starch and sugars. As expected, wheat growth and development was dramatically inhibited at the hotter temperature compared to switchgrass. Switchgrass is a C4 species used on CRP and has potential a biofuel had increased shoot and root growth at higher temperatures but wheat growth was dramatically reduced (Table 1). The concentration of starch decreased in both species at the hotter temperature.

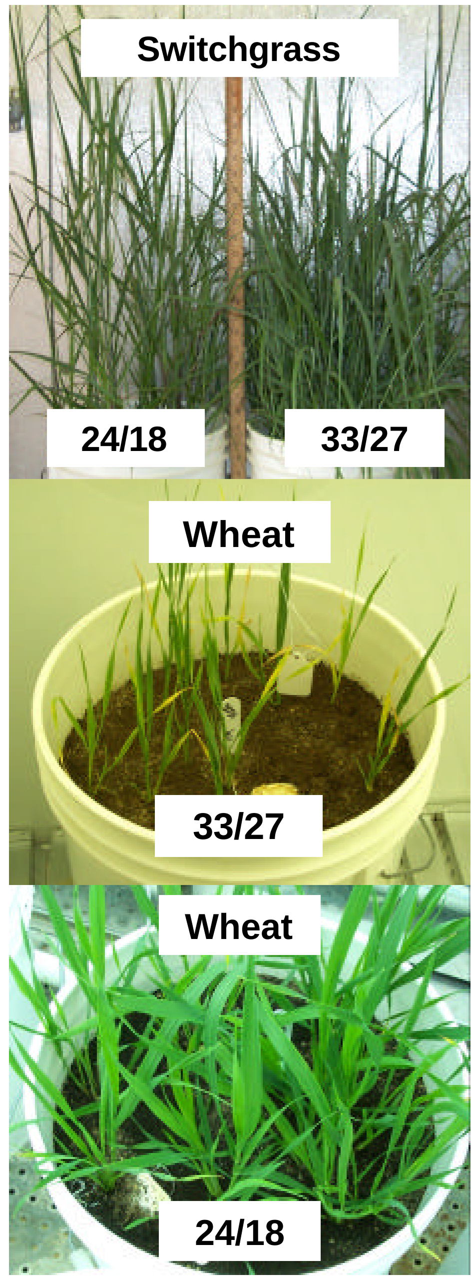


Table 1. Growth and development parameters for switchgrass and wheat measured at preanthesis.

Species	Temperature range ^{o}C	Total biomass	Shoot	Root	R/S	No. tillers	Plant height
		-----------g dry weight---------					--cm--
Switchgrass	33/27†	189.3	92.8	96.5	1.1	9.1	50.8
	24/18	112.7	64.4	48.3	0.8	4.0	57.8
$LSD_{(0.05)}$		58.6	21.9	42.8	0.4	1.5	5.4
Wheat	33/27	5.5	4.7	0.8	0.20	2.6	15.2
	24/18	45.6	34.2	11.4	0.34	7.0	34.7
$LSD_{(0.05)}$		3.2	3.6	2.5	0.12	0.8	2.0
Temp x species		****	****	****	*	****	****

†33/27 ^{o}C (91.4/80.6 ^{o}F) and 24/18 ^{o}C (75.2/64.4 ^{o}F) day/night range.

Produce Hydrogen and Char Fertilizer from Crop Residues?

By Alan Wilts and Don Reicosky

President Bush, in a recent speech to the nation, announced that additional funding -- $1.2 billion -- has been appropriated for accelerating the development of environmentally friendly hydrogen-powered vehicles. Much electricity and energy will be needed to produce hydrogen in industrial quantities. There is a potential for using agricultural crop residues as a source of hydrogen for fuel cells. The catalytic process of producing hydrogen from crop residues would generate some solid carbon (C) or char byproducts (substances much like charcoal or ash) that decompose slowly. If these byproducts add value to the production of hydrogen from agricultural biomass, large-scale handling and usage may be justified. One concept is to develop soil amendments and/or fertilizers from the char product that will sequester C and supply slow-release nutrients for plant growth.

During the summer of 2002, a hydrogen research team of technology developers and researchers, including Danny Day (Scientific Carbons Inc.) and Bob Evans (National Renewable Energy Laboratory (NREL)), investigated methods of char and synthetic gas (hydrogen and carbon dioxide (CO_2)) production from peanut hull biomass. They conducted both laboratory and pilot scale experiments in Georgia. Since the C in char is very porous and highly absorbent, ammonia (created from the hydrogen gas) was combined with the char and CO_2 to form nitrogen (N)-enriched char material. The goal was to produce ammonium bicarbonate (NH_4HCO_3) fertilizer that would act as a slow-release C sequestering fertilizer to be used to increase crop yields, soil C content and nutrient retention and help decrease farm chemical runoff, nutrient

Nutrient -enriched, sand-sized char (AAA battery shown for scale and color)

Corn plant response to char at 25 days after planting nutrient lleaching and greenhouse gas emissions.

Sufficient char byproduct material was produced from the lab and pilot-scale experiments to allow for initial evaluations of plant response. It was speculated that adsorbed nutrients in this porous activated char material would be leached or released slowly. Leaching studies are currently being conducted by NREL.

To determine the effectiveness of char byproducts to serve as slow-release fertilizer, a short-term greenhouse study was planned and conducted by Alan Wilts and Don Reicosky at the USDA-ARS Soils Lab. Treatments were established using Georgia (Cecil sandy loam) and Minnesota (severely eroded Langhei loam) soils and char byproducts (fresh, weathered and nutrient-enriched). The char amendments were either mixed with or surface applied to soil contained in PVC columns (20 cm height x 10 cm inside dia.). Corn plant response and growth were measured during a 25-day period. The role of activated char as an energy source for soil microbes, as evidenced by CO_2 fluxes, was also investigated. Preliminary results indicate limited microbial or plant response due to char amendments. Laboratory testing of the soil, char amendments and plant tissue will be done prior to reporting detailed results and further experimental plans.

The process of developing a slow-release nitrogen fertilizer from agricultural biomass that would nourish plants during a growing season is in early stages and will involve further testing for: 1) the ability of the char to act as a nutrient carrier; 2) leaching resistance and 3) plant growth response. Potential obstacles must be overcome prior to the introduction and use of this material that may allow producers of CO_2 and the agricultural community to reduce the global rise in greenhouse gas emissions while building a sustainable economic development program.

Teacher Research Fellowship Program at the Soils Lab

By Don Reicosky, Chris Wente and John Van Kempen

The recent interest in global warming issues and greenhouse gas emissions from agricultural ecosystems has prompted the need to better understand soil carbon as part of the grand carbon cycle in agricultural production systems. Because our children will inherit this world, it is important that they understand their environment and what they can do to improve the overall quality of life. Our research on agriculture's impact on the environment requires technology transfer to our stakeholders and the public. Last summer we were fortunate to be able to obtain a grant to support the Teachers Research Fellowship Program. This program is directed to elementary, junior, or senior high teachers of biology, physical science, or math. The objective is to stimulate the interest of highly motivated students into agricultural research careers through the real world scientific work experience gained by their science or math teacher.

We were fortunate to have John Van Kempen, biology and physics teacher from West Central High School, Barrett, MN, selected for this program. John is a very dynamic person with excellent skills in communicating complex science concepts to high school students. John was interested in aspects of carbon sequestration and global change research programs at our laboratory. This fellowship program provided John with an opportunity to assist in data collection to evaluate the effects of crop biomass management as soil carbon inputs and carbon dioxide losses in our Carbon Crop study.

John Van Kempen collects soil gas samples from the switchgrass plots.

Under the mentorship of Chris Wente, John learned several research procedures designed to evaluate carbon inputs and CO_2 gas concentrations in the soil. During the summer, John had opportunities to collect data and measure the CO_2 concentration in the soils under switchgrass and corn plants.

He quickly learned to collect soil gas samples and operate a sophisticated infrared gas analyzer. His computer skills allowed him to assist in the data analysis and prepare a graph.

The learning and communication in this program was a two-way street. We at the lab provided John opportunities to learn about agricultural research

John Van Kempen checks the rainfall amounts at the Swan Lake Research Farm weather station.

techniques related to carbon sequestration. On the other hand, John taught us some of his computer skills, specifically how to easily put PowerPoint presentations on our web site. Interaction between John, Chris Wente and Steve Wagner enabled us to develop a very efficient way of putting our data and PowerPoint presentations on our web site for easy access by students and anyone else interested in our research program. This was truly a win-win situation for John and our laboratory.

