Northern Great Plains Research Laboratory

NORTHERN GREAT PLAINS

INTEGRATOR

For environmentally and economically sound agro ecosystems for the northern Great Plains.

February 2007

Crop Sequence Influences Water Use and Crop Production

In the semiarid Great Plains of North America, water limits sustainable crop production. Inclusion of diverse crops in cropping systems creates a crop production environment that favors a rotation effect (synergism) and results in increased crop production when compared to monocultures. Research was conducted on the Area 4 SCD Cooperative Research Farm in 2003 (site 1) and 2004 (site 2) to determine if crop sequences of buckwheat, canola, chickpea, corn, dry pea, grain sorghum, lentil, proso millet, sunflower, and spring wheat influenced soil water depletion and storage as well as crop production and precipitation-use efficiency.

Research began in 2002 at site 1 by no-till seeding the 10 crops in adjacent strips. The following year, the same 10 crops were no-till seeded perpendicular to the previous year crops, creating a 10 x 10 crop by crop residue matrix with 100 different crop sequence treatments. The same process began at site 2 in 2003. Four replicates of the plot pattern were conducted in 2002 and 2003. The crop matrix technique allows for the evaluation of multiple crop sequences under similar weather and soil conditions. At seeding, 70 lb/a of nitrogen was banded between every other crop row in a 7.5 inch spacing for all crops except dry pea, chickpea, and lentil. For canola, 10 lb/a of sulfur was applied as ammonium sulfate. The nitrogen source was adjusted to provide 70 lb/a. Corn and sunflower were no-till planted with a row-crop planter in 30-inch rows.

Soil water to a depth of 6 feet was determined periodically using a neutron moisture meter. Relative seed yield was calculated by taking the actual seed yield of the crop grown on its own residue as the denominator to divide all values of that crop grown on the remaining nine crop residues to obtain relative seed yield. ***Hence, the crop seeded on its own crop residue has a value of 1.00.*** Precipitation-use efficiency (PUE), a measure of how well crop sequences use precipitation, was calculated by determining the quantity of precipitation that occurred from harvest of one crop to the harvest of the following crop divided by the actual crop yield (PUE = crop yield/precipitation from harvest to harvest).

Growing season precipitation (May–September) was about 86% for crop year 2003 (site 1) and 77% for crop year 2004 (site 2) of the long-term average of 11.4 inches. In the past 30 years, below average precipitation has occurred about 40% of the time. Average soil water depletion for the 10 crops was influenced by growing season precipitation. Sunflower resulted in the greatest soil water depletion of the 10 crops where 27% of the total soil water depletion occurred below 3 feet and 11% of the total soil water depletion occurred below 4 feet (Figure 1). In contrast, soil water depletion was the least for dry pea, which depleted about 50% less soil water from below 3 feet than sunflower.

Soil water recharge for the over-winter period, on average, was the greatest for spring wheat and grain sorghum residues (Figure 2). Least soil water recharge was for sunflower followed by the three pulse crops, which had low-lying less durable residues and poor snow retention. These differences in soil water recharge reflect differences in the ability of crop residues to capture and retain snow. The key factor for producers who grow crops that have differences in soil water depletion and soil water recharge is the soil water content at spring seeding time. Soil water content determined in April, showed that sunflower ground had land covered by the lowest soil water content (13.8 inches) (Figure 3). Soil water content for dry pea and spring wheat ground were greater than soil water content following sunflower residue by 4 inches. These differences were similar to earlier research conducted by Merrill et al.

Table 1. Average relative seed yield of 10 crops grown in 2003 and 2004 as influenced by crop residue at Mandan, ND.

		Second Crop Year									
		Buck-wheat	Canola	Chick pea	Corn	Dry Pea	Grain Sor-ghum*	Lentil	Proso Millet	Sun-flower	Spring Wheat
First Crop Year	Buckwheat	1.00	1.08	2.00	1.03	1.07	2.05	1.16	1.20	1.73	0.92
	Canola	1.08	1.00	2.15	2.20	1.07	3.04	1.34	1.26	2.28	0.92
	Chickpea	1.15	1.06	1.00	2.62	1.11	2.86	0.93	1.32	1.90	0.94
	Corn	1.05	0.99	1.79	1.00	1.08	1.52	1.20	0.97	1.50	0.86
	Dry Pea	1.62	1.15	2.23	2.65	1.00	3.87	1.46	1.50	2.35	1.06
	Grain Sorghum	0.89	0.79	1.60	1.65	0.93	1.00	0.97	0.92	1.92	0.86
	Lentil	1.15	1.14	1.27	2.42	1.20	3.94	1.00	1.39	2.34	1.03
	Proso Millet	1.10	1.01	2.03	1.27	1.49	0.95	1.41	1.00	2.11	0.93
	Sunflower	0.95	0.74	1.47	1.40	1.25	1.36	1.11	1.14	1.00	0.85
	Spring Wheat	1.11	0.94	2.20	1.92	1.38	2.94	1.75	1.12	2.48	1.00

* Includes only 2003 data due to lack of seed production in 2004.

