April 1, 2004

50th Anniversary of the Agricultural Research Service

Research Report

The

North Central Soil Conservation Research Laboratory

Dedicated in 1959

Lab Mission:

"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."

Did you know? - Lab History

The original Laboratory was built on a 15-acre site on the outskirts of Morris and dedicated in 1959. The first director was Dr. C.A. Van Doren, who had many years of practical research experience with the USDA Soil Conservation Service. *Incidentally, Van celebrated his 98th birthday in 2003.*

Preface

The State of The Agricultural Research Service Laboratory in 2003

A.A. Jaradat

This has been an eventful year at the USDA-Agricultural Research Service (ARS) North Central Soil Conservation Research Laboratory (Soils Lab).

Last year was a landmark year for the Agricultural Research Service (ARS) at the national level. November 2, 2003 marked the 50th anniversary for the establishment of ARS. In 1953, during a major reorganization, the Department of Agriculture consolidated most of its research activities into the newly named Agricultural Research Service. Six years later, ARS opened the Soils Lab in Morris.

For more than 40 years, the Lab's services and contributions to Minnesota and farming communities throughout the upper Midwest were remarkable. Moreover, the long and productive history of collaborative research involving our major stakeholders: farmers, the Barnes-Aastad Association, the State, the University of Minnesota and private sector contributed to our success in serving the farming community, in particular, and agricultural research, in general.

The Lab conducts its research under four major themes: Land Management, Soil Carbon Cycling, Crops and Weed Biology, and Sustainable Cropping Systems. We use a "big picture" approach to solve agricultural production issues associated with small-to-medium sized farms, organic systems, alternative pest management strategies, risk management and transition to more sustainable production systems.

In 2003, the Soils Lab carried out important research into integrated farming systems, among other topics. This interdisciplinary, long-term research is aimed at developing agricultural systems 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.

During the last year, soil scientists carried out research on strip tillage and residue management to determine crop response to various tillage methods on heavy soils to determined which crop rotations and crop species contribute to the maximum carbon input and to determine the proper technique for measuring nitrous oxide fluxes from soil and to experiment with polymer seed coating under no-till conditions.

The land management research team focused on estimating the nitrogen credits due to nitrogen fixation by legume crops and completed a study of the effect of soybean seed inoculation and treatment with magnesium.

Crop scientists carried out numerous greenhouse, growth chamber and field studies to refine management practices including nutrition, root growth, weed control and yield potential of Cuphea as a new crop. They also 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 and weed biology.

The farming systems study is already in its third year and baseline data was compiled for the economic evaluation of alternative cropping systems and costs of transitioning to alternative cropping systems. An agricultural economics study was initiated to identify economic barriers in converting to organic crop production.

The Lab collaborated with farmers to plant the new crop, Cuphea, on a larger scale, and to carry out advanced management practices to reduce soil erosion and to achieve higher yields.

The Lab was successful in building a multidisciplinary team of scientists and support staff in order to accomplish its research mission. With the recruitment of Sharon Lachnicht, a soil biologist, the Lab can assume a leading research role, in cooperation with other Agricultural Research Service (ARS) units, to exploit the vast soil biological diversity for purposes in line with the current demand for a sustainable and more environmentally friendly agriculture. We also recruited Sharon Papiernik, a soil scientist, to fill the position vacated by Mike Lindstrom. Her research objectives are to develop management practices that maintain agricultural productivity while minimizing detrimental effects on the environment, including surface water, groundwater, air and soil quality.

Dave Archer, agricultural economist received funding to hire a post-doctoral student. The first objective for this two-year position is to quantify the site-specific economic returns and ecosystem services provided by alternative cropping systems in the Northern Corn Belt. A second objective is to identify the economic incentives necessary for producers to choose production practices that maximize joint provisions of carbon storage, ecosystem services and economic returns.

The Lab hosted visiting national and international scientists and graduate students with research interests relevant to the Lab mission and objectives. Roberta Masin, graduate student from the University of Padua in Italy, worked with Frank Forcella to develop emergence models for four weed species that are problems in Italian turf. Dr. Svitlana Kokhan, a Fulbright scholar from the Ukraine, spent four months at the Lab working on incorporation of legume credits into a Nitrogen-fertilization decision aid with Alan Olness. Dr. Gudapaty Pratibha from India visited the Soils Lab to discuss her experience in dryland crop production of oilseed crops, agroforestry, cropping systems, alternative crops (medicinal, aromatics and dye yielding species) and tillage management in problem soils. Julio Scursoni, graduate student from the University of Buenos Aires in Argentina, continued his work on his Ph.D. research in Morris on weeds in Roundup-Ready cropping systems. Dr. Friday Ekeleme, a weed scientist and assistant professor at Michael Okpara Agricultural University in Nigeria, visited the Laboratory on a Foreign Agricultural Service grant. Dr. Ekeleme worked with Frank Forcella on a shoot emergence model of a tropical weed known as cogongrass, as well as finished a model and wrote a paper for another plant known as tropic ageratum.

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.

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The Barnes-Aastad Association

What is the Barnes-Aastad Association?

When the USDA-Agricultural Research Service (ARS) North Central Soil Conservation Research Laboratory ("Soils Lab") in Morris was established in the late 1950's, Dr. C.A. van Doren, the first director, recognized the need for long-term access to land for conducting soil erosion research.

In 1959 a small group of conservation-minded farmers and business people came together to support Dr. van Doren's vision for agricultural research in the upper Midwest. This group formed and incorporated the Barnes-Aastad Soil and Water Conservation Research Association with a mission to support agricultural research. They sold shares to raise capital to purchase land with the desired characteristics: predominantly Barnes-Aastad soil type with a 6% slope located near a source of water. The following year they purchased 80 acres bordering Swan Lake in Swan Lake Township of Stevens County. This property became known as the Swan Lake Research Farm.

The Barnes-Aastad Association leases the Swan Lake Research Farm to the ARS Soils Lab. The farm has since been expanded to 130 acres to accommodate a wide range of field studies, including land management, soil carbon cycling, crop and weed biology and sustainable cropping systems.

The Barnes-Aastad Board of Directors met in early 2004.

At their annual meeting held each April, they invite the ARS Soils Lab staff to present progress reports on their research. The Barnes-Aastad Association serves as a grass roots advisory group for the ARS Soils Lab by giving input on research needs not only from the farmers' standpoint, but also as a voice for rural society.

Each year the Barnes-Aastad Association sends a delegation of volunteers to Washington, D.C., to express their support for agricultural research. Recognizing that agricultural and environmental problems often do not have geographic boundaries, the Barnes-Aastad Association also interacts with groups supporting research at other institutions in the upper Midwest. This gives them a stronger voice when meeting with legislators. The 2004 delegation included Sue Dieter, John Mahoney, Dan Perkins and Jim Wink.

As a result of the Barnes-Aastad lobbying efforts, Congressman Collin Peterson accepted an invitation to visit the lab on March 19 to celebrate National Ag Week and the 50th Anniversary of the Agricultural Research Service.

Congressman Collin Peterson visited the Soil's Lab on Friday, March 19, 2004.

Since the first informational meeting in 1959, the Barnes-Aastad Association membership has increased from several people to a membership of 70. Members come from a wide range of occupations, but all have a common goal of protecting our fragile natural resources and stabilizing the economy of rural America. According to Jere Ettesvold, president of the Barnes-Aastad Association, the mission of Barnes-Aastad Association has not changed. "Barnes-Aastad is committed to supporting the research program of the ARS Soils Lab in Morris."

The Swan Lake Research Farm

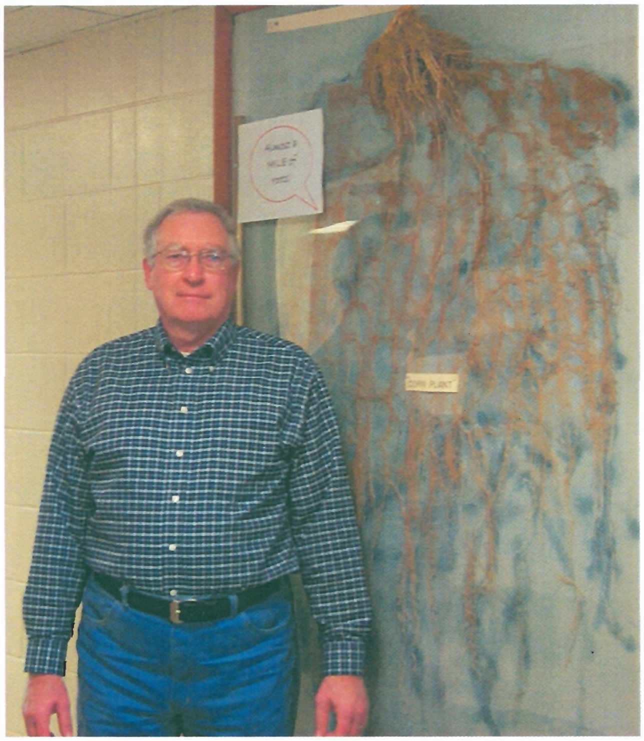
This 130-acre research farm is owned by the Barnes-Aastad Soil and Water Conservation Research Association, a non-profit organization of farm managers and agri-business personnel, committed to supporting the research program of the USDA-ARS Soils Lab in Morris, MN.

Please contact Jere Ettesvold if you would like to join the Barnes-Aastad Association.

Jere Ettesvold, President
40048 180th Street
Cyrus, MN 56232
(320) 795-2281

Photo below was taken in 2000 of the 130-acre Swan Lake Research Farm and the photo on the right was taken in 1960 of the 50-acre farm.

Collaborator Reports



Ward Voorhees, Collaborator
voorhees@morris.ars.usda.gov

Research Focus: Agronomic effects of soil compaction caused by wheel traffic of farm machinery

Now and Then

A lot of water has gone over the dam since the Soils Lab was established back in the 1950's. I finally started writing a history of the Lab a couple months ago, and currently have about 50 pages written. However, I'm having a difficult time focusing on an objective. My original intent was to document how and why the Lab was formed, to give newer employees "a better sense of belonging." Then I thought perhaps there should be discussion of the changes in research emphasis over time.

But I soon found myself drifting away from the factual, perhaps boring, topic of research to the human side of things. Now it was getting interesting! The danger in that approach is interjecting too many of my own memories and experiences, thus making the book too much like an autobiography. But I suppose if someone thinks it's too much that way, they can write their own book from their own perspective.

As it now stands, the book will probably include a mix of all the above. I'm not even sure what it will look like. It may wind up being a simple in-house document, stapled together, and put in some obscure place until 50 years from now when someone decides to write a 100-year history. Or (at least in my dreams) it may be a hard-covered book. Time will tell!

On a different note, I still do some consulting on soil compaction problems, and work with Dr. Satish Gupta, Dept. of Soil, Water and Climate at the University of Minnesota on organizing an annual lecture series called "Emerging Issues." These lectures bring in internationally known scientists to speak on a topic that is of current high interest. We also facilitate interaction between the invited guest, faculty and grad students. This year's program is on hypoxia, and will feature Dr. R. Eugene Turner, a wetlands ecologist from Louisiana State University. Willis Anthony, a producer from southern Minnesota, and a recent recipient of the University of Minnesota Steihl Award, will also be on the program. The date is April 2 on the St. Paul Campus.

Collaborator Reports

Mike Lindstrom, Collaborator
lindstrom@morris.ars.usda.gov

Research Focus: Soil movement by tillage and effects on long-term soil sustainability

This year I am serving as the program chair for the Soil and Water Conservation Society Annual Meeting to be held in St. Paul, July 24-26. Duties for this responsibility included selecting the themes for the meeting, issuing a Call for Papers and Symposia, reviewing the submissions, and selecting the oral presentations, poster presentations, and symposia that will be presented at the annual meeting. Themes selected for the annual meeting are:

Soil and Environmental Quality Agricultural Management and Environmental Quality Assessing the Effectiveness of Conservation and Environmental Programs Geo-spatial Technology for Conservation - Soil, Water, and Land

A total of 27 symposia, 190 oral presentations and 100 poster presentations were submitted. Of these submissions, 13 symposia, 85 oral presentations and 90 poster presentations were selected for the annual meeting. Theme chairs were identified for each theme and these chairs reviewed the submissions for their theme. Selection for presentation was based on the recommendations of the theme chairs.

In addition, I have participated in two committees this past year. I am serving on the Soil and Water Conservation Society - Soil Science Society of America Liaison Committee. The purpose of this committee is to further cooperation and interaction between the two societies. This committee is currently establishing the policy for joint membership and awards. I am also serving on the 2004 Best Paper Award committee for papers published in the Journal of Soil and Water Conservation.

Last October, I was invited to present a paper on Soil Conservation in the United States at a Symposium on Technology for Soil Conservation Techniques in Braunshweig, Germany.

Crop & Weed Biology

Frank Forcella, Research Agronomist
forcella@morris.ars.usda.gov

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

Wild Oat Emergence Model

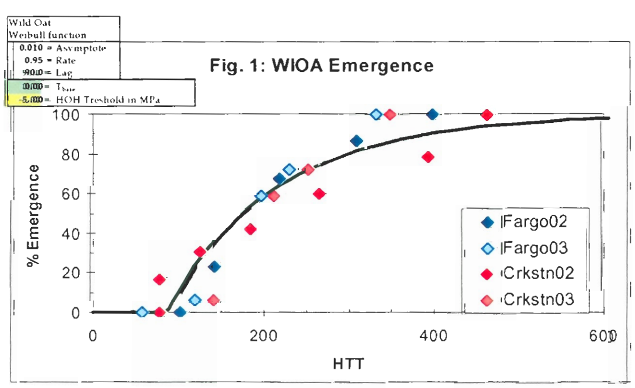
Frank Forcella, Dave Archer, Krishona Martinson, Beverly Durgan and George Kegode

Wild oat remains a serious weed of small grain crops throughout the world. Understanding when this species emerges before and after the crop is planted can aid tremendously in deciding when and how to impose management. Consequently, what is needed is a tool that permits easy, rapid and real-time assessment of the timing and extent of seedling emergence.