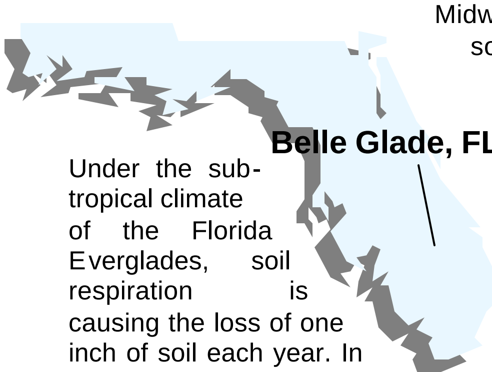
At the end of the summer appointment, John gave an exit seminar showing the data he helped collect and his scientific analysis of the results. As part of this seminar, he demonstrated the simplicity of allowing students to explore the Internet for information on carbon sequestration highlighting his recent contributions. This form of teaching opens up many avenues to the students to explore on their own to get more information on agriculture's impact on global change. This form of technology transfer is important because the sooner the students learn about and understand their ecosystem, the faster they will help solve the environmental problems. The Teacher Research Fellowship Program is an example of our efforts to inform the community and stakeholders about the importance of our research program. Interactions with students and questions received indicate that it was a resounding success, largely due to John's teaching and research skills.

John Van Kempen analyzes soil gas samples for carbon dioxide on the infrared gas analyzer.

Tillage-Induced Soil Respiration in the Florida Everglades

By Chris Wente, Don Reicosky, Russ Gesch and Steve Wagner

Recent research results at the North Central Soil Conservation Research Lab demonstrate that intensive tillage plays a critical role in the decline of organic matter by increasing soil respiration or carbon dioxide loss from Midwest soils.



Under the sub-tropical climate of the Florida Everglades, soil respiration is causing the loss of one inch of soil each year. In an effort to understand the role of tillage in soil loss or subsidence, two experiments were performed at Everglades Research and Extension Center (EREC) during the week of January 21, 2002. Collaborating in these experiments were the University of Florida; Agricultural Research Service (ARS) -Canal Point, Florida; ARS-Morris, Minnesota; and Monsanto Corporation. The Morris team included Don Reicosky, Russ Gesch, Steve Wagner, and Chris Wente.

The EREC is located near Belle Glade, Florida, which is five miles southeast of Lake Okeechobee. The location is ideal for year round crop production because of the high water table, plentiful rainfall, and warm weather. In addition, the muck soils of this area produce large amounts of nitrogen through mineralization. Thus, little commercial fertilizers are needed. The prevalent crop is sugar cane. Also grown are winter sweet corn, citrus fruits, and a variety of vegetables. However, the EREC has roughly two feet of muck soil left above the limestone bedrock. Therefore, at the current rate of soil loss, the agricultural practices in the area will experience a dramatic change in the next 50 years. Any management practices that can be adapted to reduce soil loss will increase the time these soils remain productive.

Belle Glade, Florida sign

On January 18, 2002, we left with MR GEM (Mobile Research Gas Exchange Machine) for Belle Glade, Florida. We arrived on January 21 and were greeted by Dr. Rob Gilbert, University of Florida, and Dr. Dolen Morris, ARS-Canal Point, Florida. They showed us a benchmark from fifty years ago that now stands at least 5.5 feet above the current soil surface (Fig. 2). The original buildings that were built on the EREC over 80 years ago now stand 8 to 10 feet above the soil surface. About every 10 years additional steps are added to the buildings' entrances.

The drained muck soils of the Everglades differ dramatically from the soils of the Midwest. Their density is typically only 25% of that of Midwest soils. This is the result of the soil being composed of almost 90% organic matter. Therefore, they have a rich black color and are very productive. The experimental sites resemble a freshly tilled garden. You sink in a couple of inches with every step, even though these fields had not been tilled for months. Due to the fluffiness or porosity of the soil, it is very easy to get stuck during wet periods. In fact, the EREC has a bulldozer as part of its standard field equipment.

We performed two short-term experiments to determine the effect of tillage on soil respiration (Fig. 3). The first experiment was performed on a field with no surface plant residue; the second on a field that had dead plant residue in the form of herbicide controlled weeds. Using three types of tillage equipment, four treatments were established and compared to a no-till condition. The first treatment was a Herrell-switch plow, which is similar to a moldboard plow. It tilled to a depth of 16 inches. The second treatment was a heavy disk harrow that tilled to a depth of 4 to 5 inches. The other two treatments involved a scratcher, which is similar to the spring-tooth harrow on the back of a field cultivator. It is used for weed control in sugar cane fields and only disturbs the top 1 to 2 inches of soil.

The results of these experiments indicated shallow tillage had a minor impact on soil respiration while deep tillage increased soil respiration dramatically. In fact, after Herrell-switch plowing, the respiration rates measured were 2 to 3 times greater than any rate we had measured previously in the Midwest (Fig. 4). In comparison with Midwest soils, shallow tillage had less impact on soil respiration, while deep tillage had greater impact. This is probably a result of the greater porosity of the muck soils and soil dryness on the surface. Tillage on Midwest soils increases soil porosity while the muck soils are already very porous and tillage has a minimal effect when the surface is dry. In our experiments, the deep tillage brought high-moisture-content soil to the surface, while the shallower tillage did not, thus indicating that soil respiration in muck soils is highly limited by soil moisture. In contrast, previous research indicated that soil respiration of Midwest soils is mostly limited by soil porosity.

In conclusion, soil respiration rates of muck soils increased when the tillage resulted in high-moisture-content soil being brought to the surface. Thus, to avoid additional soil loss fom tillage-induced soil respiration, tillage decisions should be based on the moisture of the soil being worked to the surface. Therefore, the best management practice would be to perform tillage during dry conditions.

Chapter

4

Crops & Weed Biology

Time may be the most overlooked resource required for effective crop management in the upper Midwest. We are using a multi-faceted approach towards demonstrating how timeliness can be maximized through improved understanding and prediction of plant and soil responses to environmental and management variables.

The objectives of this project are to: relate microclimate to crop and weed development, and include relationships in user-friendly software. Develop management strategies for consequences of adopting alternative and transgenic crops. Provide information for management and genetic improvement for tolerance of old and new crops to temperature and water stresses. Assess ability of temperature-sensitive polymer seed coatings to protect seeds in cold and wet soils. Supply basic knowledge of soil-plant-nitrogen interactions for improving fertilizer recommendation models.

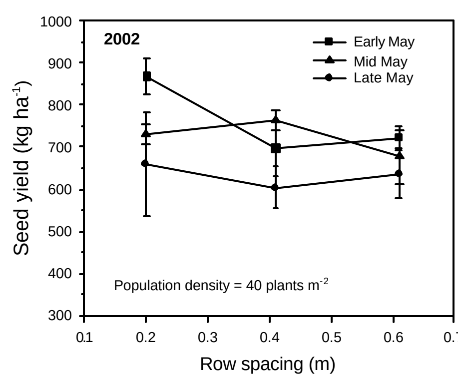
Alternative Crops and Management Techniques

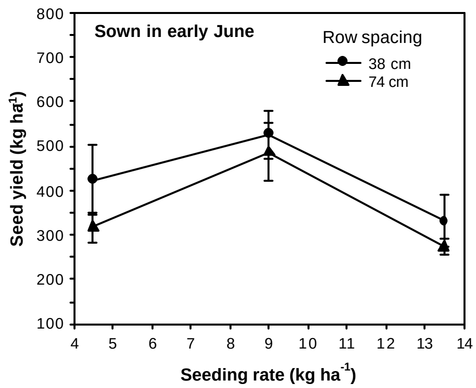
By Russ Gesch

Biodiversity in Midwest cropping systems has greatly dwindled due to major emphasis placed on corn and soybean production. One of the focuses of our lab is to identify and characterize agronomically viable new/alternative crops and cropping systems for the upper Midwest to aid in diversifying systems.

Cuphea: For a plant species to qualify as a true alternative crop, it should not directly compete agronomically with conventional crops like corn and soybean. Cuphea, a new potential crop that we are working to develop, meets these requirements. Its seed oil is different than that of any traditional oilseed crops grown in the US, yet is highly valued by the chemical manufacturing industry, which presently obtains this type of oil from coconut and palm kernel. We have discovered that cuphea grows relatively well in west central Minnesota. Last summer (2002) we successfully established and harvested a one acre test plot of cuphea (Fig.1) on a local farmer's field about 10 miles southeast of Morris, Minnesota. Seed harvested from this plot was successfully used by Archer Daniels Midland company (ADM) to run a pilot-plant-scale oil extraction.