(2004) during years of near-average growing season precipitation.

Large differences between lower and higher water-using crops and the differences in soil water recharge exert considerable effects on succeeding crops, therefore, careful consideration is needed to choose appropriate crop sequences for sustainable cropping systems.

During below-average growing season precipitation years, the greater profile soil water content for dry pea and spring wheat residues resulted in some of the greatest relative seed yields (Table 1). Some of the lowest relative seed yields were following sunflower and grain sorghum residues. Profile soil water content for sunflower residue was the lowest, and low relative seed yield would be expected, but profile soil water content for grain sorghum residue (16.1 inches) was intermediate and low relative seed yield was not anticipated.

Precipitation-use efficiency (PUE) was used as a system integrator to evaluate the interaction of the previous crop and previous crop residue on how well the crop sequence uses precipitation for seed yield (Table 2). Crops that had the most consistent PUE on average for the two years were dry pea, sunflower, and spring wheat. Dry pea, sunflower, or spring wheat need to be strongly considered when developing sustainable cropping systems for the northern Great Plains.

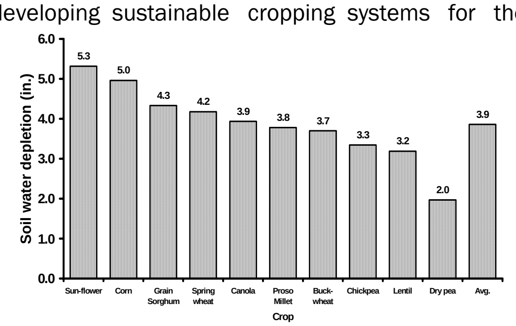


Figure 1. Average soil water depletion for 2002-2004 during the mid-May to mid-September growing period to a depth of 6 feet for 10 crops.

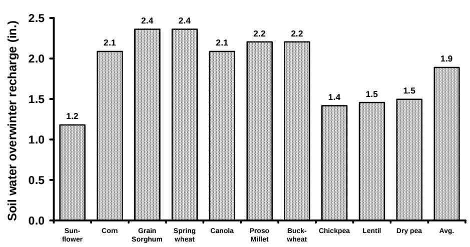


Figure 2. Average soil water recharge for the overwinter period from 2002-2005 to a depth of 6 feet for 10 crop residues.

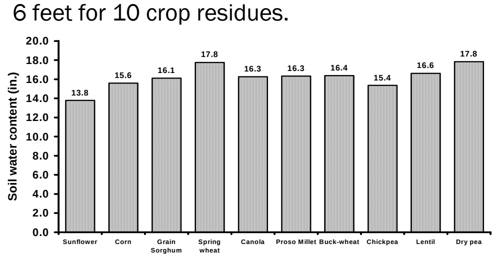


Figure 3. Average soil water content to a depth of 6 feet in mid-April just prior to seeding a crop for 10 crop residues.

Table 2. Average precipitation-use efficiency for 10 crops grown in 2003 and 2004 as influenced by crop residue at Mandan. ND.

