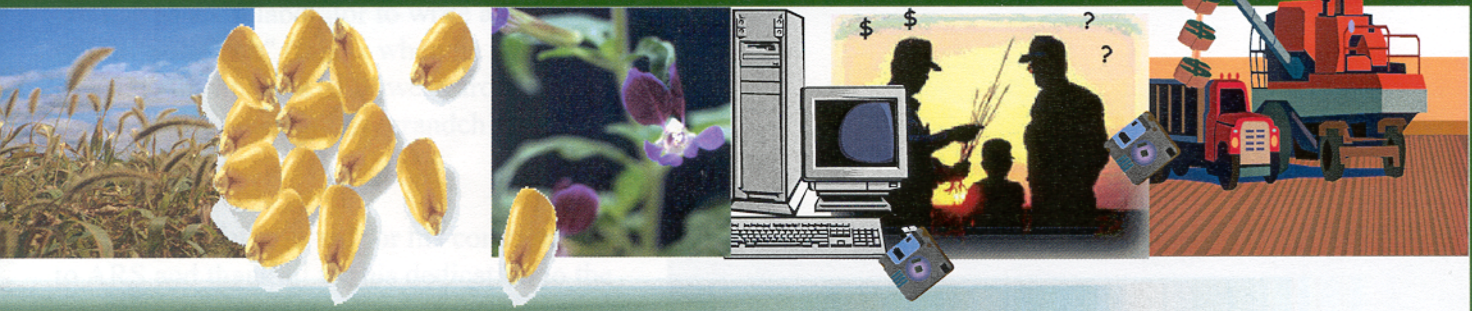
AGRICULTURE RESEARCH AGRICULTURE



The USDA-ARS

North Central Soil Conservation Research Laboratory Morris, Minnesota

Research Report

April 4, 2002

Inside the Annual Report

USDA

Agricultural Research Service

3 Barnes Aastad Association Swan Lake Research Farm

4 Meet the Scientists

Areas of Research

6 Crops & Weed Biology

13 Land Management

16 Soil Carbon Cycling

30 Sustainable Cropping Systems

35 Collaborator Notes

36 Visitors at the Lab

38 Soil's Lab Employees

40 Ag Week Open House

42 Outreach Activities

48 Retirement of W.B. Voorhees

Meet our new Research Leader...

Dr. Abdullah A. Jaradat

AGRICULTURE RESEARCH AGRICULTURE

A message from Dr. Abdullah A. Jaradat....

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

With a mission to "develop and transfer new technologies for sustainable agriculture in northern climatic regions that protect natural resources and the environment," the Lab, since its establishment in 1956, has been supported by The Barnes-Aastad Soil & Water Conservation Research Association, a non-profit organization of farm managers and agri-businesses.

During 2001, scientists at the lab conducted on-farm, field plot, greenhouse and laboratory research to address soil, crop, weed, and economic issues faced by farmers in the Midwest. They also addressed national and international agricultural problems in cooperation with fellow scientists in the U.S. and abroad.

On the soils front, research was conducted on soil erosion, tillage-induced erosion and carbon loss, soil fertility management, and water relations in frozen soils. On the crops front, research was initiated to delineate the underlying biological processes limiting corn growth during cold, wet spring seasons, plant and soil biochemical processes related to carbon and nitrogen cycles to enhance soil quality and crop productivity, weed biology, control and dynamics, and evaluated cuphea as an alternative crop. Finally, on the economics front, the economics of a set of dynamic cropping systems and net returns for alternative tillage systems were researched, and recommendations as to the highest return to land and management for alternative crop sequences were formulated.

Farmers, scientists and policy makers came to the conclusion that the prevailing systems of agricultural production in the upper Midwest are struggling with the appropriateness and applicability of new and current technology and its impact on farmers, rural communities, and the environment. What types of research can help overcome this struggle?

In large parts of the Midwest, people are faced with landscape-scale issues like soil erosion, declining soil quality, ground and surface water contamination, loss of wildlife habitats and declining rural communities. Only long-term, large- scale interdisciplinary systems research aimed at developing agricultural systems that also protect the environment and enhance rural communities, can address these multiple and inter-related issues. Moreover, farmers in the upper Midwest, with limited number of crops to grow, will continue to seek other crops which can be grown for profit. Research on alternative crops for the Midwest must be conducted.

Continued on page 2

The central location of the Lab at Morris provides an excellent opportunity to evaluate the impact of diverse cropping systems and identify farming practices and systems that will benefit and enhance rural communities and the natural resources base in the upper Midwest.

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

Therefore, the Lab is embarking on a new endeavor to translate its mission into 21st Century language, where new tools are needed to generate new information and develop new management practices in order to preserve the productivity gains of the 20th century, provide strong protection for the environment and lay down firm bases for vigorous rural communities.

A "whole farm research agenda" is one of the Lab's options to address the complexities and interactions of agroecosystems in the Midwest, using an interdisciplinary, holistic and long-term approach, where improved efficiency, productivity, profitability and environmental protection are jointly addressed as integral parts of an integrated farming system.

The Lab will strive to continue building up a multidisciplinary team of scientists and support staff in order to accomplish its mission. With the recruitment of a soil microbiologist, the Lab can assume a leading research role, in cooperation with other ARS units, to explore the vast soil microbial diversity for purposes in line with the current demand for a sustainable and more environmentally friendly agriculture. Additional expertise is required to broaden the capabilities and innovations developed by scientists at the Lab and to address emerging priority issues. A cropping systems' ecologist is needed to lead research on cropping systems that integrate the broad range of factors involved in agricultural production, and another agronomist is needed to identify, introduce and test alternative crops to diversify the crop rotation, including short-rotation woody crops for bioenergy and biobased products.

We at the North Central Soil Conservation Research Lab are indebted to the continued support of the Barnes-Aastad Association and we feel that their interest in integrated farming systems regional partnerships will help us achieve our mutual goal of enhancing rural communities and natural resources in the upper Midwest.

Swan Lake Research Farm

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

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

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

Photo taken from the east

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

Congratulations B-A

Photo taken from the northwest

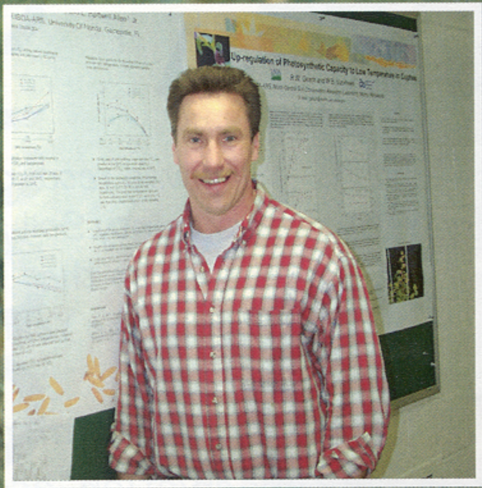
The Barnes-Aastad group was recognized this year by the Stevens County Soil and Water Conservation District as the "Conservation Cooperator of the Year."

The award is based on the farmer or group efforts in conservation, according to Dave Jungst, SWCD administrator.

The North Central Soil Conservation Research Laboratory

David W. Archer
Agricultural Economist
(320) 589-3411 ext. 142
archer@morris.ars.usda.gov

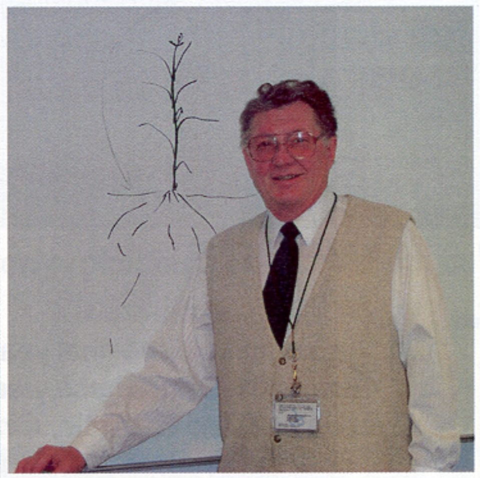
Frank Forcella
Research Agronomist
(320) 589-3411 ext. 127
forcella@morris.ars.usda.gov



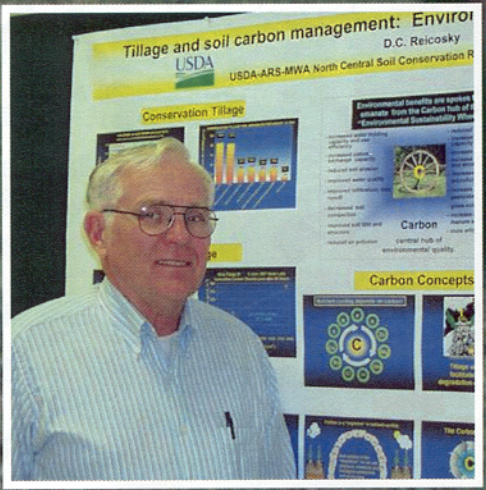
Russell W. Gesch
Plant Physiologist
(320) 589-3411 ext. 132
gesch@morris.ars.usda.gov

Jane M-F Johnson
Plant Biochemist
(320) 589-3411 ext. 161
johnson@morris.ars.usda.gov

Michael J. Lindstrom
Soil Scientist
(320) 589-3411 ext. 145
lindstrom@morris.ars.usda.gov



Alan E. Olness
Soil Scientist
(320) 589-3411 ext. 131
olness@morris.ars.usda.gov



Donald C. Reicosky
Soil Scientist
(320) 589-3411 ext. 144
reicosky@morris.ars.usda.gov

Brenton S. Sharratt
Soil Scientist
(320) 589-3411 ext. 146
sharratt@morris.ars.usda.gov

Research by: Frank Forcella, Research Agronomist
forcella@morris.ars.usda.gov
Dean Peterson, Ag Science Reserach Technician
Gary Amundson, Engineering Technician

Weed Science:

Projects related to weed biology and weed management at the Soils Lab were many and varied during 2001. These projects can be divided into three main categories: modeling of emergence and growth of perennial weeds, software development for annual weeds, and seed production. All of the projects involve a mixture of applied and basic science, anticipating that understanding basic processes of weed behavior will lead to novel opportunities for more effective and efficient weed management.

Emergence and growth of perennial weeds

We completed the final year of a three-year study on perennial weeds at our Swan Lake Research Farm. These weeds included important species in crops of northern climates, such as Canada thistle, *Cirsium arvense*; quackgrass, *Elytrigia repens*; and milkweed, *Asclepias syrica*. Less common species were hemp dogbane, *Apocynum cannabium*; perennial sowthistle, *Sonchus arvensis*; Jerusalem artichoke, *Helianthus tuberosus*; wirestem muhly, *Muhlenbergia frondosa*; and swamp smartweed, *Polygonum coccineum*. Also included were leafy spurge, *Euphorbia esula*, a weed of rangelands and natural areas, and purple loosestrife, *Lythrum salicaria*, which is invading many wetlands in Minnesota and other northern states. We also are helping scientists in other countries perform research on perennial weeds that are big problems in warmer regions. These species include johnsongrass, *Sorghum halepense*, from the southern USA and Latin America, and *cogongrass*, *Imperata cylindrical*, from tropical Africa.

Although this research project is based in Morris, Minnesota, it is done in collaboration with researchers from elsewhere; e.g. Argentina, Denmark, and Nigeria, as well as Iowa, North Dakota and Wisconsin.

Software development for annual weeds

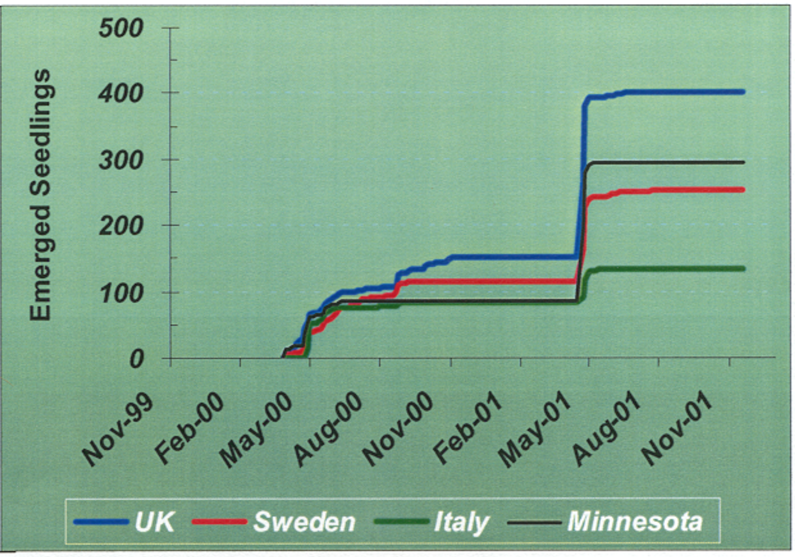
Our previous research and development that culminated with the software program, *WeedCast*, led to interest from other regions and countries for similar software. In 2001 we worked closely with the "Seedling Emergence and Growth Working Group" of the European Weed Research Society. We continued collaborative experiments wherein populations of common lambsquarters (*Chenopodium album*) and common chickweed (*Stellaria media*) from Minnesota, Italy, Sweden, and England were monitored for timing and extent of seedling emergence in Minnesota, Italy, Germany, Denmark, Sweden, and three sites in England.

Our objective is to determine if all populations within a species respond similarly to soil temperature and soil moisture in terms of timing and extent of seedling emergence. If diverse populations respond similarly to these variables then the development of universally applicable seedling emergence models holds great promise. To date, results show that diverse populations of common lambsquarters emerge simultaneously, but not in the same proportions. In other words, each population has individualistic seed dormancy characteristics, but once dormancy is lost, all populations behave the same. If these results are maintained during the forthcoming growing season, our goal of developing weed emergence models and software appropriate for any location on earth will be much closer to reality.

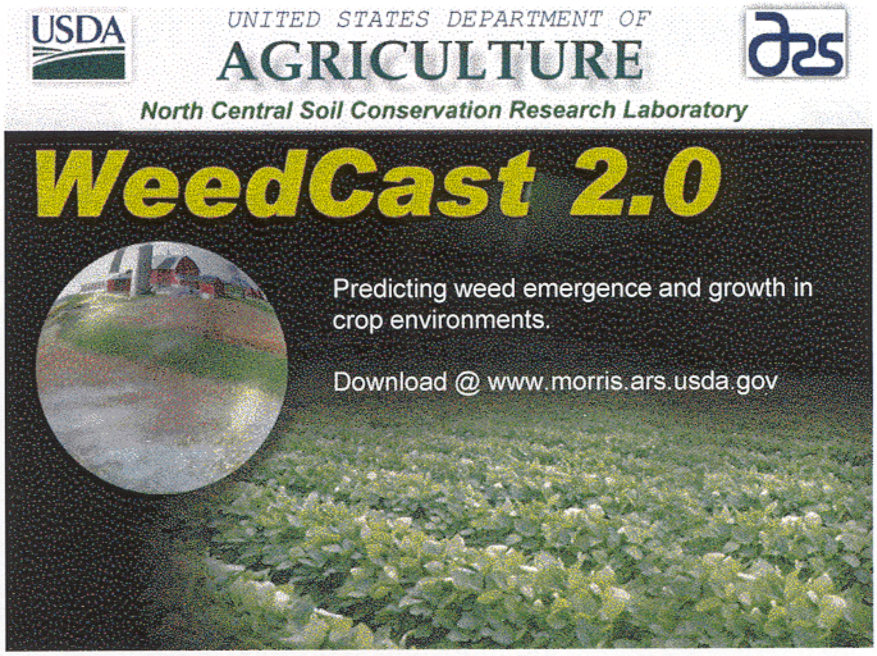
Our weed research team in Morris also is working with a group called WAHRI (Western Australia Herbicide Resistance Initiative), and scientists from Argentina, Spain, Manitoba, North Dakota and Washington state to develop emergence software (*WeedEm*) for weeds in small grain fields. To date, the weed species being studied are wild oat (*Avena fatua*), wild radish (*Raphanus raphanistrum*), and annual ryegrass (*Lolium rigidum*). All of these species are problems in the USA, Canada, Australia, South America, and Europe. This international team, led by the Morris group, is an excellent example of international cooperation, which has led to receipt of research grants from the governments of both the United States and Australia.