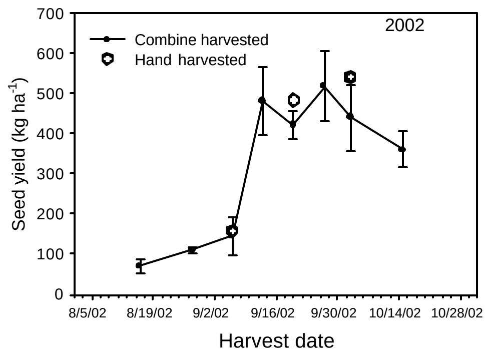
Progress continues to be made in developing best management practices for producing cuphea using row-cropping techniques. A study was completed last year to address the combined effects of planting date and row spacing on cuphea seed yield (Fig. 2). During the 2002 season, we observed that planting date had a greater affect on seed yield than row spacing, although the early planting date appeared to benefit from by the narrowest row spacing. Part of the reason for the lack of response to row spacing, is that with more growing area per plant, cuphea tends to compensate for yield by branching and producing more seed pods per plant. Therefore, with present varieties of cuphea, determining optimum plant population may be more vital to enhancing yield than row spacing. To further test this hypothesis, we began an experiment in 2002 to address planting rate versus row spacing. Figure 3 shows that row spacing had little affect on yield, except at the lowest seeding rate of 4.5 kg ha^{-1} (4 lbs per acre), where 38 cm rows gave a greater advantage. However, seeding rate had a substantially larger



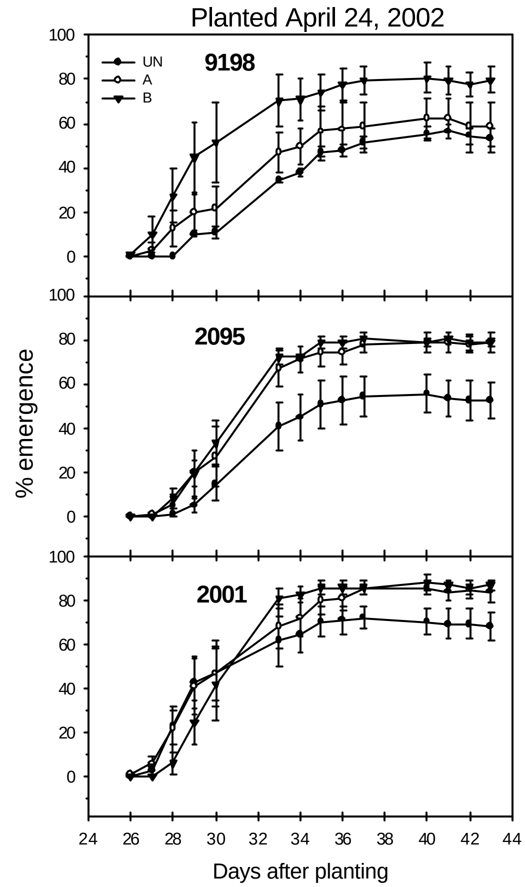


affect, with a rate of 9 kg ha^{-1} (8 lbs per acre) giving the highest yields.

From completion of our harvest date study last year, we conclude that for cuphea planted in early to mid May, the best time to harvest is late September to about the first week in October (Fig. 4).



Because cuphea has a rather long growing cycle, waiting until after the first hard frost to harvest helps to reduce the moisture content of plant material making it easier and more efficient to combine. The diamond shaped symbols in Figure 4 denote yields from hand harvested plots as compared to that harvested at the same time by combining (filled circles). These results indicate, as do previous years data, that as much as 20 to 30% of the harvestable seed might be lost during combining. The best method(s) for mechanically harvesting cuphea and controlling late season broadleaf weeds are problems that still remain to be solved.



Polymer coated seed: Last summer marked the completion of a three-year study we conducted to evaluate early planting corn and soybean seed that had been coated with a temperature-activated polymer. The coating protects the seed from absorbing water until soil temperatures have warmed up to at least 10°C (50°F). This management technique not only allows producers to spread their labor and equipment resources over a larger number of acres more efficiently, but also, by planting crops earlier, may allow longer season varieties to be utilized. Our results have proven that these coatings rotect seed from damage caused by cold, wet soils. When planted early, as shown in Figure 5 for 2002, percent emergence and stand establishment for coated seed (open circles & inverted triangles) were in most cases significantly greater than that of non-coated seed for three different corn hybrids varying in maturity from 95 to 101 days. Furthermore, the stand establishment and grain yields for "early planted" polymer coated corn, as well as soybean, tends to be as good, and in some instances even better, than non-coated seed that is planted at normal or average planting times. During the first year of this study (i.e., 2000), we planted corn and soybean as early as March 22! With similar results. Landec Ag, the company that manufactures the polymer coatings, plans to soon make polymer coated hybrid corn seed available to the public. We plan to further explore this type of management tool on conservation tillage systems and also test the potential of fall frost-seeding of temperature-activated polymer coated seed.

Alternative Crops for the Midwest

By Abdullah Jaradat and Steve Van Kempen

The U.S. and international annual medics collections provide valuable genetic diversity for a number of adaptive and agronomic traits. A collection of ~ 500 accessions was acquired from national and international resources, that is broad enough and flexible enough to serve the diverse and changing needs of research, germplasm enhancement and crop improvement.

Medics: Recent interest in sustainable cropping systems has renewed interest in forage legumes. Forage legumes provide ground cover, enhance nitrogen fertility though symbiotic nitrogen-fixing bacteria, reduce weed pressure by smothering weeds and act as living mulch reducing soil erosion. Annual medics (*Medicago* ssp.) are closely related to perennial alfalfa (*Medicago sativa* L.). Medic grows rapidly, produces large a biomass and many pods. Medics have hard seeds, which remain viable in the soil. Medics are adapted to a wide range of soil types with potential uses in sustainable agriculture systems. Research is needed to clearly define their niche especially in the Upper Midwest. A large (>500 accessions) germplasm collection was assembled from international sources. The growth rate, biomass production and potential to store carbon below ground are being evaluated and characterized to identify those best adapted to the short-growing season of the of the Upper Midwest. The objectives of this study are to identify accessions with the maximum combinations of these desired characteristics 1) rapid growth rate, high nitrogen fixation rate in symbiosis with the soil bacterium *Sinorhizobium* and a high biomass production, 2) adequate levels resistance to *Phytophthora* root rot in cool, wet soils, 3) dual utilization as a grazing forage or as hay, 4) shade tolerance as a companion crop, and 5) high below-ground carbon storage capacity.

Medics have the potential as a component of cropping systems that reduce chemical fertilizer N requirements in winter canola (*Brassica napus* L.); however, further studies are needed to identify adapted species and proper management practices for this purpose.

Winter canola: Winter canola primarily is a winter annual and can reach maturity in approximately 280 to 310 days depending on the variety and environment. Plants of this species range from four to five feet tall (depending on moisture conditions), are high-yielding, and flowers four to six weeks. Winter canola is roughly 70% self-pollinated. Generally, oil content ranges from 42 to 48 percent.

Traditional Midwest farming systems continue to degrade soil through erosion and loss of soil organic matter. An option for reducing soil degradation is to grow a broadleaf crop following wheat using reduced tillage systems. Stand establishment of broadleaf crops after wheat is one of the biggest challenges to developing these systems. Good seed germination and emergence is especially difficult to obtain when seeding a small seed broadleaf crop such as winter canola following wheat. The wheat crop depletes the soil of water and it is difficult to place small canola seeds at a constant depth through wheat straw and chaff.

Winter survival in rapeseed is dependent on many morphological and physiological characteristics of the plant, soil conditions and weather fluctuations and that freezing tolerances differed between cultivars. As a result, screening methods that allow for accurate and precise assessment of cold hardiness potential are critical to the success of this research.

Pearl Lupine: The objectives of this study are to: 1) develop a diverse germplasm collection (~ 1,000 accessions) from several sources (550 accessions from the Plant Introduction Station, Ames, IA), 2) screen (in the lab and field) and select winter hardy oil seed winter canola adapted to the environmental and edaphic conditions in the Midwest, 3) evaluate selected germplasm in replicated field experiments for planting date and seeding rate, and 4) evaluate the top

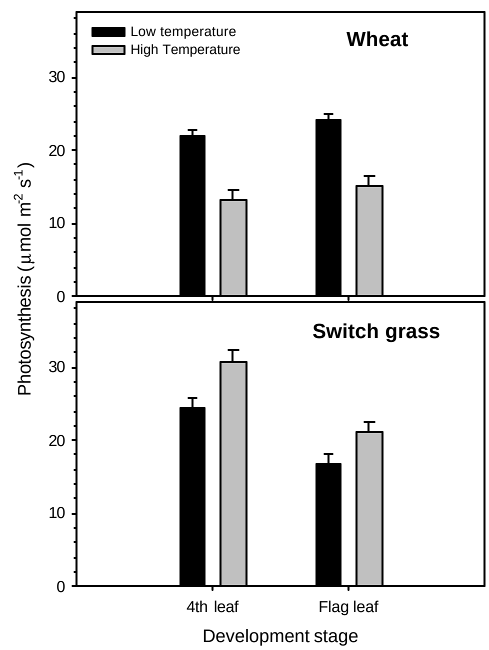
performing 5-10 selected accession in crop rotations with spring wheat and annual medics..