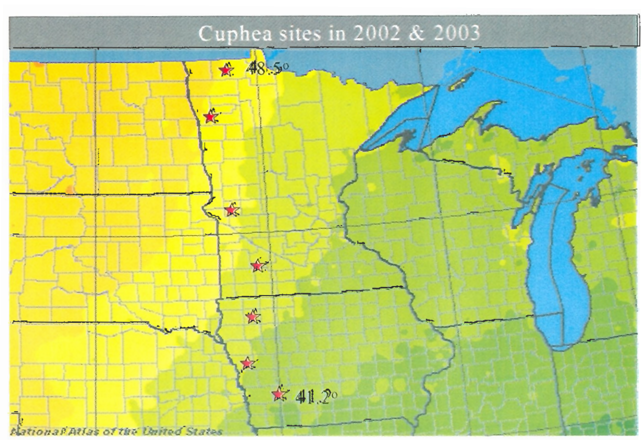
Such a tool is being developed by a team of research involving the USDA-ARS Soils Lab, University of Minnesota faculty and extension personnel and NDSU faculty. They have been constructing a wild oat seedling emergence model based on a concept known as soil HTT or "soil hydrothermal time." HTT is exactly the same as growing degree days except that it includes soil water stress. That is, when the soil is dry or cold, HTT does not accumulate. It only accumulates when the soil is both warm and moist.

The following chart represents our current idea of how wild oat seeds respond to soil HTT measured at 5 cm (2") soil depth, using a base temperature of 0°C (32°F) and a base water potential of -5 MPa. The solid line represents the "model" of wild oat emergence. The symbols represent observations of wild oat emergence recorded by Krishona Martinson in 2003 and 2004 at Crookston, MN and Fargo, ND., in a collaborative project between UM, NDSU and ARS.

The wild oat emergence model is being inserted into a computer program known as WheatScout, which is discussed elsewhere in this report. WheatScout combines crop and weed biology and ecology (such as the wild oat emergence model) with management options and economic forecasts to help crop consultants and farmers make the best management decisions.



Results from Krishona Martinson

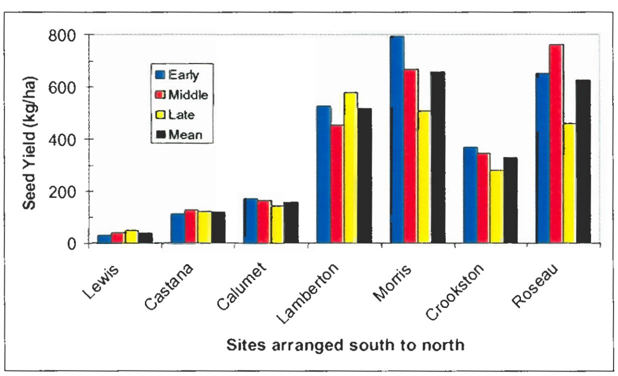


Crop & Weed Biology

Cuphea Production Zones

Frank Forcella, Dean Peterson, Gary Amundson and Russ Gesch

We have shown previously that the potential alternative oilseed crop, cuphea, grows well in west-central Minnesota. However, we know little about its range of adaptation. Consequently, in both 2002 and 2003, we examined location and planting date effects on cuphea seed yield and biomass accumulation. Cuphea was sown at three times beginning in mid to late April through late May to early June at sites ranging from southwestern Iowa to northwestern Minnesota, as seen on the map on the previous page.

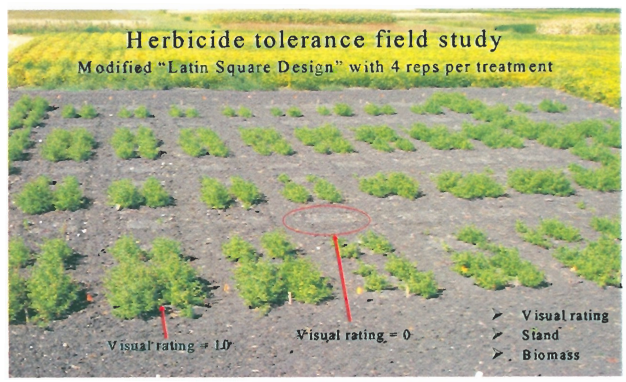


Seed yields in 2003 followed the same trends as in 2002. Yields were relatively high in Minnesota (except at Crookston) and relatively low in Iowa. We concluded that the variety of cuphea that currently is available is adapted to latitudes above 43 degrees. Thus, cuphea may be a specialty crop specifically tailored to conditions in Minnesota and other northern states.

Cuphea Herbicide Tolerance

Gary Amundson, Frank Forcella, Dean Peterson and Russ Gesch

An important aspect of growing any crop is weed control. For a new crop like cuphea, however, nothing is known about its tolerance to herbicides. Consequently, we undertook two studies to identify herbicides that cuphea tolerates.



The first study was conducted in the greenhouse using a "herbicide spray chamber" that was constructed at the Soils Lab. For preplant incorporated or preemergence herbicides, soils were sprayed and cuphea seeds planted. Emerged cuphea plants were evaluated for tolerance in comparison to that that emerged from soils not treated with herbicides. For postemergence herbicides, cuphea seedlings were sprayed at the 3-leaf stage and evaluated for tolerance two weeks later in comparison to seedlings not treated with herbicides. The most promising herbicides identified from the spray-chamber experiments were tested during 2003 in a field experiment, as shown in the above photograph. Not all of the promising herbicides kept their promises, cuphea tolerated a number of them quite well. Good tolerance was shown to the four herbicides:

Ethalfluralin (Sonalan) PPI
Isoxaflutole (Balance) PRE
Mesotrione (Callisto) POST
Trifluralin (Treflan) PPI

And fair tolerance was shown to four herbicides or herbicide mixtures:
Mesotrione (Callisto) PRE
Isoxaflutole (Balance) PRE and Mesotrione (Callisto) POST
Ethalfluralin (Sonalan) PPI and Mesotrione (Callisto) POST
Imazethapyr (Pursuit) POST

Crop & Weed Biology

Canada Thistle Emergence, Growth and Management

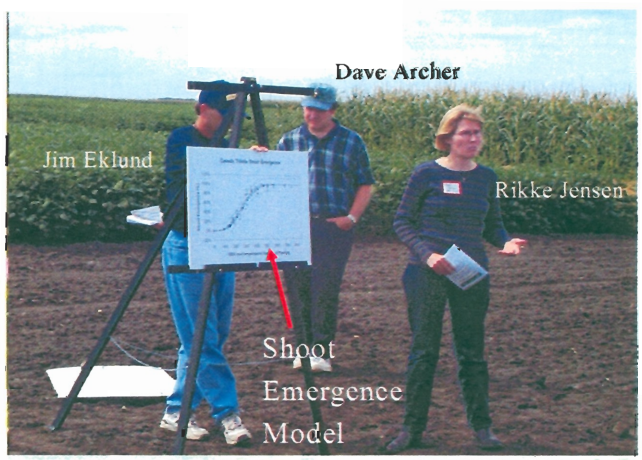
Frank Forcella, Dean Peterson and Gary Amundson

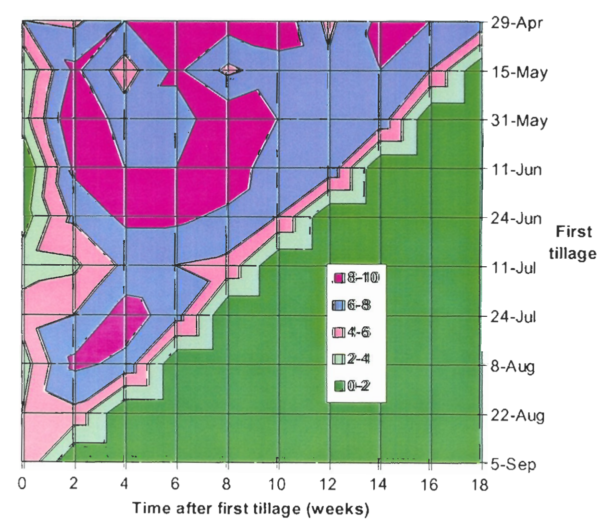
Canada thistle remains a problem to crop production in northern states despite the advent of herbicide-tolerant crops such as Roundup-ready soybean. On many organic farms systems, Canada thistle can be so important that it threatens continuation of production without herbicides.

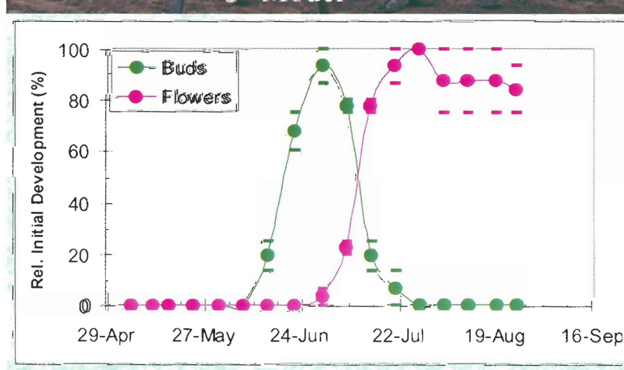
As part of a collaborative project between the Southwest Research and Outreach Center, the University of Minnesota-St Paul and the USDA-ARS Soils Lab, we have been studying Canada thistle shoot emergence, shoot growth and management in simulated organic and conventional farming systems on the Bartz farm in Grant County.

We have found that soil tillage at the time of flower bud formation (typically mid June) is the most effective time to suppress Canada thistle mechanically. This very narrow "window of opportunity" is enlarged dramatically if an effective herbicide, such as glyphosate, is used any time in June or July.

If these results are repeatable in 2004, organic farmers have the opportunity to develop cropping systems and make more informed decisions for managing Canada thistle. For instance, fresh peas can be sown in April, harvested in mid June, at which time the soil may be plowed and subsequently sown to buckwheat, which can be harvested in the fall.







Crop & Weed Biology

Russ Gesch, Plant Physiologist

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

Cuphea—A New Alternative Crop for the Upper Midwest

As a part of our research mission to develop sustainable agricultural cropping systems for the upper Midwest, one of our primary goals is to identify and characterize viable new or alternative crops. Cuphea is a new experimental oilseed crop that we have been studying since 1999. Though it has not yet been commercialized, the gap between research and commercial production of cuphea is closing quickly. Largely, this is due to the research success achieved by our Lab, including developing best management practices for cuphea production and identifying soil and climatic limitations for its growth. Cuphea has excellent potential as becoming a "third" crop that can be rotated in corn-soybean cropping systems.

Seed oil of cuphea is uniquely different than that of conventional oilseed crops presently grown in the U.S. Cuphea oil is rich in small and medium-chain triglycerides making it similar to tropical plant oils, which are currently imported into the U.S. at a rate of about 650,000 metric tons annually. Therefore, cuphea can serve as a domestic replacement for tropical plant oils, which are used by the chemical manufacturing industry to produce a wide range of products. Also, because cuphea oil is vastly different than that of conventional oilseeds like soybean, it will not directly compete for the same markets.

In 1999 our cuphea research program began with little more than a teaspoon of seed. Last summer we successfully ran acre-size test plots on farms in Minnesota, Michigan and Illinois. Figure 1 shows a two-acre field of cuphea that was grown last summer at our Swan Lake Research Farm. This cuphea was successfully produced and later harvested (~840 kg/ha) using best management practices that our Lab has developed.

Fig. 1. Two acre plot of cuphea grown at the USDA-ARS Swan Lake Research Farm.

Planting: Because of small size and density of cuphea seed and shallow seeding-depth requirement, planting cuphea can be difficult. This past year we collaborated with a company called Germains to test various seed coatings for cuphea to increase the ease and accuracy of planting and improve stand establishment. Germains provided cuphea seed covered with five different coatings. Although they would not reveal to us the specific chemical composition of these coatings, the formulations used were to aid in plant-ability and germination.

Crop & Weed Biology

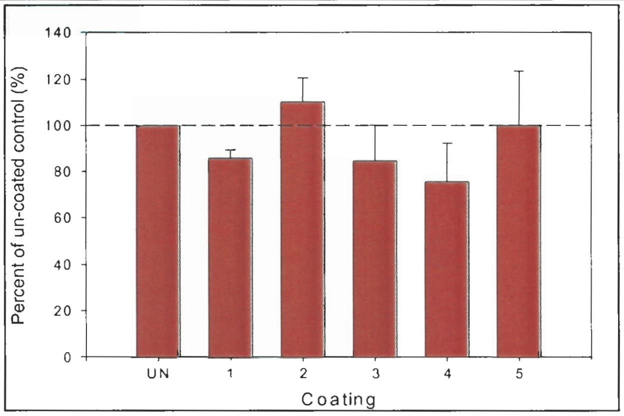


Fig. 2. Percent of plant emergence in the field from coated cuphea seed as compared to un-coated control seed. Five different seed coatings were tested. All treatments were planted at a rate of 252 seeds per meter of row.

Coated and un-coated cuphea seed were planted in replicated field plots at the same rate of 252 seeds per meter of row. Figure 2 shows the percentage of emerged plants from coated seed as compared to un-coated seed. Only coating 2 provided better seedling emergence than the un-coated control seed. However, all five coated seed treatments tended to be easier to plant than the uncoated control. Also, there was greater uniformity in stand establishment for coated seed, which is likely related to increased accuracy at which seed could be delivered to a specific depth. In 2004 we will further test coatings such as treatment #2, and variations of it, for cuphea seed.

Irrigated Cuphea

We know from previous research that water is a highly limiting factor for cuphea seed production. In part this is because cuphea has a low-water use efficiency of seed production. It does not develop a deep root system, thus not allowing it to extract moisture from deep in the soil profile. Therefore, in 2002 we began an irrigation study to address the issue of what the yield potential of cuphea is when water is not a limiting factor during the growing season. Using tensiometers placed at soil depths of 10, 30, 80, and 100 cm in experimental plots, we monitored soil matric potentials and then drip irrigated as necessary to maintain treated plots at either 50% or 100% field capacity for soil moisture. Last summer we received a grant to hire a science teacher intern to help conduct a research project at the NCSCRL. We were fortunate to hire John Van Kempen, a local area science teacher, who assisted in conducting the cuphea irrigation study.

Seed yield results for both 2002 and 2003 are shown in Figure 3. In 2002 there was little difference in yield between non-irrigated and irrigated cuphea. This is because soil moisture levels among all treatments including non-irrigated plots remained relatively high and did not differ throughout the 2002 growing season due to a high amount of precipitation. During the summer of 2003, little precipitation fell between mid July and late August, and soil moisture was very low in the non-irrigated cuphea plots throughout this period. This is a very critical time for cuphea development as the plants enter reproductive phase typically in late July and continue to set seed through early September. Irrigating to 50% field capacity in 2003 resulted in nearly doubling seed yield, while watering to 100% field capacity nearly tripled yields. Clearly, present varieties of cuphea may not be well suited for areas with low precipitation or light soils with poor water-holding capacity, unless irrigation is available to optimize yields.