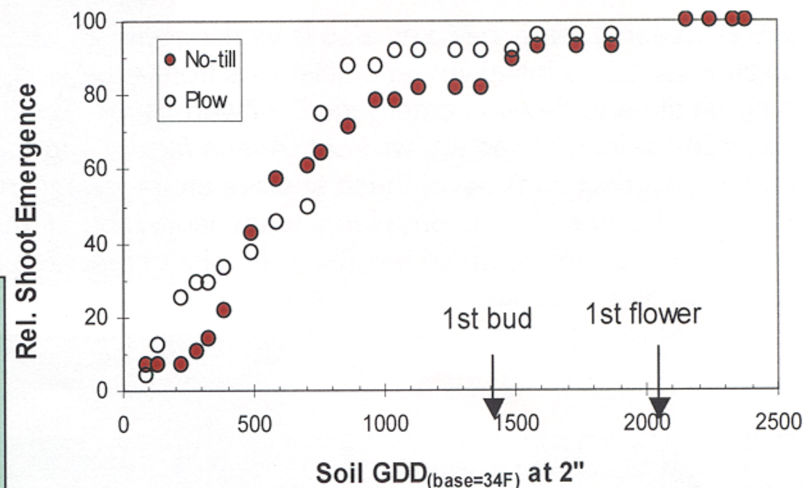
Two-year sequence of seedling emergence at the Swan Lake Research Farm from seeds of common lambsquarters derived from MN, Italy, Sweden, and England.

Common lambsquarters seedlings from differing parts of the world emerged from soil at similar times when planted at one site. This indicates that genetic variationwithin lambsquarters has little effect on emergence timing, and this allows development of universal emergence models.

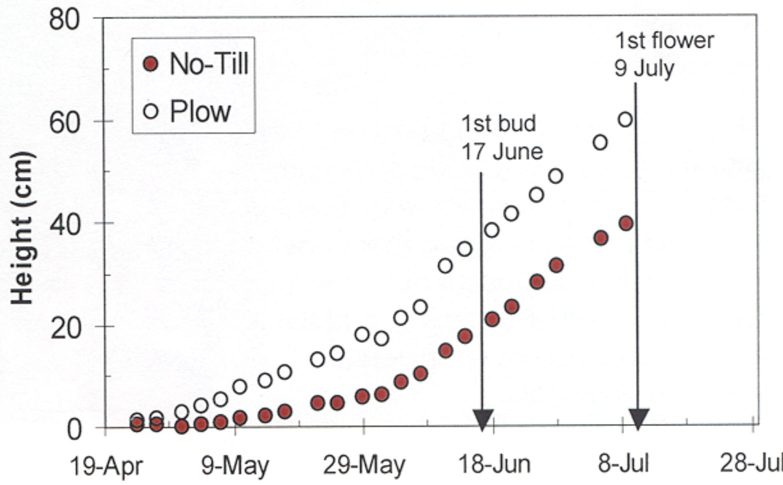


The models that we are constructing will be used to predict shoot emergence, plant growth, and reproductive development of these weeds. The predictions are based upon daily-measured environmental variables, namely soil temperature, air temperature, rainfall, and daylength. We expect to package these models into computer software, similar to what we did for annual weeds in *WeedCast*. Once these models are finished and available in easy-to-use software, they can be employed by others to help plan management operations. These management operations may include timely tillage, mowing, and spraying operations, as well as the best times to release biological control agents.





Canada thistle shoot emergence is not affected greatly by tillage, but subsequent growth of shoots is influenced by tillage. Initiation of flowers appears independent of tillage system. Prediction of these events is important for managing perennial weeds such as Canada thistle.

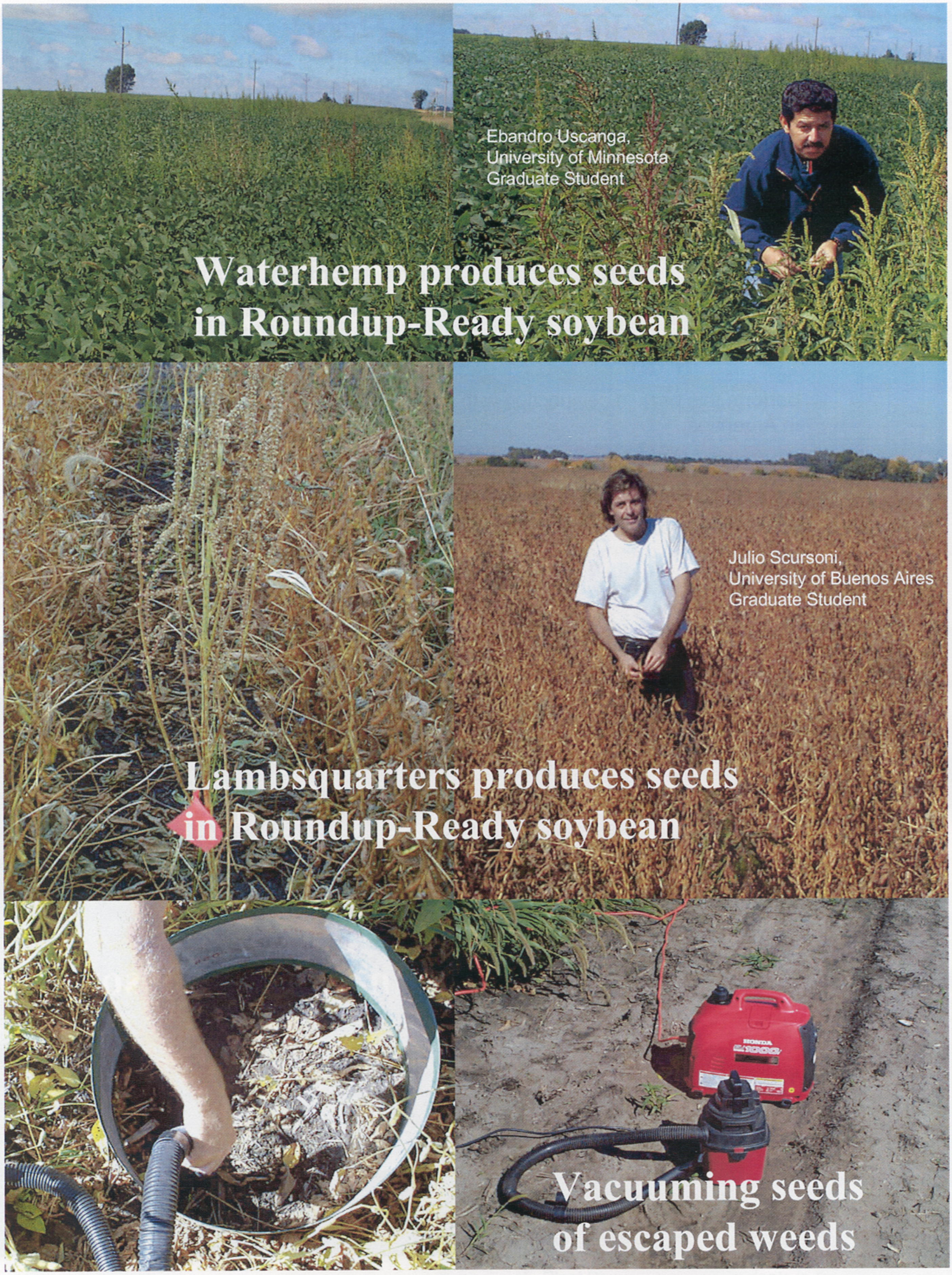


Weed Seed Production

One of largest problems in weed science that remains poorly studied is the production of seeds by weeds that escaped control during the current growing season. This problem has increased in significance recently because of the widespread adoption of crops that have been engineered for tolerance to broad-spectrum, burndown herbicides, such as Roundup (glyphosate) and Liberty (glufosinate).

Our goal has been to document and understand the mechanisms of escape from control in Roundup-Ready cropping systems. Accordingly, we study species composition, emergence patterns, growth stages, and herbicide tolerances of weed populations that survive one-pass and two-pass glyphosate treatments in comparison to standard PRE, standard PRE + POST, and weedy check treatments in experiments throughout Minnesota, as well as in Iowa, Missouri, Arkansas, and Louisiana. We perform this work in conjunction with collaborators in all of the listed states, as well as in Argentina.

Warm-weather weeds, such as common waterhemp, *Amaranthus tuberculatus*, are particularly prone to escaping control by these herbicides, because their seedlings often emerge after the last application of these non-residual herbicides. However, even some early-emerging weeds escape control, because by the time Roundup, for example, finally is applied, the weed plants sometimes are large enough to tolerate this herbicide. Common lambsquarters, *Chenopodium album*, is an example of this latter type of species. Additional mechanisms of escape from control almost certainly exist.


Ebandro Uscanga,
University of Minnesota
Graduate Student
Waterhemp produces seeds
in Roundup-Ready soybean
Julio Scursoni,
University of Buenos Aires
Graduate Student
Lambsquarters produces seeds
in Roundup-Ready soybean
Vacuuming seeds
of escaped weeds

Research by: Russell W. Gesch, Plant Physiologist

gesch@morris.ars.usda.gov

One of my primary objectives at the NCSCRL is to identify and characterize biological factors of crops (traditional and alternative) limiting their growth to sub-optimal environmental conditions often encountered in the northern Corn Belt region. This information helps farmers select the best crops and varieties for a given environment and identifies genetic traits for plant breeders to improve in certain crops making them better adapted to cope with environmental stresses.

Every farmer knows that corn does not grow well under cold wet spring conditions. But what are the underlying biological processes that limit its growth? Why is it that some crops such as wheat and certain weed species are not as adversely affected? Part of the reason may lie at the heart of the processes utilized by corn to fix atmospheric carbon dioxide (CO_2) into sugars (i.e., photosynthesis), which are then used for growth. Wheat, which tends to be quite tolerant to low, non-freezing temperatures, does so by increasing its ability to photosynthesize and store sugars for growth. Primarily, wheat's photosynthetic capacity increases under cold temperatures because of acclimation of an enzyme responsible for converting atmospheric CO_2 into usable organic carbon in leaves. This enzyme is known as ribulose bisphosphate carboxylase/oxygenase, or Rubisco for short. In addition to Rubisco, corn has another enzyme called phosphoenolpyruvate carboxylase (PEPCase), which works in concert with Rubisco to fix CO_2.

A field study was initiated in 2001 to compare photosynthetic processes of two corn hybrids, which have been found to differ in their growth response to cold temperatures. The two hybrids were Pioneer 38W36, which is somewhat cold tolerant, and Fielder's Choice 8195 a more cold sensitive hybrid. Photosynthetic comparisons were made June 1 following several days of growth under cold but non-freezing temperatures. The hypothesis tested was whether the two hybrids differed in their photosynthetic capacities due to growth under cool conditions and if so, whether this is due to differences in the activity and amounts of PEPcase and Rubisco caused by acclimation.

The corn hybrids were sown on April 30, 2001. Figure 1 shows leaf photosynthetic rates for three separate plants each of 38W36 (green circles) and 8195 (yellow squares). Measurements were taken on leaf #2 (the newest fully expanded leaf) on June 1. The data clearly show that the photosynthetic ability of 38W36 leaves was much greater than that of 8195 leaves.

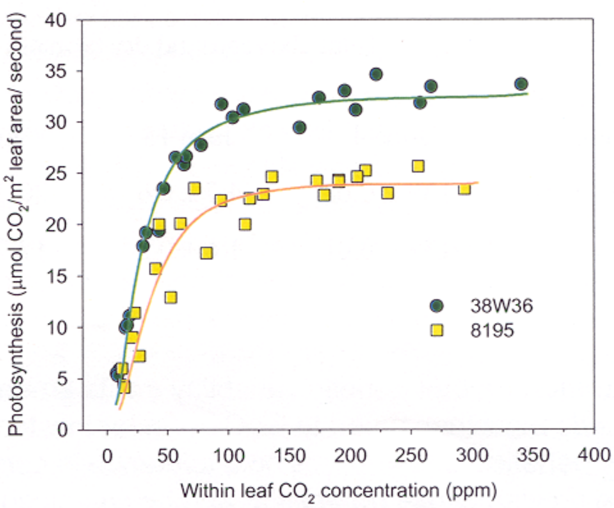


Figure 1. Effect of early spring growth on corn leaf photosynthesis.

The same leaves used to measure photosynthesis were clipped from plants while in the field and immediately froze in liquid nitrogen to suspend them in their physiological state. The leaf tissue was later extracted in the laboratory, and the activity and amount of PEPCase and Rubisco were measured. Figure 2 shows maximum rates of PEPCase (**A**) and Rubisco (**B**) activity. In comparison to hybrid FC-8195, PEPcase and Rubisco activity were 28 and 35 % higher, respectively, in leaves of hybrid 38W36. Changes in amount of the two enzymes (indicated by the black bands directly above the bar graphs) corresponded similarly to the differences in their activity. These results indicate that PEPcase and Rubisco in leaves of 38W36 plants acclimated more favorably to low temperature than in leaves of 8195 and also helps explain the differences in photosynthetic rates between the two hybrids shown in Fig. 1.

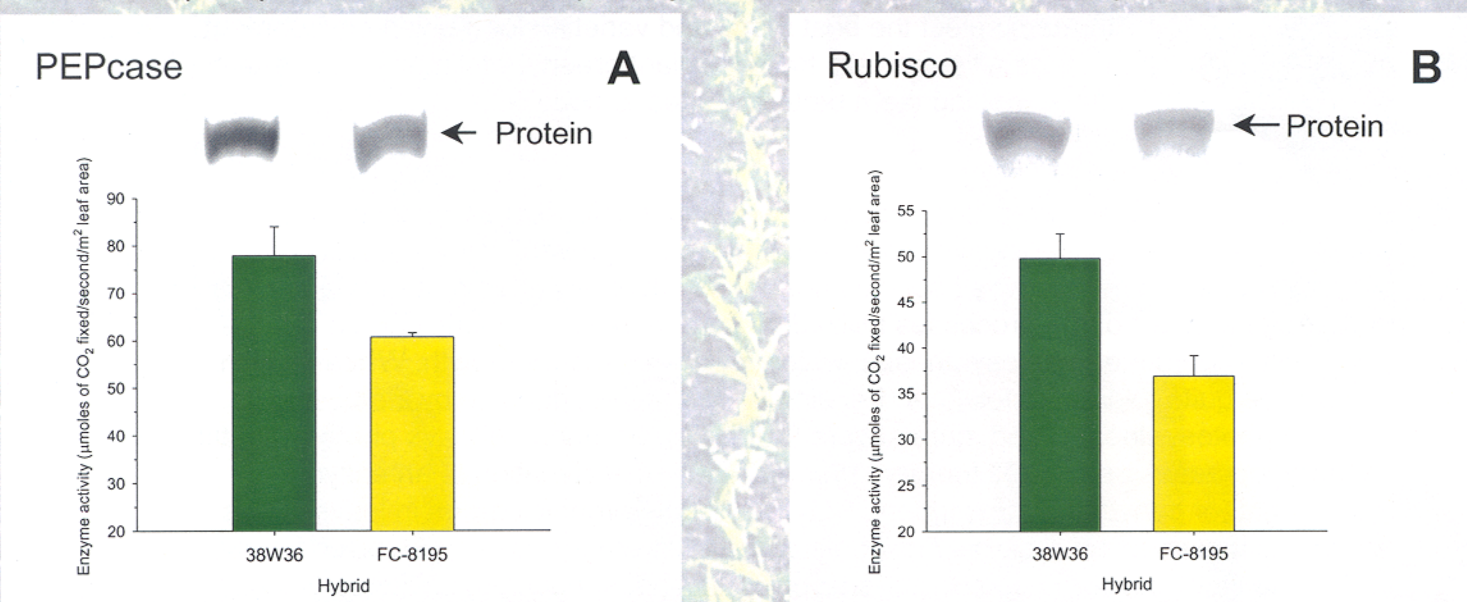


Figure 2. Effect of early spring growth on the enzyme activity and amount of PEPcase (A) and Rubisco (B).