Another potential crop for the Midwest is pearl lupine (*Lupinus mutabilis*), which is one of more than 300 species in the genus *Lupinus.* It is endemic to the Andean region of South America and its seeds have been used since antiquity. This legume contains alkaloids that repel insects and controls nematodes. A further advantage is that it can use soil phosphorus that is not readily available to other plants. Pearl lupine, therefore, is less dependent on added phosphate fertilizers. Pearl lupine is high in protein, a high N-fixer, has value in rotation with non-legumes, produces high biomass, and has an upright, non-shattering habit. However, other factors such as economics and competition from established crops are unknown but likely important to the success of pearl lupine as a new crop. Pearl lupine is one of the few grain legumes that exceeds soybean in protein and oil content of the seed. The work reported by researchers in Chile in producing a sweet cultivar of pearl lupine means that this species, given its high oil and protein content, now has the potential to be developed as a new, multi-purpose crop. The breakeven seed yield for white lupine, a related species already domesticated, is about 1100 lb/acre.

Environmental Stress and Crop Production

By Russ Gesch

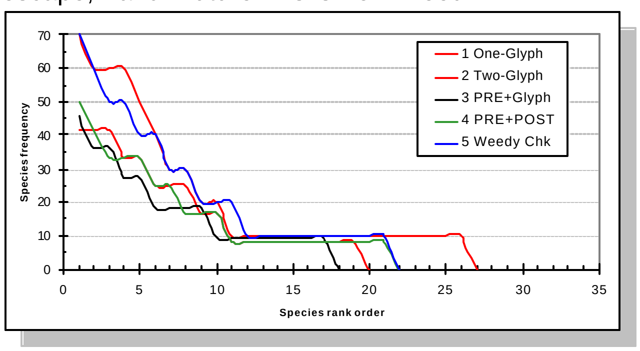
The intensity and frequency of extreme climatic events (e.g., drought and heat) are likely to increase in the future given that the earth's mean near-surface temperatures are slowly but steadily rising due to global climate change factors (e.g., elevated "greenhouse gases"). Understanding how crops respond to environmentally stressful conditions is important in terms choosing the best suited species or varieties to grow and how to management them. Presently, there is considerable interest in the Midwest region in the production of "biomass crops" (i.e., crops used for biofuels and for sequestering carbon in agricultural systems). Last year a study was devised with Jane Johnson (NCSCRL) to look at the effects of high temperatures on the growth and carbohydrate partitioning of two potentially important biomass crops, wheat and switch grass. We grew both of these species at moderate day/night temperatures of 24/18°C (75/64°F) and high temperatures of 33/27°C (91/81°F). It was found that high temperatures greatly increased the growth of switch grass particularly its roots, but wheat growth was considerably suppressed. The heart of this difference lies in the plants ability to photosynthesize (i.e., fix atmospheric CO_2 into carbohydrates) and utilize the sugars produced. As shown in Figure 6, photosynthesis at both the four-leaf and flag-leaf stage increased with temperature for switch grass, whereas it greatly decreased in wheat. Further work is being conducted to determine physiological reasons for this difference in photosynthesis and how the two species differ in terms of their allocation of carbohydrates between roots and aboveground tissues. Results thus far indicate that if mean temperatures or extreme high temperature episodes continue to increase, switch grass and species similar to it, may be better suited for biomass production in the Midwest.



Biodiversity and Risk of Weed Escape from Glyphosate (Roundup)

By Frank Forcella

Weed biodiversity and weed escapes are merely two sides of the same coin. We conducted a series of experiments that address simultaneously questions regarding levels of weed biodiversity and weed escape, current frequencies of weed escape, and future risks of weed escape in glyphosate-tolerant (GT) cropping systems. These questions were raised by the National Research Council in its 2002 report entitled "Environmental Effects of Transgenic Plants." Additionally, we sought answers to the questions of how and why weeds can escape GT cropping systems.

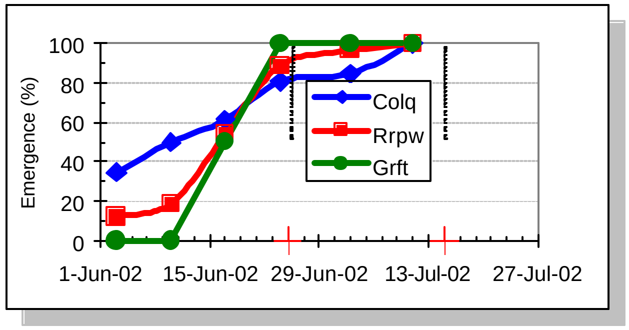


Experiments included field studies that were "piggybacked" upon statewide herbicide trails along a transect from Minnesota to Louisiana. In these trials weed diversity and weed escapes were examined in treatments with differing intensities of glyphosate use compared to traditional treatments and weedy checks. This provides information on which species escape glyphosate, frequencies at which they escape, and measures of biodiversity.

Common lambsquarters was the species that escaped glyphosate treatments most often, followed by nightshades, pigweeds, foxtails, and morningglories. Lambsquarters escaped with a frequency of about 70% when glyphosate was applied just once (see "One-Glyph" line in the figure below). This was nearly identical to the frequency of lambsquarters escaping in weedy check plots, but quite different from that for traditional weed control practices (PRE+POST) or heavier glyphosate use (e.g., two-Glyph treatment). Thus, biodiversity actually can be enhanced with limited use of glyphosate in GT cropping systems.

Delayed emergence and escape from glyphosate

Data on differing densities, locations, seedling emergence times, and growth rates of surviving weed species each suggest various mechanisms for escaping glyphosate. For example, our results indicate that delayed emergence clearly plays a role as an escape mechanism in GT systems. The following figure shows cumulative emergence curves for three weed species in GT soybean at the University of Minnesota's West Central Research and Outreach Center during 2002. These data were collected by Ms. Susan Hennen, a science teacher at one of the local schools in Stevens Co., MN. The dates of glyphosate applications are depicted in the figure by arrows; the first arrow for the one-glyphosate treatment, and both arrows for the two-glyphosate treatment. Despite emergence of lambsquarters (Colq) commencing earlier than that of foxtail (Grft) and pigweed (Rrpw), lambsquarters emergence was less than that of pigweed at the time of the first glyphosate application. Moreover, pigweed emergence was less than that of foxtail at this time. As might be expected, the densities of these species that escaped in the one-glyphosate treatment were highest for lambsquarters and lowest for foxtail. In contrast, at the time of the second glyphosate application in the two-glyphosate treatment, all species had approached 100% emergence. Not surprisingly, no escaped weeds were found in the 2-Glyph plots. Thus, emergence timing has a pronounced influence on which species escape and the densities of escapes in GT crops.

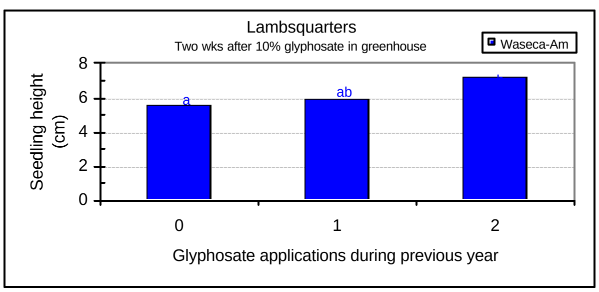


Evolution of Glyphosate Tolerance

By Frank Forcella

There are many other mechanisms that plants may use to escape control by glyphosate. One of the most interesting is evolution of tolerance through selection after repeated exposure to glyphosate.