		Second Crop Year									
		Buck wheat	Canola	Chick-pea	Corn	Dry Pea	Grain Sor-ghum*	Lentil	Proso Millet	Sun-flower	Spring Wheat
		(lb/ac/in.)									
First Crop Year	Buckwheat	64.2	62.6	96.7	66.7	101.5	75.7	69.2	146.9	33.9	156.6
	Canola	60.8	50.6	106.7	104.4	95.1	97.2	68.7	143.7	52.2	142.8
	Chickpea	52.0	48.4	90.6	134.5	97.9	102.6	50.2	142.2	51.5	141.0
	Corn	63.5	59.2	106.9	96.7	115.5	51.3	73.9	129.7	52.0	151.9
	Dry Pea	73.5	48.1	102.6	141.5	85.4	105.5	66.7	161.8	54.9	152.1
	Grain Sorghum	51.5	54.2	106.9	121.1	101.2	65.1	58.3	132.9	49.7	151.6
	Lentil	57.9	45.0	100.3	135.8	107.8	117.5	57.2	150.5	51.5	151.9
	Proso Millet	57.9	52.9	120.5	132.2	139.0	42.3	84.8	136.3	59.4	156.8
	Sunflower	61.2	46.3	105.1	99.7	133.3	61.0	67.8	142.6	31.2	150.3
	Spring Wheat	64.4	43.6	108.5	132.7	117.1	96.5	84.1	131.1	57.4	149.4
	2003 Crop Avg.	19.1	71.9	136.1	57.0	113.0	81.7	80.7	99.5	54.4	146.0
	2004 Crop Avg.	102.4	30.5	73.3	176.5	106.3	—	55.7	184.7	44.5	155.6
	Overall Avg.	60.7	51.1	104.5	116.5	109.4	81.5	68.1	141.8	49.4	150.4

* Includes only 2003 data due to lack of seed production in 2004.

For more information please reference: "Water Use and Crop Production: Crop Sequence Influences", Manitoba Agronomist Conference Proceedings (www.umanitoba.ca/afs/agronomists_conf/2006/proceedings.html).

Crop Sequence Influences:

Soil Water

- Greatest soil water depletion by sunflower and corn.
- Least soil water depletion by dry pea.
- Greatest soil water recharge when residues were grain sorghum and spring wheat.
- Least soil water recharge when residues were sunflower, chickpea, lentil, and dry pea.
- Soil water content in the spring prior to seeding was greatest for spring wheat and dry pea residues and least for sunflower residue.

Relative Seed Yield

- Crops most responsive to crop sequence – chickpea, corn, grain sorghum, and sunflower.
- Crops least responsive to crop sequence – canola, proso millet, and spring wheat.

Precipitation-Use Efficiency

- Most consistent over years: spring wheat, dry pea, and sunflower.
- Least consistent over years: buckwheat, canola, corn, grain sorghum, and proso millet.

Drs. Don Tanaka, Steve Merrill, Joe Krupinsky, Mark Liebig, and Jon Hanson
Email: tanakad@mandan.ars.usda.gov

Research Results Conference

The USDA-ARS Northern Great Plains Research Laboratory and Area 4 Soil Conservation Districts Cooperative Research Farm will present their annual Research Results & Technology Conference at the Seven Seas Inn on February 27th beginning at 8:30 AM.

Annual research findings from this integrated crop and livestock USDA research facility will be highlighted.

Data on the most advantageous rotation sequencing of buckwheat, barley, canola, chick pea, corn, crambe, dry bean, dry pea, flax, grain lentil, proso millet, safflower, sorghum, soybean, spring wheat, and sunflower will be presented.

Crop sequencing research has been the major focus of the cropping systems scientists at the Mandan lab. Over 11,000 copies of their "Crop Sequence Calculator", CD-ROM cropping decision making tool that is available free on the lab's web site, have been distributed to users.

Dr. Dave Archer, new Agricultural Economist at the USDA campus, will also be presenting the economic analysis of the cropping systems research results.

Improved opportunities for cow and backgrounding calf feeds will also be addressed.

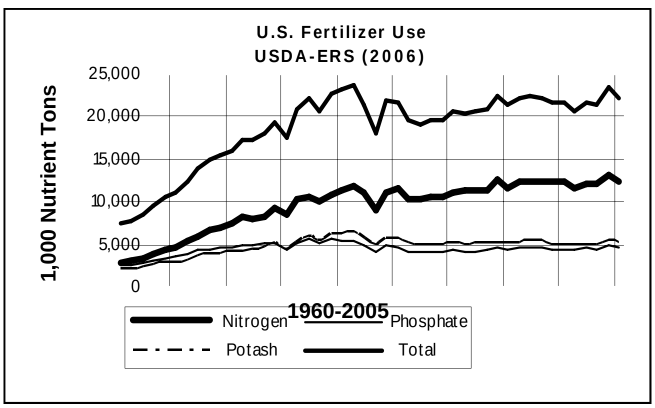
Is Agricultural Altruism a One-way Street?

