Eastern South Dakota Soil and Water Research Farm

1998

Annual Report to the Board of Directors

March 17, 1999

USDA, ARS, Brookings, SD
USDA, ARS, Morris, MN
South Dakota State University

Annual Report

Eastern South Dakota Soil and Water Research Farm, Inc.

Volume 10, March 1999

Eastern South Dakota Soil and Water Research Farm, Inc.
Board of Directors

Brookings County – Mark Stime

Clark County – Delwin Bratland

Codington County – Lynn Johnson

Day County – Alden Hanson

Deuel County – Gary Bandemer

Hamlin County – Clinton Rudebusch

Kingsbury County – Otto Sckerl

Lake County – Orland Olson

Lincoln County – Gene Thormodsgard

Marshall County – Arthur Steiner

McCook County – Eugene Painter

Miner County – Pat Keleher

Minnehaha County – Carol Sieg

Moody County – Ed Duncan

Turner County – Leon Jorgensen

Executive Secretary – Tom Pardy, Howard, SD

Research Partners

The Eastern South Dakota Soil and Water Farm is an outstanding example of cooperation between federal, state, and local organizations to accomplish a research mission. The Northern Grain Insects Research Laboratory, ARS, Brookings, SD, the North Central Soil Conservation Research Laboratory, ARS, Morris, MN, the South Dakota Agricultural Experimentation, Brookings, SD, and South Dakota State University, Brookings, SD have developed cooperative research programs directed towards cropping systems. These programs provide needed answers to crop production and environmental problems producers in the Northern Great Plains, and eastern South Dakota in particular, face each year. The participants in these research activities, both scientists and support staff, are dedicated to finding solutions to these important problems.

Research participants during 1998 were:

Northern Grain Insects Research Laboratory, ARS, Brookings, SD

Dr. Laurence D. Chandler, Research Leader
Dr. Michael M. Ellsbury, Research Entomologist
Dr. Leslie Hammack, Research Entomologist
Dr. Louis S. Hesler, Research Entomologist
Dr. Jan J. Jackson, Research Entomologist[1]
Dr. Barb Mulock, Research Entomologist
Dr. Joseph L. Pikul, Jr., Soil Scientist
Dr. Walter E. Riedell, Research Plant Physiologist
Dr. W. David Woodson, Research Entomologist[2]
Mr. Dave Beck, Biological Research Technician
Ms. Amber Beckler, Biological Science Technician
Ms. Erika Beste, Biological Science Technician
Ms. Julie Bugg, Biological Science Technician
Mr. Kurt Dagel, Biological Science Technician
Ms. Janet Fergen, Biological Science Technician
Ms. Rae Jean Gee, Biological Research Technician
Mr. Dave Harris, Agricultural Research Technician
Ms. Deb Hartman, Biological Research Technician
Ms. Darlis Kneebone, Biological Aid
Mr. Dan Kriese, Agricultural Research Technician
Mr. Chad Nielson, Biological Research Technician
Mr. Max Pravecek, Biological Research Technician and Farm Manager
Mr. Dave Schneider, Biological Research Technician
Mr. Cecil Tharp, Biological Science Technician
Mr. Dale Tlam, Agricultural Research Technician
Mr. Travis Trudeau, Agricultural Research Technician
Ms. Jackie Zafft, Biological Aid

North Central Soil Conservation Research Laboratory, ARS, Morris, MN

Dr. Ward B. Voorhees, Research Leader
Dr. Lynne Carpenter-Boggs, Microbiologist
Dr. Michael J. Lindstrom, Soil Scientist
Mr. Gary Amundson, Agricultural Research Technician
Ms. Terry Lemme - Agricultural Research Technician
Mr. Steve Van Kempen, Agricultural Research Technician

[1] Currently Pioneer Hi Bred, Inc.
[2] Currently USDA-ARS, New Orleans, LA

South Dakota Agricultural Experiment Station, Brookings, SD

Dr. Kevin Kephart, Acting Associate Director

South Dakota State University, Brookings, SD

Dr. Fred Cholick, Dean
Dr. Dale Gallenberg, Professor, Head of Plant Science Department
Dr. Thomas E. Schumacher, Professor, Plant Science
Dr. Sharon Clay, Professor, Plant Science
Dr. David Clay, Assoc. Professor, Plant Science
Dr. Ron Gelderman, Professor, Plant Science
Dr. Marie Langham, Assoc. Professor, Plant Science
Dr. Neil Reese, Professor, Biology and Microbiology
Dr. Arvid Boe, Professor, Plant Science
Dr. Scott Haley, Asst. Professor, Plant Science[1]
Dr. Doug Malo, Professor, Plant Science
Dr. Mike Catangui, Asst. Professor, Plant Science,
Mr. Leon Wrage, Distinguished Professor, Plant Science
Mr. Thomas Klosterman, Agricultural Foreman
Mr. Joseph Schumacher, Research Engineer, Plant Science
Ms. Susan Selman, Research Assoc., Plant Science

South Dakota State University, Brooking, SD (contract employees and/or students working at the Northern Grain Insects Research Laboratory)

Mr. Terry Hall, Biological Research Technician
Ms. Sharon Nichols, Biological Research Technician
Eric Bettendorf
Mark Bettendorf
Jeremy Brady
Sherri Brende
Sarah Bulfer
Eric Ewalt
Chad Galles
Justin Haugen
Nate Hofstadter
Cole Irish
Peter Jauert
Lora Kluis
Allison Link
Travis Nelson
Caleb Shillander
Nicole VandeWeerde
Cara Wulf

Other Cooperators
Dr. Robert Schroder, USDA-ARS, Beltsville, MD
Dr. Merle Vigil, USDA-ARS, Akron, CO
Tracy Blackmer, Univ. of Nebraska, Lincoln
Shannon Osborne, Univ. of Nebraska, Lincoln

A special thank you is extended to Shawn Rohloff (purchasing agent) at the North Central Soil Conservation Research Laboratory, Kathy Reese (secretary), Sharon Telkamp (purchasing agent), Anna Hiedeman and Doug Nemitz (maintenance mechanic) at the Northern Grain Insects Research Laboratory, and Darwin Longieliere (SDSU-ABS Fiscal Officer) for providing the needed administrative and operational support for our research activities.

Eastern South Dakota Soil & Water Research Farm, Inc.
3714 Western Avenue
Brookings, SD 57006-9421

March 17, 1999

As Chairman of the Board of Directors of the Eastern South Dakota Soil & Water Research Farm, Inc., I would like to make a few comments that come to mind pertaining to our partnership with those doing research on the Farm. Our interests in conserving and protecting the nation's soil and water resources and stabilizing rural economies prompts us to support USDA-ARS, South Dakota State University, and any other group doing research in this or related areas. I believe the research programs now in place are directed toward finding solutions to national and regional concerns related to soil and water conservation and the efficiency and sustainability of agricultural production.

We have take a big and important step this past year with the purchase of additional land, almost doubling the size of our research farm. I believe this will create many more opportunities for significant research to take place that will, in time, improve and protect our soil, water, and air. This will in turn improve and protect our environment and all the citizens of the United States and our global community.