Collections of lambsquarters from four of the 12 experimental sites in 2001 yielded viable seeds. These collections came from plots that were not previously treated with glyphosate (0), received one application of glyphosate during the growing season (1), or received two applications of glyphosate during the growing season (2). The seeds were germinated under greenhouse conditions and tested for susceptibility to glyphosate. The herbicide was applied in a precision spray cabinet at one-tenth label rate. No differences in seedling sizes were measured among the 0-, 1-, and 2-glyphosate exposed accessions prior to glyphosate treatment. At two weeks after treatment, plants not treated with glyphosate also attained similar sizes among the three seed accessions, which indicated that they all had the same natural growth potential. However, in two of the four populations, 0- glyphosate plants were significantly smaller than 1- glyphosate and 2- glyphosate plants if all were exposed to glyphosate. An example of these results is shown in the figure, below, for lambsquarters whose seeds collected at Waseca, MN. Although the differences are small, they still are very exciting. The differences in tolerance suggest the possibility for rapid selection of incremental increases in glyphosate tolerance upon prior exposure to glyphosate in half of the populations tested for one common species.



The Weed Research team that conducted these studies includes Frank Forcella, Dean Peterson, and Gary Amundson. They were helped by considerably by Julio Scursoni (University of Buenos Aires, Argentina) and Susan Hennen (St Mary's School, Morris, MN).

Area Teachers Participate in Research Opportunities at the USDA-ARS Lab

By Dean Peterson and Chris Wente

This past summer the USDA-Agricultural Research Service (ARS)-North Central Soil Conservation Research Laboratory ("Soils Lab") had the opportunity to hire two area teachers through the Teacher Research Fellowship Program. This program is directed at elementary, junior, and senior high school teachers of biology, physical science, or math. The objective is to stimulate the interest of highly motivated students into agricultural research careers through the scientific work experience gained by their teachers.

Susan Hennen is measuring seedling height.

Ms. Susan Hennen, a sixth grade science teacher from St. Mary's School in Morris, was selected to work with the weed science research unit. While Mr. John Van Kempen, a biology and physics teacher from West Central High School in Barrett, was chosen to work with the soil carbon research group.

Susan participated in two projects involving the management of weeds. The objective of these two projects was to determine the mechanism that allows some plants to escape herbicide applications in the field. Susan traveled to several locations throughout the state of Minnesota, where she monitored weed emergence, species composition, plant growth, and crop development.

In addition, Susan conducted a greenhouse experiment using seeds collected from plots from Minnesota to Arkansas. She monitored the growth and development of several different weed species. After emergence, the weeds were treated with reduced rates of Roundup® herbicide. These plants were then monitored for an additional period of time.

Data collected from this experiment were plant height, width, weight, and leaf number. Some populations of some species were found to be more tolerant of Roundup® than others simply due to prior exposure to this herbicide which is a very exciting result.

Some unique aspects to Susan's experience, was working with two Ph.D candidates, Mr. Julio Scursoni, from the University of Buenos Aries, in

Argentina, and Mr. Ebandro Uscanga Mortera, from Mexico, attending the University of Minnesota. In December, Susan presented the results of her research at the North Central Weed Science Society Meeting in St. Louis, Missouri.

John Van Kempen worked on aspects of carbon storage in soils, which is referred to as "carbon sequestration." His work included quantifying carbon dioxide levels in soil, measuring gas exchange of soil and plants, and collecting crop biomass. At the end of the 2002 program, John presented a seminar on what he learned during the summer. In addition, he demonstrated how this information will be presented to students. He prepared an internet site which allows students to explore how agriculture impacts global change.

John Van Kempen is measuring switch grass height.

The Teacher Research Fellowship Program is a tool used nation-wide by USDA-Agricultural Research Service to inform students through their teachers about agricultural research. It exposes teachers to the agricultural research field and allows them to take their experience back to the classroom. It opens lines of communication between researchers and teachers. It also helps researchers learn how to present their results to a different audience. In addition, it is one of the first steps in motivating students to pursue a career in agricultural research.

For more information about the Teacher Research Fellowship Program, please contact Beth Burmeister at (320) 589-3411.

Chapter

5

Sustainable Cropping Systems

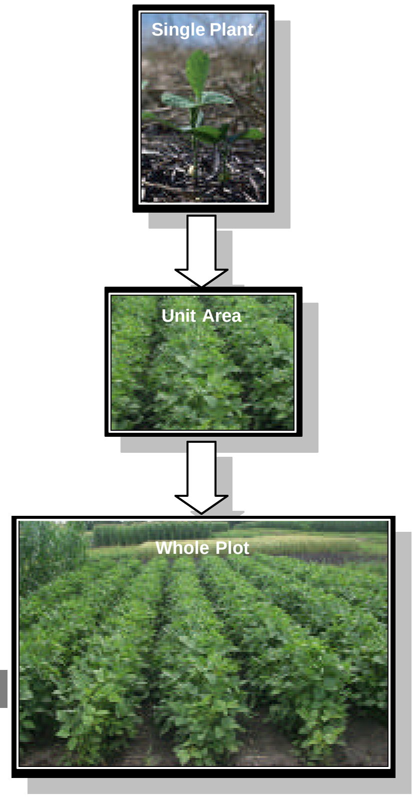
The prevailing systems of agricultural production in the upper Midwest are struggling with the appropriateness and applicability of new and current technology and its impact on farmers, rural communities, and the environment. Only long-term, large scale interdisciplinary research aimed at developing agricultural systems that protect the environment as well as enhance rural communities, can address multiple and inter-related agronomic, environmental and economic issues.

The objectives of this project are to: Determine the agronomic, economic and environmental risk/benefits of adopting and transitioning into alternative cropping systems including organic and minimum tillage production systems and the introduction of alternative crops. Develop the technologies to facilitate the transfer of research results to customers, including on-farm research and involvement of farm managers in research planning. Develop decision aids that include economic analysis of various crop and resource management strategies.

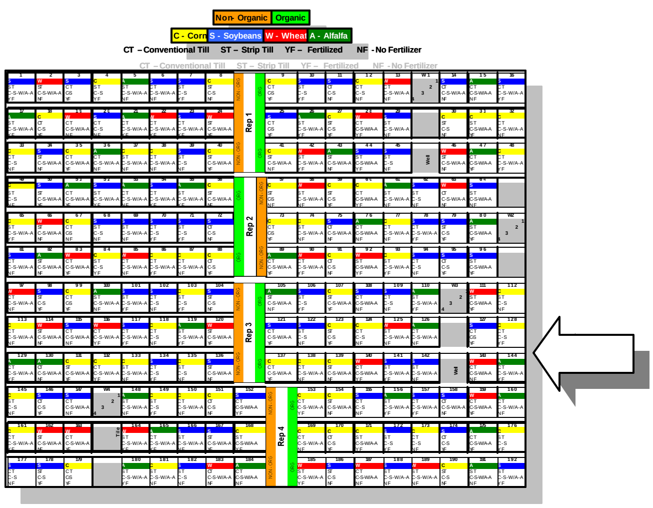
Hierarchical Spatial Monitoring of Cropping Systems in a Field Plot Setting

By Abdullah Jaradat and Dave Archer

Detailed measurements on sub-samples of single plants and plant populations are needed to 1) quantify spatio-temporal dynamics in crop rotations and cropping systems, 2) adjust biological and grain yields when measured in large plots, and 3) provide reliable information to formulate long-term strategies for crop sequencing that optimize crop and soil use options. Permanent geo-referenced sites will be established within individual plots where plant, soil, and environmental data will be recorded. Data will be collected at the plant, unit area, and whole plot levels on plant phenology, key physiological and agronomic traits, yield and yield components.



Baseline soil information was collected across the entire study area prior to initiating treatments, providing a spatial map of initial conditions.

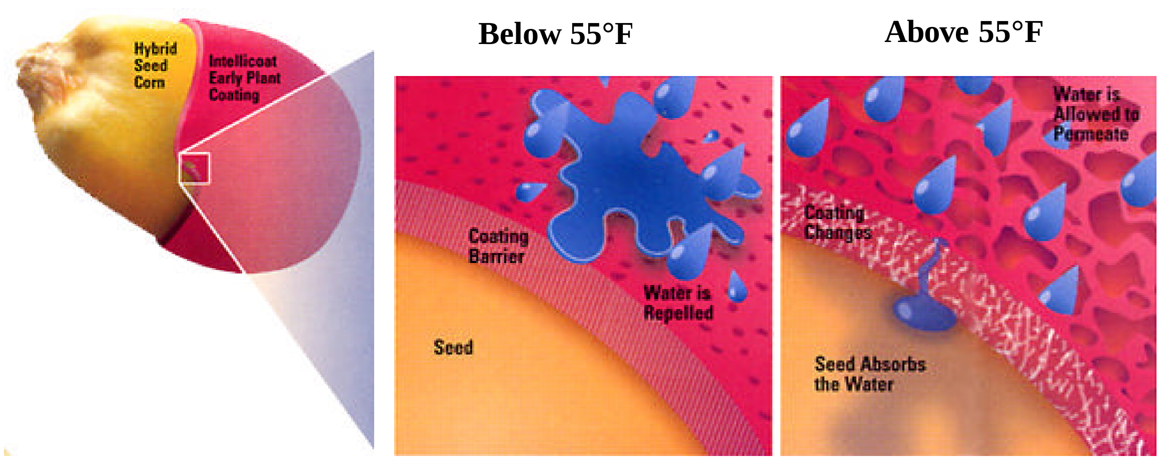


Value of Temperature-Activated Polymer Seed Coating

By Dave Archer

Temperature-activated polymer seed coatings have been tested in the field at the NCSCRL for the past three years (see Russ' report). Based on the initial positive results in the field, simulation modeling was used to identify the potential economic value and extent of use for polymer coated seed in the northern Corn Belt.