We live in a society were people feel they are entitled to certain comforts and a high standard of living. That is to say, we have expectations regarding the environment and our social, political and economic systems and that these should contribute to our quality of living. We call these items "basic needs." In a perfect world, we would genuinely be concerned about others; their well-being and general security. As such there would be a certain give and take between environmental groups, producers, and industry. In an altruistic world, we would all hold to the general belief that acting for the benefit of others is right and good. We would legitimately be concerned about the well-being of others and they would be concerned about us. I have some a concern that altruism, i.e. selflessness, is not going to be extended from agricultural industry and various environmental groups toward the producer. A group of us recently visited producers in Alabama to discuss their observations regarding production agriculture. These producers were passionate about their chosen livelihoods. One producer said, "I want to stay on the farm…keep growing…" Another said, "Farmers…they want to stay on their land, like to grow livestock, be out in the woods…to make a living…" Yet, they still had major concerns with how their industry functions. A poultry producer made the statement, "The Company owns the feed, the chicken houses, the processing plant, and the chickens… All I own are the dead chickens." He felt he was limited to being an indentured servant. And of course, he was since an indenture is a written contract or agreement between two or more parties. But what is my point in all this? We are entering an exciting yet scary era in North Dakota agriculture. With the high profile of biofuel development, many opportunities are being presented. This will allow North Dakota producers to not only produce food and fiber for our country, but also to become involved in energy production. Past experience teaches us that energy production has always been a lucrative industry. Current technology calls for large amounts of corn to be used in the development of biofuel. As a result, contracts are being developed to guarantee delivery of enough corn to keep the biofuel plants operational. For the western two-thirds of North Dakota, the monoculture production of corn is not a sustainable enterprise, but must be a component of an entire crop sequencing scheme. So, my caution is this: Before becoming indentured to an energy giant, weigh the costs regarding your way of life. I am confident these companies will not extend to you the altruism which you hold as a life-long value.

Dr. Jon Hanson, NGPRL Research Leader
Email: jon@mandan.ars.usda.gov

Soil Acidification from Nitrogen Fertilizer: A Cause for Concern?

Application of nitrogen (N) fertilizers to soil is necessary in most cropping systems to overcome declining inherent soil fertility and ensure economic crop yields. Excessive application of fertilizer N over the long-term, however, can compromise critical soil functions and contribute to potential agronomic and environmental problems through increased soil acidity. While this issue might not be a concern for many of our calcareous soils in the northern Great Plains, there are some soils (such as those found in southwestern North Dakota) where increased soil acidity is apparent, especially in no-till management systems where surface soil isn't mixed with deeper, more alkaline soil.



Effects of fertilizer-induced acidification on soil properties and processes are significant. Increased soil acidity can contribute to the decline in availability of macro- and micro-nutrients, such as phosphorus and molybdenum. In contrast, increased soil acidity can enhance the availability of certain micronutrients (e.g., Fe, Mn, and Zn) to the extent of toxicity to plants.

Soil acidification from long-term application of fertilizer N has been shown to accelerate the weathering of clay minerals, resulting in decreased cation exchange capacity. The abundance and activity of soil microorganisms can decline under high-N, low pH cropping systems. While most microbially-mediated processes have an optimum pH range between 5 to 8, bacterial nitrification has been observed to decline below a pH of 5.5 under conditions where basic cations (e.g., Ca, Mg) are limiting. Such a result can undermine the inherent capacity of the soil to cycle N.

Research in Australia has found the effect of soil acidity on crop yield to be proportional to the amount of the root zone acidified. Subsoil acidity, in particular, is a critical contributor in lowering crop yields. Based on this observation, surface acidification found in cropping systems of southwestern North Dakota is unlikely to negatively affect crop yields due to the calcareous subsoil found in the region. Stated differently, our alkaline subsoil should effectively 'mask' near-surface soil acidity caused by N fertilization. It is important to note, however, that there still will be negative consequences of surface acidity to soil properties (as reviewed above) and possibly to agronomic production (in instances of reduced herbicide efficacy from low soil pH, poor germination, and reduced seedling vigor).

Based on the amount of N fertilizer applied to cropland in the U.S., it would take 20 million metric tons of limestone to neutralize the acidity produced by that fertilizer each year. While we're likely decades away from needing to apply lime to our soils in North Dakota, it would be prudent to begin tracking soil pH across multiple soil types over time in both near-surface and subsoil depths. Such information may prove useful in identifying critical thresholds in soil pH where management intervention becomes necessary.

How does N fertilizer increase soil acidity?