We strongly support research now being conducted by ARS at the Northern Grain Insects Research Laboratory in Brookings, South Dakota State University, also in Brookings, and the North Central Soil Conservation Research Laboratory in Morris, MN. I would also urge them to continue future research in areas that are directly or indirectly related to clean water, clean air, soil stewardship and sustainable agriculture.

Mark Stime

EASTERN SOUTH DAKOTA SOIL AND WATER FARM EXPANSION
NEW OPPORTUNITIES FOR FUTURE RESEARCH

Larry Chandler, Research Leader
USDA-ARS, Northern Grain Insects Research Laboratory

During 1998 the Board of Directors of the Eastern South Dakota Soil and Water Farm approved the purchase of an additional 70 acres of farmland directly adjacent and to the north of the existing farm. With this acquisition new research projects can be developed by USDA-ARS and South Dakota State University scientists that will prove beneficial to producers in eastern South Dakota and the surrounding region.

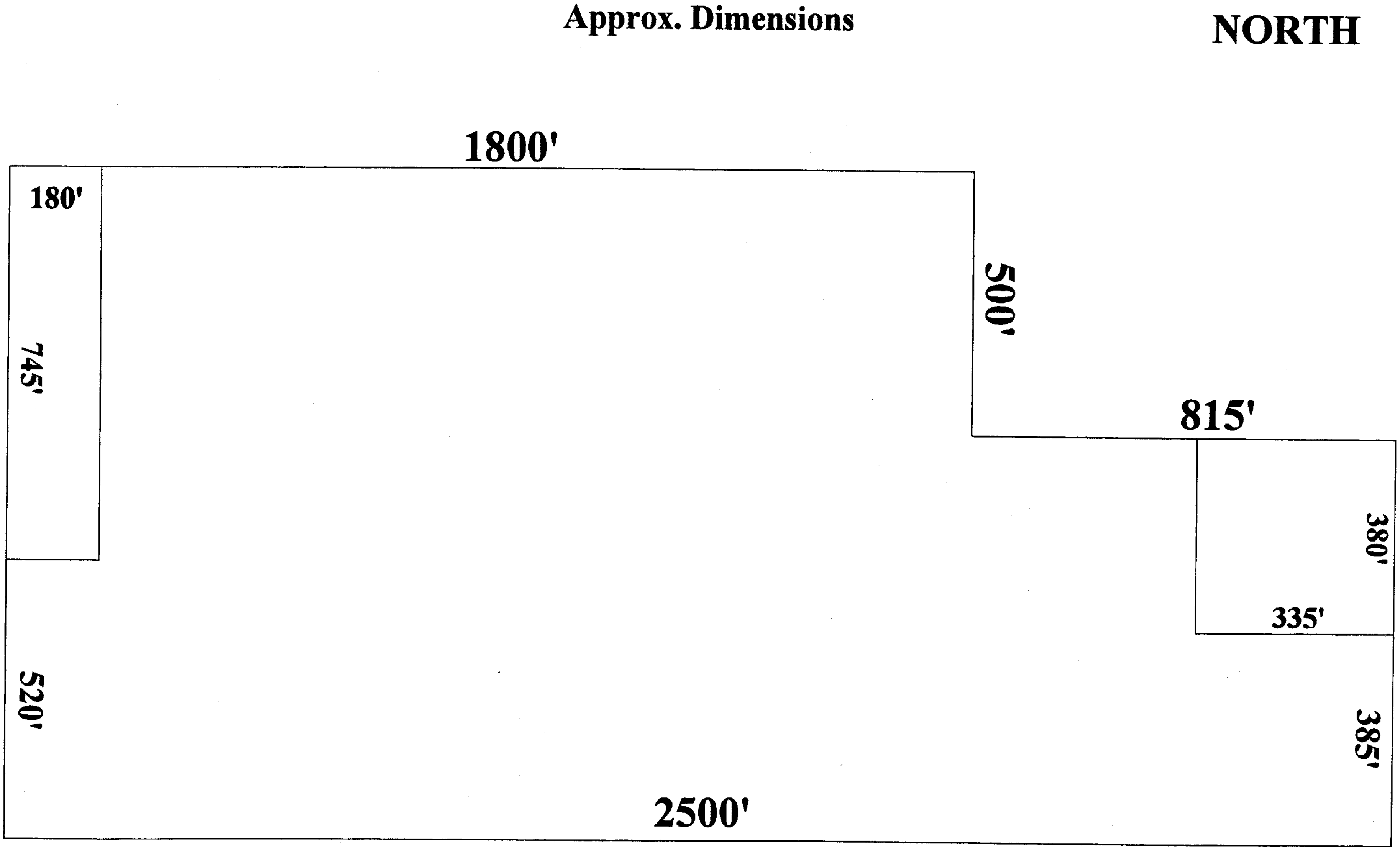
Plans are currently underway to evaluate the soil and agronomic characteristics of the new acreage, and to determine the research needs and focus of research projects to be conducted on the farm. During the late summer and fall of 1998 the Northern Grain Insects Research Laboratory initiated improvements of the property that included removal of old fence lines, trees and brush, and leveling of property lines to provide easy access between the two farm parcels. In addition, we removed numerous pieces of old farm equipment, storage bins, etc. that would not be of value for future farm operation. In 1999 the entire cultivatable acreage will be planted to spring wheat. This will be done to allow cooperators an opportunity to evaluate soil fertility, herbicide carry over, and other needs that could affect crop production prior to establishment of research plots later in the year. We fully expect to have a full complement of research related activities conducted on the farm by the year 2000.