Table 1 shows total aboveground dry biomass for 38W36 and 8195 plants throughout the early part of the growing season up to the beginning of reproductive phase (i.e., July 17). By mid June, 38W36 plants were almost three times larger than those of 8195. However, this difference in size diminished as the season progressed and by July 17 38W36 plants only had 13 % greater mass. Generally, larger plants during late vegetative and early reproductive phase are able to contribute more carbon and nitrogen to seed development, hence translating to greater grain yield. As shown in Table 1, grain yield for 38W36 was about 14 % greater than that of 8195.

Table 1.

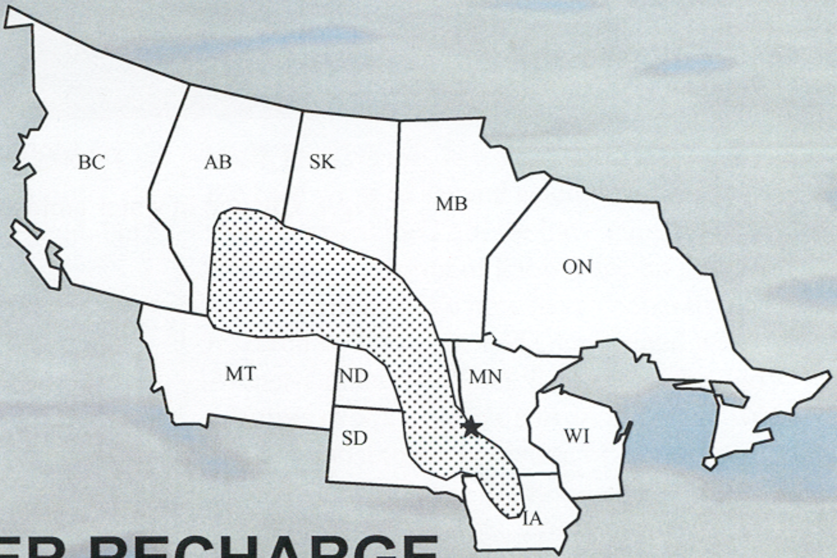
Total aboveground dry biomass (grams per plant)

Hybrid	June 4	June 18	July 3	July 17	Grain yield (Bu/acre)
Pioneer 38W36	0.39 ± 0.02	4.7 ± 0.6	20.3 ± 2.1	78.1 ± 2.1	172.4 ± 6.7
FC-8195	0.31 ± 0.01	1.6 ± 0.2	17.7 ± 1.4	69.3 ± 4.4	151.8 ± 9.2

Results thus far indicate that genetic variability exists among corn hybrids with respect to acclimation of the photosynthetic machinery used to fix CO_2 under low temperatures. This is important information that can be used by geneticists to improve cold tolerance in corn. Future research endeavors are aimed at determining the precise cause (molecular and biochemical) for differences in acclimation of PEPCase and Rubisco to low temperatures in corn hybrids.

Research by: Brenton Sharratt, Soil Scientist
sharratt@morris.ars.usda.gov

The eastern Dakotas and west central Minnesota lie within the Prairie Pothole Region of North America. This region of 300,000 square miles in the north central US and southern Canada (depicted below) is considered to be the most important breeding ground for waterfowl in North America. Millions of potholes of various shapes and sizes are embedded within the prairie landscape.



GROUNDWATER RECHARGE

Groundwater is frequently replenished in the Prairie Pothole Region by depression-focused recharge. Depression-focused recharge is the process whereby runoff (from rain or snowmelt) is channeled to the bottom of landscape depressions. Runoff collected in these depressions can then infiltrate through the soil and enter groundwater aquifers. Snowmelt is an important source for replenishing groundwater in cold regions. In the Prairie Pothole Region, snowmelt collects in landscape depressions and forms temporary ponds as a result of frozen soil impeding infiltration. These ponds drain and replenish groundwater during spring thaw.

Recent observations at the North Central Soil Conservation Research Laboratory suggest that infiltration of snowmelt in landscape depressions occurs prior to soil thawing in the spring. These observations, while unique, are by no means singular in nature as scientists in Sweden have found discharge from drain tiles occurring before the soil profile thaws in spring. Likewise, scientists at St. Paul, Minnesota have also observed the water level of an ephemeral pond dissipate during spring even though the soil remained frozen below the pond.

WATER TABLE FLUCTUATIONS

In the early 1990's, we found that groundwater levels at Swan Lake rose sharply at the onset of spring thaw. Figure 1 (next page) indicates the water table can change abruptly, by as much as 3 meters (10 feet) in a matter of days during spring. These changes occurred while the soil profile was frozen.

Depth of water table below the soil surface. The arrows indicate onset of spring recharge.

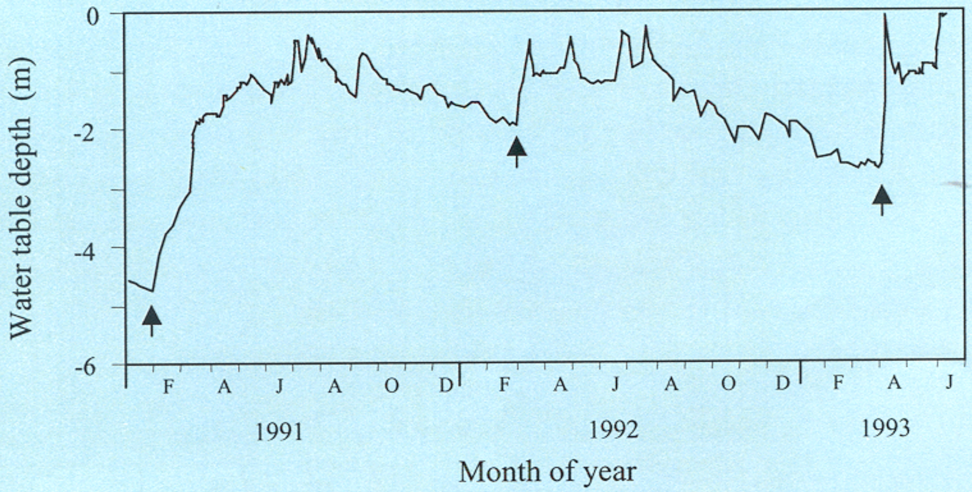


Fig.1. Change in water table at Swan Lake during 1991-1993.

WATER FLOW THROUGH FROZEN SOIL

The rise in the water table in early spring suggested that water must flow through frozen soil. Yet, no studies revealed a mechanism by which surface water flows through frozen soil and enters the groundwater system. Our investigations during the late 1990's tried to identify this mechanism. A landscape depression at Swan Lake was instrumented during the winter of 1999-2000 to monitor changes in pond depth and water table. Changes in pond depth and water table are noted below. After pond formation, the depth of the pond continued to rise as a result of snowmelt. A 0.4-inch rain caused an abrupt rise (0.05 meters or 2 inches) in the depth of the pond on February 25. Thereafter, the pond quickly dissipated as a result of opening the drain tile.

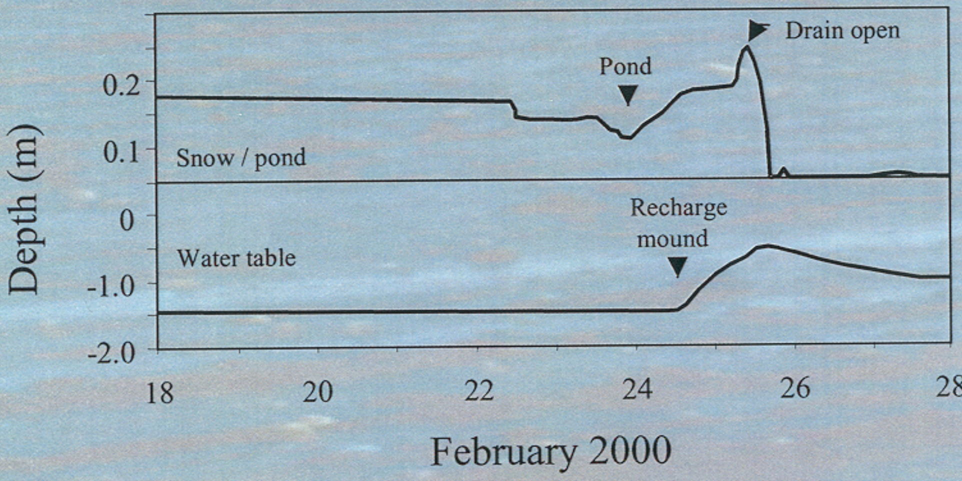
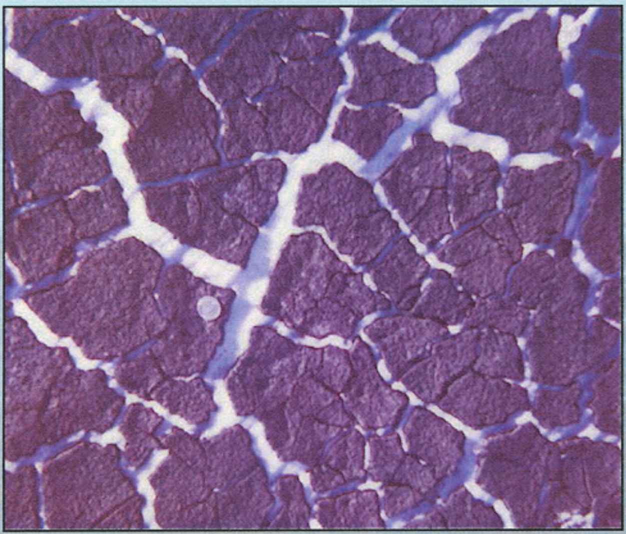


Fig.2. Changes is pond depth and water table during Feb, 2000.

The rise in the water table was initiated 15 hours after pond formation. The water table rose 1 meter (3 feet) within 24 hours. At the time of recharge (afternoon of February 24), the soil was frozen 2 to 35 inches below the soil surface around the perimeter of the pond. Water from the pond therefore appeared to infiltrate and flow through the soil despite a 33-inch frozen layer in the soil profile.

On February 25, the soil underlying the pond was probed to determine if unfrozen conduits or pathways in the soil profile existed that might allow water to flow through the 33-inch frozen soil layer. Five thawed conduits were found within a 100 square foot area near the center of the pond. These conduits had a surface area of 1 to 4 square feet. Two of the 5 conduits were completely thawed through the frozen soil layer; the remaining 3 conduits were thawed to a depth of 12 to 24 inches.

Measurements during the spring of 2001 revealed no abrupt changes in the water table nor the existence of thawed conduits. The reason why thawed conduits were formed in the spring of 2000 and not in the spring of 2001 is still uncertain, but extensive cracking of the soil surface was only apparent during the autumn of 1999 (see below). Weather conditions and soil physical properties likely caused the soil to crack as it froze in the autumn of 1999. These cracks then perhaps contributed to the formation of thawed conduits in the spring of 2000.



Soil cracks formed in autumn. A coin (quarter) is visible near the center of the photo.

IMPACTS OF RAPID GROUNDWATER RECHARGE

Water infiltrating from ponds and entering groundwater systems during the spring could have serious implications for groundwater quality. Chemicals are normally filtered as water percolates through soil. During spring recharge in cold regions, observations in Minnesota and elsewhere suggest that water can bypass the frozen soil matrix and enter groundwater systems via large thawed conduits. Chemicals contained in this water have little chance of being absorbed by the soil and thus enter groundwater supplies. A better understanding of the formation of soil cracks in autumn may help to prevent transmission of chemicals to groundwater during spring thaw.

On Farm Research -Tillage Erosion and Carbon Loss

By D.C. Reicosky, M.J. Lindstom, C.D. Wente and A.R. Wilts

A new type of erosion, called tillage erosion, has been identified that appears to have similar negative consequences. Tillage erosion or tillage-induced translocation is the net movement of soil downslope through action of mechanical implements and gravity forces acting on loosened soil. Soil is not directly lost from the fields by tillage translocation, rather it is moved away from the convex slopes and deposited on concave slope positions. Repeated plowing accelerates the movement of soils from the hilltops to the down slope areas and causes some soil degradation. Plowing also releases carbon dioxide (CO_2) to the atmosphere and has contributed to the increase in CO_2 related to concerns about potential global warming. The cumulative effect of tillage and many cropping rotations has been a 30-50% decrease in soil organic matter that causes undesirable changes in soil physical, chemical and biological properties. Today's faster and more powerful tractors compound this problem by moving the soil even faster and farther and with more soil carbon loss. Tillage erosion and soil carbon loss have become important factors in soil and crop management considerations.

The relationship between soil productivity across a rolling landscape and erosion is complex. Soils are not the sole factors controlling crop yields. The degree to which crop yield losses are related to soils is a function of several interacting factors including soil physical, chemical and biological properties, landscape position, crop grown, management practices and weather conditions before and during the growing season. There are many reasons for intensive tillage. Tillage sets up the soil to be loose, open and susceptible to high intensity rainfall and subsequent erosion. The net effect of soil translocation from the combined effects of tillage and water erosion is an increase in spatial variability of crop yield and a likely decline in overall soil productivity.

Figure 1. Spatial variation of tillage-induced soil erosion.

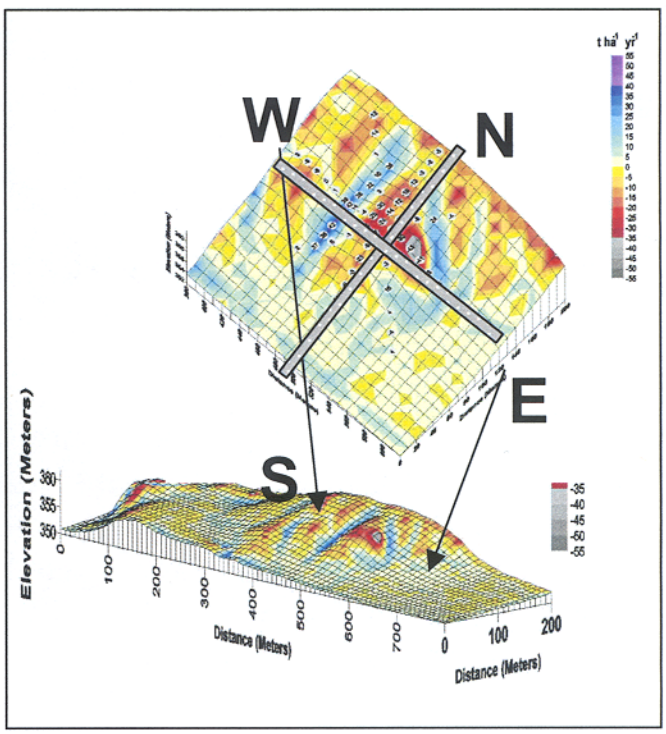


Figure 2. Digital elevation map of the study site.