Urea and anhydrous ammonia are commonly used N fertilizers in the northern Great Plains. Acidification from these two sources of synthetic N is generated via nitrification through the following reactions:

Urea: $(NH_2)_2CO + 4O_2 \rightarrow 2NO_3^- + 2H^+ + CO_2 + H_2O$

Anhydrous Ammonia: $NH_3 + 2O_2 \rightarrow NO_3^- + H^+ + H_2O$

Based on these reactions, each mole of N oxidized to NO_3^- produces one mole of H^+. Plant uptake of NO_3^- results in the release of an equivalent amount of OH^- into the soil solution, effectively neutralizing the acidity (creating H_2O). However, loss of NO_3^- by leaching and/or its conversion to nitrous oxide (an important greenhouse gas) and to N_2 via denitrification results in permanent acidification. This permanent acidification can be further enhanced with the export of basic cations from the soil in harvested material.

Dr. Mark Liebig Email: liebigm@mandan.ars.usda.gov

Late-Autumn Manure Application Increases Greenhouse Gas Emissions from Frozen Croplands

Nitrous oxide, a major greenhouse gas, is predicted to contribute significantly to global warming and climate change. Nitrous oxide emissions are often high from croplands that are fertilized with nitrogen, but emissions during winter are not expected where soils are below freezing.

Dr. Rebecca Phillips, a Plant Physiologist at the USDA-ARS Northern Great Plains Laboratory, has evaluated the effects of autumn manure application on nitrous oxide emissions from croplands. Specifically, she measured over-winter emissions of nitrous oxide from frozen soils following dehydrated manure fertilization in late-autumn using small surface chambers and gas chromatography. Results from the study were published in the January-February issue of the *Journal of Environmental Quality*.

Integrated cattle-crop farmers and organic crop producers commonly apply manure as fertilizer to crop fields in late-summer and autumn with the expectation that nutrients will remain frozen on the soil surface until spring. Little has been known about the effects of fall application of dehydrated manure on winter emissions of nitrous oxide from croplands in the Northern Great Plains. Since both organic and inorganic fertilizers are often applied in autumn, emissions during winter may contribute to an unappreciated, but significant amount of nitrous oxide to the atmosphere.

Phillip's study revealed nitrous oxide emissions occurred during winter when soil temperatures were below freezing for both fertilized and unfertilized soils. Emissions were higher, however, from soils fertilized with dehydrated manure in late-autumn. Overall, winter emissions from croplands fertilized in late-autumn were 57% greater than for croplands where fertilization was delayed until spring.

In the *Journal of Environmental Quality* article*,* Phillips stated "Identification of best management practices is necessary to curb nitrous oxide emissions to the atmosphere, for both economic and environmental reasons. The assumption that nutrients applied in late-autumn remain in the soil over-winter needs to be scientifically challenged. These results indicate that gaseous losses of nitrogen occur when soil temperatures are below freezing. Consequently, nitrogenous gases emitted over-winter should be factored into crop management decisions to maximize conservation and minimize fertilizer costs."

Research to investigate how total nitrous oxide emissions vary among organic, conventional, and variable-rate management application systems is ongoing at the Northern Great Plains Research Laboratory. The impacts of soil moisture and inorganic fertilizers are also being investigated. Fertilizer form, application timing, and amount interact with climate to substantially affect nitrous oxide emissions. Further research is needed in other geographical and climatic regions, and with other types of organic and inorganic fertilizers, to refine the effects of management and environmental conditions on nitrous oxide emissions in croplands.

Dr. Rebecca Phillips Email: phillips@mandan.ars.usda.gov

Fall and Winter Grazing to Reduce Cow Costs

If you have driven Highway 6 in and out of Mandan this past fall or winter, you've probably noticed Angus cows grazing rows of grass on some of the lab's pastures. The pasture grass is Altai wildrye that we seeded several years ago. Altai wildrye is a large cool-season grass from the Altai Mountains of central Asia. It maintains higher forage quality as it matures than most grasses do and is probably best suited for late fall and winter grazing. This past fall, the cows grazing Altai wildrye were part of an experiment comparing the nutritional response of 1st trimester cows to grazing Altai wildrye versus windrowed millet then corn and standard mixed grass prairie plus grass hay. The cows had similar gains while consuming the wildrye, millet and prairie grass/hay in mid-October and early November (all about a half pound of gain per day). However, when cows on the annual forage treatment were moved to the corn windrows, they gained about 3 pounds per day compared to a third of a pound per day for the cows grazing Altai wildrye and almost 2 pounds per day for cows on the prairie grass and hay treatment. Economic analysis has not yet been conducted as part of this study, and our intention is to harvest grain from the corn and windrow the aftermath for the cows. With the drought and poor performance of corn last summer, no grain was harvested and the windrows were small. The Altai wildrye's production wasn't great either, but it did respond to the late summer and early fall rain we received and grew in the fall.