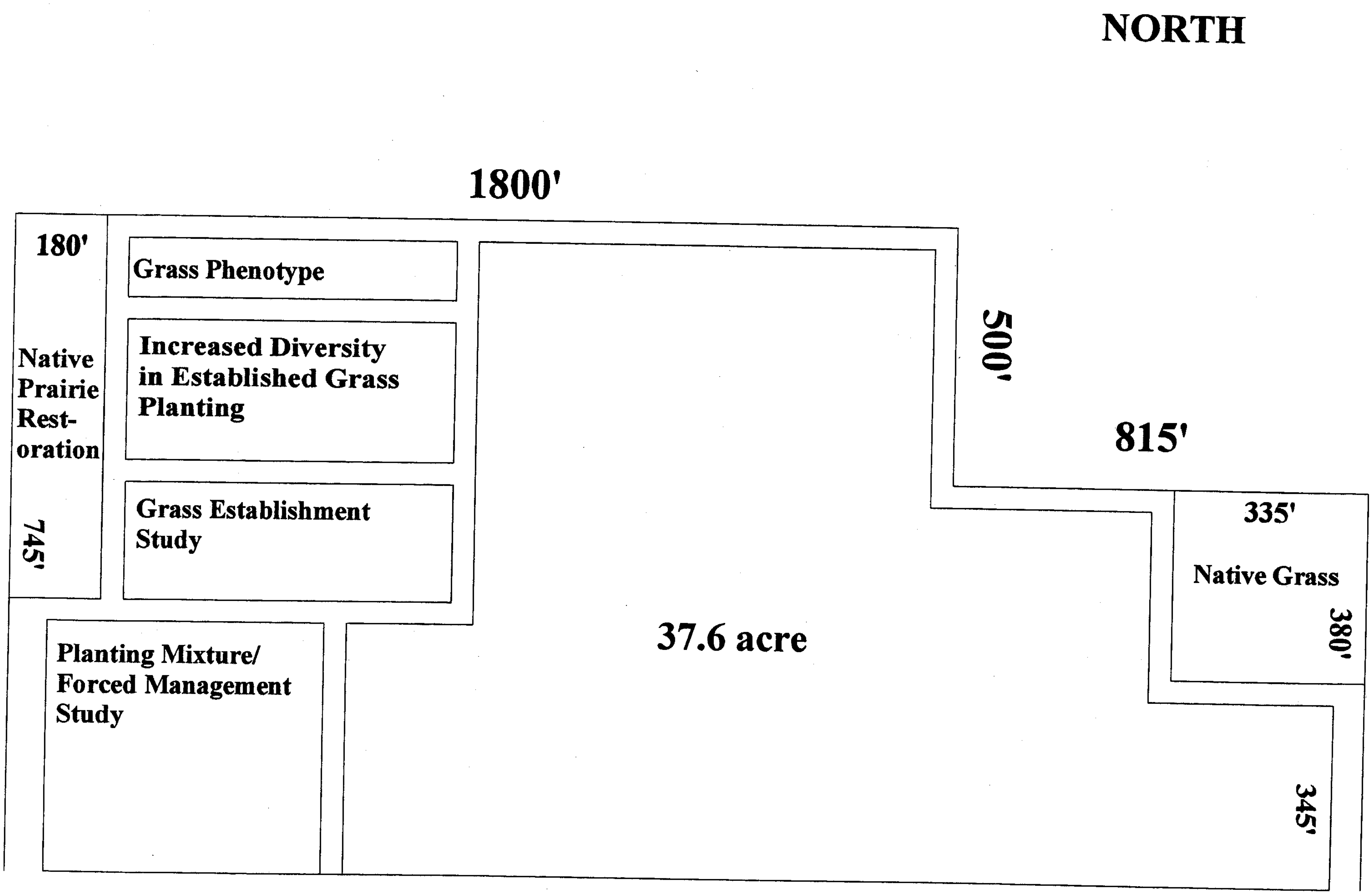
Late in the summer of 1998 the Northern Grain Insects Research Laboratory entered into a research agreement with the Brookings County Conservation District. This agreement was developed to facilitate cooperative research activities targeted at addressing the agronomics of native grass plantings being used in the Conservation Reserve Program. Information will be gathered that will provide producers a better data base for optimal production of grasses on their CRP acres and to better understand the interrelationship of grasses, pests, and crop systems. Information on seeding techniques, grass mixtures, fertility needs, and pest populations harbored within the plantings will be gathered. A portion of this cooperative research will be conducted on the new acreage at the Eastern South Dakota Soil and Water Farm. The three maps provided by Max Pravecek show the overall dimensions of the new acreage and two tentative plans for placement of native grass plots for cooperative research purposes. Final decisions on the exact layout of these plots will be made after spring wheat is harvested. Cooperators from the USDA Natural Resource Conservation Service, South Dakota State University, the Brookings County Conservation District, the USDA-ARS Northern Grain Insects Research Laboratory, and other ARS laboratories will play key roles in the conduct of these studies. In addition, two designated wetland areas will be planted to native grasses and allowed to return to a native prairie type habitat. Local schools will be invited to use these areas for science field trips.

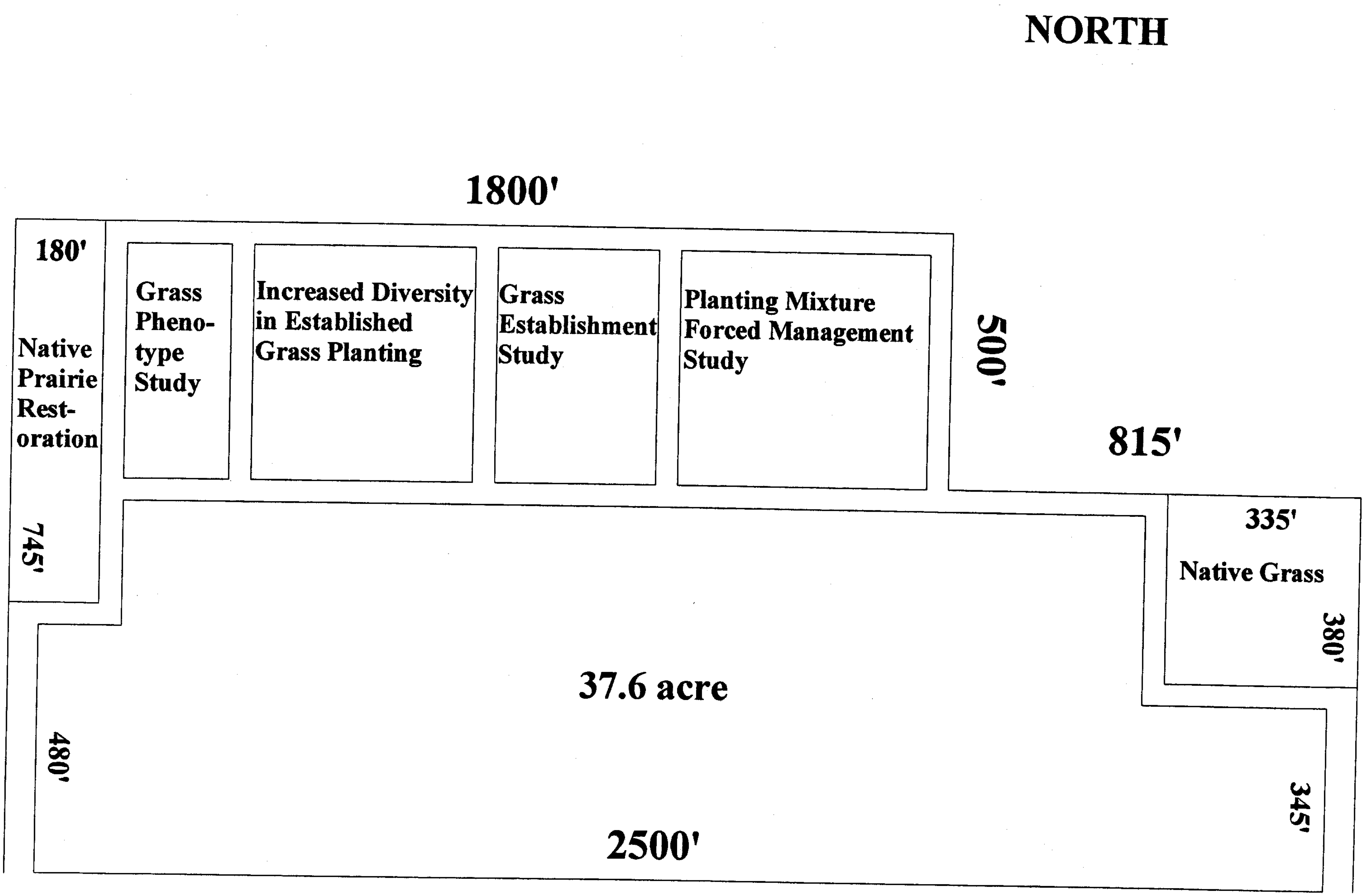
These are exciting times for all of us. We are extremely appreciative of the efforts the Board of Directors have made to secure this new property and to allow all the scientific community further opportunity to expand our research programs. We look forward to many years of continued cooperative activity and successful research beneficial to the producers of eastern South Dakota.