How the coating works:



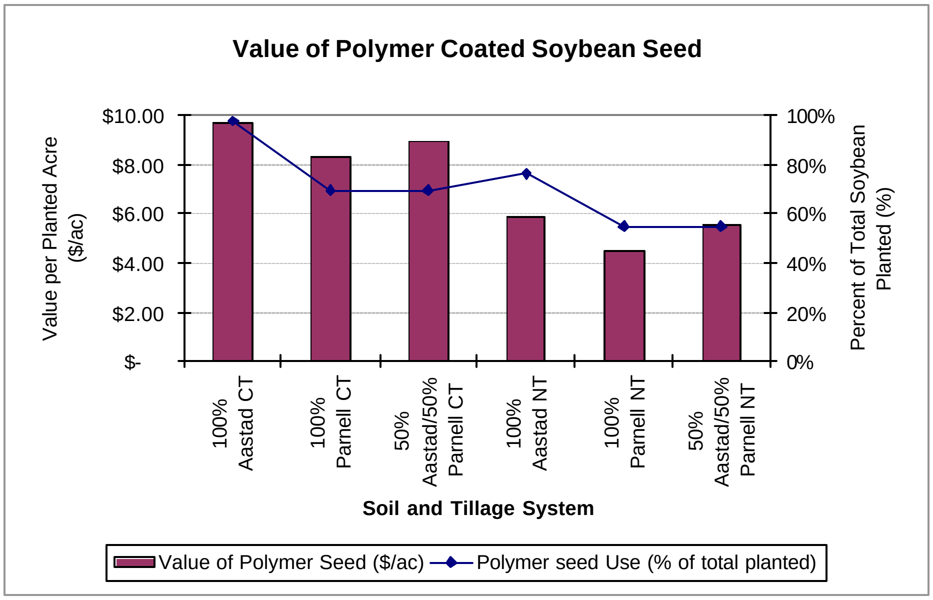
Coating is a barrier to moisture. Coating is permeable to moisture.

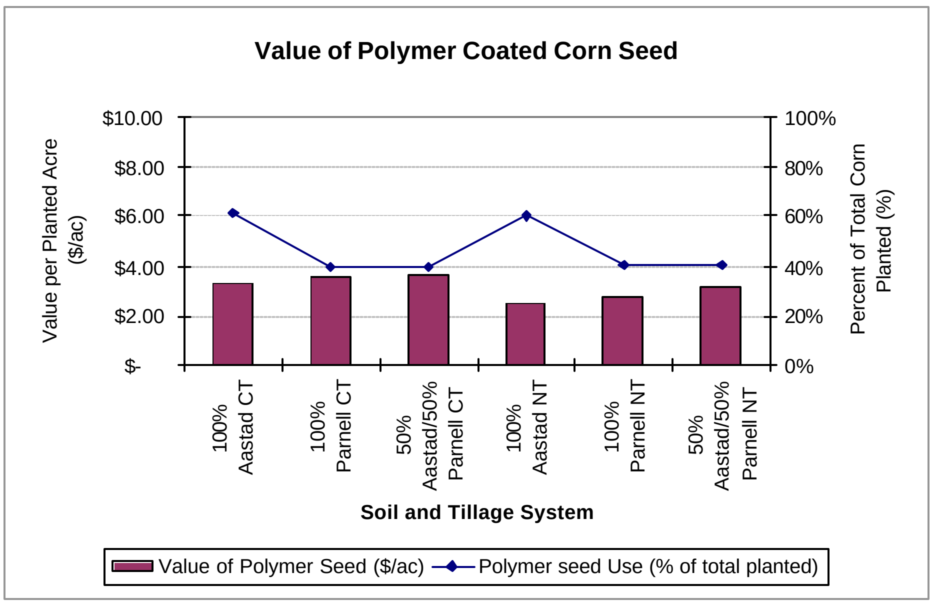
Source: LandecAg, Inc.

The benefits of temperature-activated polymer seed coating occur when field conditions allow producers to get crops planted early. The EPIC crop simulation model was used to estimate:

1. how often field conditions were conducive to early planting, and
2. crop yields that would be realized in the years when early planting occurred.

The results were used to estimate the economic returns both with and without polymer seed coating to determine the value of the seed and the acres of use for a typical farm. To determine the effect of soil type on the value of polymer coated seed, the analysis was conducted for farms with 100% Aastad soil, 100% Parnell soil, and for a 50%-50% mixture of Aastad and Parnell soils. Also, there has been considerable interest in this technology among no-till producers, so the analysis was conducted for both a conventional tillage system (CT) and a no-till system (NT).





Conclusions:

- Value of this new technology ranges from $2.50 to $9.70 per acre.
- Potential use ranges from 40% to 60% of corn acres and 49% to 97% of soybean acres.
- Although polymer coated seed will be valuable for NT systems, even higher benefits occur under CT systems.

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Appendix 2

USDA Soil's Lab Employees

Jaradat, Abdullah- Research Agronomist, Research Leader and Location Coordinator

Archer, David - Ag Economist/Ag Scientist

- **Eklund, James** - Computer Assistant

Forcella, Frank- Research Agronomist

- **Amundson, Gary** - Engineering Technician
- **Peterson, Dean** - Ag Science Research Technician

Gesch, Russell - Plant Physiologist

- **Boots, Dana** - Ag Science Research Technician (Plants)

Johnson, Jane - Soil Scientist/Plant and Soil Biochemist

- **Barbour, Nancy** - Biologist

Olness, Alan- Soil Scientist

- **Hanson, Jay** - Physical Science Technician
- **Rinke, Jana** - Chemist

Reicosky, Donald - Soil Scientist

- **Wente, Christopher** – Ag Science Research Technician
- **Wilts, Alan** - Chemist

Groneberg, Sandra - Program Support Assistant OA

- **Burmeister, Beth** - Office Automation Assistant

Eystad, Kathryn - Program Support Assistant

Gagner, Jill - Biological Science Lab Technician

Hennen, Charles - Ag Science Research Technician

Groth, Pam - Administrative Officer

- **Rohlloff, Shawn** - Purchasing Agent OA

Larson, Scott - Ag Science Research Technician (Soils)

VanKempen, Steven - Ag Science Research Technician (Soils)

Wagner, Steven - Electronic Engineer

Winkelman, Larry - IT Specialist (Customer Service)

Retirements

Congratulations to Dr. Mike Lindstrom who retired on May 3, 2002, after more than 25 years of service with USDA-ARS as a Soil Scientist. Dr. Lindstrom began his ARS career in August 1976 with the North Central Soil Conservation Research Laboratory, Morris, MN, where he served until his retirement. Prior to attending college, Mike served three years with the U.S. Marine Corp, 1957-1960. He received his BS and MS degrees in Soil Science from the University of Idaho in 1965 and 1967. Upon completion of the MS degree, Dr. Lindstrom started his research career as a Senior Experimental Aide at the Dryland Research Unit, Lind, Washington. (The Dryland Research Unit is part of the Washington State University Experiment Station network.) While at Lind, he continued his studies at Washington State University where he completed his Ph.D. degree in Soil Science in 1973. At that time, he took a Research Associate position with Oregon State University, funded by the Rockefeller Foundation, at the Wheat Research and Training Center, Ankara, Turkey, 1973-1976.

Dr. Lindstrom's research focused on soil management with emphasis on tillage and crop production. Early research focused on increasing water storage in a winter wheat-summer fallow production system in the Pacific Northwest and Turkey. Later research with ARS in annual row crop production systems concentrated on crop residue management, soil erosion-crop production relationships, management of CRP lands, development of conservation tillage systems which maintain or increase crop productivity, and soil movement by tillage. Research has shown that residue management systems used to abate soil erosion are viable systems in the upper Midwest provided adequate surface drainage is

present; however, in depressional areas where cold, wet soils are an annual problem, heavy residue levels were a severe detriment to optimum crop production. The soil erosion-crop productivity work was part of a regional University State Experiment Stations project (NC-174) that started in 1983 and is still active.