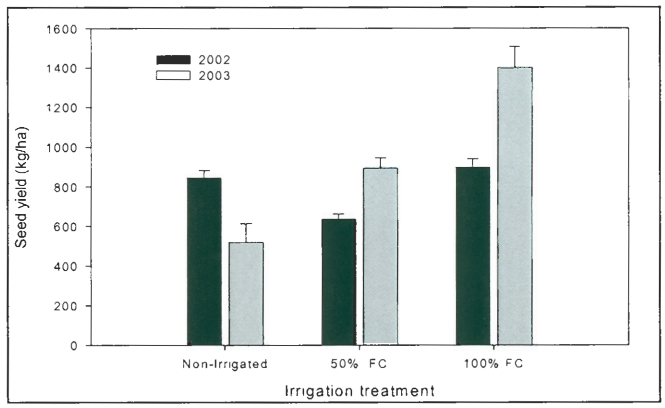
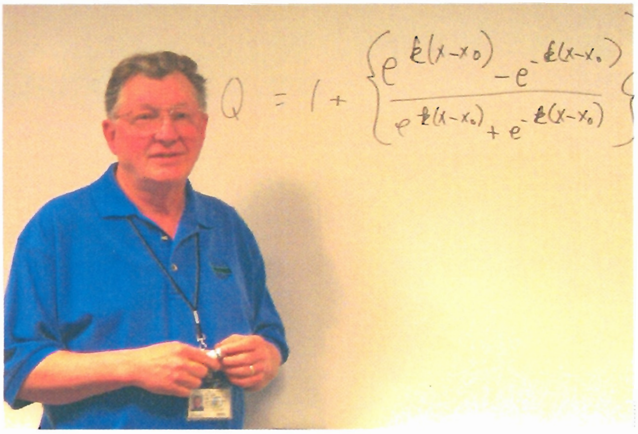


Fig. 3. Cuphea seed yields response to irrigation during the 2002 & 2003 growing seasons

A Final Note

Over this past year, certain U.S. chemical manufacturing companies have expressed serious interest in buying processed cuphea oil. In fact, the amount of oil requested by one company alone is large enough to require scaling-up cuphea production to 300,000 acres or more in the near future. There are still scientific and non-scientific hurtles to overcome before commercial success of cuphea can be achieved. Currently, the NCSCRL along with other cuphea researchers are working closely with an international company whose expertise is in commercializing new/specialty crops. The company, called Technology Crops Incorporated, will be contracting growers in the upper Midwest region during 2004 to grow 50 to 60 acres of cuphea for seed production.

Land Management



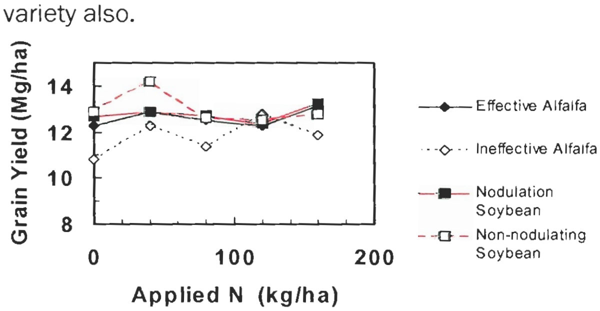
Alan Olness, Soil Scientist
olness@morris.ars.usda.gov

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

Do Legumes Really Add Nitrogen to the Soil for the Next Crop?

This question has been asked in a study at the Barnes-Aastad Research Farm at Swan Lake.

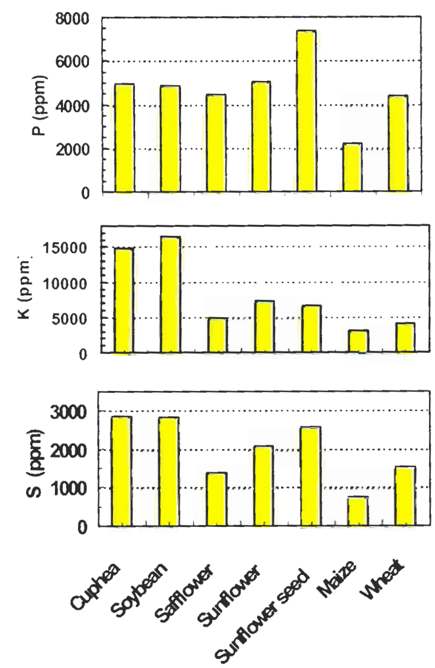
An effectively nodulated alfalfa variety and a non-effectively nodulated variety were grown side by side and then corn was grown the next year. The corn was fertilized with nitrogen at rates ranging from 0 to 160 lbs per acre. The experiment was repeated with a nodulating variety of soybean and a non-nodulating variety also.



In both cases, little benefit was obtained from fertilizing with nitrogen in the year following the legume even when the legume didn't fix nitrogen (Fig. 1).

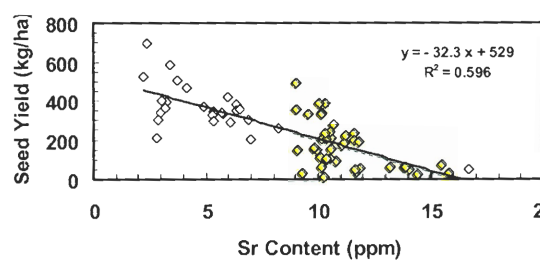
Clearly, some of the benefits of having legumes in the rotation come from some factor other than nitrogen.

Some benefits undoubtedly come from interrupted of plant disease cycles, enhanced soil structure (especially with alfalfa) and interrupted plant insect pests cycles.



Using new technology to evaluate seed may provide clues to fertility management of crops, new and old.

For example, analysis of cuphea seed grown at several locations in the region show that this crop grows best in the Morris, MN area. Analysis of the seed indicates that it contains rather large amounts of phosphorus, potassium and sulfur compared to other crops grown in the area (Fig. 2, 3, and 4.)



More dramatic is the evidence that Strontium (Sr) accumulation by the crop is inhibiting yield and seed production (Fig. 5).

Taken together with other observations that cuphea has a weak root system, the research results suggest that fertilizer should be applied in band applications near the row. Also, that cuphea will respond to potassium, sulfur and phosphorus fertilizer even though soil tests suggest the soils are rather rich in these nutrients.

Land Management

Sharon Papiernik, Soil Scientist
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Research Focus: Interdisciplinary research to develop management practices for American agriculture that minimize environmental contamination while maintaining production

Education:

Ph.D. 1995 Soil and Water Science, University of Nebraska, Lincoln, Nebraska

B.A. 1991 Chemistry, University of Minnesota, Morris, Minnesota

Previous Professional Experience:

1997 - 2003 Soil Scientist, United States Department of Agriculture, Agricultural Research Service, George E. Brown Jr. Salinity Laboratory, Riverside, California

Development of management practices for soil fumigation that minimize the potential for off-site transport of fumigant compounds, focusing on fumigant emissions into the atmosphere

1995 - 1997 Post-Doctoral Scholar, Woods Hole Oceanographic Institution, Department of Chemistry and Geochemistry, Woods Hole, Massachusetts

Fate and transport of industrial contaminants in marine environments

1991-1995 Graduate Research Assistant, Department of Agronomy, University of Nebraska, Lincoln, Nebraska

Assessment of the mobility and persistence of pesticides in groundwater

Research Interests

Agriculture is often implicated as a source of environmental contamination. For example, agriculture was the most commonly-listed source of surface water quality impairment in the USEPA's 2000 National Water Quality Inventory. Production agriculture has the potential to adversely impact air quality (for example, emissions of dust, odors and methane), soil quality (depletion of topsoil, increase in soil salinity), and water quality (sediments, nutrients and pesticides in surface water and groundwater). While non-agricultural activities have a large capacity and a sordid history of environmental contamination, it cannot be denied that production agriculture impacts, and is impacted by, environmental quality. Agriculture is being increasingly regulated, and I intend my research to contribute information so that decisions affecting farmers are based on sound science.

My specific research interests are in developing management practices that minimize the adverse impacts of production agriculture on environmental quality while maintaining productivity. My training is interdisciplinary, and I have expertise primarily in soil chemistry and soil physics. Thus, I am well-equipped to investigate the factors that affect the transport of agricultural pollutants (including sediment, nutrients, pesticides and others) away from their target. My short-term research goals are to investigate (a) the impact of soil tillage on soil quality variations on a landscape scale, (b) runoff of nutrients and other potential contaminants from manure-treated fields and (c) the fate and transport of agricultural chemicals under conditions typical of the upper Midwest.

Soil Carbon Cycling

Don Reicosky, Soil Scientist
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Research Focus: Tillage-induced CO_2 loss and developing improved soil and residue management practices to enhance Carbon sequestration and environmental quality

Predicting Effects of Corn Stover Harvest on Soil Organic Matter

Alan Wilts, Don Reicosky, Jane Johnson and Ray Allmaras

Farmers and those in favor of producing ethanol from corn stalks need information to help them predict how corn stalk removal may affect soil organic matter levels in specific fields. Soil organic matter is formed from carbon-containing compounds that originate from plants, animals and other organisms. Soil organic matter improves vital soil functions and characteristics such as nutrient cycling, water retention and texture and plays a role in lessening erosion and leaching losses. High soil organic matter concentrations are associated with good soil quality.

If corn stalks are harvested, how much residue needs to be left on the field to maintain soil organic matter and soil organic carbon? To answer this question, we need to understand the carbon contribution from both above- and belowground plant material to the formation of soil organic matter. Total source carbon is generally defined as the cumulative carbon input to the soil from both above- and belowground plant material over several years. During the last decade, a research study in France indicated that source carbon from corn roots was 1.5 times more than source carbon from aboveground corn plant material. Many researchers continue to investigate soil carbon and find that it may be partially controlled by crop residue return or removal. The cumulative effect of tillage and many cropping rotations has been a 30 to 50% decrease in soil organic carbon.

Local scientists, including Don Reicosky and Jane Johnson, conducted studies to help them understand how removal of corn stalks may change the amount and characteristics of soil organic carbon. The amount of corn residue remaining in a field after silage harvest was assumed to be similar to that remaining after grain harvest plus corn stalk removal for energy purposes. To help answer questions about long-term effects of stalk removal, scientists use basic chemistry and plant physiology. One method relies on the fact that stable carbon has different weights in nature; the most common form of carbon has a molecular weight of 12 (abbreviated $C^{12)}$ and the other stable form of carbon exists with a molecular weight of 13 ($C^{13)}$. Different plant species may consist of different proportions of these forms of carbon. For example, corn plants are characterized by a higher $C^{13/C12}$ ratio than soybean plants. In soil, the $C^{13/C12}$ ratio approaches that of the plants when the same plant species is grown over a long period of time. These ratios are determined from soil samples collected at the beginning and end of a long period to estimate the proportion of soil organic carbon that was derived from stable plants (i.e., same crop grown year-after-year).

Recently, staff at the Soils Lab in cooperation with other USDA-ARS staff from St. Paul used the $C^{13/C12}$ ratio method, data from a long-term continuous corn experiment and an experimental model to obtain a direct measure of the source carbon input to the soil from roots and other unharvestable plant material during a 29-year time period. A long-term corn experiment was established at a West Central Research and Outreach Center (WCROC) field site that had a long history of mixed cropping. The study included 16 plots, each 50 x 50 ft. (15 x 15 m), from which data was collected from 1965 through 1995 by WCROC staff in cooperation with USDA-ARS staff from Morris and St. Paul. Treatments included silage removal, grain harvest only,

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low [74 lb nitrogen/acre (83 kilograms nitrogen/hectare)] and high fertility [148 lb nitrogen/acre (166 kilograms nitrogen/hectare)], and an unfertilized check. Grain or silage yields were monitored annually. Fertilizer was fall broadcast and all plots were moldboard-plowed. In addition to determining the amount of source carbon input to soil from roots, another objective of this work was to evaluate the long-term effects of corn stover harvest or return on soil carbon.

Fig. 1. A long-term corn study conducted near Morris included a treatment where corn stalks were harvested as silage (left) and a treatment where corn stalks remained (right) and grain only was harvested a few weeks later. The effects of silage harvest versus grain only harvest on soil carbon were noted. If corn stalks are removed for ethanol production, appropriate and site-specific harvest rates need to be determined to reduce the risk of losing soil organic matter and long-term productivity.

There are few such experiments with data available to estimate source carbon from corn stalks and unharvestable materials. The method of analysis requires the historical record of the experimental plots and grain yields. The change to continuous corn was reflected in the C^{13}/C^{12} values that gradually increased over the 29-year test period which indicated the transformation of corn-derived carbon into soil organic carbon.

A model developed by USDA-ARS scientists Ray Allmaras, Dennis Linden and Ed Clapp from St. Paul was used to estimate source carbon. Briefly, the model consists of three steps: 1) for the silage-harvested treatment, the corn root-derived soil organic carbon was equal to the calculated total corn-derived soil organic carbon since there was no contribution from corn stalks; 2) cornstalk-derived soil organic carbon from the grain-harvested treatment was obtained by subtracting out the total corn-derived soil organic carbon (from roots only) estimated in step 1; and 3) source carbon from roots was obtained by assuming that the ratio of corn-stalk-derived soil organic carbon to total source carbon from stalks was equal to the ratio of corn-root-derived soil organic carbon to total source carbon from roots.

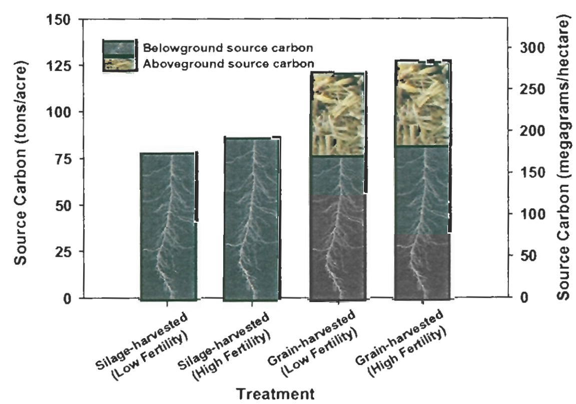


Fig. 2. Source carbon input to soil during a 29-year period (1965 to 1995).