The tillage erosion research at the Soils Lab is a cooperative effort led by Mike Lindstrom, from the Soils Lab; Tom Schumacher, Joe Schumacher and Doug Malo, from South Dakota State University; Brookings, South Dakota; and David Lobb, University of Manitoba, Winnipeg, Manitoba. One objective of this work was to quantify the variability in tillage-induced CO_2 loss by moldboard and chisel plowing across an eroded landscape and relate the soil organic matter loss to soil properties. Large amounts of data have been collected on a 30 ft. by 30 ft. grid spacing on an 8-acre field of sloping land on the farm of Don and Joyce Skogstad north of Cyrus, Minnesota. Soil properties were measured at several depths along east-west and north-south transects that included severely eroded, moderately eroded and non-eroded sites. The wealth of scientific information available on this field site provided an excellent opportunity to evaluate spatial variation of tillage-induced soil organic matter losses across an eroded landscape. The tillage and cropping history of the field is known for the last 30 years and provides a valuable resource to evaluate the effects of tillage erosion. The on-farm research site showing the soil color differences across the sloping landscape is shown in Figure 1. The lighter soil colors reflect the removal of topsoil and soil organic matter as a result of erosion. Figure 2 shows the location of the two transects in this study imposed on the digital elevation map that also shows predicted tillage erosion.

Conventional moldboard plow (10 inches deep shown in Figure 3) and chisel plow (6 inches deep shown in Figure 4) equipment were used along the pre-marked transects. Gas exchange measurements utilized a large, portable chamber (MR. GEM) within 6 ft. of each sample site following tillage. The measured CO_2 fluxes were largest with the moldboard plow > chisel plow > not tilled (before tillage). The variation in CO_2 flux in the north-south transect was nearly four-fold immediately after plowing. The CO_2 loss was partially related to soil properties with lower CO_2 flux on the severely eroded sites. The CO_2 loss partially reflected the degradation of soil properties as a result of wind and water erosion and tillage-induced soil translocation. The spatial variation across the landscape suggests non-point sources of soil C loss are complex and the need for improved conservation tillage methods to maintain soil and air quality in sloping agricultural production systems.

Figure 3. Measuring gas exchange of soil plowed with a moldboard plow.

Figure 4. Measuring gas exchange of soil plowed with a chisel plow.

Soil Respiration and Evaporation after Planting and Row Drying on Ridge Tillage Systems

By: Chris Wente, Agricultural Research Science Technician

Our research demonstrated that tillage increases soil respiration (release of carbon dioxide from soil) and evaporation (release of water from soil). The increase of both respiration and evaporation is dependant on the amount of soil disturbed and soil conditions such as temperature, water content, organic matter, and residue at the time of tillage. On April 25, 2000, a series of experiments were conducted at the Doug and Duane Adams farm near Cosmos, MN and the Al Cotter farm near Hutchinson, MN. The purpose of these experiments was to determine the short-term effect of row drying (de-ridging) and planting on soil respiration and evaporation in a ridge tillage system.

Row drier at the Adams Farm

Row drier and planter at the Cotter Farm

While Doug and Duane Adams performed row drying and planting with 12-row equipment on ridge-tilled soybean stubble spaced on 30 inch rows, MR GEM (Mobile Research Gas Exchange Machine) was used to make soil respiration and evaporation measurements starting about 8:30 a.m. and ending at about 10:30 a.m. Air temperature during the measurements was between 55 to 65º F. The area had received no rain for a week prior to the measurements. The soil moisture in the ridges was dry in the top 2 inches 15.9%, while the lower layers contained ample moisture 30.0% for 2 to 4 inches and 33.4% for 4 to 8 inches. The wind was out of the southeast at 10 to 15 mph, and it was mostly sunny.

Similar conditions were encountered at Al Cotter's farm. Measurements were made after row drying and planting with 4-row equipment on ridge tilled soybeans spaced on 36 inch rows between 1:00 p.m. and 4:30 p.m. A unique feature of Al Cotter's ridges that two rows of crop are planted about 8 inches apart on top of the ridge. In addition, measurements were made on an area that was chisel plowed to be able to compare an aggressive spring tillage event to the planting and row drying events. Air temperature during the measurements was between 70 to 80º F. Soil moisture conditions in the ridges was 22.1% for the top 2 inches, 37.3% for 2 to 4 inches, and 34.8% for 4 to 8 inches. The wind was out of the southwest at 10 to 15 mph with mostly clear skies.

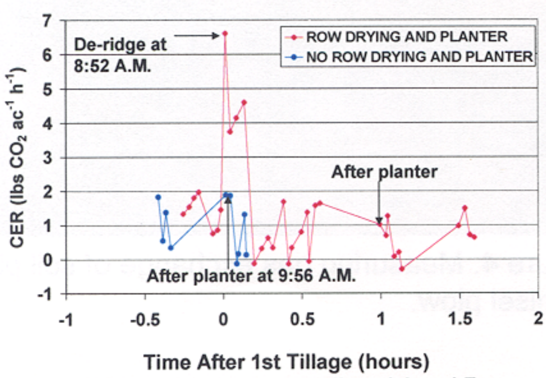


Figure 1. Carbon Exchange Rate Adams' Farm

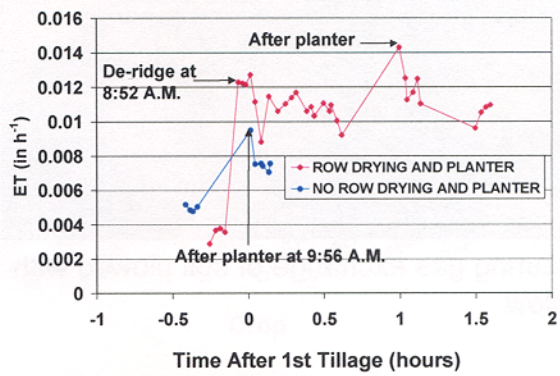


Figure 2. Evaporative Transpiration Adams' Farm

Figure 1 shows the amount of carbon dioxide released per acre per hour after the various treatments at the Adams farm while Figure 3 is at the Cotter farm. In Figure 1 the measurements made after one hour on the plot with row drying are after the secondary tillage event of the planter while the measurement made immediately after tillage on no row drying plot are after the planter that row drying and planting cause very little carbon dioxide to be released. This was due to the small amount of dry soil being disturbed on top of the ridge. Finally, the magnitude of carbon dioxide loss with row drying and planting are lower than with intensive tillage, especially the moldboard plow. This can be seen in Figure 3 by comparing the chisel plow with the other treatments.

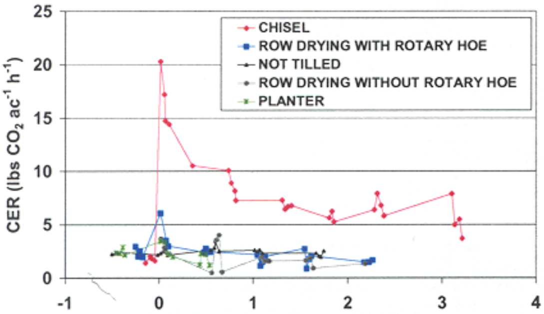


Figure 3. Carbon Exchange Rate Cotter's Farm

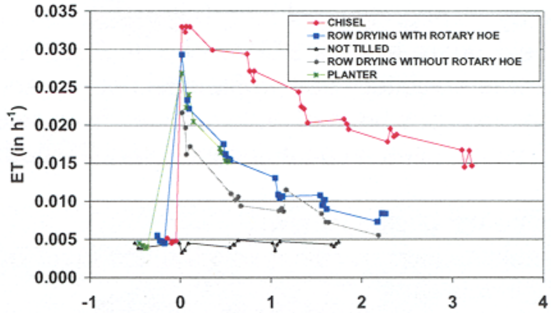


Figure 4. Evaporative Transpiration Cotter's Farm

Figures 2 and 4 show the amount of water released by evaporation after the various treatments. Figure 2 is data from the Adams' farm, the measurements made after one hour on the plot with row drying are after the secondary tillage event of the planter while the measurement made immediately after tillage on no row drying plots are after the planter. As shown in the data from these graphs, row drying and planting caused increased evaporation by exposing moist soil to the atmosphere. Due to the dry conditions, it is difficult to assess if row drying increases evaporation enough to allow planting sooner than without row drying. However, row drying did increase evaporation a significant amount compared to no row drying.

Results of this study agree with those found previously. Soil disturbance or tillage in the form of planting and row drying does increase soil respiration and evaporation slightly. During this study, evaporation was increased after the tillage and its effects lingered throughout the measurement cycles while respiration was increased for only a short time before it approached its pre-tillage values. Therefore, row drying appears to increase water loss, which accomplishes its purpose without causing excess carbon dioxide loss. This is due to the small amount of soil disturbance occurring at a relatively shallow depth. These results could be magnified by the relative dry conditions of the upper 2 inches of soil at both locations, and these results may have been different if the soil was wetter when evaporation and soil warming may be beneficial. Noteworthy is the chisel plow with higher tillage intensity lost considerably more carbon dioxide and water than row drying or the planting operation alone.

Soil erosion effects on soil carbon

Research by: Mike Lindstrom, Soil Scientist
lindstrom@morris.ars.usda.gov

Soil erosion is a soil degrading process that has a negative effect on soil physical and chemical properties and in turn soil productivity. Soil erosion levels from two soil erosion processes (tillage and water) were calculated using established soil erosion models for a 17 ha (40 acre) field in west central Minnesota. Tillage system simulated was a moldboard plow and disc tillage sequence. Detailed soil profile descriptions and chemical analysis for soil carbon by identified soil horizons was determined in multiple transects on a 10 by 10 m grid on a 4 ha (10 acre) portion of the larger field where evidence of varying degrees of soil erosion was exhibited. Soil profile descriptions and chemical analyses were also determined from selected corresponding sites on an adjacent non-cultivated hillslope.

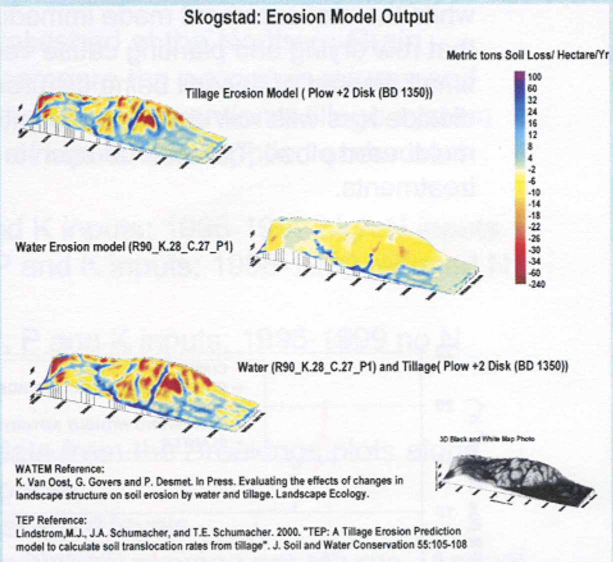
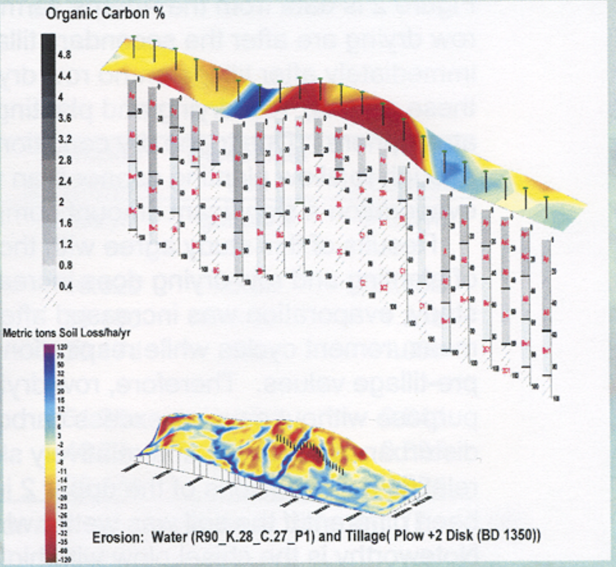


Figure 1. Calculated soil erosion from a 17 ha (40 acres) field with rolling topography in West Central Minnesota showing soil erosion levels for tillage only, water only, and combined tillage and water erosion. Satellite black and white photo shows exposed subsurface soil material exposed at the soil surface (areas of lighter color).

Results from this study show:

- Soil redistribution by tillage was the dominant erosion process in this field.
- Soil erosion increased the variability of soil organic and inorganic carbon over the landscape.
- Crop cultivation and soil erosion over the past 100 years drastically reduced soil organic carbon content in the surface horizon.
  - A horizon, non-cultivated grass hillslope contained: 3.5-3.7% organic carbon
  - Ap horizon, Cultivated field contained: 0.5-2.4% organic carbon
- Two year average spring wheat yields were positively related to organic carbon content in the Ap and mollic horizons and negatively related to inorganic carbon content of the Ap horizon and calculated soil erosion.



Figures 2. Soil organic carbon content by identified soil horizons measured across the west to east transect at 10 m intervals in the 4 ha (10 acre) portion of the larger field. As soil erosion levels increase, soil organic carbon content decreased.

Note: Soil erosion levels were calculated on soil surface elevations as measured in 1999 and may not accurately reflect erosion levels over prior years. Tillage erosion is concentrated on convex slopes leading to reduced slope angles and infilling of concave slopes and lowland areas, in effect reducing topographic gradients. In contrast, landscapes dominated by water erosion are characterized by increase incision of concave slope position and waterways leading to a gradual increase in slope angles on upland convex positions.

distribution and yield relationships

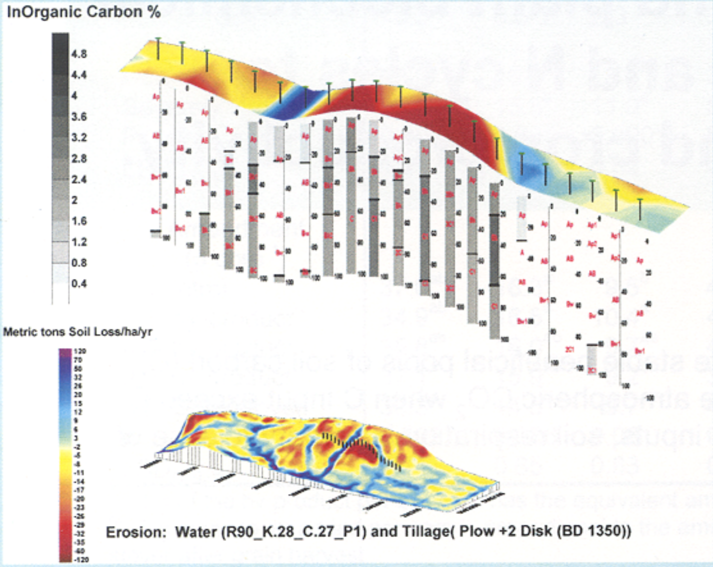


Figure 3. Soil inorganic carbon content identified by soil horizons was measured across the west to east transect at 10 m intervals in the 4 ha (10 acre) portion of the larger field. As soil erosion levels increase, soil inorganic carbon content of the tilled zone increased.