We plan to use our herd of smaller-framed cows to investigate various ways to reduce production costs while maintaining good productivity. Following this philosophy, we turned most of the cow herd into a larger pasture of Altai wildrye in mid-December and hope to have them there grazing Altai wildrye through the snow until mid- to late-February. We received about a foot of snow in the early part of January but the rows of wildrye protruded up through this snow and the cows could find them. We supplement their diet of wildrye with a small amount of whole peas to make sure they're consuming enough protein. Had the growing season been better last year, we might have been able to graze them on the wildrye through March and save even more hay and money.

Drs. Scott Kronberg and Eric Scholljegerdes EMAIL: kronberg@mandan.ars.usda.gov

Cows on the Altai wildrye pasture this winter

Cows on standard grass pasture

Cows grazing corn windrows last fall

Cows grazing Altai wildrye last fall

NORTHERN GREAT PLAINS INTEGRATOR

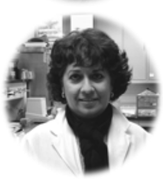
Northern Great Plains Integrator is published and distributed by the USDA-ARS, Northern Great Plains Research Laboratory, 1701 10th Ave., S.W., Mandan, ND 58554. Persons with disabilities who require alternative means for communication of program information (Braille, large print, audiotape, etc.) should contact USDA's TARGET Center at 202-720-2600 (voice and TDD). The United States Department of Agriculture prohibits discrimination in all its programs and activities on the basis of race, color, national origin, gender, religion, age, disability, political beliefs, sexual orientation, and marital and family status. To file a complaint of discrimination, write USDA, Director, Office of Civil Rights, Room 326-W, Whitten Building, 14th and Independence, SW, Washington, DC 20250-9410 or call 202-720-5964 (voice or TDD). USDA is an equal opportunity provider and employer. Mention of trade or manufacturer names is provided for information only and does not constitute endorsement by USDA-ARS. **Any material in this publication may be copied and distributed in part or whole if due credit is given to the authors.** Editor: Cal Thorson, Technical Information Specialist, USDA-ARS Northern Great Plains Research Laboratory, 1701 10th Ave., S.W., Mandan, ND 58554. O:701 667-3018 F:701 667-3077 E: thorsonc@mandan.ars.usda.gov

New Faces

Dr. Dave Archer, USDA-ARS Agricultural Scientist, joined NGPRL as an agricultural economist in January. Prior to coming to Mandan, he worked on cropping systems economics evaluating the economic feasibility of alternative cropping systems, and identifying barriers to adoption of more sustainable practices at the USDA-ARS laboratory in Morris, MN. He was previously the NRCS agricultural economist in Bismarck, Spokane and Colfax, WA. He received a Ph.D. in Agricultural Economics from Iowa State University in 1995 and a B.S. in Mathematics from Rocky Mountain College in Billings MT in 1988. His specific research interests include risk management, simulation modeling, decision aid development, and decision making to achieve both economic and natural resource goals.

Amy Kulackoski joined the NGPRL staff as a Biological Science Aid in December. Kulackoski received her B.A. in Biology and Latin from Concordia College of Moorhead, MN in 2005. She is currently working with Dr. Kristine Nichols on the study of glomalin, a component of soil organic matter.

Dr. Mohammed Iddrisu, NDSU Forest Geneticist, has began a multi-year effort to complete research on shelterbelt tree plantations begun by Dr. Rich Cunningham prior to termination of the USDA-ARS tree genetics research in 1992. Iddrisu, a native of Ghana, accomplished his undergraduate work in Cuba and received his doctorate from the University of British Columbia in Vancouver in 2005. He began his work in Mandan in November.



Dr. Marcia Toro, Soil Microbiologist from the University of Central Venezuela in Caracas, was a visiting scientist working with Dr. Kris Nichols. She returned to South America on December 19th.

USDA ARS

NORTHERN GREAT PLAINS

INTEGRATOR

Technology Transfer Product of the
Northern Great Plains Research Laboratory
United States Department of Agriculture
Agricultural Research Service

USDA-ARS-NGPRL
1701 10th Avenue SW PO Box 459
Mandan, ND 58554-0459

Phone: 701 667-3018 Fax: 701 667-3077