NEW LAND

Approx. Dimensions




NORTH
1800'
180'
Grass Phenotype
Increased Diversity in Established Grass Planting
Native Prairie Rest-oration
Grass Establishment Study
745'
Planting Mixture/ Forced Management Study
500'
815'
335'
Native Grass
380'
37.6 acre
345'


NORTH
1800'
180'
Native Prairie Rest-oration
745'
Grass Pheno-type Study
Increased Diversity in Established Grass Planting
Grass Establishment Study
Planting Mixture Forced Management Study
500'
815'
335'
Native Grass
380'
37.6 acre
480'
345'
2500'

FARM ACTIVITIES - 1998

Max Pravecek

Field day at the Eastern South Dakota Soil and Water Research Farm was held September 3, 1998 with about 125 people in attendance. A meal of pork sandwiches, potato salad, baked beans and a dessert were served. After the meal a 1-hour riding field tour has given.

Presenters and topics for the field tour were:
Dr. Dave Clay, SDSU Soil Scientist, Site-specific soil sampling for phosphorus.
Dr. Mike Catangui, SDSU Extension Entomologist, Grasshopper management for eastern South Dakota farmers.
Dr. Arvid Boe, SDSU Forage Breeder, Alternative legume cover crops.
Dr. Lynne Carpenter-Boggs, ARS-Morris Soil Microbiologist.
Dr. Louis Hesler, ARS-Brookings Entomologist, Insect management in small grains.
Dr. Tom Schumacher and Dr. Doug Malo, SDSU Soil Scientists, Soil quality after 100 years of crop production.

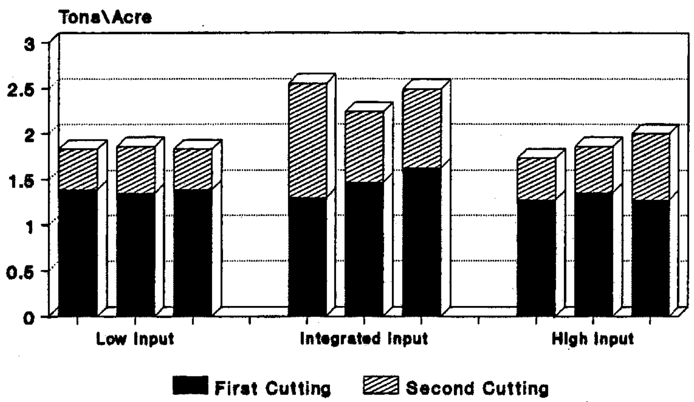
Posters were displayed in the farm shop with exhibitors from SDSU:
Dr. Dan Humburg, Dr. Ken Stange, Dr. Bill Campbell, and Dr. Dan Robbins and from USDA ARS Brookings: Dr. Joe Pikul, Dr. Walt Riedell, Dr. Leslie Hammack, Dr. Jan Jackson, Dr. Louis Hesler, and Dr. Dave Woodson.

1998 saw new experiments being started and new researchers using the Eastern South Dakota Soil and Water Farm facilities. Scientists doing experiments at the farm for the 1998-growing season were:
Dr. Joe Pikul - input and forage experiments
Dr. Leslie Hammack – corn rootworm sampling techniques and monitoring of corn rootworm populations
Dr, Larry Chandler – corn rootworm effect on white and high oil corn and experimental insecticide trial
Dr. Barb Mulock – suppression of adult corn rootworm using a fungal entomopathogen
Dr. Walt Riedell – cereal aphid effect on oat and wheat crops
Dr. Louis Hesler –winter wheat as affected by cereal aphids, variety, and tillage.
Dr. Arvid Boe – alternative legume cover crops
Dr. Tom Schumacher – alternative legume cover crops
Dr. Schroeder – suppression of adult corn rootworm using an experimental feeding stimulant
Dr. Lynne Carpenter-Boggs – nitrogen and microbial activity in rotation trials
Also Dr. Malo, SDSU soil scientist, brought SDSU students to the farm for field trips.

Precipitation for April through October, 1998 was almost 2 inches below normal (16.88 vs. 18.77). October precipitation being above normal by almost 4 inches made the shortage of moisture during the critical growing period even greater. So we can say that it was a very dry year in this local area.

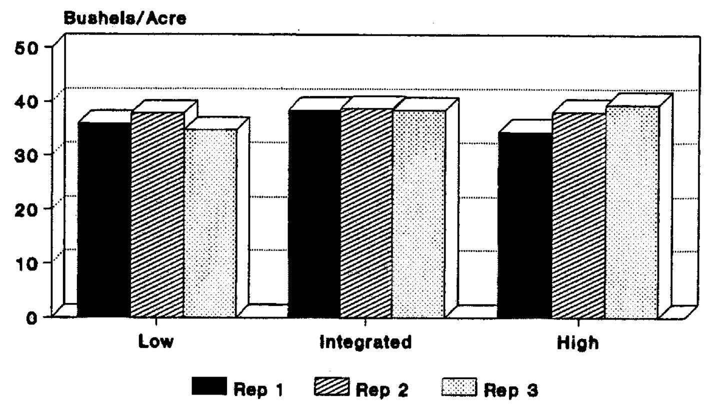
Yields were down for all crops and rotations. Only 2 cuttings of alfalfa were taken. The following graphs show all yields on the Input plots at the farm.