Dr. Lindstrom has been a member of the American Society of Agronomy, Soil Science Society of America, Soil and Water Conservation Society, and International Soil Tillage Research Organization. He has been most active in the Soil and Water Conservation Society, where he served on the Minnesota State

Chapter Executive Board for three years, 1988-1990; President of Minnesota Chapter in 1989 and Associate Research Editor for the Journal of Soil and Water Conservation for six years, 1994-2000. He became a Fellow of the Soil and Water Conservation Society in 1994 and was awarded the President's Citation in 1996. He was also active in the formation of the Tillage Erosion Working Group within the framework of the International Soil Tillage Research Organization and was appointed Chairman in 2000. Mike plans to continue work as a collaborator at the North Central Soil Conservation Research Laboratory.

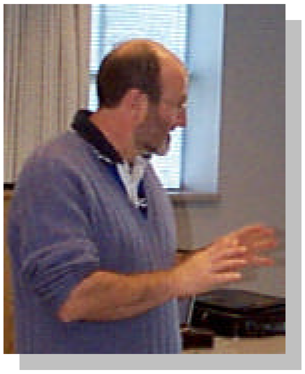
Skip Maanum began his career at the North Central Soil Conservation Research Laboratory on September 6, 1960, as a wage grade laborer, assisting in getting the newly constructed research facility fully functional and assisting scientists in establishing field research plots. His attention to detail and commitment to scientific field research protocol played a critical role in the Morris location's early establishment as a nationally and internationally respected research program. Since 1973, Skip has been responsible for the overall management of the 130-acre Swan Lake Research Farm leased to the Lab by the Barnes Aastad Association.

This involved coordinating the field research needs of ten scientists, plus occasional visiting foreign scientists. In 1979 Skip assumed the responsibility for the operation and maintenance of the Lab facility consisting of 50,000 square feet of office/laboratory/greenhouse space and several storage buildings on a 15-acre campus. In essence, Skip "takes care of things."

Although Skip may not have told you, he was chosen from all the support staff in ARS locations in eight states to receive the first awarding of the "Midwest Area Research Support Person of the Year." We are proud of Skip and his accomplishment!

Visitors

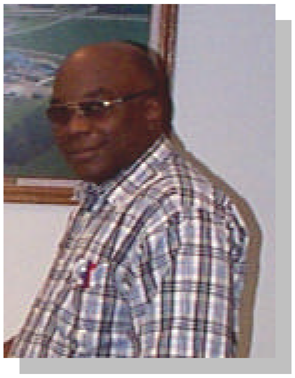
Jose Manuel Blanco, University of Barcelona (Spain), visited our lab from February 15 to early April 2002. He is interested in spatial variability of weeds as influenced by soil and landscape position. The tillage-erosion work here at Morris had a direct application for Jose.



Roger Cousens is the department head in the Institute of Land and Food Resources, University of Melbourne, in Australia. He spent one month of his sabbatical in Morris at the Soils Lab.

He received his Ph.D. in Canada under the famous biometrician, E.C. Pielou. After spending many years at the Long Ashton Research Station (University of Bristol), he left Britain and relocated in Australia.

Roger is the author of the highly acclaimed textbook "Dynamics of Weed Populations," and he is one of the most widely respected weed scientists in the world.



Friday Ekeleme is a weed scientist and assistant professor at Michael Okpara Agricultural University, Umudike, Nigeria. He worked with Frank Forcella and Dave Archer to develop simulation models of two tropical weeds. The work was funded through a grant from the USDA-Foreign Agricultural Service.

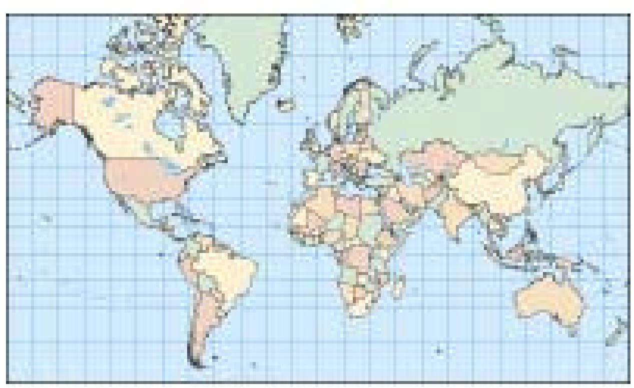
Rikke Klith Jensen is a researcher at the Danish Institute of Agricultural Sciences (DIAS) in Flakkebjerg, Denmark. Rikke also is a Ph.D. student at the Royal Agricultural and Veterinary University in Copenhagen. Her main research interest is the biology and management of Canada thistle, which is the most important perennial weed that affects organic farmers in Denmark and Minnesota. Rikke is developing computer models that predict Canada thistle shoot emergence and growth based upon site-specific microclimate variables. This research was conducted in association with Dave Archer and Frank Forcella at the Soils Lab from July through September in both 2001 and 2002.

Roberta Masin is from the University of Padua (often spelled Padova) in Italy. She is a PhD student in the Department of Agronomy & Vegetable Production. She is working on weed emergence in turfgrass. She's been using WeedCast in her studies. Her goal is to develop emergence moels for four weed species that are problems in Italian turf - - we have all of these species here in the USA too.

Roberta is being sponsored by the University of Minnesota through Professor Roger Becker. Consequently, she will be spending some time in St Paul as well as Morris.

Julio Scursoni is an instructor at the University of Buenos Aires (UBA), Argentina. He also is in the process of obtaining his Ph.D. degree. During 2001-2002, Julio spent 7 months each year in Argentina and 5 months (May-September) in Minnesota performing research on Roundup Ready crops. Julio's main research centers on understanding the biological and managerial reasons that allow some weed species to escape Roundup treatments. His stay in Minnesota is sponsored by the Monsanto Company.

Ebandro Uscanga is a Ph.D. student at the University of Minnesota, who is origially from Mexico. He is advised by Professor Jeffrey Gunsolus and Frank Forcella. Ebandro's work involves understanding how seed production of four species of pigweeds (redroot pigweed, Powell amaranth, common waterhemp, and prostrate pigweed) is influenced by the timing of emergence in Roundup Ready crop production systems. Ebandro spends the academic year at the UM-St Paul campus and the summer months in Morris.



Summer Field Day

The USDA-Agricultural Research Service "Soil Lab" in cooperation with the Barnes-Aastad Soil and Water Conservation Research Association hosted a field day at the Swan Lake Research Farm on Wednesday, August 14 from 2:30-5:00 p.m.

Registration began at 2:30 p.m. Two field tours featuring cropping systems and biotech/crops were given simultaneously beginning at 3:00 p.m.

Cropping Systems Tour: Researchers presented cropping systems, crop rotations and management practices farmers may be able to adopt in the coming years.

Also, ideas were presented about how to manage weeds with high precision.

This was the first year of the Cropping Systems Study that compares the economic returns as well as the affects on soil quality of conventional versus reduced tillage, traditional versus organic farming systems and two crop rotation (corn and soybean) versus a four crop rotation (corn, soybean, spring wheat and alfalfa).

This was the tenth and final year of the GIS Soybean Study on continuous soybeans using GIS to monitor yield, soil nutrients, weed emergence, weed seed bank and weed population movement.

Canada Thistle Emergence Study monitors shoot emergence based on soil temperature. This data can be used as a management tool to more effectively control Canada thistle.

Biotech/Crops Tour: Researchers presented a new oil-producing crop and a package of management practices for its production in the Midwest. Also, tillage practices and how they contribute to carbon loss from agricultural soils was presented.

Cuphea (pronounced coo-PHEE-ah) is a potential new/alternative oilseed crop that is being introduced into the northern Corn Belt.

Currently, the United States depends on imported coconut and palm kernel oil to manufacture products such as soaps and detergents, pharmaceuticals and ceratin dietary products. In an average year the United States imports about 500,000 tons of coconut and palm kernel oil at a cost in excess of $1 billion with future demand projected to increase. Cuphea can potentially replace this market, making the United States less dependent on foreign oil imports to meet industrial demands. Furthermore, cuphea will not compete with pre-existing agronomic crops.