The cumulative 29-year corn stalk yield was an initial parameter used to estimate the total carbon available from stalks. Soil organic carbon and $C^{13/C12}$ were measured from soil samples taken in 1965 and 1995 and this data was used in the model to estimate the total source carbon input to the soil from corn.

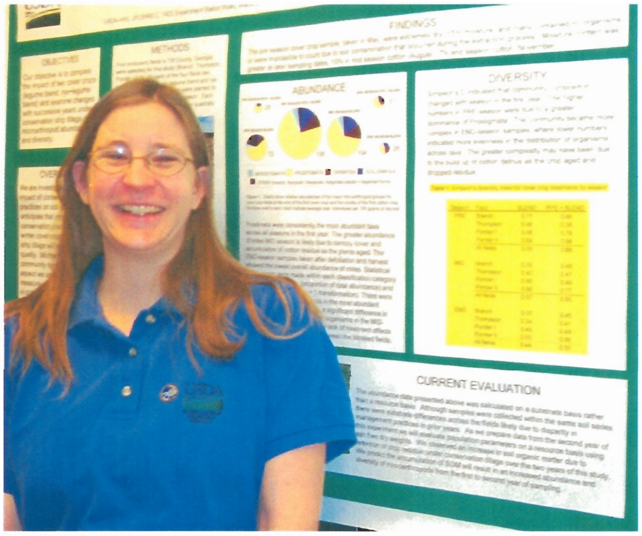
After 29 years, total source carbon input to soil from the corn crop was 119 to 127 tons/acre from the grain-harvested plots and 77 to 84 tons/acre from the silage-harvested plots (Fig. 2). Source carbon input to the soil from grain-harvested plots was about 43 tons/acre more than from silage-harvested plots. In the 0 to 12 inch (0 to 30 cm) soil depth, only 4.1 to 7.4 tons of corn-derived soil organic carbon per acre was retained in the soil organic matter.

Soil Carbon Cycling

An important finding from the long-term corn study was that roots and other material input 1.8 times more source carbon to the soil than corn stalks. Soil organic carbon derived from corn was estimated to be only 5% of the total source carbon input to the soil over 29 years. Soil organic carbon that was derived from corn was reduced when silage was harvested from the same plots each year compared to harvests of grain only which was expected since there was no source carbon input to the soil from aboveground plant materials. The vast majority of the total source carbon input to all plots (silage-harvested and grain-harvested) was cycled back into the atmosphere through soil respiration, which was increased by moldboard plow tillage.

It is desirable to increase the efficiency of soil organic matter build up to enable farmers to maintain crop production with minimal impact on the environment. Research findings showed that corn stalk harvest options and residue management may have important implications to build soil organic matter. If corn stalks are removed for ethanol production, appropriate and site-specific harvest rates need to be determined to reduce the risk of losing soil organic matter and long-term productivity.

Soil Carbon Cycling



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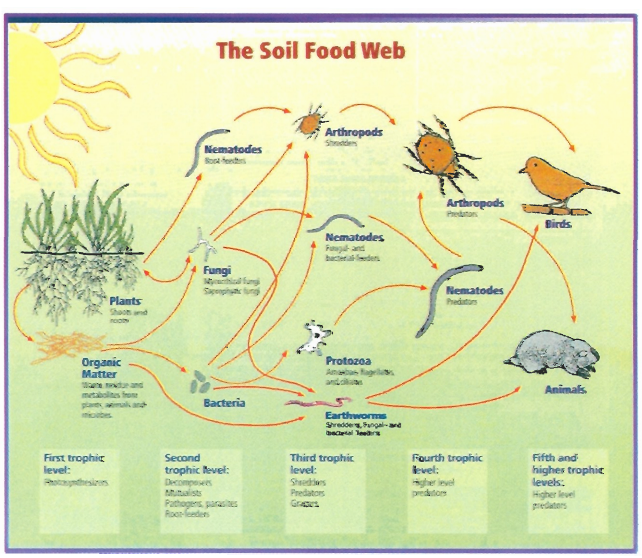
Research Focus: Soil biology in relation to soil quality and land management issues

Aims of Soil Biology Research at NCSCRL

Soil biota are important for the turnover of nutrients in the soil system. Studies that analyze nutrient cycling processes can be useful in determining the relationship of soil biota to management strategies used in agricultural fields. The impacts of different management strategies on crop productivity can be identified by establishing how these strategies affect the relationship of soil biota to organic matter dynamics and nutrient availability. Soil organic matter (SOM) complexity is an aspect of interest in the examination of the management strategies applied to agricultural fields. SOM complexity is an issue raised in systems that are managed with crop rotations. Residue quality, that varies among crops, residue quantity and location (i.e. standing, flat or buried), as affected by tillage management affects the capacity of the soil biota to turn over this organic matter into available nutrients for current and future crop production. Tillage effects on soil aeration, water availability, soil organic matter content and physical disturbance have positive and negative feedbacks on the soil micro-, meso- and macro-biota which need to be addressed. Analyses that include the soil biota are important in identifying the impact of nutrient management regimes that make use of inorganic fertilizers or organic fertilizer sources (green and/or animal manures).



Studies examining decomposition rates and nutrient mineralization give an indication of soil biota activity but not their dynamics. It is important to conduct holistic studies that address not only nutrient turnover and availability, but changes in soil biota biomass and community assemblages. Decomposition and mineralization studies that include soil biota analyses will allow us to develop ways to establish short-term (e.g. one time) investigations that indicate soil biota relationships in residue, tillage and nutrient management regimes. Research is needed to establish the utility of soil biota as indicators of healthy and productive land in relation to the farming practices currently in use in Minnesota.

All soil biota, from the microbiota including bacteria, fungi and actinomycetes to the meso- and macro-biota including microarthropods, enchytraeids and earthworms are important in the turnover of soil nutrients. These organisms act on the physical, chemical and biological soil components at different scales depending on their size, biomass potential and community composition. No single group should be considered any more significant than another since the soil is a complex food web of interactions, for instance, microbes are just as dependant on the activity of earth

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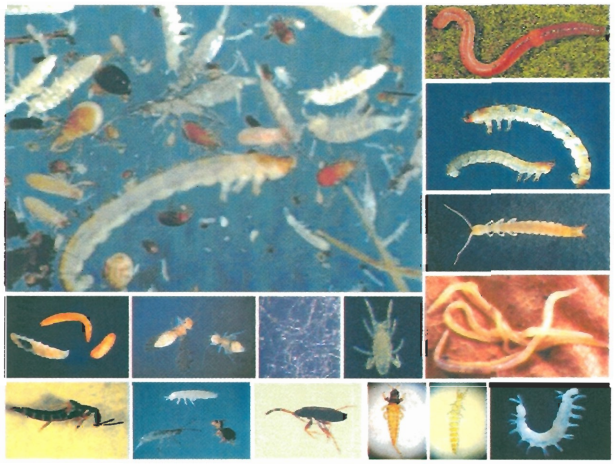

These photos show a sample of the types of organisms that live in the soil. If you took a sample of healthy soil, the size of a styrofoam cup, you could collect between 600 and 800 different microscopic organisms (other than bacteria and fungi). These soil biota play an important roll in the turnover of soil nutrients.

worms for restructuring soil aggregates, as earthworms are on microbial conditioning of the organic matter they ingest. As such, examination of different groups can yield a more complete picture of soil dynamics, and allow determination of a "best indicator" to suit each management condition for evaluating soil quality.

Nutrient mineralization studies, soil organic matter and residue decomposition studies will be a part of the soil biology research program. Studies will:

- Establish the contribution of soil biota to nutriaent turnover in soil and from crop residue
- Establish how residue characteristics, tillage and crop rotation affect soil biota dynamics
- Determine the contribution of soil biota to carbon sequestration and nitrogen availability
- Determine appropriate measures of soil biota that can be linked to and developed into indicators of soil quality

Soil Carbon Cycling

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Research Focus: C and N dynamics of plants and soils as related to C sequestration and greenhouse gas emissions

A Balancing Act: Uses for Crop Biomass

Jane Johnson

Over-reliance on foreign oil is one of the many problems facing our society. Improved energy efficiency, increased energy conservation and development of renewable fuels are methods of addressing this issue. Renewable fuels are diverse ranging from solar, wind and hydrogen to biomass and/or biofuels. Ethanol from corn grain and soy-diesel are examples of biofuels, which are agricultural products. Crop biomass also has potential to be used for ethanol production or used directly as fuel in boilers. Based on production levels, corn stover (leaves and stalks) has potential as a biofuel feedstock. Perennial grasses like switchgrass and fast-growing trees like poplar may also have potential.

As with many technologies there are both benefits and risks. Producers and researchers understand that crop biomass serves an important function in the field. Crop biomass protects the soil from wind and water erosion, provides inputs to form soil organic matter (a critical component determining soil quality) and plays a role in nutrient cycling. The benefits of using crop biomass as fuel, which removes crop biomass from the field, must be balanced against potential negative environmental impacts (e.g. soil erosion), maintaining soil organic matter levels and preserving or enhancing productivity.

USDA-ARS researchers at locations across the corn-growing regions of the United States including the North Central Soil Conservation Research Laboratory (Soils Lab) at Morris, MN are involved in research to answer the question "Where and how much biomass can be removed while maintaining soil quality, productivity and long-term sustainability?" There is recognition that biomass removal from erodible lands should not occur. A more difficult question is "How much biomass could be removed from lands at low-risk for erosion and still provide sufficient inputs to maintain the soil organic matter?" Changes in soil organic matter typically happen slowly and can be difficult to measure accurately. There are few long-term (over 10 years) studies across the country available to answer this question. Due to interactions with climate, management, soil type the yield response and soil response to crop biomass removal ranges from negative to negligible.

Don Reicosky and I are working to better understand how crop biomass and crop roots are converted into soil organic matter. From our and other's research, it is becoming clear that roots are very important in the production of soil organic matter, contributing 1.5 to as much as 3.5 times more carbon to soil organic carbon compared to the above-ground material. This is an impressive number, considering that roots represent only 20 to 50% of the total plant biomass.

The shoot portion of a plant is responsible for photosynthesis, which takes in carbon dioxide and converts it into high-energy forms of carbon (sugars and starch) utilizing energy from the sun. It is normal for plants to send sugars to their roots, some of this carbon is put into the soil in the form of sugars, amino acids, organic acids, proteins or other compounds. While it is possible some of these molecules leak out of the root, in many cases the plant actively put these compounds in to the soil for a variety of reasons. For example, plants put a variety of substances (protons, organic acids and proteins) into the soil to help them acquire mineral nutrients. Some times plants emit chemicals to attract specific beneficial microorganisms (e.g., nitrogen fixing

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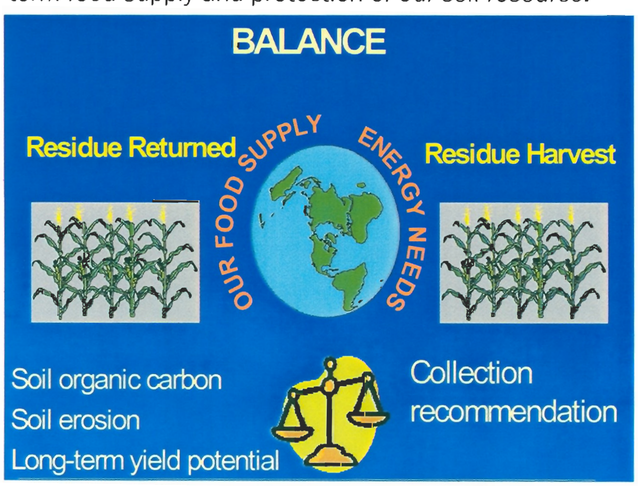
bacteria or mycorrhizal fungi). Plant roots also are surrounded with a substance called mucilage, which helps protect the root tips as they grow through the soil. Root cells can be shed and decompose. All of these forms of carbon that came from the root become part of the root-derived carbon into the soil. A large percent of the carbon from the roots is used to support the surrounding soil ecology (microorganisms and nematodes). After being digested by microorganisms, root carbon products can interact with soil particles to help stabilize aggregates.

Only a small percent (5 to 10%) of the carbon that plants put into the soil will be converted into stable organic carbon. The rest is used and cycled through the soil food web. A steady supply of carbon from plants is needed to maintain its soil organic carbon. The rate of carbon released into the soil much match or exceed the carbon released due to soil respiration or tillage or soil carbon concentration will decrease. Long-term records indicate that many of our farm soils have lost large amounts of carbon since they were first plowed. It is critical to maintain soil carbon if the long-term productivity of our soils are to be sustained.

The challenge is still before scientists to develop a tool that provides producers and the energy industry an answer as to how much biomass can be used while sustaining soil productivity for future generations. The key is a balance between the need for energy, our long-term food supply and protection of our soil resource.



Corn stover and switchgrass are potential biofuels.

Soybean and Corn Response to Soil Amended with the By-Product from Corn Stover Ethanol Production

Jane Johnson and Nancy Barbour

Hypothesis

Application of the by-product from corn stover ethanol production to soil increases humic acid and water stable aggregates. However, there have been no reports on how corn or soybeans would respond to this material. It was hypothesized that if the crops received adequate fertilizer and moisture, there would be no adverse no growth response by soybeans or corn.

Material and Methods

A study using a Barnes soil mixed with peat moss and sand in 19-L buckets was conducted to assess corn and soybean response to corn stover or by-product. There were five replications of each treatment: 1)

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control, no amendment, 2) amended with 0.1 g/cm² ground corn stover, and 3) amended with 0.1 g/cm² by-product. This rate is equivalent to 10 Mg ha^{-1} (160 bu/acre). The amendments were mixed into the surface 15 cm of the buckets.

Corn and soybeans were started in growth chambers, which were programmed to 28/20 °C, 16/8 hours day/night, with lights ramped over one hour. Soybeans remained in the growth chamber for the entire experiment, but the corn was moved into a greenhouse after 15 days. The plants received regular fertilizer application of a commercial blend (20-19-18) and received adequate moisture from an auto-watering system. After 60 days, the plants height and biomass were determined.