1998 Legume Yield
4 Year Rotation



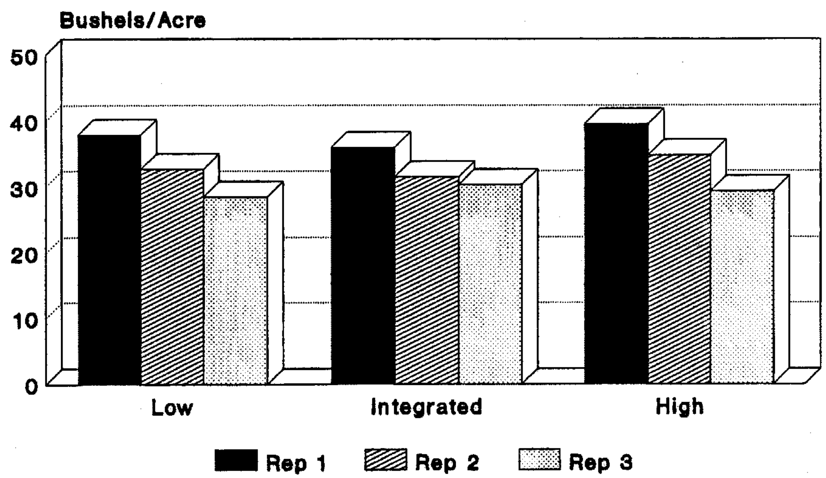
USDA Research Farm

1998 Wheat Yield
4 Year Rotation



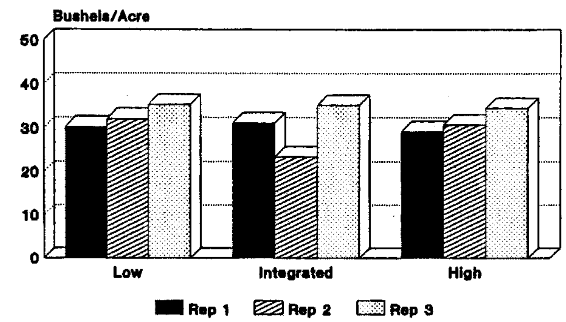
USDA Research Farm

1998 Soybean Yield
4 Year Rotation



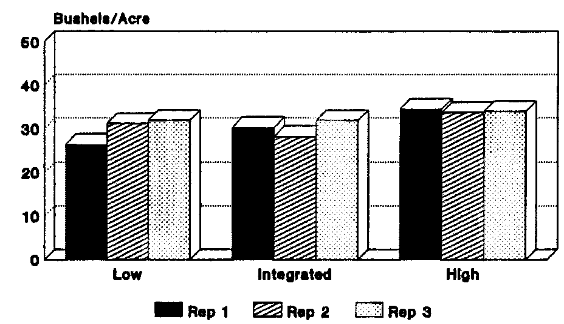
USDA Research Farm

1998 Soybean Yield
Corn Soybean Rotation on Ridges



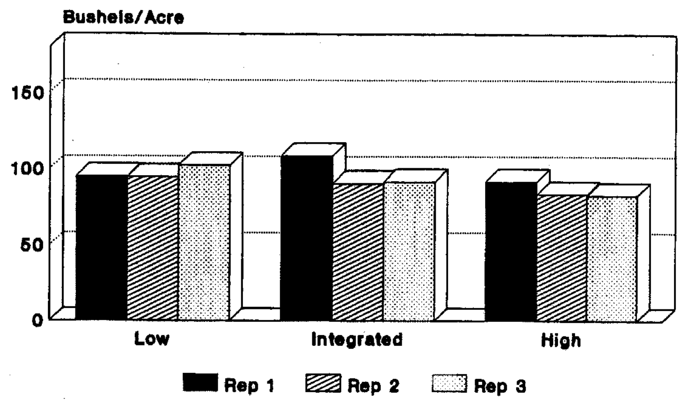
USDA Research Farm

1998 Soybean Yield
Corn Soybean Rotation



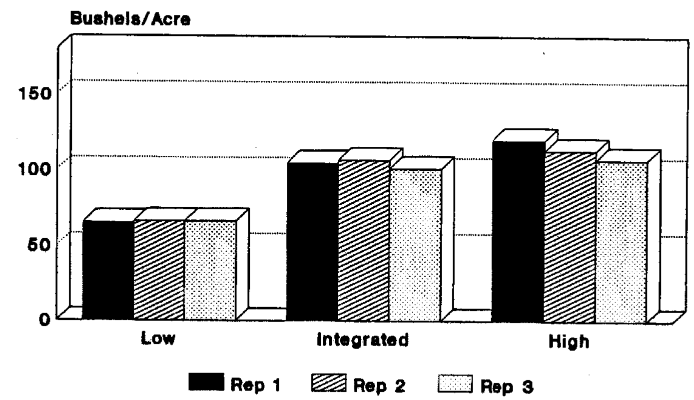
USDA Research Farm

1998 Corn Yield
4 Year Rotation



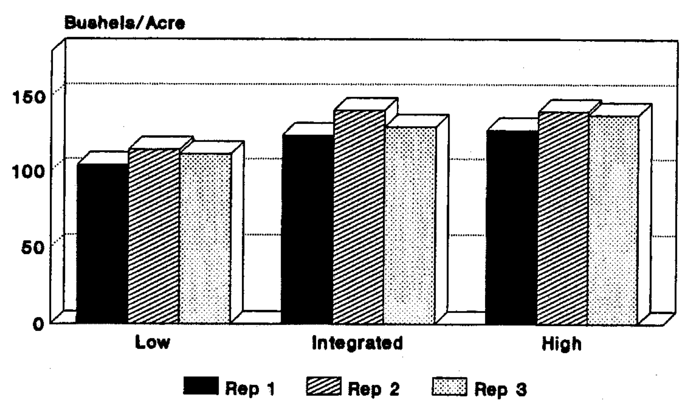
USDA Research Farm

1998 Corn Yield
Continuous Corn



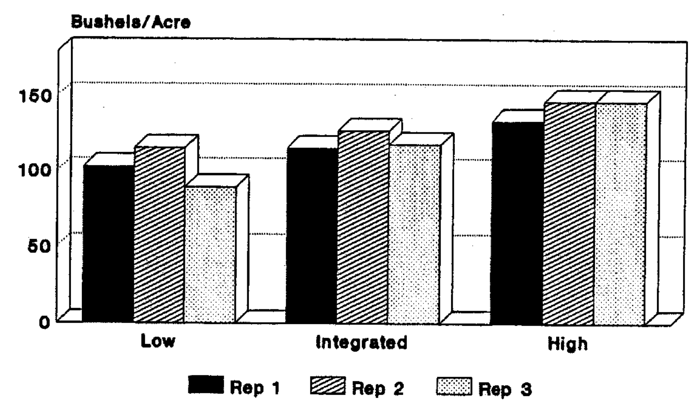
USDA Research Farm

1998 Corn Yield
Corn Soybean Rotation



USDA Research Farm

1998 Corn Yield
Corn Soybean Rotation on Ridges



USDA Research Farm

CORN AND SOYBEAN YIELD USING REDUCED TILLAGE AND CONVENTIONAL TILLAGE

Joseph L. Pikul Jr[1]., Lynne Carpenter-Boggs, Merle Vigil, and Walter E. Riedell

INTRODUCTION

Tillage is conducted to incorporate residues or amendments, control weeds, or prepare soil for seeding. The purpose of tillage for crop production is to create the best possible environment for crop-seed germination and emergence. In an ideal environment, the soil surface would always be covered with growing plants or residues; soil temperature would be optimum for seed germination; and soil water content would be ideal for plant growth and field operations. Farmers often face field conditions that are less than ideal. Northern soils are especially difficult to manage because of cool and wet conditions. Many farmers in the northern Corn Belt prefer some type of tillage to create a suitable seedbed environment.

Recent advancements in soil science have identified important consequences of tillage on carbon retention in soil. Generally, soil carbon loss is directly proportional to tillage intensity. For example, there is more carbon loss from moldboard plowing than from field cultivation. Soil organic matter (carbon) has a disproportionate effect on soil productivity. Management that maintains soil organic matter will maintain soil productivity. Additionally, destruction of soil surface cover is proportional to tillage intensity. Management practices that maintain surface residues will decrease the potential for wind and water erosion.