Carbon Crop Study: The concern about global warming and attempts by international governments to agree to a reduction in carbon dioxide emissions has provoked quite a bit of interest in storing carbon in the soil. Soil contains about three times as much carbon as that contained in living matter and it contains more carbon than exists in the atmosphere. Crops grown to enhance soil carbon storage also have the potential to be utilized for biofuels. The purpose of the study is to identify crops, species and rotations to maximize the carbon returned to the soil in the event that payment for carbon credits becomes a reality while still producing a marketable commodity. This study compares corn, wheat, soybeans and a mixture of legumes and grasses.

The Swan Lake Research Farm is located approximately 11 miles northeast of Morris. From the intersection of State Highways 59 and 28 go north 5.5 miles on State Highway 59. Turn right (east) on County Road 74/150th Street for 5.2 miles. Turn right at the dead end and follow the signs.

Tomato Fest

NCSCRL conducted "Seeds in Space" experiment with the Morris Area Elementary School fifth graders.

Students measured tomato plants six times. They learned about making observations, collecting data and analyzing data.

Morris Area Elementary School fifth graders along with NCSCRL hosted

Tomato Fest. Students presented results of the "Seeds in Space" experiment to the community including information about USDA-ARS.

Appendix 7

Ag Week

In honor of National Ag Week, the Soils Lab invited local schools to visit and hosted an open house for the community on Thursday, March 20. The 30-minute tour included the soil conservation and photosynthesis measurement demonstrations and the science in your shopping cart and economic displays.

The theme for the event was A***Science in your Shopping Cart.***@ Many of the products you see on the grocery store shelves have a direct link to agricultural research being conducted by the USDA-Agricultural Research Service. Tour guides told the students how the strawberries, peas, shampoo, toothpaste, body lotion and laundry detergent in the shopping cart have a tie to the research we conduct at the North Central Soil Conservation Research Laboratory.

Strawberries
Problem: Weeds are hard to control when strawberry plants are being established. There are few chemicals (herbicides) that are labeled to kill weeds at that time.

Research: Frank Forcella worked with the West Central Research and Outreach Center to study the use of mats made with inexpensive and locally produced wool. The mats were laid over the rows before transplanting strawberries. Slits in the mat were cut so the strawberry transplants could grow through the mat. With the wool mats, weeds were suppressed better than with herbicides, and strawberry yields the following year were higher than in any other treatment.

Canning Peas
Problem: Nightshade is a weed that has berries approximately the same size as peas. When it comes time to harvest the peas and prepare them for canning, the machines do not recognize the difference between the peas and the green (unripened) nightshade berries. Once the berries are processed with the peas (frozen or canned), they turn brown, are unsightly on a dinner plate, and prompt consumer complaints.

Research: Frank Forcella studied rates of growth of nightshade berries and peas in collaboration with Pilsbury/Green Giant and the University of Minnesota. The research led to a computer-based system by which growing degree-days since pea planting could be used to predict the necessity of spraying a herbicide, like Pursuit, to control nightshade in peas.

Shampoo, Laundry Detergent, Tooth Paste and etc.
Problem: The oils we use in many products come from palm kernel oil grown in far away places outside of the United States. Many of these palm trees are being cut down and not

replanted. In the future, we may have a shortage of this type of oil.

Research: Russ Gesch is conducting research on a plant called cuphea. He has found that this plant can grow in Minnesota. Cuphea will lessen our dependence on other countries for a stable supply of important oils.

Gary Amundson demonstrated the importance of cover crops and residue in preventing erosion. By artificially raining on bare soil, a sparsely planted area of alfalfa and an established oats cover crop, he showed the difference in water runoff and filtration.

Chris Wente explained that plants "breathe" by taking in carbon dioxide and giving off oxygen. With the help of a miniature chamber, he showed the students how he uses the instruments to measure photosynthesis in plants.

Approximately 46 teachers and 450 students ranging from Kindergartners to high school seniors visited the laboratory from St. Mary=s, Herman-Norcross, Cyrus, Morris Area, Hancock, Appleton-Milan and Chokio-Alberta Elementary Schools, Morris Area High School and West Central High School.

The laboratory hosted an open house from 4-6 p.m. Two facility tours were given at 4:30 and 5:30 p.m.

The community had the opportunity to watch a six-minute overview of the history, staff and research conducted at the laboratory as well as to meet the researchers and enjoy locally produced refreshments. Approximately 50 people attended the event.

Other Outreach

Over the past year, the NCSCRL teamed up with local schools and organizations to promote agricultural research through several outreach events.

Super Saturday Science
Nancy Barbour and Jane Johnson worked with the University of Minnesota-Morris to co-host Super Saturday Science. This was a fun, hands-on event for young women in grades 6-8 to enhance and encourage their excitement about science and math. They encouraged the participants to consider careers in crop and soil science.

National Agronomy Student Speech Contest
Jane Johnson and Brenton Sharratt served as judges in the preliminary and final competition at the National Agronomy Student Speech Contest. The contest was held during the tri-society national meeting of the American Society of Agronomy, Soil Science Society of America and Crop Science Society of America in Indianapolis, IN. The speech contest provides and excellent opportunity for Agronomy students to improve their public speaking skills.

Science Fair
Throughout the year, Russ Gesch, Jane Johnson, Mel Bossert and Nancy Barbour partnered with the Morris Area Elementary and High Schools to design science fair projects and to serve as judges for the Science*Math Expo and the high school science fair.

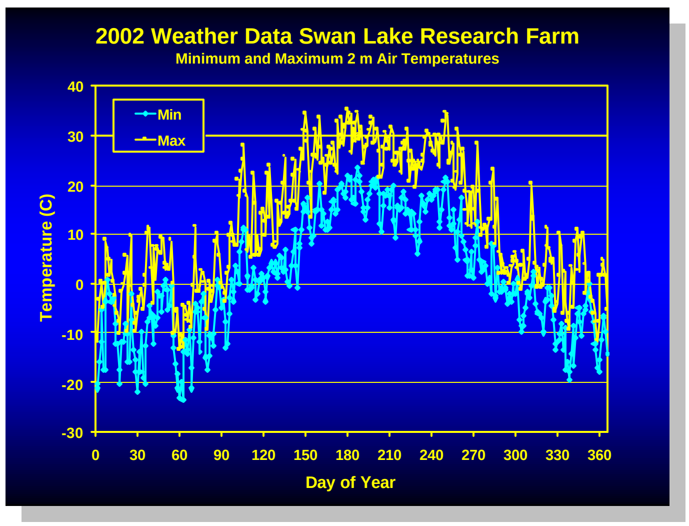
UMM Biology Club
The UMM Biology Club invited Abdullah Jaradat to give a presentation on careers in biology.

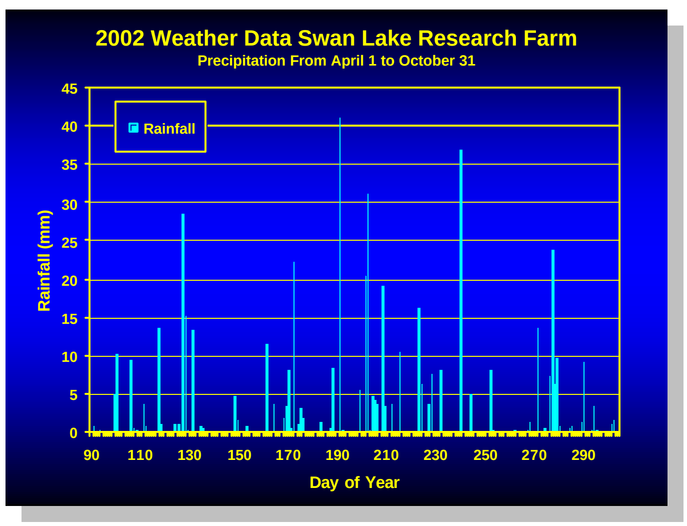
Eyeglass Drive
As part of National Disability Awareness Month, the NCSCRL employees partnered with the Morris and Hancock Lions Clubs and the Federal Executive Board of Minnesota to collect eyeglasses for Vision 2020: The Right to Sight. This is a global partnership of United Nations Agencies, governments, eye care organizations, health professionals, and philanthropic institutions working together to eliminate preventable blindness by the year 2020.

Weather Data

By Chris Wente and Don Reicosky

The following data was collected at our Swan Lake Research Farm. The growing season began a little cool with our last light frost on May 24. The precipitation between April 1 and October 31 was 499 mm/19.6 inches. The end of the growing season occurred with a frost on October 9th. The growing season was highlighted by an extreme storm on July 21 with wind gusts of 23 meters/second/51.4 mph which leveled some of the corn at Swan Lake.





A special thank you to all who contributed to the 2003 Research Report.