Results:

After 60 days, there was no difference in plant height for corn or soybeans among the three treatments (Photo 1 and Table 1). Plant biomass also did not differ among treatments. These results do not suggest any reason to expect adverse crop response if by-product was applied to the soil at a rate of 10 Mg ha^{-1}, which is a comparable rate to stover in a field with a grain yield of about 10 Mg ha^{-1} (160 bu/acre).

Treatment	Corn		Soybean	
	Height cm	Biomass g $plant^{-1}$	Height cm	Biomass g $plant^{-1}$
Control	187	50.2	198	14.4
By-product	184	54.4	215	15.1
Corn Stover	181	48.0	192	14.8
LSD	12	8.1	46	3.7

Table 1. Corn and soybean response after growing for 60 days in soil mix amended with 0.1 g cm^{-2} of corn stover or the by-product of corn stover fermentation compared to control (no amendment), n=5

Corn (top) and soybean (bottom) response to growing in soil amended with corn stover, by-product compared to control (no amendment)

Soil Carbon Cycling

Trace Gas, Global Change and Agriculture

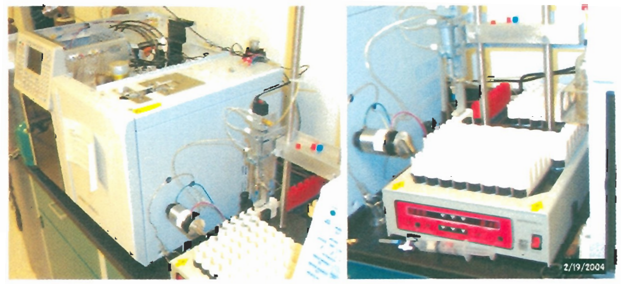
Jane Johnson and Nancy Barbour

Trace gas research at USDA-ARS laboratories moves forward. Many ARS locations including the Morris location are coordinating their research efforts for GRACEnet (Greenhouse Gas Reduction through Agriculture Carbon Enhancement Network). The goal of GRACEnet is to identify management systems, which maximize carbon sequestration while minimizing trace gas (carbon dioxide, nitrous oxide and methane) emissions and negative environmental impacts.

Carbon dioxide, nitrous oxide and methane are major greenhouse gases that arise from agricultural sources. The global warming potential of methane and nitrous oxide are about 20 and 300 times that of carbon dioxide, respectively. Nitrous oxide has the additional environmental impact of being long-lived in the atmosphere, which allows it to reach the stratosphere where it can contribute to the breakdown of ozone.

Carbon dioxide is taken up by plants during photosynthesis and released during respiration by living organisms. The increase in carbon dioxide in the atmosphere is from releasing carbon that had been stored for million of years in fossil fuels (e.g., oil and coal). The carbon being released exceeds the ability of plants to capture carbon dioxide during photosynthesis. Methane concentrations have more than doubled since the industrial revolution and agriculture (e.g., rice paddies and animals) is considered to be responsible for about 50% of that increase. Agricultural soils are capable of taking methane out of the atmosphere, but the addition of nitrogen fertilizer will decrease a soil's ability to remove methane. Nitrogen fertilizer can increase the release of nitrous oxide. Measuring atmospheric gases is challenging, especially methane and nitrous oxide, which are present in very low concentrations.

In March 2003, a trace-gas workshop was held in Fort Collins to train USDA-ARS researchers in sampling protocols for measuring trace gases (carbon dioxide, nitrous oxide and methane). Jane Johnson, Nancy Barbour and Chris Wente attended the three-day training session. The training covered field sampling techniques, laboratory analysis techniques and calculations, based on a standard sampling protocol written by an ARS scientist, who had many years experience in sampling gases.



Gas chromatograph with auto-sampler for measuring nitrous oxide and methane gas

Since then, we have made great strides in bringing our gas chromatograph (GC) used for measuring nitrous oxide and methane on-line (Photo 1). Currently, we are out-fitting this GC with an auto-sampler. It should be ready before spring thaw. The auto-sampler will allow us to make about 240 injections per day compared to manually injecting, which allowed a maximum of 75 injections.

Two undergraduate interns have worked in the biochemistry laboratory helping optimize sampling and sample handling. It is best to inject samples within 24 hours of sampling, as the sample syringes are not gas tight, and gases can leak in or out. Storing the syringes below freezing slows the diffusion process. Additional tests are planned to optimize the performance using a different style vial and the autosampler.

Trace gas measured before and after chisel plowing and moldboard plowing in systems corn plots, fall 2003.

Initial samples have been collected in the field to compare release of trace gases before and after tillage in the systems plots (Photo 2). In the field, we use simple, closed-vented chambers that capture the gas for a known period of time.

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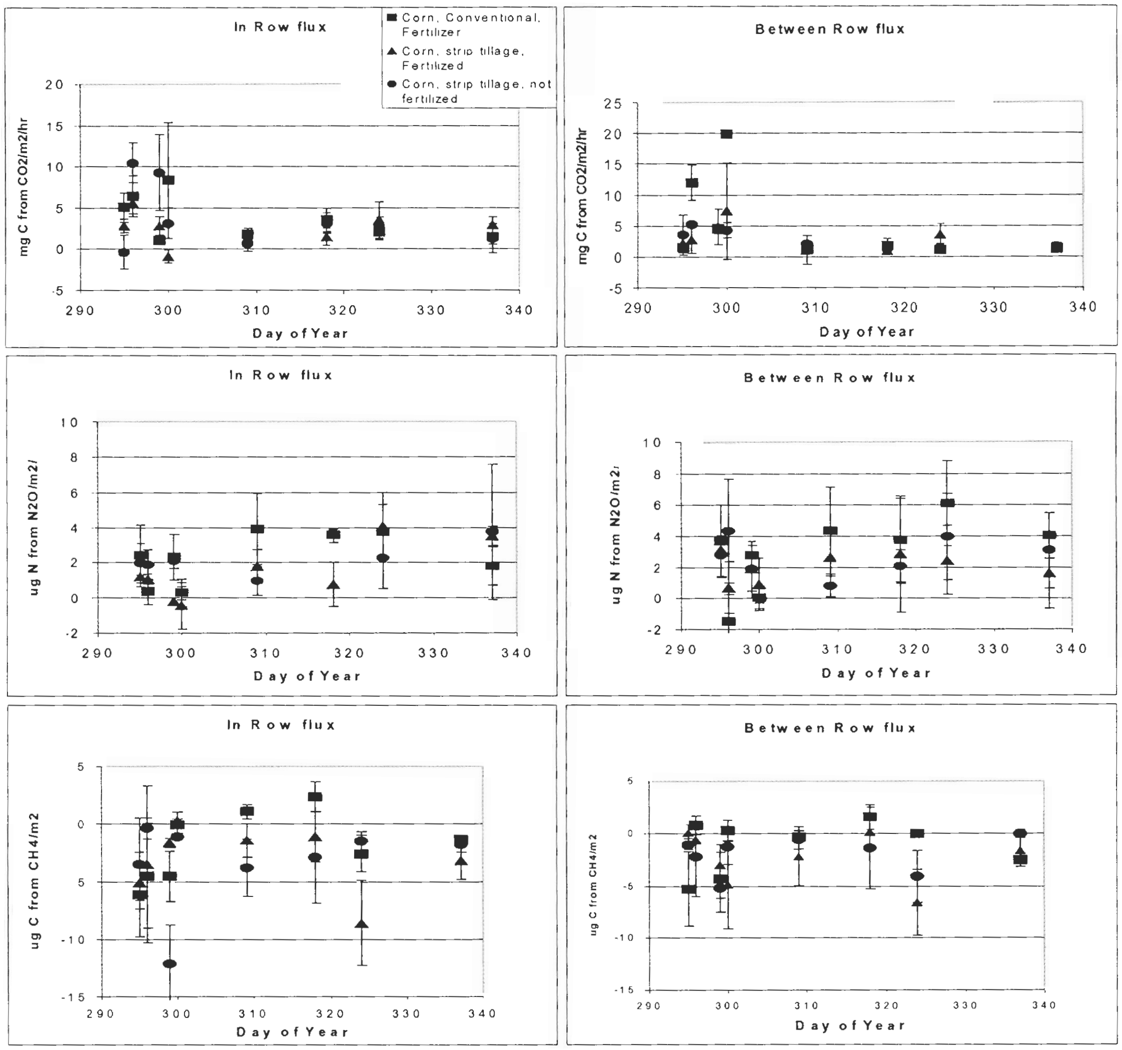

Figure 1. Flux rates of carbon dioxide, nitrous oxide and methane. A negative flux indicates gas was being moved into the soil. The first two sample dates are before and after tillage.

Nitrous oxide and methane fluxes can occur during the winter. Therefore, winter samples were collected until our sample collars were buried under the snow. The fluxes of carbon dioxide, nitrous oxide and methane measured to date are very small (Figure 3). Carbon dioxide flux was increased by tillage as expected, but little change was measured in nitrous oxide or methane, perhaps due to the cool, dry conditions. We are set up to take samples in corn, wheat, alfalfa and soybeans comparing two tillage systems and two levels of nitrogen fertilizer and two rotations, the systems plots in collaboration with Dave Archer. The plan is to take sample at regular intervals and around episodic events, such as tillage and rainfall, during 2004.

Collar installed in alfalfa plot. Fall 2003

Soil Carbon Cycling

Humic Acid and Aggregate Stability in Amended Soils

Jane Johnson

Corn stover is a potential biofuel, to be used for ethanol production from high cellulose materials. Part of the overall feasibility of using corn stover as a biofuel includes studies that address soil sustainability. 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 crop residues). Corn residue production is very large, although current cultural practices do not typically include harvest of the corn residue after grain harvest.

The Soils Lab together with other ARS locations has been working with DOE studying the implication of removing corn biomass from the field. The Soils Lab has the unique distinction of working with the material, which is left after the corn stover has been fermented. Corn stover refers to both stalks and leaves, which remain after grain harvest. It is important to have a disposal plan for this by-product of fermentation. After producing ethanol from high cellulose feedstock, the remaining material has 60 to 70% lignin. In contrast, corn stover is about 20% lignin and about 60% cellulose plus hemicellulose.

Lignin decomposes very slowly compared to other molecules like sugars, starch or protein. Because of the chemical characteristics of lignin, it is thought to contribute to the formation of soil organic matter, specifically humic acid. Humic acid is not a single molecule but rather collection of material with similar chemical properties, which allow it to be extracted from soil with a strong base solution and precipitated with acid.

Lignin has been implicated as having a role in soil stabilization. The impact of lignin could be direct or lignin may contribute to the formation of humic acid, which increases soil stability. Water stable aggregates are one indicator of soil stability.

It was hypothesized that humic acid concentration and aggregate stability should increase if lignin inputs were increased. Core incubation studies were conducted. The first study (2000) used three soils collected from the 0-15 cm (0-6 inches) layer from a farmer's field. The soils were Svea from the toe slope with 20 g organic C kg^{-1} soil, Barnes from the back-slope with 17 g organic C kg^{-1} soil and Langhei from the shoulder slope with 3 g organic C kg^{-1} soil. Air-dried and sieved soils were either not amended or amended with either ground corn stover or an analog of a stover fermentation by-product (712.5 g lignin, 140.0 g cellulose and 2.5 g hemicellulose kg^{-1} soil). The soil cores were incubated at 60% water-filled pore space (WFPS) at nearly constant temperature (18-22 °C) for 60 days.

In the second study (2001) only the Svea and Langhei soils were used. Cores were brought to an initial WFPS of 60% and allowed to dry to 35% WFPS before watering to 60% WFPS and air temperature varied from 14 to 32 °C during a 123 day incubation. In 2001 the amendment treatments included a control (no amendment), corn stover (2.4 g kg^{-1}) and three rates of fermentation by-product (0.75, 3.1 and 6.0 g kg^{-1}). The corn stover rate is equivalent to 4.3 Mg ha^{-1} (70 bu $acre^{-1}$). The by-product contained 62.4% lignin, 12.5% cellulose, 2.8% hemicellulose and 16.8% total ash and corn stover contained 19% lignin, 35.5% cellulose and 23% hemi-cellulose.

In the final study (2002), Svea and Langhei soils were amended and incubated 120 days at: 1) constant temperature (25°C) and constant soil water (60% water-filled-pore space), 2) constant temperature (25°C) and variable water (35 to 60% water-filled-pore space), 3) ambient temperature (12 to 40°C) and constant soil water (60% water-filled-pore space), and 4) ambient temperature (12 to 40°C) and variable soil water (35 to 60% water-filled-pore space). The amendment treatments included control (no amendment), corn stover (6 g kg^{-1}) and three rates of fermentation by-product (0.6, 6.0 and 60.0 g kg^{-1}). The corn stover rate is equivalent to 10 Mg ha^{-1} (160 bu $acre^{-1}$). The amendments were added to air-dried, sieved (3 mm) soil and mixed thoroughly. Cores were filled with soil and amendment mixture and tapped to adjust the bulk density to 1.2 Mg m^{-3}.

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After the incubations, the soil was removed and allowed to air dry. An aliquot of soil was used to extract crude humic acid. After rotary sieving the soil, aggregate stability of the 1 to 2 mm aggregates was determined, after remoistening the soil samples to near field capacity.

On the Langhei soil, which has a very low organic carbon, and on the Svea in 2002 the concentration of humic acid (r^2=0.99; Figure 1) increased linearly with lignin input from corn stover, by-product of stover fermentation or the by-product analog. This relationship would not have been seen if the initial humic acid concentration was above 30 g humic acid kg^{-1} soil, as was the case in the Barnes and Svea soil in 2000 and 2001.

On the Langhei soil only, aggregate stability increased linearly with the increased lignin inputs (r^2 = 0.31) (Figure 2). The relationship between humic acid concentration and water stable aggregates was logarithmic for the Langhei soil (r^2 = 0.50) and included all soil (r^2 = 0.39) (Figure 3). This suggests a relationship between humic acid (soil organic carbon) and water stable aggregation. However, there are other components of soil organic matter, which can contribute to soil particle stabilization. The logarithmic model suggests a rapid increase in aggregate stability with increased humic acid and assumes that after some critical value there would be little gain in aggregate stability with increased addition of soil humic substances.