This report deals with crop response to tillage with only minor discussion of soil quality attributes. Objectives were to compare crop performance at three nitrogen-fertilizer levels in a reduced tillage system and a conventional tillage system.

METHODS

The study was located on the Eastern South Dakota Soil and Water Research Farm at Brookings, SD on a Barnes (formerly Vienna loam) clay loam (fine-loamy, mixed Udic Haploboroll) with nearly level topography. Prior to the start of the experiment in 1990, the field was cropped to soybean in 1988 and spring wheat in 1989. Crop performance for only 1995-1998 is summarized in this report. But, soil conditions in 1998 reflect long-term management of this experiment.

Whole plots (tillage) in the split plot experiment were arranged as a randomized complete block with three replications. Split plots were N treatments. Corn and soybean were present every year in each tillage trial. Plots were 100 ft by 100 ft.

Conventional tillage (CT) plots were moldboard plowed in the spring of the year in 1995 and 1996 and chisel plowed in fall of 1996 and 1997. Seedbeds for corn and soybean in all years were prepared in spring using a tandem disk and field cultivator. Crops are row-cultivated twice each year. Rows are oriented in the east-west direction.

Reduced tillage (RT) plots receive only row cultivation for both corn and soybean crops. Corn and soybean were no-till planted on the previous crop row. Crops are row-cultivated twice each year and this cultivation has maintained a raised seedbed similar to ridge tillage. Unlike traditional ridge tillage, no effort has been made to build or knock down soil ridges. Rows are oriented in the east-west direction.

Soil test nitrate (STN) has been the basis for N fertilizer prescription for corn. Soil samples were collected in the fall or spring, depending on weather conditions (Table 1). In 1995 and 1996 samples were taken from 0- to 6-inch and 6- to 24-inch depths. In 1997 and 1998 samples were taken to a depth of 48 inches at increments of 0 to 6 in, 6 to 12 in, 12 to 24 in, 24 to 36 in, and 36 to 48 in. In 1998, prior to corn seeding, soil samples were taken to 10 feet at 1-foot increments to measure nitrate accumulation. Soil nitrate was determined using a 2 M KCl extraction and automated copperized Cd reduction column procedure (Zellweger Analytics, 1992). Soil organic carbon was determined by combustion and potentially mineralizable N was determined from a 189-day soil incubation.

[1] Soil Scientist, microbiologist, plant physiologist, and soil scientist, USDA-ARS, located at Brookings, SD, Morris, MN, Akron, CO, and Brookings, SD. Contribution from USDA-ARS, Northern Grain Insects Research Laboratory, 2923 Medary Ave., Brookings, SD, 57006. Direct correspondence to jpikul@ngirl.ars.usda.gov. The U.S. Department of Agriculture offers its programs to all eligible persons regardless of race, color, age, sex, or national origin, and is an equal opportunity employer.

Soil phosphorous levels were rebuilt prior to spring fieldwork in 1996 with an application of 395 lb/acre of triple super phosphate (0-45-0) on all plots.

Nitrogen treatments for corn were corn fertilized for a yield goal (YG) of 135 bu/acre (N1), corn fertilized for a YG of 85 bu/acre (N2), and corn not fertilized (N3). Fertilizer N prescription (NP) for each N treatment was calculated as NP = 1.2YG - STN. Adjustments (Gerwing and Gelderman, 1996) to NP for previous crop or sampling date were not made. NP for each rotation and N treatment, expressed as an average of three replications, was met by applying starter fertilizer with the seed and sidedressing appropriate amounts of urea (46-0-0). Starter fertilizer was applied as 14-36-13, 7-36-13, and 0-36-13 (N-P_2O_5-K_2O) on N1, N2, and N3 treatments, respectively, at 100 lb/acre.

Nitrogen treatments for soybean were starter fertilizer only. Starter fertilizer was applied as 14-36-13, 7-36-13, and 0-36-13 (N-P_2O_5-K_2O) on N1, N2, and N3 treatments, respectively, at 100 lb/acre. Starter fertilizer for both corn and soybean was applied 2 inches to the side and 2 inches deeper than seed.

Seeding date and rate were the same for all treatments in a given year (Table 1). Row spacing was 30 in. All plots were cultivated twice during the early growing season and urea-N was broadcast immediately before the 2nd cultivation. Corn and soybean yields were determined from eight 100-ft-long rows.

Statistical comparisons were made using analysis of variance and multiple factor analysis of variance (MINITAB, Release 12, State College, PA). The split plot arrangement within randomized blocks was such that factor 1 was rotation (whole plot).

RESULTS AND DISCUSSION

Corn yield data taken in the first year of the study (1990, data not shown) showed that our test site was responsive to N fertilizer and that prior to imposing our tillage systems there were no differences in corn yield among the test plots that were in corn.

Soil testing for nitrate-N is a key nitrogen management tool for corn producers in eastern South Dakota and western Minnesota (Gerwing and Gelderman, 1996, Rehm et al., 1994). There has been little difference between tillage treatments in STN in 1996, 1997, and 1998 following soybean. Average STN (average of 3 years and 3 fertilizer treatments) was 32 lb/acre on RT and 29 lb/acre on CT treatments.

Nitrogen use efficiency (NUE) is the ratio of corn grain yield to available nitrate-N and is used as an indicator of production efficiency within similar fertilizer management plans. Available nitrate-N is the sum of soil nitrate-N and applied N. There have been no differences between tillage treatments in NUE. Average (4 years) NUE for both tillage systems has been 0.8 bushel of corn per pound of nitrate-N on plots managed for a 135 bu/acre yield goal. This ratio is very close to the value used in the South Dakota and Minnesota fertilizer management guides (Gerwing and Gelderman, 1996, Rehm et al., 1994).

Efficient use of nitrogen can minimize potential for ground water contamination by water soluble nitrates. We did not detect excessive nitrate accumulation in either tillage treatment. Total nitrate-N in the top 10 feet of soil on N1 plots was 110 lb nitrate-N/acre on RT and 129 lb nitrate-N/acre on CT plots. Samples for these tests were taken before the 1998 crop year and reflect soil conditions after 8 years, or 4 crop-rotation cycles.

Soil organic matter was greater on RT plots compared with CT plots. Organic carbon in the top 8 inches of soil averaged 1.9% on RT and 1.8% on CT. The amount of nitrate-N potentially available from conversion of organic forms (not usable by plants) to inorganic forms (readily available to plants) was 20 lb/acre greater on N2 treatment of RT compared with CT.

There have not been consistent differences between tillage systems in soybean yield (Table 3). However, 1997 was exceptional because soybean grain yields on RT exceeded CT by 6 bu/acre. We attribute this yield difference to early stand establishment on RT treatments. Spring 1997 turned unusually dry and seedbeds that were conventionally tilled dried out. Soybean was planted on May 28, but we did not receive significant rainfall until June 19. Consequently, emergence on CT was delayed until late June following a series of rain storms that re-wetted the seed zone. On June 18, before the rains, we counted 167,000 seedlings per acre on RT and only 25,000 seedlings per acre on CT. On July 1, following 2.3 inches of rain, we counted 173,000 seedlings/acre on RT and 150,000 seedlings/acre on CT. Superior crop performance on RT plots in 1997 demonstrated a measurable yield advantage for no-till planted soybean. Average soybean yield has been 34 bu/acre on both RT and CT. There were no differences between tillage treatments in soybean grain quality (protein or oil content).