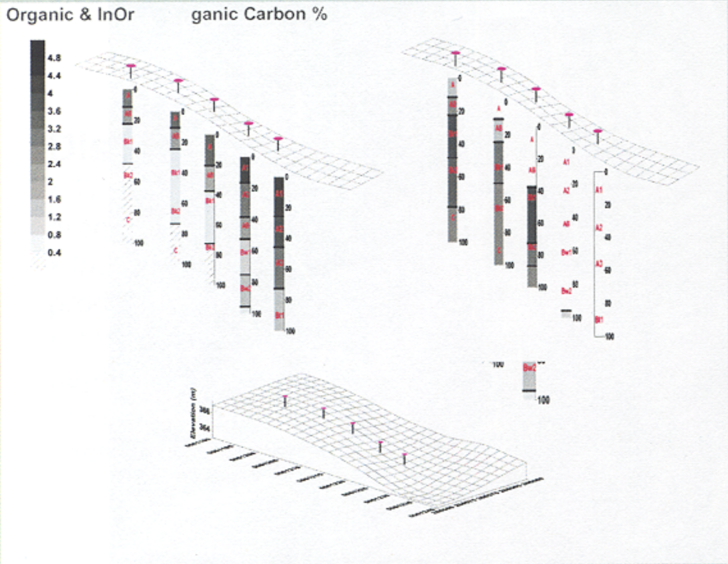


Figure 4. Soil organic carbon content from corresponding soil series from the non-cultivated adjacent grass hillslope

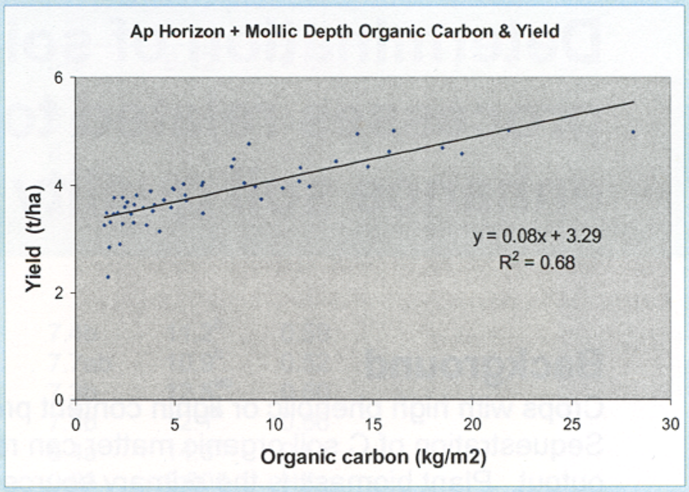


Figure 5. Soil organic carbon content of the Ap and mollic horizons and yield

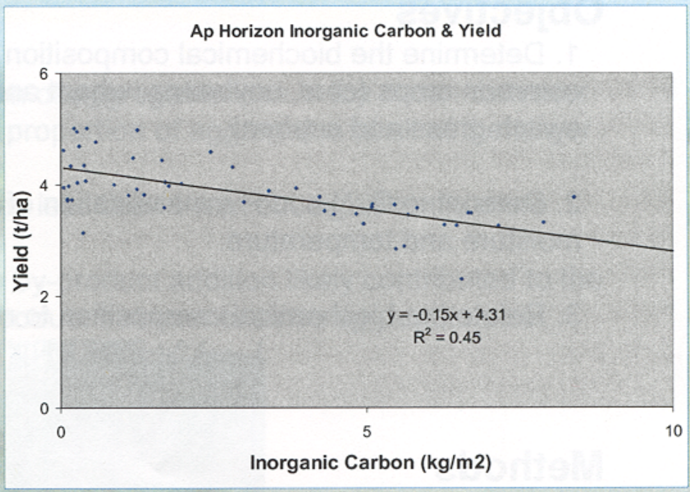


Figure 6. Soil inorganic carbon content of the Ap horizon and yield

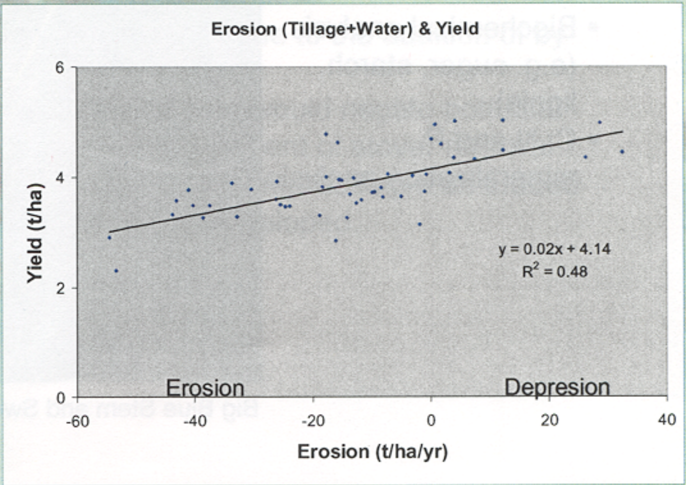


Figure 7. Calculated combined soil erosion (tillage and water) and yield

Research by: Jane M-F Johnson, Plant Biochemist
johnson@morris.ars.usda.gov

Determination of soil and plant biochemical processes related to C and N cycles to enhance soil quality and crop productivity.

Background

Crops with high phenolic or lignin content promote stable beneficial pools of soil carbon (C). Sequestration of C soil organic matter can reduce atmospheric CO_2 when C input exceed C output. Plant biomass is the primary source of C inputs, soil respiration is primary release of soil C.

Objectives

1. Determine the biochemical composition of stems, leaves and roots collected from common crops (corn, soybeans, wheat and alfalfa) and alternative crops (big blue stem, switch grass and cuphea).

2. Determine C, N and P mineralization of plant organs of the above species under controlled moisture and temperature.

3. Relate the biochemical composition to mineralization rates.

Methods

- Collect plants from field and in growth chamber
- Biochemical analysis (e.g. sugar, starch, lignin)
- C, N and P mineralization analysis

Big Blue Stem and Switchgrass (background) growing in growth chamber

Progress/Results

Table1. Concentration of sugars and starch in several crop species, biofuel and alternative crop species grown in a growth chamber or in the field.

		Growth Chamber				*Field*			
Crop	*Organ*	Soluble Sugar (mg/g)		Starch (mg/g)		Soluble Sugar (mg/g)		Starch (mg/g)	
Alfalfa	Leaves	18.8	(±4.8)	20.9	(±6.3)	23.3	(±0.9)	46.2	(±13.6)
Alfalfa	Stem	35.4	(±5.7)	16.6	(±6.0)	49.5	(±3.5)	6.0	(±1.4)
Alfalfa	Root	15.7	(±2.4)	202.6	(±30.5)	46.6	(±6.5)	111.3	(±19.4)
Big Bluestem	Leaves	40.1	(±4.2)	3.7	(±1.0)	NA[a]	NA	NA	NA
Big Bluestem	Stem	45.0	(±5.5)	3.9	(±1.3)	NA	NA	NA	NA
Big Bluestem	Root	15.9	(±1.6)	26.9	(±5.8)	NA	NA	NA	NA
Corn	Leaves	48.1	(±12.9)	2.3	(±0.3)	31.9	(±7.3)	1.8	(±0.2)
Corn	Stem	NA[a]	NA	NA	NA	127.2	(±15.7)	1.1	(±0.2)
Corn	Root	36.2	(±11.9)	0.6	(±0.3)	19.2	(±3.3)	0.4	(±0.2)
Cuphea	Leaves	37.6	(±3.7)	5.5	(±1.5)	27.9	(±4.5)	15.7	(±2.7)
Cuphea	Stem	12.7	(±2.3)	0.9	(±0.1)	16.9	(±2.4)	1.6	(±0.0)
Cuphea	Root	1.8	(±0.2)	2.6	(±0.8)	14.5	(±2.5)	2.0	(±0.2)
Soybean	Leaves	12.8	(±3.2)	6.7	(±1.3)	22.9	(±4.3)	8.4	(±2.5)
Soybean	Stem	3.6	(±0.1)	1.0	(±0.3)	36.2	(±2.2)	3.0	(±1.2)
Soybean	Root	3.9	(±0.7)	1.1	(±0.1)	13.3	(±2.0)	0.7	(±0.3)
Switchgrass	Leaves	28.3	(±1.7)	17.3	(±5.4)	32.8	(±4.4)	3.8	(±1.4)
Switchgrass	Stem	32.9	(±3.8)	18.8	(±2.6)	51.8	(±5.5)	8.3	(±2.6)
Switchgrass	Root	9.2	(±1.2)	15.2	(±2.5)	30.6	(±4.0)	3.9	(±0.9)
Wheat	Leaves	8.0	(±1.7)	0.6	(±0.5)	NA	NA	NA	NA
Wheat	Stem	27.9	(±4.3)	1.7	(±0.6)	NA	NA	NA	NA
Wheat	Root	16.0	(±3.5)	0.6	(±0.4)	NA	NA	NA	NA

a. NA= not available

- Differences between growth chamber and field-grown plants may be because:
  - they were harvested at different points in their diurnal cycle.
  - alfalfa in growth chamber was one-year growth but second-year growth in the field.
  - growth chamber plants not exposed to environmental stimuli (e.g. rain, wind).

- Experiments have been initiated to compare mineralization rates to correlate with biochemical composition.

Future Plans

- Complete biochemical analysis
- Complete mineralization studies
- Initiate experiments assessing environmental stress on biochemical composition and decomposition.

Implications of using corn stalks as biofuel source

Background

- US-DOE – funded experiment
- Multi-agency project (USDOE-ORNL/USDA-ARS).
- Multi-location: Ames, Brookings, Ft. Collins, Lincoln, **Morris**, St. Paul)
- Morris collaborators: Jane Johnson, Mike Lindstrom, Don Reicosky, Brenton Sharratt and Ward Voorhees.
- Second year of study

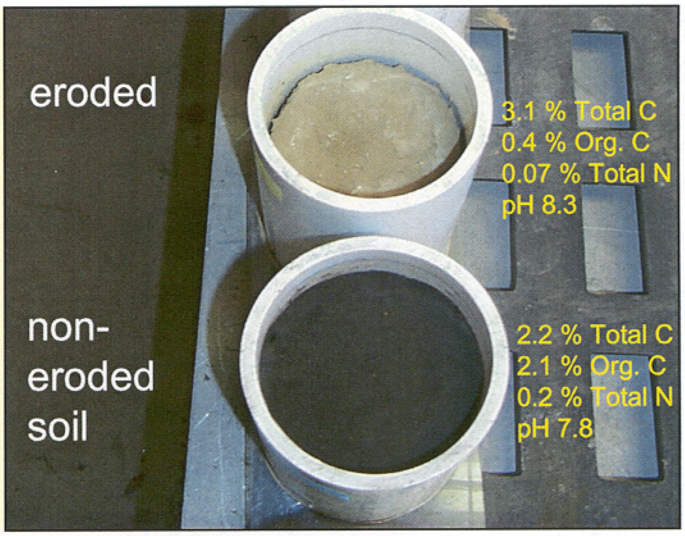
Objectives

1. Determine the effect of by-product from corn stover ethanol production on soil processes and properties.
2. Determine the amount of by by-product needed to compensate for the removal of corn stover from the field.

General Methods

Soil Cores

- 1.47 kg dry, sieved soil
- B.D. = 1.3 Mg m^{-3}
- Initial: 60% WFP
- Dry to 35% WFPS
- 7 w/d cycles
- 5 reps
- Terminated after 123 d



Parameters measured

- CO_2 flux
- Soluble C
- Microbial Biomass C
- Total C, Total N, Inorganic C
- Humic, Humin factions
- Phenolic acid concentration
- H_2O retention
- Aggregate stability

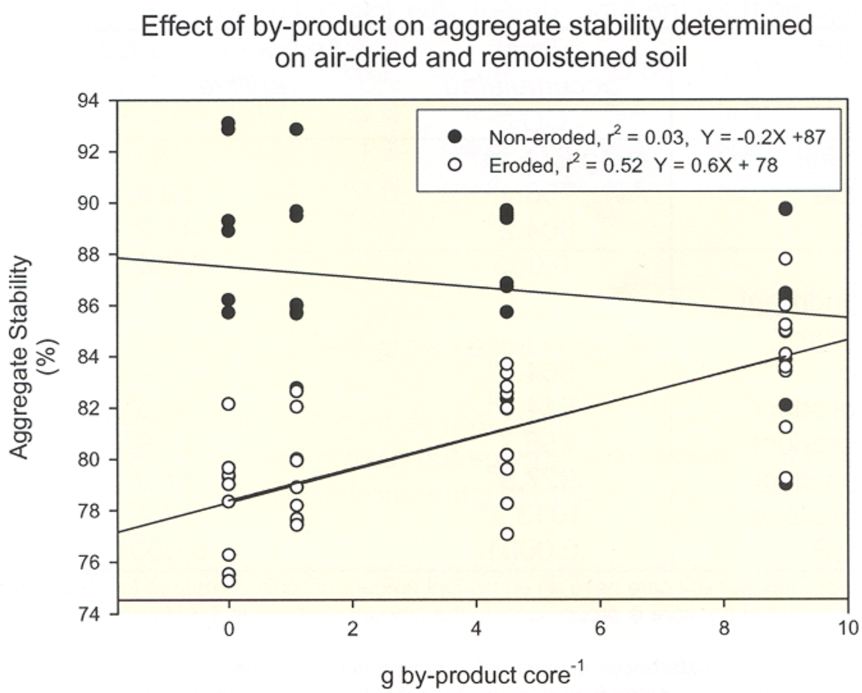
❑ Soluble C and Microbial biomass C

- The eroded soil had an average of 141-µg soluble C kg^{-1} soil compared to 190-µg soluble C kg^{-1} soil for the non-eroded soil.
- The eroded soil had an average of 657-µg microbial biomass C kg^{-1} soil compared to 806-µg microbial biomass C kg^{-1} soil for the non-eroded soil.
- The maximum coefficient of determination between g of by-product added and soluble C or microbial biomass C occurred seven days after application.
- Microbial biomass and soluble C were more sensitive the addition of by-product on the eroded soil than on the non-eroded soil. The non-eroded soil has a high concentration of organic matter, which would buffer changed caused by the amendments.

❑ Humin and humic acid concentration

- The amount of humin was higher in the eroded soil (983 mg humin g^{-1} soil) compared to the non-eroded soil (943 mg humin g^{-1} soil), but not significantly altered by amendment.
- The eroded soil had more than an order of magnitude less humic acid (2.1 mg humic acid g^{-1} soil) compared to non-eroded soil (30.9 mg humic acid g^{-1} soil).
- On the eroded soil with very low organic matter the addition of by-product could account for >80% of the variability on humic acid concentration, but on the non-eroded soil cores it only accounted for 10%.

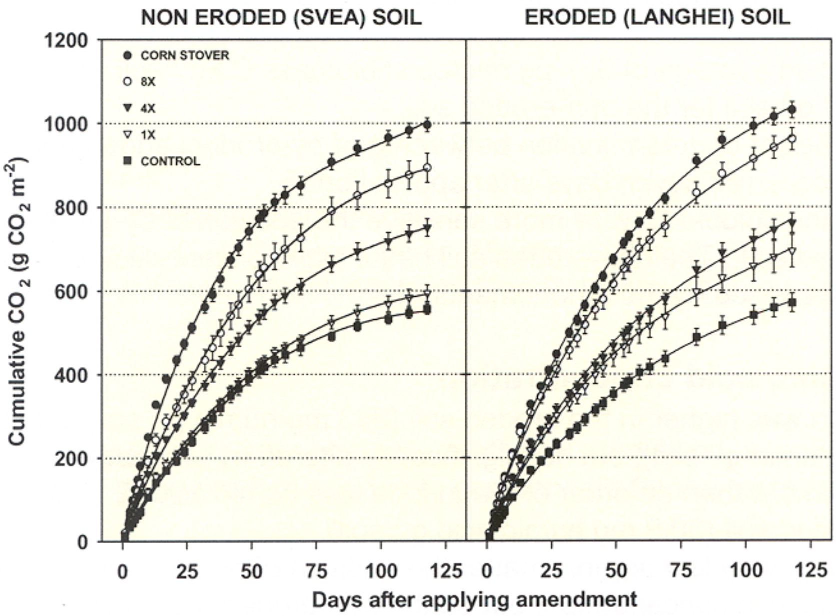
❑ Aggregate Stability



The aggregate stability resulted show a linear increase (r^2=0.5, p=0.0001) with increasing additions of by-product on the eroded soil, but not on the non-eroded soil.