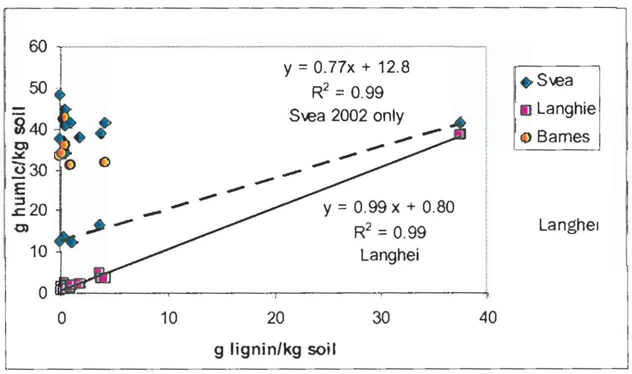


Fig. 1. Humic acid increase in soil after amending with lignin, from commercial source, corn stover or stover fermentation by-product. Soil incubated 60 to 120 d.

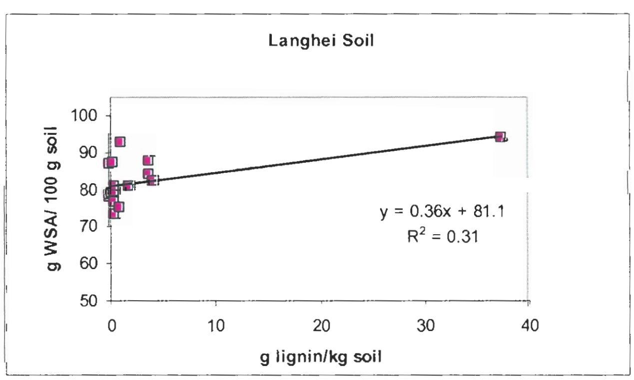


Fig. 2. Water stable aggregates (WSA) increase in soil after amending with lignin, from a commercial source, corn stover or stover fermentation by-product. Soil incubated 60 to 120 d.

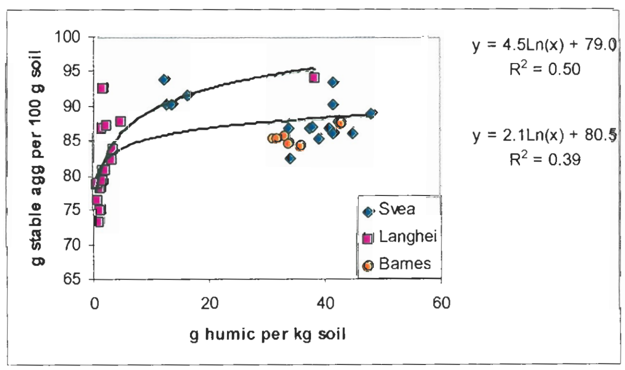
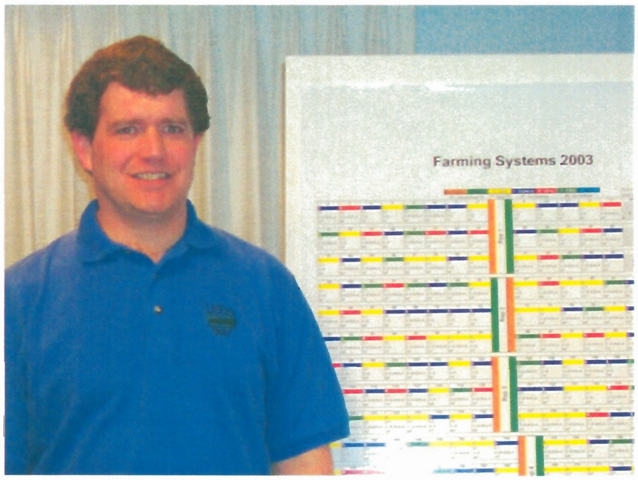


Fig. 3. Water stable aggregates (WSA) increased concentration of humic acid after amending soils with commercial source of lignin, corn stover or stover fermentation by-product. Soil incubated 60 to 120 d. The relationship was stronger when using only the Langhei soil, n=13; compared to using all three soils together, n=32.

Sustainable Cropping Systems



Dave Archer, Ag Economist
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Research Focus: Economics and management of alternative cropping systems, and the development of decision aids to improve cropping systems management

Cuphea Economics

The U.S. currently imports 625,000 metric tons of coconut and palm kernel oil (Figure 1) with a value of over $400 million, annually. Cuphea can serve as a domestically-grown replacement for these oils. However, for cuphea to be economically viable, it must both be profitable for farmers to raise and produce oils at a cost competitive with existing sources.

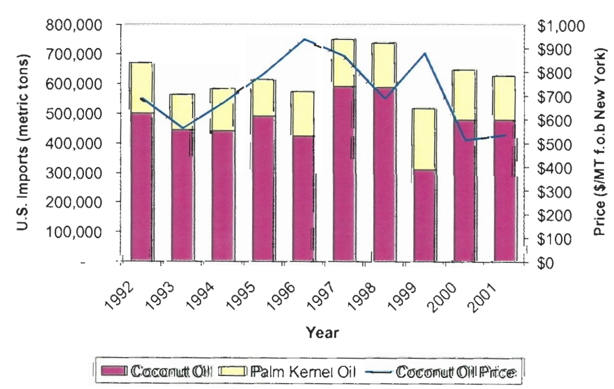

Fig. 1. Historical U.S. imports of coconut and palm kernel oil, and import price for coconut oil.

Although, there is much to be learned about the best production practices for cuphea, a crop enterprise budget was developed based on the production practices used at the NCSCRL in 2003 (Table 1). Yields at the NCSCRL in 2003 were approximately 750 pounds per acre. With this yield, a producer would need to receive at least $0.279 per pound for cuphea to become profitable. At the current cuphea oil content of 32%, this translates into an oil price of $2100 per metric ton of cuphea oil. This assumes costs of $0.035 per pound for transportation and processing of cuphea to oil, and assumes a value of $0.025 per pound for cuphea meal. In comparison, coconut oil prices over the past 10 years have ranged from $514 to $939 per metric ton, with an average price of $713 per metric ton.

Table 1. Cuphea enterprise budget

Operations	Equipment Cost/Acre[1]	Materials Cost/Acre	Total Cost/Acre
Chisel Plow	$4.69		$4.69
Broadcast Fertilizer	$2.38	$35.85	$38.23
Field Cultivate	$4.22		$4.22
Plant	$7.53	$10.00	$17.53
Spray Herbicide	$1.32	$5.69	$7.01
Row Cultivate	$5.08		$5.08
Row Cultivate	$5.08		$5.08
Spray Herbicide	$1.32	$3.13	$4.45
Spray Desiccant	$1.32	$3.25	$4.57
Harvest	$26.49		$26.49
			$117.35
Interest on operating capital			$2.92
Drying Costs			$9.18
Crop insurance			$5.00
Land Costs			$75.00
TOTAL COST			$209.45

1 Includes all ownership and operating costs (interest, insurance, housing, fuel, lubricants, repairs and maintenance, labor, power and implement depreciation).

Break-even prices decline when cuphea yields increase as more is learned about best management practices and as cuphea genetics are improved (Table 2). It is anticipated that average yields of 2000 pounds per acre will be achievable with continued research. In addition, it is expected that cuphea oil content can be increased. With the yield increase alone, cuphea could be produced profitably at an oil price of $856 per metric ton, which falls within the historical 10-year price range of coconut oil. If oil content is increased to 40% in addition to the yield increase, the equivalent oil price

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would be further reduced to $695 per metric ton, which is below the 10-year average coconut oil price (Figure 2). While it is recognized that increasing the supply of these oils will tend to drive prices down, recent research at the ARS facility in Peoria, IL has shown promising potential for cuphea oil to be used as a substitute for petroleum-based lubricants which could dramatically increase demand.

Table 2. Breakeven prices for varying cuphea yields.

Yield (lbs/acre)	Break-even Price ($/lb)
750	$0.279
1000	$0.209
1250	$0.168
1500	$0.140
1750	$0.120
2000	$0.105

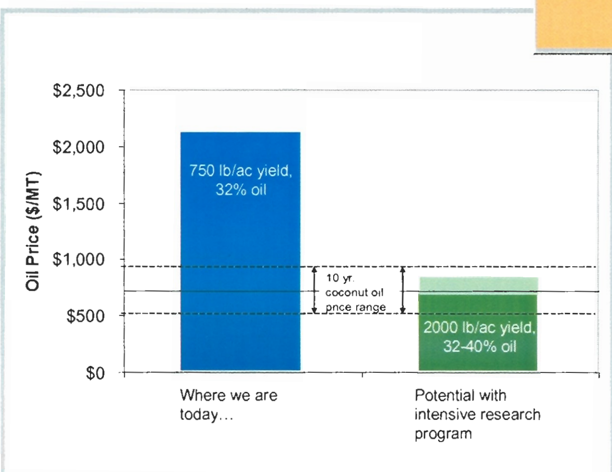
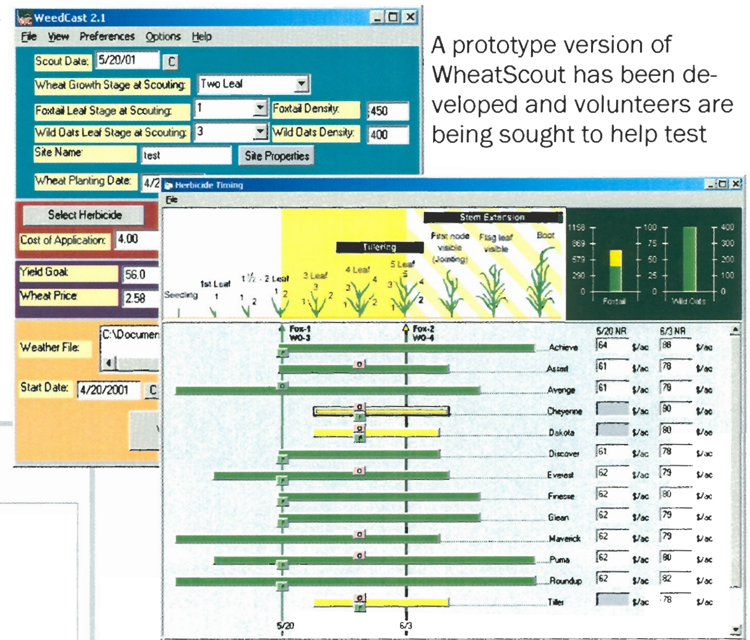


Figure 2. Oil prices needed for cuphea to be grown profitably versus historical coconut oil prices.

WheatScout

WheatScout is a computer decision based on the existing WeedCast model. WheatScout will aid spring wheat producers and crop scouts in managing the timing and type of weed control for green foxtail and wild oat, two of the most troublesome grass weeds in the northern Great Plains. The software is designed to be used in conjunction with field scouting observations. The user enters basic scouting information and either observed or forecasted weather information. WheatScout simulates weed and wheat emergence and growth, and uses these in identifying available herbicides and estimating net returns and weed seed production for different herbicides and herbicide application rates.



A prototype version of WheatScout has been developed and volunteers are being sought to help test the model and provide guidance on changes needed before a final version is released. If you are interested in testing the model, please contact me by phone at 320-589-3411 ext. 142, or email me at archer@morris.ars.usda.gov.

Value of Soil Carbon

Soil organic carbon is often identified as a key indicator of soil quality providing both environmental and crop production benefits. However, because changes in organic carbon happen slowly over time and effects on crop productivity may be masked by technological change, the direct economic value of organic carbon to producers is not readily apparent.

Consequently, producers may under-invest in carbon conserving practices. Although organic carbon can affect crop production in many ways, one of the more

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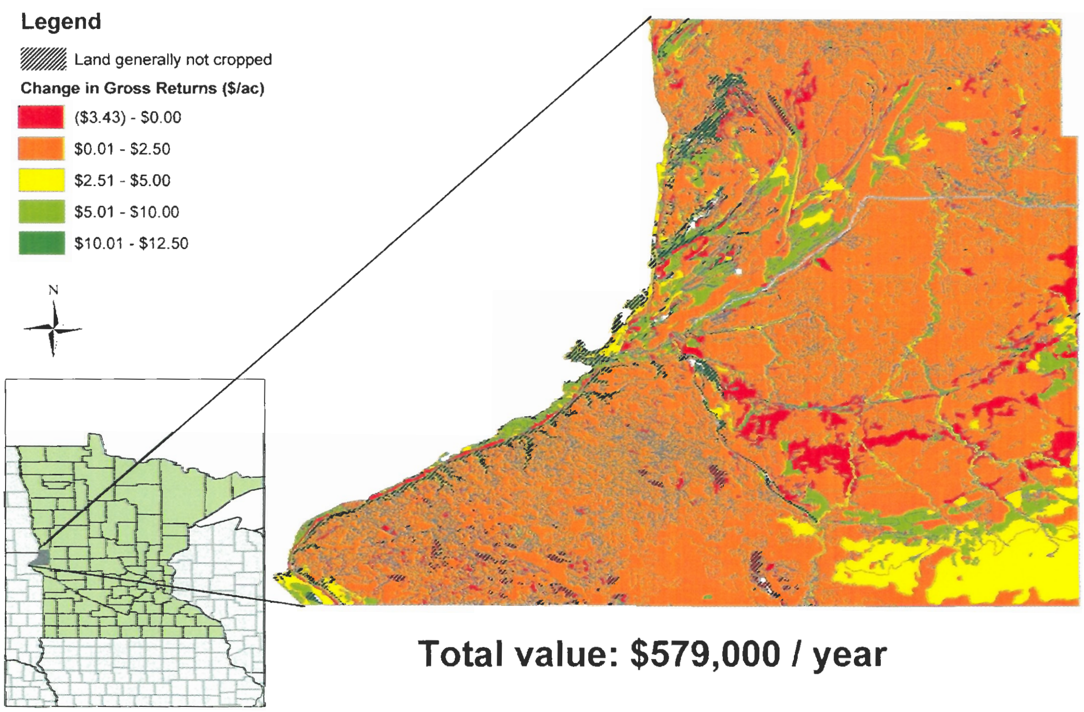
important effects occurs via changes in available water capacity. In general, available water capacity increases with increasing organic carbon, and additional available water can be beneficial for crop production even in areas where water is only occasionally limiting. However, the extent to which available water is increased by increases in organic carbon, and the crop production benefits of additional available water vary by soil type and weather conditions.

Crop simulation modeling was used with Soil Survey Geographic Database (SSURGO) data to quantify the effect of increased available water capacity (via increased organic carbon) on crop yields for each soil map unit within Traverse County, Minnesota.