In contrast to our soybean crop, we did not experience difficulties in establishing a corn stand in 1997. Corn was planted 20 days earlier than soybean in 1997. Seedbeds on CT were adequately moist, unlike that for soybean. Corn-plant population on June 11, 1997 was 29,500 plants/acre on RT and 28,800 plants/acre on CT.

Corn yield on RT treatments has been less than yields on CT treatments. Average (4 years and 3 fertilizer levels) yield on RT has been 108 bu/acre versus 115 bu/acre on CT (Table 3). There were no consistent differences in plant populations between tillage systems. Average number of plants on RT was 29,500 plants/acre and 28,850 plants/acre on CT.

There were no significant differences between tillage treatments in soil water reserves at corn planting. Average water content for the 6-foot soil profile was 28% on RT and 29% on CT.

CONCLUSION

Tillage or no tillage continues to be the subject of considerable controversy. Northern crop production systems of the United States are unique from southern ones because of cool and wet conditions. Some tillage may be desirable. For example, strip tillage has gained considerable attention because the system has boosted yields over no tillage and provided soil and water conservation benefits typically associated with no tillage (Hillyer, 1999). Our study has shown no difference between reduced tillage and conventional tillage in respect to soybean yield, but avearge corn yield was 7 bu/acre greater on conventional tillage compared with reduced tillage. There has been little difference between the two tillage systems in grain quality, NUE, water use efficiency, or soil nitrate accumulation. In dry years, such as the spring of 1997, no tillage boosted soybean grain yield over conventionally planted soybean. We attributed this yield difference to early and improved stand establishment on reduced tillage treatments. Reduced tillage can protect soil from erosion and maintain soil productivity. Soil on the reduced tillage system had slightly greater organic matter than soil on conventional tillage. Results suggest that soil on reduced tillage has improved compared to conventional tillage. The cost of soil improvement from using reduced tillage has been a slightly lower corn yield.

REFERENCES

Gerwing, J., and R. Gelderman. 1996. Fertilizer Recommendations Guide, South Dakota State University Pub. EC 750. Brookings, SD.

Hillyer, G. 1999. In the Zone: Strip till warms up and dries out soil to provide an ideal growing area for no-till corn. Progressive Farmer. January 1999: 18-20.

Rehm, G., M. Schmitt, and R. Munter. 1994. Fertilizing corn in Minnesota. University of Minnesota Pub. FO-3790-C. St. Paul, MN.

Zellweger Analytics. 1992. Nitrate in 2M KCl Soil Extracts, QuickChem Method 12-107-04-1-B. (12 Nov. 1992) Zellweger Analytics, Inc., Lachat Instruments Div., Milwaukee, WI.

ACKNOWLEDGMENTS

We thank Max Pravecek, Biological Science Technician, and David Harris, Agricultural Science Research Technician Soils, for careful maintenance of the experimental plots. David Harris is also recognized for work in sample collection and technical laboratory analysis.

We thank Larry Mahlum, Plant Manager, and Renae Doescher, Laboratory Technician, South Dakota Soybean Processors, Volga, SD for measuring soybean grain quality.

Table 1. Corn and soybean planting date, variety, seeding rate, harvest date, and date of soil sample for nitrate-N.

	----------------Crop Year----------------			
	1995	1996	1997	1998
Corn planting date	5 May	16 May	8 May	30 Apr.
Variety (Pioneer)	3769	3769	3769	3751
Seeds per acre	26,300	29,620	30,500	30,066
Harvest date	30 Oct.	23 Oct.	10 Oct.	8 Oct.
Soybean planting date	24 May	21 May	28 May	14 May
Variety	9171	9171	9171	9171
Inoculant	no	yes	yes	Yes
Seeds per acre	161,650	180,774	182,700	199,505
Harvest date	11 Oct.	4 Oct.	30 Sept.	28 Sept.
Sample date for soil nitrate-N	30 Nov. 1994	1 May 1996	30 Oct. 1996	17 Oct. 1997

Table 2. Precipitation and growing degree days for 1995-1998 and long-term average precipitation and growing degree days for 1961-1990. Weather data courtesy of Alan Bender, South Dakota State Climatologist, Brookings, SD.

	----------------Crop Year----------------					Average
	1995	1996	1997	1998	Ave.	1961-90
	------------------------Precipitation (inches)--------------------					
April	2.71	0.26	1.98	1.82	1.69	2.07
May	4.52	4.92	1.17	1.54	3.14	2.93
June	2.73	2.84	2.55	2.04	2.54	4.34
July	6.85	0.86	2.99	1.59	3.07	3.32
August	4.46	3.02	1.74	3.51	3.18	2.81
September	3.93	2.61	2.00	0.76	2.33	2.64
October	3.20	2.75	1.46	4.86	3.07	1.66
Total (June-Sept.)	17.97	9.33	9.28	7.9	11.12	13.11
Total (April-Oct)	28.40	17.26	13.89	16.12	18.92	19.77
Year total	32.37	20.12	16.07	18.71	21.82	22.89
	Growing Degree days (air temperature, base 50 °F)					
April	36	120	100	149	101	123
May	187	247	205	414	263	302
June	508	552	542	413	504	479
July	602	601	625	617	611	620
August	656	657	543	597	613	558
September	326	380	401	465	393	336
October	108	195	208	159	168	162
Total	2423	2752	2624	2814	2653	2580

Table 3. Mean soybean and corn yield (15.5% grain moisture)
for reduced tillage (RT) and conventional tillage (CT).
Nitrogen treatments for soybean were starter fertilizer only.
Starter was applied as 14-36-13, 7-36-13, and 0-36-13 (N-P_2O_5-K_2O)
on N1, N2, and N3 treatments, respectively, at 100 lb/acre.
Corn N fertilizer treatments were corn fertilized for a yield of 135 bu/acre
(N1), corn fertilized for a yield of 85 bu/acre (N2), and corn not fertilized (N3).