Progress/Results

❑ CO_2 flux



- CO_2 flux is described by a complex, third order polynomial function.
- The dynamics and maximum rate of CO_2 flux are altered by the soil type and amendment addition.

Table 2. Total CO_2 released from soil cores and the relative amount of C that originated from the amendment after incubating for 118 days.

Treatment	*Total accumulated CO_2*[C]	*Amount C released as CO_2 relative to C added*[D]
Soil	($g\ CO_2\ m^{-2}$)	(%)
Non-erode	758.4[b]	22.8[b]
Eroded	804.2[a]	41.2[a]
P	0.005	0.0023
Amendment $g\ core^{-1}$		
0, control	564.0[e]	-------
1.1, by-product[A]	644.5[d]	36.5[b]
4.5, by-product	756.7[c]	17.9[c]
9.0, by product	927.9[b]	17.2[c]
3.5, Corn stover[B]	1013.5[a]	56.4[a]
P	0.0001	0.0001

[A]1.1g of the by-product per soil core have an equivalent amount of lignin compared to 3.5 g of corn stover.
[B]3.5 g corn stover added per core is proportional to the amount of stover in 4.3 Mg ha-1 dry stover after grain harvest.
[C]Letters indicate significant differences at least p=0.05 using least squares means analysis, within a column.
[D]Net C flux = (treatment flux – control flux) relative C = net C flux/g C in amendment *100

- More CO_2 released from eroded soil than from non-eroded soil after 118 days.
- Even with 2.5 times as much by-product applied CO_2 flux still less than evolved from corn stover.
- Corn stover decomposes faster than by-product, presumably due to differences in biochemical composition (C:N, lignin concentration).
- About 50% of the variability in cumulative amount of CO_2 and the rate of CO_2 flux at day seven could be attributed to soluble C and microbial biomass C. The coefficient of determination decreased on early and later sampling dates.

❑ Aggregate Size

Table 3. Aggregate size distribution (percentage in each class size of soil after incubating for 123 days with differing concentrations of by-product or corn stover.

Soil	<0.5	0.5-1	2-3	3-5	5-9	9-12	>12
Non-eroded	42.9[a]	16.4[a]	8.4[b]	3.3[b]	6.5[b]	9.5[b]	0.3[b]
Severely Eroded	28.3[b]	15.8[b]	11.0[a]	5.1[a]	8.7[a]	14.9[a]	0.8[a]
P	0.0001	0.005	0.0001	0.0001	0.0001	0.0001	0.04
$LSD_{(\alpha\ 0.05)}$	1.4	0.41	0.52	0.25	0.48	1.16	0.48
Amendment ($g\ core^{-1}$)							
0, control	37.0[ab]	16.3[a]	9.5[b]	4.2	7.4b	11.2[b]	0.59
1.1, by-product[A]	34.9[ab]	16.5[a]	10.4[a]	4.3	7.7ab	10.9[b]	0.52
4.5, by-product	35.8[ab]	16.0[ab]	9.7[ab]	4.1	7.3b	12.5[ab]	0.50
9.0, by product	37.1[a]	15.9[ab]	9.2[b]	3.9	7.3b	12.1[b]	0.66
3.5, Corn stover[B]	33.3[c]	14.5[c]	9.7[ab]	4.4	8.4a	14.3[a]	0.51
p	0.005	0.026	0.08	0.09	0.03	0.005	NS
$LSD_{(\alpha\ 0.05)}$	2.14	0.65	0.83	0.40	0.76	1.83	0.75

[A]1.1 g of the by-product per soil core has the equivalent amount of lignin as 3.5 g of corn stover.
[B]3.5 g corn stover added per core is proportional to the amount of stover that would be returned in 4.3 Mg ha-1 dry stover after grain harvest

- The non-eroded soil had significantly higher proportion of aggregates less in the 1 mm diameter class size, while the erode soil had significantly higher proportion of aggregates at all of the larger class sizes.
- The soil treated with corn stover had fewer aggregates less than 1 mm but significantly more aggregates in the 5-9 and 9-12 class ranges.
- The lack of response in aggregate size distribution to by-product addition likely contributed to the similarity in water retention characteristics among by-product treatments since aggregate size distribution influences pore water retention.

Discussion

- The addition of the residual by-product of corn stover fermentation or corn stover did not result in dramatic improvements in soil quality.
- Increased humic acid concentration and increased aggregate stability due to the addition of by-product were only seen on the eroded soil.
- It would not be prudent to assume that returning by-product to the field would negate potential negative effects of removing corn stover. However with careful management of stover removal (avoiding highly eroded areas) and selective placement of the by-product (spreading it on eroded knolls) a sustainable use of corn stover for ethanol production can be developed.

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

Focus on soil carbon

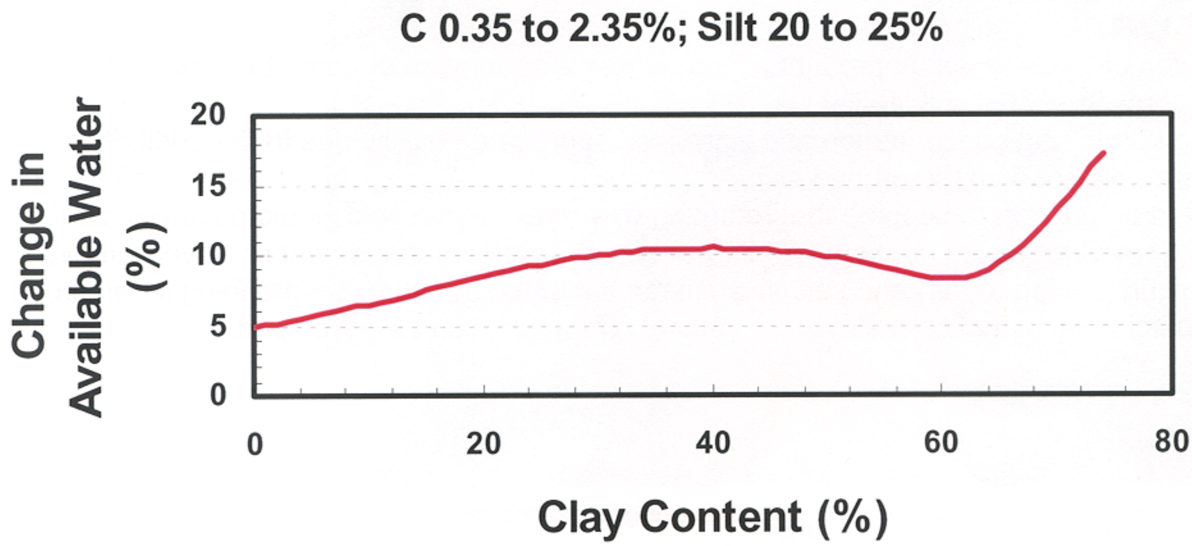
The concern about global warming and attempts by international governments to agree to a reduction in carbon dioxide emissions has provoked quite a bit of interest in storing carbon in soil. In order to meet expected emissions limits, utility companies are looking at soil storage of carbon and some are even offering $35 a ton to farmers who increase their storage of soil carbon. These events are provoking several questions regarding carbon storage in soil.

Soil contains about three times as much carbon as that contained in living matter and it contains more carbon than exists in the atmosphere. We have also lost from cultivated soils between 20 and 50 % of the carbon that they originally contained.

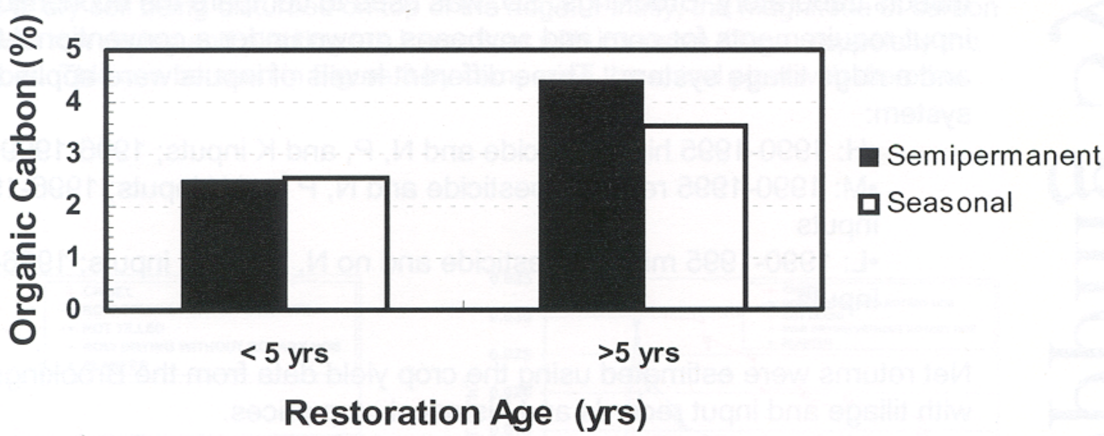
One of the benefits of storing carbon in soil is an increase in the storage capacity of water for crop production. To evaluate this effect, we analyzed data collected by the USDA-Natural Resources Conservation Service using a complex mathematical equation.

We determined the available water content by subtracting the amount of water that is unavailable to plants from the maximal amount of water that soil will hold. By repeating this procedure for two different carbon levels within the same clay and silt content ranges, we find that the effect of organic carbon is different for each combination of clay, silt and organic matter content.

Thus, the benefit to the crop producer changes with soil texture and with climatic zone.



Storing carbon in soil may be easier in Northern Prairie Potholes than in other landscapes. Results of a collaborative study conducted with staff at the Northern Prairie Science Center at Jamestown, ND (USDI-USGS) over the states of Montana, North and South Dakota, Minnesota, and Iowa show large increases of carbon in restored semipermanent wetlands. After an initial lag period, these wetlands rapidly regained carbon in the soil so that after 20 years, they are approaching carbon levels typical of wetlands that have never been drained and farmed.



The North Central Soil Conservation Research Laboratory has hosted a class of students taking an introductory course on soils currently taught at the University of Minnesota-Morris. These students are shown conducting a laboratory exercise under the direction of Dr. Olness and Dr. Peter Whelan (UMM).

Net Returns and Input Use for Alternative Tillage Systems

By Dave Archer, Ag Economist
archer@morris.ars.usda.gov

Information from long-term crop rotation plots established at the Northern Grain Insects Laboratory, Brookings, SD, was used to compare the economic returns and input requirements for corn and soybeans grown under a conventional tillage system and a ridge tillage system. Three different levels of inputs were applied under each system:

- •H: 1990-1995 high pesticide and N, P, and K inputs; 1996-1999 high N inputs
- •M: 1990-1995 reduced pesticide and N, P and K inputs; 1996-1999 reduced N inputs
- •L: 1990-1995 minimal pesticide and no N, P and K inputs; 1996-1999 no N inputs

Net returns were estimated using the crop yield data from the Brookings plots along with tillage and input records and historical crop prices.

- •Highest net returns occurred at the highest input levels.
- •At the high input level ridge tillage had the highest average net returns. Annual net returns for ridge tillage exceeded net returns for conventional tillage in 6 out of 10 years.
- •There was no significant difference in nitrogen fertilizer use between tillage systems.
- •Pesticide expenditures at the high input level were about 10% higher under ridge tillage than under conventional tillage.
- •Diesel fuel use at the high input level under ridge tillage was 23% lower than under conventional tillage.
- •Labor use at the high input level was 27% lower under ridge tillage than under conventional tillage.

Tillage and Input level	Net Returns	N fertilizer applied	Pesticide expenditure	Diesel fuel use	Labor use
	$/ac/yr	lb/ac/yr	$/ac/yr	gal/ac/yr	hr/ac/yr
Conventional					
High	23.91b	61.8a[1]	46.32b	6.2a	1.15a
Medium	13.08c	33.5b	38.48c	6.0b	1.11b
Low	-12.17d	0.0c	30.17d	5.8c	1.06c
Ridge					
High	31.49a	62.3a	51.28a	4.8d	0.84d
Medium	11.58c	33.1b	40.77c	4.8d	0.83d
Low	-6.04d	0.0c	36.17c	4.7d	0.81d

1 Means within columns joined by the same letter are not significantly different (P = 0.05)

Although use of ridge tillage has declined over the past ten years, there has been no decline in profitability compared to conventional tillage.

In addition to increased profitability, ridge tillage can significantly reduce fuel and labor use, however, pesticide use may significantly increase.

Dynamic Cropping Systems: Economics and Crop Sequences

By: Dave Archer, Agricultural Economist

A project was established at the Northern Great Plains Research Laboratory, Mandan, North Dakota, in 1998 to determine the benefits and/or disadvantages of previous crop and crop residues in diverse cropping systems. A crop X crop residue matrix was formed by no-till seeding 10 crops in strips in 1998. In 1999, the same 10 crops were seeded in strips perpendicular to the strips seeded in 1998. The result was 10 crops grown on 10 residues. The same design was used on an adjacent site in 1999 and 2000, providing two years of crop on crop data.

The project involves a multi-disciplinary team of scientists examining various aspects of the system. Investigating economic returns for alternative crop sequences is a part of this effort. Details on this and other aspects of the project are available in an interactive computer program, Crop Sequence Calculator, v.2. The program is available on CD-ROM by filling out a form on-line at www.mandan.ars.usda.gov or by mailing a request to Crop Sequence Calculator, Northern Great Plains Research Laboratory, Agricultural Research Service-USDA, Box 459, Mandan, North Dakota 58554-0459.

Economic returns for alternative crop sequences were estimated by multiplying observed yields in the cropping sequences study by the crop price and subtracting estimated production costs. Crop prices were estimated by the higher of a three-year average (1998-2000) of North Dakota season average prices and the 2001 commodity loan rate. Crop prices and estimated production costs for each crop are listed in Table 1. Production costs included herbicides and herbicide application costs, fertilizer costs, seed costs, and planting and harvesting costs. Herbicide costs were estimated based on the quantities of herbicides actually applied and prices from the 2001 North Dakota Weed Control Guide. Seed costs were estimated from the planned seeding rates and prices from Projected 2001 Crop Budgets South Central North Dakota. Planting, harvesting and herbicide application costs were estimated from Minnesota Farm Machinery Economic Cost Estimates for 2000.

An additional cost of $43.05 per acre was subtracted from the net returns for dry beans to reflect lost government support payments under the current farm program for planting a vegetable crop. This reduction reflects the loss in payments that would have occurred in 2000 if a producer lost one acre of wheat base payments with a proven yield of 35 bushels per acre for every acre of dry beans planted.

Crop production practices (and hence, crop production costs) were <u>not</u> adjusted for individual crops based on previous crop residues. As a result, effects of crop sequence on net returns through changes in herbicide and fertilizer use were not considered in this analysis.

Table 1. Crop Prices and Production Costs.