The results were used to generate a county-wide map of organic carbon values which can be used to identify where carbon conserving practices might provide the greatest economic benefits to producers.

Traverse County, Minnesota

Productivity Value of a 1 Percentage Point Increase in Soil Carbon in the Top 12 in. of Soil



Total value: $579,000 / year

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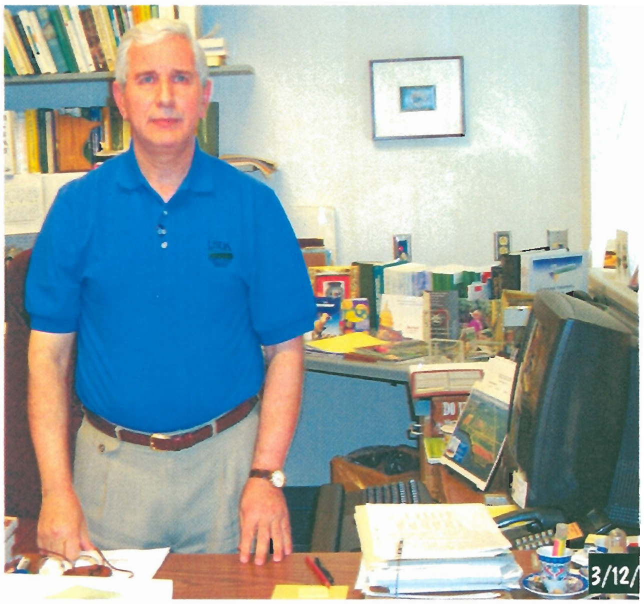

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Research Focus: Accelerated domestication, evaluation and management of alternative crops to fit current and alternative cropping systems

Introduction

My research team and collaborators carried out a number of lab, greenhouse and field experiments as a part of the Crop and Weed Biology CRIS and the Cropping Systems CRIS.

We planned and carried out a comparative assessment of wild and semi-domesticated Cuphea to quantify levels of divergence between the species, identify traits of phenological and agronomic importance for Cuphea as a crop and to develop a selection methodology for genotypes with better agronomic performance. Additionally, we assessed cold tolerance of Cuphea during germination and estimated temporal variation as a means of selecting genotypes with rapid seed germination and seedling establishment under the cold soil conditions at planting.

We evaluated a large collection of annual medics as potential cover and forage crops in the upper Midwest. A subset was selected for further evaluation for their potential as carbon sequesters.

Sixty-four main plots were geo-referenced for spatial and temporal sub-sampling. We monitored plant growth and development during the growing season and estimated yield at harvest. We built a multi-layer two-dimensional soil map, including electrical conductivity, soil physical, chemical, biological variables and crop yield.

In the following, we report on the data generated during the establishment phase of the cropping systems CRIS and on the germination and comparative assessment of wild and domesticated Cuphea during 2003.

Alternative Cropping Systems — Establishment Phase

Abdullah Jaradat, Dave Archer, Jane Johnson, Steve Van Kempen, Steve Wagner and Jim Eklund

Greater reliance on the corn-soybean crop rotation in the upper Midwestern USA during the last 50 years was brought about by the development of more efficient management practices, effective external inputs, governmental policies and favorable economics. However, environmental concerns and the economic and social ramifications of increased reliance on government subsidies have triggered an interest in developing alternatives to the present agricultural system.

Research is needed to identify systems that simultaneously improve the economic and social viability of farms and rural communities in the upper Midwest while protecting the environment and improving or maintaining the natural resource base. It is postulated that systems, which increase crop diversity, reduce tillage and reduce external inputs will improve economic, social and environmental sustainability. Long-term experiments are needed to determine yield trends, estimate nutrient dynamics and balances, understand changes in yield, predict soil carrying capacity and assess system sustainability. The objective of this research was to map initial soil and crop yield variability, quantify patterns of spatial yield variability in response to increased crop diversity and contrasting management practices and determine optimum levels of sampling plant, crop, soil and environmental variables throughout the experimental plots and during the growing season.

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The study aims at developing a more diverse crop rotation and environmentally-friendly management practices which include corn, soybean, wheat and alfalfa in two crop rotations.

The experimental plots represent typical corn-soybean fields in the upper Midwest of the US. Factor analysis of 42 soil physical, chemical and biological variables resulted in extracting three factors. The first factor (F1) was dominated by variables related to soil carbon and pH. The second factor (F2) was dominated by the nutrients phosphorus and potassium, as well as by soil microbial biomass. The third factor (F3) was related to nitrogen in the soil. These factors combined explained 49.2% of total variation in the original 42 variables brought together under one "factor."

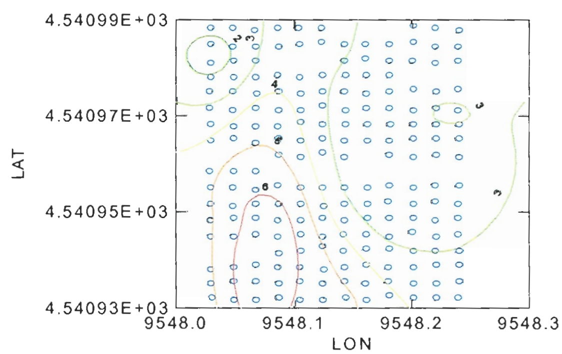

Fig 1. Apparent electrical conductivity (ECa).

Researchers at the Soils Lab are studying the use of electomagnetic induction (EM) as a non-contact method for measuring variability in the soil. Electrical conductivity or EC measurements have been used in the past to determine moisture and salinity in the soil. Probes were inserted in the soil and the ability of the soil to conduct electrical current provided an indicator of these soil properties. Measurements of this type are labor intensive and time consuming. A new commercially-available instrument allows us to measure conductivity by electromagnetic induction and it does not require the use of probes. The instrument which is powered by a 9 volt battery is pulled across the field in a non-metallic cart with the instrument suspended over the soil and continuous EM readings and corresponding GPS readings are recorded. The Soils Lab researchers are studying this technique to determine if the EM measurements could become a useful tool for characterizing field variability for site specific management on the farm.

Steve Wagner, Electronics Engineer

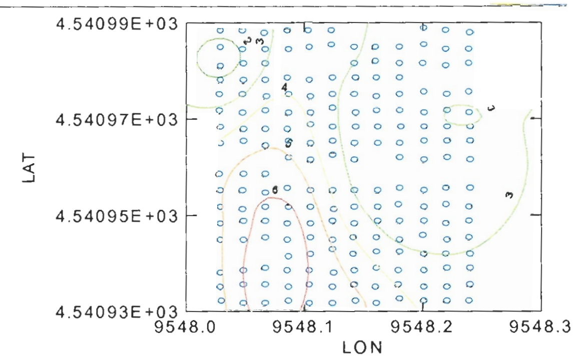

Fig 2. Factor 1 derived from soil analysis and accounted for 23.7% of total variance in 42 soil variables and was dominated by variables related to soil carbon and soil pH.

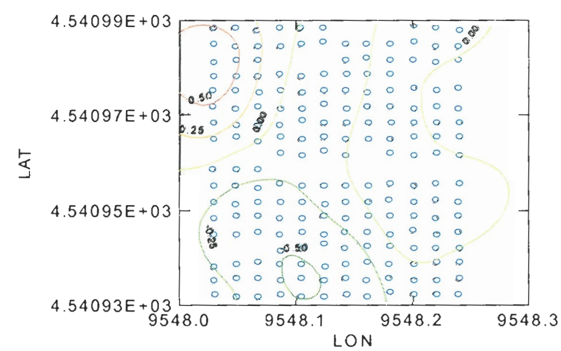

Fig 3. Factor 2 derived from soil analysis and accounted for 13.4% of total variation in 42 soil variables and was dominated by variables related to soil phosphorus, soil potassium, microbial biomass and soil texture (sand and silt).

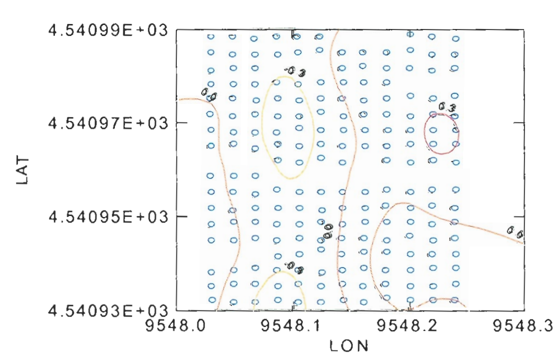

Fig 4. Factor 3 derived from soil analysis and accounted for 12.1% of variation in 42 soil variables and was dominated by variables related to soil nitrogen.

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We developed an initial map of soil (Fig 1-4), crop and plant variables and measured the impact of soil characteristics and management practices on plant growth, crop yield and yield components. Three to four samplings of plant growth, yield and yield components were adequate to account for a large part (75-83%) of the variation in whole plot yield.

Stepwise multiple regression analysis was employed to predict grain yield in main plots as a function of repeated measures (green area/unit soil area, GA; number of plants/unit area, NP, number of seed/unit area, NS, seed weight/unit area, SW; plant height, PH and midday differential canopy temperature, D, in sub-plots.

The first regression model explained 75% of total variation in grain yield of main plots, involved three repeated measures of GA, PH, and D, and included the following variables as predictors (followed by the Julian date when the reading was recorded): GA(128) + GA(136) + GA(170) + PH(153) + PH(170) + PH(181) + D(164) + D(188) + D(196). A second model explained 83% of total variation in grain yield of main plots, involved two repeated measures of GA, PH and D, in addition to NP, NS and SW in sub-plots at harvest, and included the following variables as predictors: GA(212) + GA(223) + PH(206) + PH(223) + D(212) + D(251) + NP + NS + SW.

A database was established to measure and predict the impact of soil variables, management factors, and crop sequences on crop yields and economic viability of new cropping systems. Initial results of the impact of these factors on treatment groupings are presented in Fig 5. This research will increase understanding of alternative cropping systems. It will also produce a less costly, more rapid, and more accurate method for identifying sustainable cropping systems.

This extensive sampling of plants, crops, soil and environmental variables is a valid approach to answering questions on efficient use of resources. Moreover, it is a prerequisite for technology generation within a cropping systems' context. The next step, which will be based on these findings, will be to verify the generated technologies in the "real world" in farmers' fields, with farmers being fully involved in designing and carrying out large-scale field experiments to answer specific questions and solve emerging production problems.

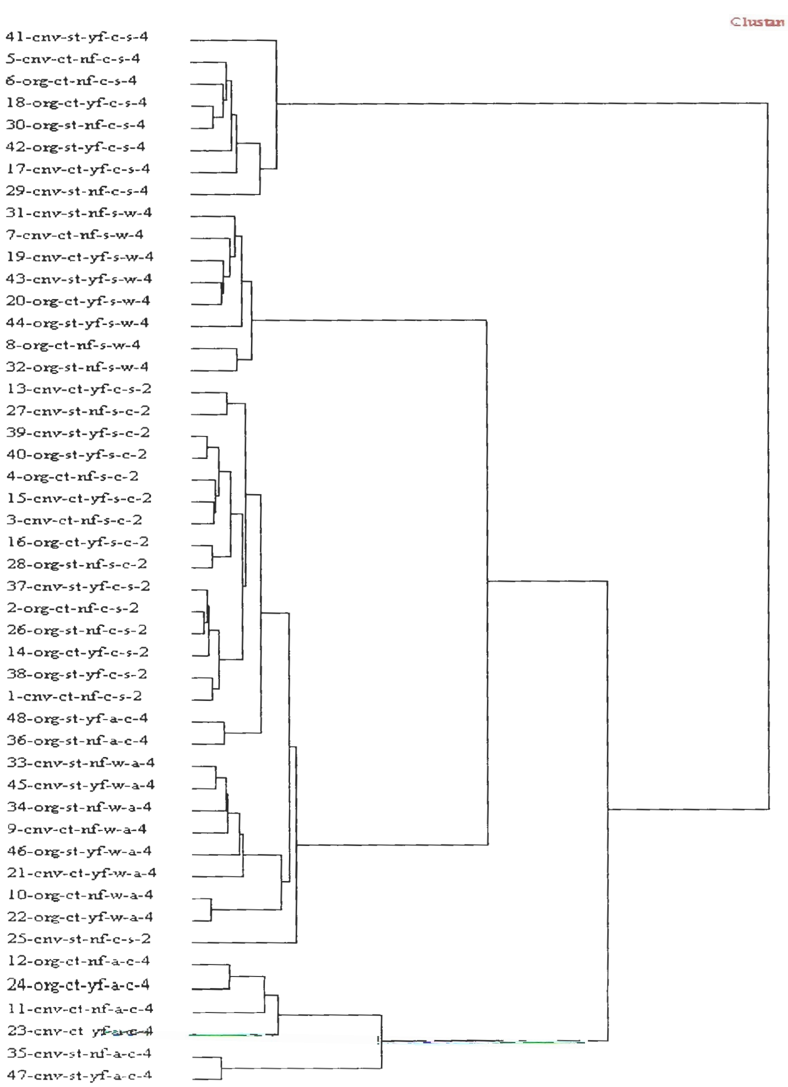

Fig 5. Hierarchical clustering dendrogram describing relatedness of 48 treatments [combinations of systems (organic vs. conventional), tillage (conventional vs. strip), nitrogen fertilizer (with vs. without N), ECa, and three factors (latent variables) derived from 42 soil physical, chemical and biological variables] on the performance of four crops [alfalfa, a; corn, c; soybean, s; and wheat, w] in 2- and 4-year crop rotations]. Numbers and symbols (left to right) refer to: treatment number, system, tillage, nitrogen fertilizer, previous crop, current crop and length of crop rotation in years.

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Comparative Assessment of Semi-domesticated and Wild Cuphea

Abdullah Jaradat and Steve VanKempen

Detailed morphological and agronomic characterization of Cuphea germplasm are important pre-requisites for the development of cultivars that can be managed by farmers at a large scale. In an effort to quantify the level of divergence between the semi-domesticated cuphea and its wild parents, a comparative assessment of a large number of plants was carried out in the laboratory, greenhouse and the field. We carried out experiments to identify traits of developmental and agronomic of cuphea as a crop, and are in the process of developing a selection methodology of genotypes with better agronomic than the currently used bulk germplasm.

Seed germination of the two main "genotypes" PSR 23 and PSR 57 was assessed under increasing temperatures (7, 10, 15, 20 and 25°C). A preliminary analysis of the germination tests indicates that, although PSR 57 achieved lower germination levels at all temperatures as compared with PSR 23 (Fig 1), its temporal variation was twice as high as the temporal variation of PSR 23. Similarly, temporal variation for seed germination at the extreme temperatures (7 and 25°C) was higher than its respective value at the most appropriate temperature (i.e., 15°C). Additionally, variation in germination percentage and germination speed within germplasm of PSR 23 and PSR 57 is still high. This indicates that high variability still exist within these two "genotypes." These preliminary results suggest that either single plant or a modified bulk selection could improve the germination percentage and germination speed, and reduce temporal variation in germination. These characteristics are necessary for an early and vigorous stand establishment in the field under the Midwest environmental conditions.

A greenhouse experiment was carried out to compare several developmental and morphological attributes of PSR 23, PSR 57 and wild Cuphea accessions used in the original cross.

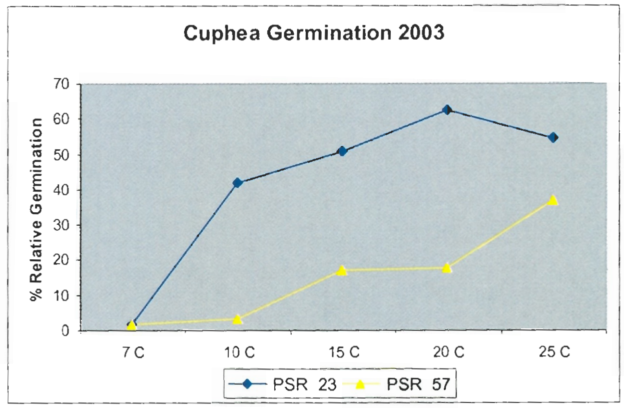

Fig 1. Mean germination percentage of PSR 23 and PSR 57 at four temperatures (7, 10, 15, 20 and 25°C) after 10 days' germination test.

We identified two factors (Fig 2) that explained 66.3% of total variation in the whole germplasm of semi-domesticated and wild Cuphea. Factor 1 accounted for 44.6% of total variation and was associated with plant height, plant weight and number of primary branches per plant. Factor 2 explained 21.7% of total variation and was associated with number of flowers per plant, number of secondary branches per plant and number of primary branches with secondary branches (PwS).

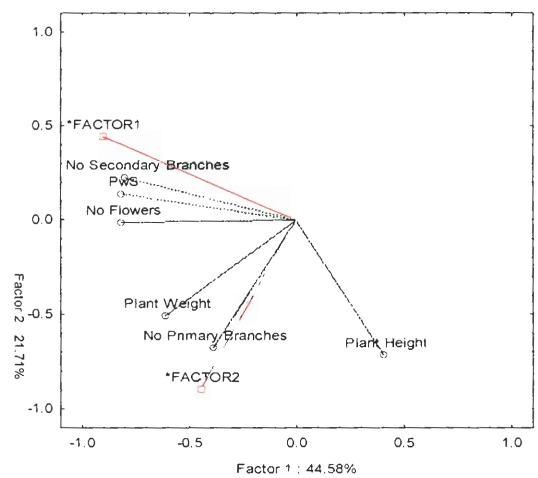

Fig 2. Two-dimensional plot of morphological traits in two factors accounting for 66.3% of total variation in a germplasm of semi-domesticated and wild Cuphea germplasm.

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These results, in addition to results of canonical discriminant analysis (see below) will be utilized in designing a field experiment in 2004 to select single plants based on their plant architecture and development throughout the growing season in an effort to identify variants of appropriate plant architecture and rate of development of both PSR 23 and PSR 57.

The same data set was utilized in constructing classification functions for each of the semi-domesticated and wild accessions in this study. The results are plotted in Fig 3 for individual plants and in Fig 4 for PSR 23, PSR 57 and six wild accessions used in the original cross between *C. lanceolata* and *C. viscosissima*. Fig 3 indicates that Root 1 mainly separates the semi-domesticated from the wild accessions, however, the level of overlapping is noticeable across Root 2. A clear-cut separation between the semi-domesticates and the wild accessions (Root 1) is presented in Fig 4. However, Root 2 failed to separate the semi-domesticates from the wild accession, indicating that a large morphological resemblance still exists between the domesticates and the wild accessions.

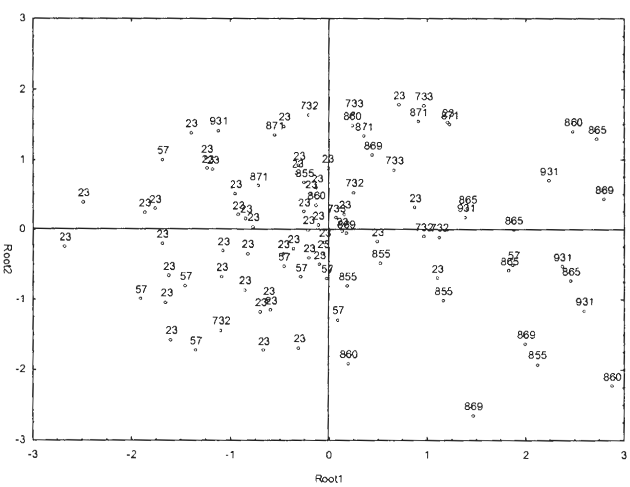

Fig 3. Canonical discriminant plot of the first two roots of Cuphea single plants based on morphological traits. Correct classification based on a combination of six morphological traits: PSR 23 95.9%, PSR 57: 77.8%, PIxxx732: 0.0%, PIxxx733: 50.0%, PIxxx855: 20.0%, PIxxx860: 20.0%, PIxxx865: 100.0%, PIxxx869: 0.0%, PIxxx871: 40.0% and PIxxx931:40.0%.

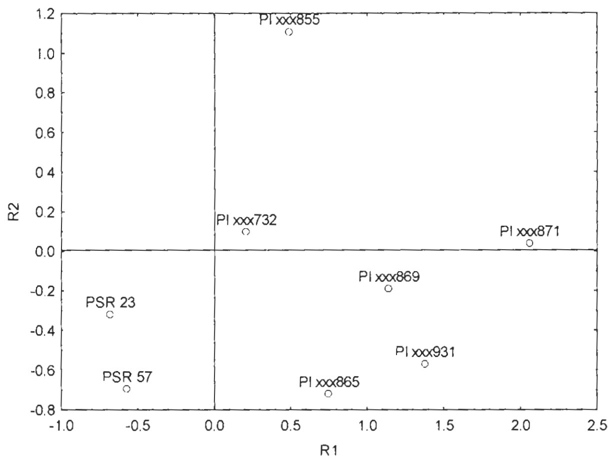

Fig 4. Canonical discriminant plot of the first two roots showing PSR 23 and PSR 57 in relation to six wild accessions of Cuphea based on morphological traits.

Appendix 1

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Appendix 2

Lab Employees

Jaradat, Abdullah – Supervisory Research Agronomist, Research Leader and Location Coordinator

Archer, David – Agricultural Scientist (Ag Economist)
- **Eklund, James** – Computer Assistant

Forcella, Frank – Research Agronomist
- **Peterson, Dean** – Ag Science Research Technician

Gesch, Russell – Plant Physiologist
- **Boots, Dana** – Ag Science Research Technician (Plants)
- **Lenz, Allen** – Biological Science Aid

Lachnicht, Sharon – Soil Scientist (Soil Biologist)
- **Wilts, Alan** - Chemist

Johnson, Jane – Soil Scientist (Plant Biochemist)
- **Barbour, Nancy** – Biologist

Olness, Alan – Soil Scientist
- **Burquest, Erin** – Biological Science Aid
- **Hanson, Jay** – Physical Science Technician
- **Rinke, Jana** – Chemist

Papiernik, Sharon – Soil Scientist
- **Amundson, Gary** – Engineering Technician

Reicosky, Donald – Soil Scientist
- **Wente, Christopher** – Ag Science Research Technician

Bossert, Melissa – Biological Science Lab Technician
Eystad, Kathryn – Program Support Assistant
Groneberg, Sandra – Program Support Assistant OA
- **Burmeister, Beth** – Office Automation Assistant

Groth, Pamela – Location Administrative Officer
- **Rohloff, Shawn** – Purchasing Agent OA

Hennen, Charles – Ag Science Research Technician
Larson, Scott – Ag Science Research Technician (Soils)
VanKempen, Steve – Ag Science Research Technician (Soils)
Wagner, Steve – Electronics Engineer
Winkelman, Larry – IT Specialist (Customer Service)

Appendix 3

Visitors

Friday Ekeleme is a weed scientist and assistant professor at the Michael Okpara Agricultural University, Umudike, Nigeria. He returned to spend four months at the Lab to work with Frank Forcella and Dave Archer. Dr. Ekeleme's research project was to develop a shoot emergence model of a tropical weed known as cogongrass, as well as finish a model and write a paper for another plant known as tropic ageratum. The Foreign Agricultural Service funded Dr. Ekeleme's visit to the Lab.

Svetlana Kokhan from the University of Kiev (Ukraine) received a 4-month Fullbright scholarship to study with Alan Olness. Her work focused on use of the ARS nitrogen (N)-fertilizer decision aid in predicting N credits from legumes (and perhaps translation of this tool for use in the Ukraine).

Svetlana and Al Olness

Ebandro Uscanga is a Ph.D. student at SDSU, Brookings, who is originally from Mexico. He is advised by Professor Sharon Clay and Frank Forcella. Ebandro's work involves understanding how seed production of four species of pigweed (redroot pigweed, Powell amaranth, common waterhemp, prostrate pigweed) is influenced by the timing of emergence in Roundup Ready crop production systems.

Roberta Masin is a Ph.D. student in the Department of Agronomy & Vegetable Production from the University of Padua (often spelled Padova) in Italy. She worked with Frank Forcella using WeedCast to predict weed emergence in turfgrass. Her goal was to develop emergence models for four weed species that are problems in Italian turf, which are also present in the United States. Roberta's visit was sponsored by the University of Minnesota through Professor Roger Becker.

Frank Forcella, Roberta's fiancé Fransisco and Roberta

Julio Scursoni, a Ph.D. student from the University of Buenos Aires (Argentina), returned to complete his research that he started in 2001-2002. Julio's research centered on understanding the biological and managerial reasons that allow some weed species to escape Roundup treatments. The Monsanto Company sponsored his visit to the Lab.

Appendix 4

Summer Field Day 2003

The USDA-Agricultural Research Service "Soils Lab" in cooperation with the Barnes-Aastad Soil and Water Conservation Research Association hosted a field day at the Swan Lake Research Farm on Thursday, August 21 from 3-5 p.m. Tours were available with stops: the Alternative Crops, Carbon Sequestration and Cropping Systems plots. Speakers were Russ Gesch, Don Reicosky and Dave Archer.

Lunch was served by the West Central Cattlemen's Association.

The *Swan Lake Research Farm is located (from the intersection of Highways 59 and 28 at Morris) 5.5 miles north on Highway 59 to County Road 74. Turn right (east) on 74 and travel 5.2 miles. Turn right at the dead end.*

Alternative Crops

Carbon Sequestration

Cropping Systems

Appendix 5

Ag Week

In honor of National Ag Week and the 50th anniversary of the Agricultural Research Service, the Soils Lab invited local schools to tour the Laboratory on Thursday, March 18. The 30-minute tour included demonstrations on tillage erosion, microscopic bugs in the soil and products produced from oilseed crops.

Tillage Erosion Demonstration by Gary Amundson

The "Bug Stop" by Sharon Lachnicht

"Our Soils Produce Oils" station by Dean Peterson

Approximately sixteen teachers and 207 elementary school students visited the Laboratory from Chokio-Alberta, Cyrus and Morris Area Elementary Schools, Benson Christian School and the H.O.M.E. school group.

Open House

The Soils Lab hosted an open house for the community in honor of National Ag Week and the 50th Anniversary of the Agricultural Research Service on Thursday, March 18.

The theme of the event was "Proud Past and Promising Future." The open house highlighted two ongoing research projects: cuphea commercialization and weed emergence prediction software.

Russ Gesch, plant physiologist, gave an update on how cuphea research has progressed from a couple of tablespoons of seed in 1998 to the verge of commercial production. Industry requests enough cuphea oil to warrant growing 300,000 acres by 2006. Currently, farmers in the Upper Midwest are being sought to grow cuphea for seed production.

Dave Archer, agricultural economist, discussed how WheatScout, a division of the popular WeedCast software program, can help users make more informed decisions regarding immediate profitability as well as the potential impacts of weed management choices on future weed populations.

Approximately, twenty-five people from a wide geographical area from Fergus Falls to Canby attended the event.

Appendix 6

Other Outreach

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

Tomato Fest

NCSCRL conducted an experiment with the Morris Area Elementary School fifth graders.

Students measured tomato plants a number of times at the lab greenhouse facility. They learned about making observations, collecting data and analyzing data. The MAES hosted a Tomato Fest on December 18, 2003, and presented the results of their experiment to the community.

Super Saturday Science

Nancy Barbour, Melissa Bossert, Jane Johnson and Stephanie Vlaminck worked with the University of Minnesota-Morris-Division of Science and Mathematics and West Central Research and Outreach Center to sponsor Super Saturday Science. This was a fun, hands-on event for young women in fifth through eighth grades to enhance their excitement about science and math. The goals of the event were to give young women a chance to experience science and to work with women scientists. The sponsors encouraged the participants to consider careers in crop and soil science.

Science Fair

Throughout the year, staff members 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.

Student Mentorship

Nancy Barbour coordinated a high school student's use of the greenhouse for her science fair project. The science fair project showed the relationship between wheat seed size and plant growth. The project was selected to go on to regional competition.

UMM Internship

Jane Johnson supervised and mentored two University of Minnesota, Morris students (John Determan and Stephanie Vlaminck), who were interns from the chemistry department. Both students worked closely with Nancy Barbour to develop sampling protocols for measuring greenhouse gases. Each student will present a poster of their results at the Undergraduate Research Symposium, University of Minnesota-Morris on April 21, 2004.

UMM Chemistry Club

The Chemistry Club from the University of Minnesota-Morris invited Sharon Papiernik to participate in a panel discussion on careers in chemistry.