Crop	Crop Price ($/lb)	1999 Herbicide and Application Costs ($/ac)	2000 Herbicide and Application Costs ($/ac)	Seed Costs ($/ac)	Fertilizer, Planting, and Harvest Costs ($/ac)	Base Loss Cost ($/ac)*
Canola	$0.095	$22.01	$32.43	$13.75	$48.45	$0.00
Crambe	$0.090	$22.01	$22.58	$5.40	$48.45	$0.00
Dry Bean	$0.140	$43.32	$48.52	$25.00	$48.45	$43.05
Field Pea	$0.049	$22.01	$25.11	$24.00	$48.45	$0.00
Flax	$0.093	$30.49	$29.46	$5.25	$48.45	$0.00
Safflower	$0.122	$27.49	$28.37	$8.75	$48.45	$0.00
Soybean	$0.078	$48.80	$66.19	$16.80	$48.45	$0.00
Sunflower	$0.092	$39.82	$40.34	$13.20	$48.45	$0.00
Wheat	$0.049	$24.81	$30.95	$7.80	$48.45	$0.00
Barley	$0.035	$24.81	$30.95	$5.63	$48.45	$0.00

* Government payments that would have been lost in 2000 if an acre planted to dry beans resulted in a loss of one acre of wheat base with a proven yield of 35 bu/ac.

The average of the 1999 and 2000 net returns for each crop sequence are shown in Table 2. Six out of the 10 crops produced the lowest net returns for crops grown on their own residue. For 3 of the 10 crops lowest net returns occurred on canola residue, mainly due to problems with volunteer canola in 2000 that could not be controlled. There was wide variation in net returns for each crop depending on crop sequence. The difference between the highest and lowest net returns for each crop indicates the potential cost of making cropping decisions without considering the effect of crop sequence (Figure 1). For dry beans, net returns differed by as much as $105 per acre depending whether they were planted on wheat residue or crambe residue.

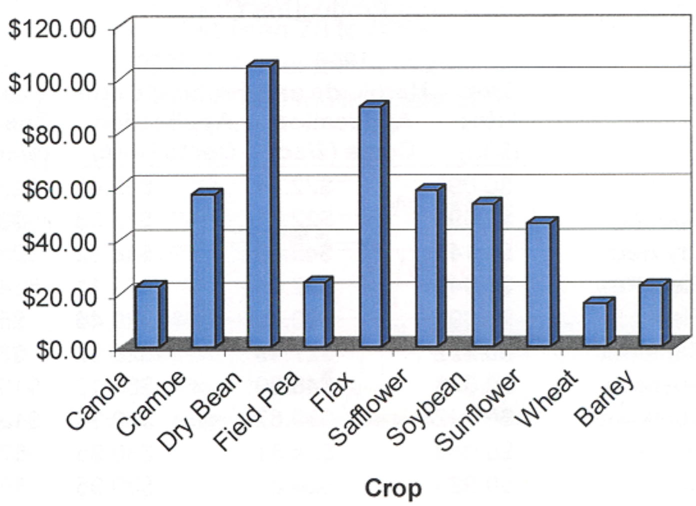
Wheat had the highest average net returns on each of the crop residues except field peas and wheat. Crambe had the highest net returns on field pea residue. Dry beans had the highest net returns on wheat residue.

Table 2. Net Returns to Land and Management ($/acre) for Alternative Crop Sequences.

Crop Residue \ Crop	Canola	Crambe	Dry Bean	Field Pea	Flax	Safflower	Soybean	Sunflower	Wheat	Barley
Canola	$26.96	$9.96	($21.89)	$28.38	$38.27	$10.07	$33.93	$18.26	$75.74	$51.91
Crambe	$34.19	$46.65	($40.54)	$35.40	$41.64	$18.32	$10.25	$13.78	$73.52	$65.61
Dry Bean	$49.17	$32.44	$15.86	$43.01	$48.67	$17.45	$25.19	$36.21	$73.59	$50.18
Field Pea	$47.04	$66.79	$32.39	$31.59	$38.19	$43.46	$30.86	$42.41	$66.33	$57.27
Flax	$45.51	$56.80	$28.24	$42.22	($24.90)	$44.60	$35.08	$34.20	$77.71	$60.33
Safflower	$37.93	$30.50	$50.34	$44.40	$51.29	($10.95)	$7.84	($2.98)	$71.22	$54.83
Soybean	$27.25	$44.12	$34.60	$45.41	$64.78	$20.93	$60.81	$16.70	$65.98	$49.04
Sunflower	$37.51	$65.26	$54.76	$33.39	$57.49	$26.68	$50.37	($3.39)	$68.94	$53.21
Wheat	$37.59	$54.23	$64.04	$52.24	$49.96	$42.70	$23.76	$21.87	$61.82	$60.01
Barley	$47.64	$66.03	($3.06)	$40.61	$56.66	$47.53	$41.80	$28.20	$70.08	$42.85

Blue, Underline = Highest average net returns for each crop
Red, Underline = Lowest average net returns for each crop
Blue, Shaded = Highest average net returns for each residue

Figure 1. Potential Cost of Ignoring Crop Sequence Effects ($/acre).



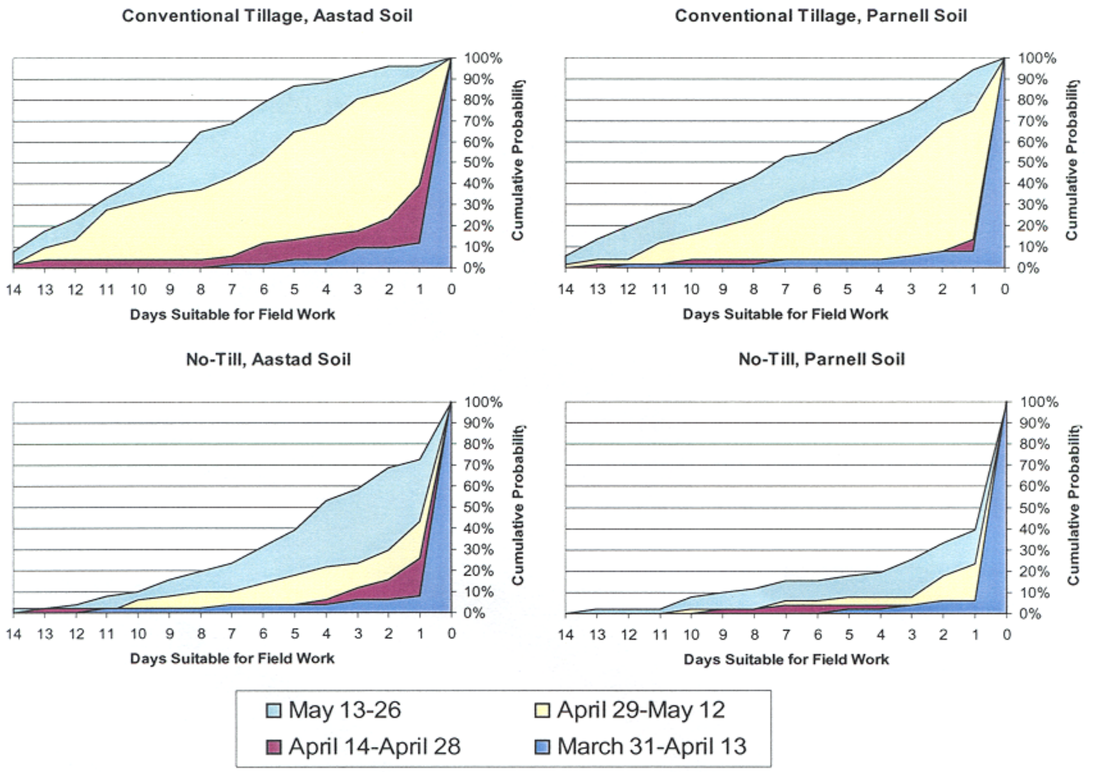
Field Day Availability and Cropping Systems Economics

by Dave Archer

The ability to get into the field and get fieldwork done has a tremendous impact on the economic viability of alternative crop production systems. Field day availability is affected by many factors beyond a producer's control, such as weather and soil type. It also is affected by many factors that are within a producer's control, such as tillage system and crop sequence.

As a first step in evaluating the feasibility of alternative crop production practices and/or systems, 50 years of historical weather data is being used with the EPIC computer model to estimate the effect of management and soil type on field day availability. Field day availability can then be related to economic performance.

Initial model results show that tillage and soil type can have a large effect on field day availability. For example, during the two week period of April 29-May 12, there was a 69% probability of having at least 4 days suitable for field work under conventional tillage and on an Aastad soil. However, during the same period there was only an 8% probability of having at least 4 days suitable for field work under no-till and on a Parnell soil.



The relevance of this information to the viability of alternative crop production practices can be seen by considering the potential for using temperature sensitive polymer coated seed. A potential benefit of polymer coated seed is that it may allow planting to begin earlier than the normal planting time, reducing the risk of delayed planting and associated yield loss. Suppose it will take 4 days for all of the corn acres to be planted on a farm. Also, suppose that the farm is all an Aastad soil type, and the farmer uses a conventional tillage system. During the normal planting period of April 29-May 12, the farmer would expect to get all of the corn acres planted 69% of the time. This means the farmer will experience planting delays 31% of the time. With polymer coated seed, planting might begin as early as March 31. During the period of March 31-April 13 all of the corn acres could be planted only about 4% of the time, and during the period April14-April 28 all of the corn acres could be planted about 16% of the time, so polymer coated seed could be used to plant corn early 16-20% of the time potentially reducing planting delays by this amount as well.

From the Collaborator

A note from Ward…

Collaborator: Webster's dictionary defines it as "someone who works jointly in scientific production." Well, that sounds pretty good, but the government's definition is more like "someone who retires but continues to work without a salary." My wife would define it as "someone who is too dumb to know when to quit!"

Whatever definition is used, the Soils Lab was gracious enough to let me move forty-four years of memories and a computer into a small unused office that even has a window. My intentions are to organize much of the historical materials that are scattered here and there around the building and write up a history of the Lab and the Barnes-Aastad Association.

I especially want to maintain a personal interest in the Lab's research on developing agronomic guidelines for *Cuphea*. My first knowledge of this crop came during a casual conversation I had with Dr. Rick Dunkle, former Director of the ARS Midwest Area in Peoria, IL. When I mentioned that we were considering alternative cropping systems, he introduced me to an Oil Seed Chemist who was extracting oil from this native wild plant, *Cuphea.*

He didn't have any seed, but gave me the name of a plant breeder in Oregon who was making good progress on developing a domestic variety of *Cuphea*. I managed to get a teaspoon of seed, and suggested that we try growing it in our greenhouse that winter, just to see what it was like.

Well, here we are, two years later, and thanks to the hard work of several scientists and technicians at the Lab, we have gained a tremendous amount of knowledge on how to grow this plant. We now have cooperative research with Proctor and Gamble and with Archer-Daniels Midland. It seems particularly adaptive to Minnesota's soil and climate. We hope to enlist the cooperation of some local producers in the near future for some on-farm trials. While *Cuphea* will never replace corn and soybeans, it does have the potential to be a very nice alternative crop for certain systems.

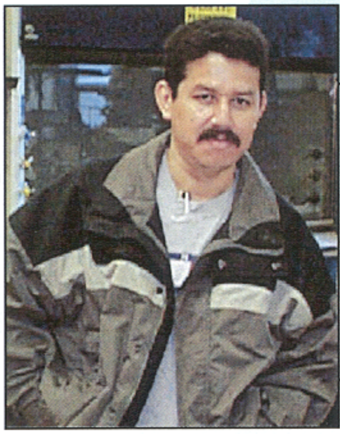
People have also invited me to speak to various groups about the Lab's research program, and my previous research on soil compaction, which is gratifying.

Bottom line: retirement is nice. It's even nicer when a person can continue some connections with a great bunch of people and continue to dabble in productive activities. I especially welcome Dr. Jaradat as new Research Leader. He brings a wealth of experiences and knowledge that should serve the Lab well in the coming years.

My email address is still the same voorhees@morris.ars.usda.gov. However, my phone extension has changed to (320) 589-3411, ext. 182.

VISITORS at the Soils Lab

Jose Manuel Blanco is a PhD student from the University of Barcelona in Spain. His primary research interest involves understanding the spatial variability of weed populations and their effects on crop yields. He is analyzing his data sets on weeds, crop yields, and soil variables from Spanish wheat fields using models and microclimate and soil information developed by researchers at the Soils Lab. In particular, Alan Olness, Brenton Sharratt, Dave Archer, Don Reicosky, and Frank Forcella are assisting in these efforts, as is Professor Gregg Johnson from the University of Minnesota's Southern Experiment Station. The principles derived from these results are expected to be as applicable to Minnesota as they are to Spain.



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

Professor Eduardo Leguizamon was awarded a Fullbright Fellowship to spend three months at the Soils Lab working with Frank Forcella. Eduardo is the head of the weed science section within the Faculty of Agronomy at the National University of Rosario, Argentina. His recent research interest has been weed biology and management in Roundup-Ready crops, which are common in Argentina. Eduardo's time at the Soils Lab was spent developing weed seedling and shoot emergence models for crabgrass and johnsongrass, both of which are important in Argentina and the USA.

Mr. Julio Scursoni is an instructor at the University of Buenos Aires (UBA), Argentina. He also is in the process of obtaining his PhD degree. Coadvisors for his degree program are Professor Roberto Benech-Arnold (UBA) and Frank Forcella at the Soils Lab. Julio spends 7 months each year in Argentina and 5 months (May-September) each year in Minnesota performing research on Roundup-Ready crops. His stay in Minnesota is sponsored by Monsanto Co. Julio's main research centers on understanding the biological and managerial reasons that allow some weed species to escape Roundup treatments.

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

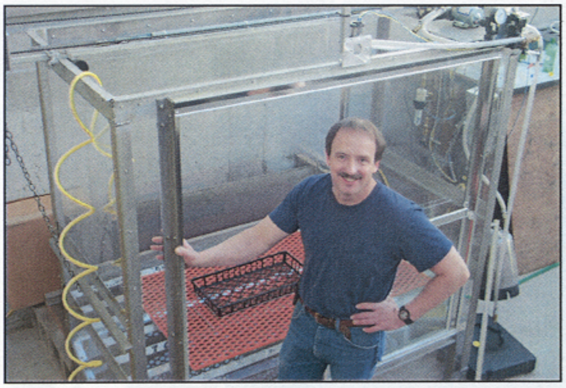
Dr. Yong Li, visiting scientist from the Center for Mountain Environment Research, Chinese Academy of Sciences in Chengdu, China.

Dr. Li received a financial grant from the Chinese Academy of Sciences for travel to the United States. Purpose of the travel was to obtain assistance in analysis and interpretation of soil quality parameter data resultant from soil movement by tillage. These data were collected by Dr. Li in the Chinese Loess Plateau prior to travel to Morris. A manuscript " Variations in surface soil quality as affected by intensive tillage on steep slope" was prepared during Dr. Li's stay in Morris and is presently in the ARS internal peer review process.

Tom Denmead Dr. Tom Denmead (retired)
Division of Land and Water
CSIRO, Canberra, Australia

Dr. Tom Denmead was a visiting scientist in 1998 and in October, 2001. Dr. Denmead's expertise encompasses many aspects of measuring trace gas fluxes between biosphere and the atmosphere. He utilizes mass balance techniques for small and large plots to characterize water and trace gas exchange. He utilizes sophisticated aerodynamic and meteorological techniques for measuring trace gas fluxes from agricultural systems. During his visit to the Morris lab, we utilized a few of his methods to evaluate tillage-induced carbon dioxide losses using meteorological and aerodynamic techniques. The objective was to compare tillage-induced fluxes measured with these techniques with those measured by the portable dynamic chamber. The turbulent mixing inside the portable chamber created an artificial wind profile that enhanced carbon dioxide loss from the tilled soil. The gas fluxes measured using the aerodynamic and meteorological techniques showed strong relationship to wind speed. The results pointed out a "chamber effect" related to the turbulent mixing and that gas exchange after tillage was affected by ambient wind speeds. This cooperative work will lead to a better understanding of gas exchange following intensive tillage and to improved methods of conservation tillage with minimum impact on environmental quality.

USDA Soil's Lab Employees

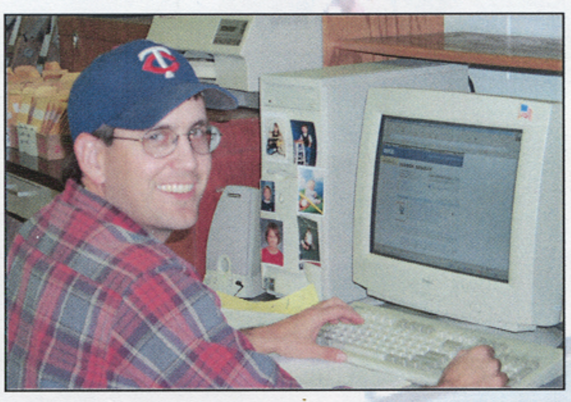


Gary Amundson, Engineering Technician

Nancy Barbour, Biologist

Joe Boots, Agricultural Science Research Technician (Plants)

Beth Burmeister, Office Automation Assistant



Jim Eklund, Computer Assistant

Kathy Eystad, Program Support Assistant

Sandra Groneberg, Program Support Assistant

Pam Groth, Location Administrative Officer

Randy Hamling, Student

Chuck Hennen, Agricultural Science Research Technician

Jill Gagner, Biological Science Laboratory Technician

Jay Hanson, Physical Science Technician

Scott Larson, Agricultural Science Research Technician (Soils)

Julie Retrum,Student

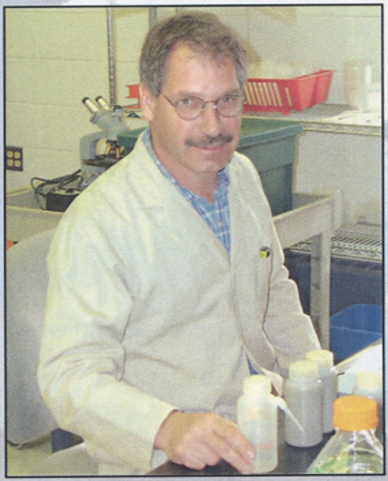
Skip Maanum, Agricultural Science Research Technician (Soils)

Dean Peterson, Agricultural Science Research Technician

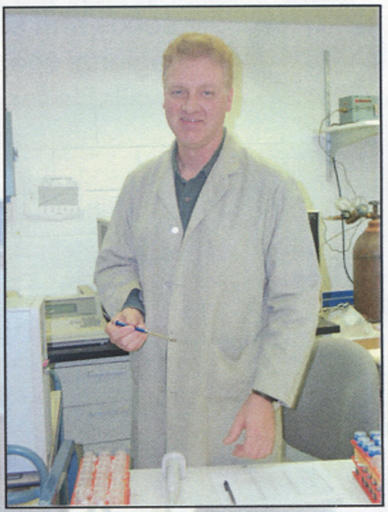
Nichole Ricke, Student

Jana Rinke, Chemist

Shawn Rohloff, Purchasing Agent



Steve Van Kempan, Agricultural Research Science Technician (Soils)



Alan Wilts, Chemist

Chris Wente, Agricultural Research Science Technician

Steve Wagner, Electronics Engineer

Larry Winkelman, Mathematician (Computer Network Manager)

Ag Week Open House

National Ag Week 2002 was celebrated at the Soil's Lab on Thursday, March 21. During the day, 300 students ranging from first graders to high school agriculture students toured the laboratory. Schools bringing students to the lab were Minnewaska Area High School, Morris Area Elementary School, Chokio Alberta Elementary School and the Starbuck Home Support Group. The Open House was held from 3-6 p.m. when 95 people toured the facility, saw displays in the conference room, and enjoyed locally produced refreshments.

The WeedCast and Nitrogen Decision Aid computer programs were presented in the conference room. Weed seeds and seedlings of regional species were available for identification. Several informative posters relating economics to production were also displayed. A "Science In Your Shopping Cart" exhibit, patterned after the Agricultural Research Service promotion, was filled with products ARS research has touched. We realized that the economic posters and "Science In Your Shopping Cart" display would be informative for future visitors, so their display at the lab is continuing.

Nancy Barbour, Biologist, with students

Students looking at weed seeds under the microscope and weed seedlings under a magnifying glass

Russ Gesch, Plant Physiologist with students in the greenhouse

The tour, a "behind-the-scene" view of research being done at the NCSCRL, included stops in the chemistry and biochemistry lab. The cuphea research was highlighted in the greenhouse. Possible uses for cuphea oil were discussed and cuphea herbicide evaluation was demonstrated. In the shop, tours saw how carbon dioxide is measured both in the field and in the lab, as a way to evaluate tillage and residue management.

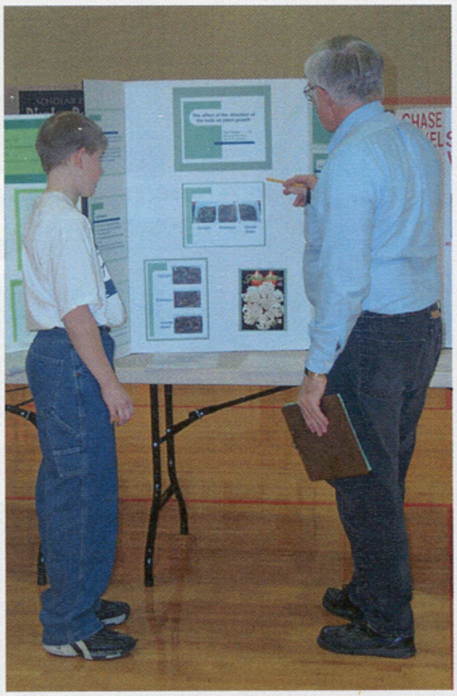
Shawn Rohloff and Kathy Eystad created the "Science In Your Shopping Cart" display. Dave Archer developed the economic posters and manned the software, with Jim Eklund. Dean Peterson set up a weed seed and seedling display. Tour presenters were Jill Gagner, Nancy Barbour, Russ Gesch, Steve Wagner, Gary Amundson, Chris Wente and Alan Wilts. Tour guides were Julie Retrum, Larry Winkelman, Steve VanKempen, Beth Burmeister, Scott, Larson, Dean Peterson, Dave Archer, Jim Eklund, Jane Johnson, and Brenton Sharratt. Kathy Eystad was the contact person for the event.

Chris Wente, Ag Science Research Technician, talking about MR. GEM

Alan Wilts, Chemist, giving CO_2 demonstration for the tour

Dean Peterson, Ag Science Research Technician, explaining the "Science in Your Shopping Cart" Display

Science Fair Judging



On January 9 & 10, 2002, Soil Scientists' Don Reicosky and Jane Johnson participated in the Morris Area Science Fair as judges.

Nancy Barbour and Mike Lindstrom were also judges.

Dr. Jane Johnson met with 5th graders at the Elementary School and assisted with science fair proposals in the fall of 2001.

Outreach Activities

Tours

Dr. Russ Gesch, Plant Physiologist, gave a Polymer Coated Seed presentation and lab tour to the Minnesota Corn Growers Association in December, 2001.

In March, 2001, the Pioneer Hi-Bred, Inc., held a herbicide meeting at the lab and it was followed by a tour provided by guides Gary Amundson and Dean Peterson.

Gary Amundson explaining the spray booth he recently constructed.

Steve Dudding, Pioneer Hi-Bred, Inc.

Dean Peterson with Pioneer group in the greenhouse.

Outreach Activities

Tomato Fest is based on an experiment Morris Area Fifth Graders have been conducting at the USDA-Soil's Lab with the coordination of Nancy Barbour. Students looked (and are looking) at how certain variable affect germination, growth, and reproduction in tomato plants. The seeds were planted on September 12, 2001 and data collection ended on December 13, 2001. One third of the seeds were flown aboard the Space Shuttle Atlantis in 1997, one third of the seeds were sealed in a dry container and kept underwater at the Scott Carpenter Space Analog Station in Key Largo, Florida and one third of the seeds were kept as a control group at Park Seed Facilities. The seed packets (three packets per student) were donated by the Challenger Center for Space Science Education.

The experiment results were presented at the Tomato Fest 2001 held on Thursday, December 20 at 1:30 p.m. in the Elementary South Gym (Auditorium).

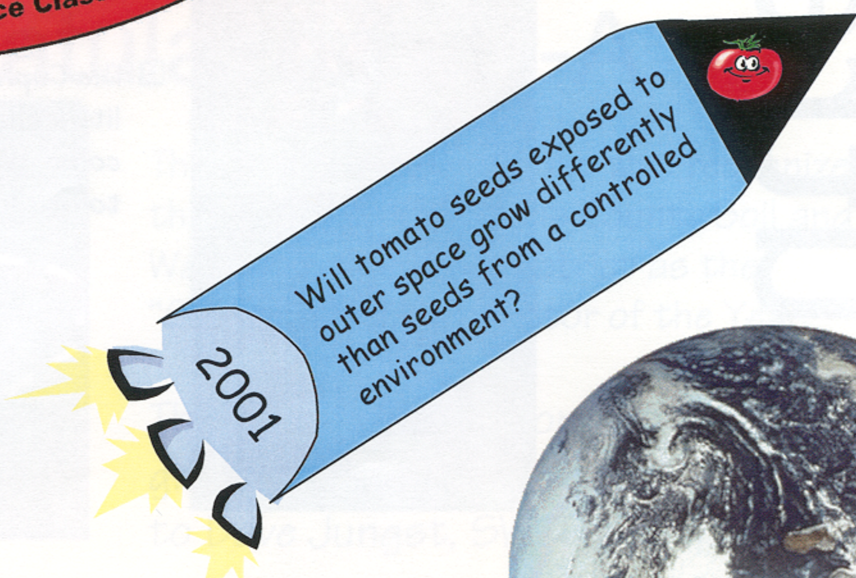
Nancy Barbour works with MAES Fifth Graders on Tomato Experiment

	Space	Under Water	Control
Average Number of Leaves	26.7	28.9	29.1
Average Height	89.1 cm	93.3 cm	90.8 cm
Average Germination Rate	67%	70%	67%
Average Fruit Mass	76.1g	71.7g	70g
Average Dry Mass	50.1g	48.1g	51.4g
Average Flowers	23.6	26.1	25.9

Will tomato seeds exposed to an underwater environment grow differently than seeds from a controlled environment?

Mr. Gagner's Fifth Grade Science Classes, MAES

mato Fest



Outreach Activities

future
SCIENTIST
USDA-ARS

Soil's

Mrs. Solvie's C

We learned about Cuphea!

- This is a new crop called Cuphea. The oils from the seeds give soaps and detergents their cleaning power.
- The Scientists are trying to grow it in Minnesota.
- The Cuphea seeds are really little and a brownish black color. We brought some back to school.

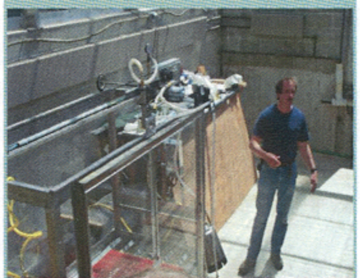
Nancy Barbour worked with Mrs. Solvie's first grade class, Morris Area Elementary School providing a lab tour and presentation explaining what a scientist is, what a scientist does and the tools a scientist uses.

Lab Tour

lass - May 14, 2001

We learned about the Soils Lab

- We watched a slide show about Cuphea.
- We saw the Robot working. It was really neat. He has three arms but can only move one arm at a time!
- The Robot has a big hand and a little hand.
- We went to the greenhouse and looked at the growth chambers.
- We asked lots of questions about soil!



Retirement

Please join me in congratulating Ward B. Voorhees, Soil Scientist and Research Leader at the USDA-ARS North Central Soil Conservation Research Laboratory in Morris, Minnesota, who retired on July 3, 2001, after 44 years of federal service.

Ward grew up on a farm near Danvers, Minnesota.

He was first employed by USDA under the Soil Scientist Student Trainee program during his junior year at the University of Minnesota in St. Paul.

Upon receiving his B.S. degree in Soil Science in 1959, he began full-time research as a Soil Scientist at the NCSCRL in Morris, studying various aspects of tillage, soil structure and root growth.

He obtained his M.S. degree from Iowa State University in Ames, IA under Dr. M. Amemiya, with a major in Soil Management and a minor in Plant Physiology. Upon returning to Morris, he started a long and productive research career concentrating on various aspects of soil compaction.

His research in the 1970's and 1980's clearly identified and quantified for the first time, the significant impact that ordinary farm machinery wheel traffic has on soil compaction, plant productivity and soil erosion.

In 1980, he and Dr. Inge Hokansson from Upsalla, Sweden, organized a 5 year international cooperative field experiment involving 30 research projects in northern Europe, the United States, and Canada, quantifying the extent and persistence of deep subsoil compaction caused by heavy harvest equipment.

Results from this research have had world-wide impact as reflected in changing design of tires and tracks on farm equipment, and the manner in which farmers use this equipment.

Ward authored or co-authored over 125 scientific publications, and was frequently invited to speak at professional and user-oriented group meetings, nationally and internationally.

He received the ASA Crops and Soils Magazine Award for Excellence in Agricultural Journalism in 1978, and was elected Fellow of the Soil Science Society of America in 1986, and Fellow of the American Society of Agronomy 1989. He served on the Board of Directors of the International Soil Tillage Research Organization (ISTRO) from 1988-1994.

Additionally, he served as Editor-in-Chief of Soil & Tillage Research from 1985-1988, and is currently Secretary of the ISTRO Working Group on subsoil compaction, and Chair of the ISTRO National Branch Development Committee.

In1990, he was appointed Research Leader at the USDA-ARS North Central Soil Conservation Research Laboratory in Morris.

During this tenure, Ward led the Laboratory through a facility and multi-disciplinary staff expansion, negotiated ARS' first CRADA with a private software engineering firm, hired the first Agricultural Economist in ARS, and re-directed the Lab's mission towards developing alternative and sustainable cropping systems for cool, wet soils.

Ward plans to stay in the Morris area and at the Lab as a Collaborator to write a history of the "Soils Lab" (that is when he isn't pursuing his hobbies of flower gardening, community organizations, grandchildren and travel).

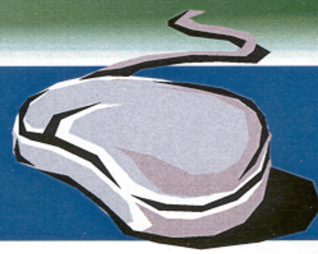
We are grateful to Ward for his commitment to ARS and thankful for his dedication to the scientific community.

Research Leader Ward Voorhees is honored at his retirement party by the first Research Leader of the USDA-ARS Soils Lab.

Dr. Cornelius A. Van Doren was the Director from November 1956 until September 1961.

RESEARCH AGRICULTURE RESEARCH

www.morris.ars.usda.gov



The North Central Soil Conservation Research Lab
USDA-Agricultural Research Service
803 Iowa Avenue
Morris, MN 56267

Postage

RESEARCH AGRICULTURE RESEARCH