	----------Crop Year----------				
	1995	1996	1997	1998	Ave.
	Soybean Yield (bu/acre)				
Tillage (T)					
RT	27	39	37	31	34
CT	31	41	31	31	34
Fertilizer (N)					
N1	34	40	36	33	36
N2	26	42	34	30	33
N3	26	38	33	31	32
p value T	ns	ns	0.049	ns	
p value N	0.001	0.006	0.025	ns	
p value TxN	0.018	ns	ns	ns	
	Corn Grain Yield (bu/acre)				
Tillage (T)					
RT	85	119	107	121	108
CT	92	131	110	125	115
Fertilizer (N)					
N1	114	144	116	138	128
N2	81	122	115	125	111
N3	72	109	96	106	96
p value T	ns	0.057	ns	0.076	
p value N	0.001	0.001	0.004	0.001	
p value TxN	ns	ns	ns	0.008	

CROP ROTATION IMPROVES SOIL FERTILITY AND PLANT MINERAL NUTRITION

W. E. Riedell, J. L. Pikul, and L. Carpenter-Boggs

INTRODUCTION

Long-term experiments conducted at eastern US corn-belt locations have demonstrated 10 to 17 % greater yield in corn grown in rotation with other crops than when grown in monoculture. Improved yield under rotation is related to both soil and crop parameters. Crop rotations that include legumes increase soil nitrogen levels. Various scientific studies have concluded that much of the yield benefit observed from crop rotation with legumes, however, was due to factors other than increased soil nitrogen. Crop rotation improves soil structural stability, increases crop water use efficiency, increases soil organic matter levels, improves nutrient use efficiency, provides better weed control, and disrupts insect and disease cycles.

Research conducted previously at the Eastern South Dakota Soil and Water Research Farm has demonstrated that mineral nutrient accumulation and grain yield were greater in corn grown under annual rotation with soybean than in corn grown in monoculture. We were interested in determining whether a corn-soybean-wheat/alfalfa-alfalfa rotation would have similar beneficial effects on soil fertility and crop mineral nutrition. Our experimental objectives were to investigate the effects of complex crop rotation on soil fertility and corn mineral nutrient composition. Understanding the complex interactions of soils, plants, and management practices is a first step towards development of agricultural systems that sustain food and fiber production.

MATERIALS AND METHODS

Crop rotation treatments were established in the 1990 growing season at the Eastern South Dakota Soil and Water Research Farm near Brookings, SD. The Barnes loam (fine-loamy, mixed Udic Haploborolls) soils on the farm are characteristic of those found in eastern South Dakota and western Minnesota and are similar to soils common to the northern corn belt. The field study was conducted during the 1998 growing season. Three crop rotation treatments were evaluated in a randomized experimental arrangement with three replications. Treatments were a continuous corn monoculture (CC), a corn-soybean rotation (CS) and a corn-soybean-wheat/alfalfa-alfalfa rotation (CSGL). The experiment was designed to have a corn crop present in each rotation each year of the study. Crop management for all rotation treatments included soil test-based fertilizer application for 135 bushel acre^{-1} yield goal, prophylactic pre- and post-emergence herbicide application, and tillage consisting of fall chisel plow/spring disk/spring field cultivator operations. Starter fertilizer (banded 2 inches to the side and 2 inches deep from the seed and corn at a rate of 28,000 kernels acre^{-1} were applied to experimental plots with an 8-row planter. All plots received two row cultivation operations early in the growing season.

Soil samples (0 to 12 inches depth) were taken at the 6th leaf stage (Fig. 1) of corn crop development (June 12, 1998) using a soil auger. Three separate cores were taken at random from each plot, bulked, and analyzed for nitrate-nitrogen (NO_3-N) using calcium phosphate extraction, phosphorus (P) using the Bray P1 method, and available iron (Fe) using DTPA extraction. Soil water at the one to two foot depth was also measured using a neutron probe on June 5, 1998. Corn leaves were sampled for dry weight and mineral nutrient concentration when shoot development reached the 6th leaf stage (June 12, 1998). Tissues were dried to constant weight at 60 C in a forced air oven, weighed, and ground in a Wiley mill equipped with a 1 mm screen. Ground tissue from each plot was combined and analyzed for nitrogen using the Kjeldahl method. Phosphorus concentration was measured spectrophotometrically while an atomic absorption spectrometer was used to measure iron concentrations. Data were analyzed using ANOVA procedures in SAS. With the occurrence of a significant ANOVA for rotation effects, means were separated using the LSD option.

RESULTS AND DISCUSSION

Soil Fertility

Soil water data from the six foot profile indicated that the soil under the CSGL rotation was dryer than the other rotations (data not shown). However, statistical analysis of soil water data from the portion of the soil profile sampled for soil fertility measurements (one to two foot depth) revealed that the soil water content was not affected by crop rotation

---

Cooperative investigations of the USDA Agricultural Research Service at Brookings SD and Morris MN. Mention of commercial or proprietary products does not constitute endorsement by the USDA. USDA offers its programs to all eligible persons regardless of race, color, age, sex, or national origin.

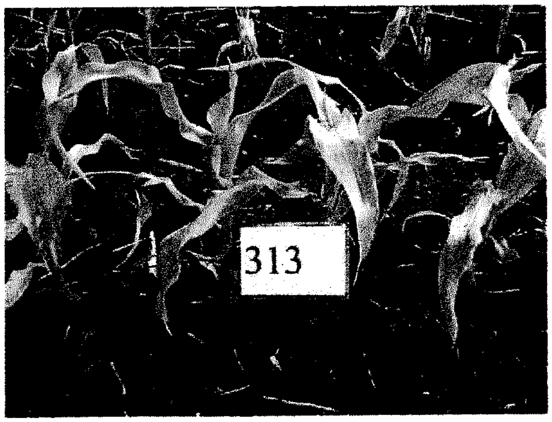


Figure 1. Appearance of corn at the 6th (V6) leaf stage.

treatments (Table 1). The CSGL rotation treatment had significantly higher levels of NO_3-N than the CC monoculture (Table 1). The NO_3-N levels for the CS rotation were intermediate between CC and CSGL. These data show that the crop rotation treatment that included alfalfa increased soil NO_3-N even under conditions of high N fertilizer applications. We observed significantly lower soil P levels and higher Fe levels in the CSGL rotation treatment when compared with the CC monoculture or the CS rotation (Table 1). Differences in soil P level may be related to the fertilizer rates used on the crops grown in the rotation treatments or to a differential removal of P by the different crops. The corn, soybean and wheat phases of the rotation treatments received P fertilizer, but the alfalfa crop did not. Alfalfa accumulates about the same amount of P as corn. Of this accumulated P, approximately 80 % is removed at corn harvest while nearly 100 % is removed the alfalfa crop. Thus, the lack of P fertilizer applied to the alfalfa as well as the greater P removal by the alfalfa crop likely resulted in these decreased soil P levels. The reasons for increased soil Fe levels following alfalfa are unknown. Possible explanations include increased available Fe resulting from organic matter decomposition or as a result of previous crop root activity (release of H^+ or chelating compounds by the alfalfa roots during the previous growing season). Additional data from future experiments are needed to help explain the mechanisms involved.

Corn Leaf Mineral Concentration

Corn leaf dry weight was significantly less in the CS rotation than in the CC monoculture (Table 2). The leaf dry weights from the CSGL treatment were intermediate between the CS and CC treatments. Leaf nitrogen concentration at the V6 leaf development stage was significantly affected by rotation treatments. Corn plants following alfalfa in the CSGL rotation had significantly higher N and Fe concentrations (Table 2) than plants following soybean (CS) or corn (CC). These higher leaf N and Fe concentrations may be the result of the higher levels of soil NO_3-N and available Fe as measured in plots which previously contained alfalfa (Table 1). The lower soil P level seen after alfalfa (Table 1) was not accompanied by decreased leaf P concentrations in the corn crop (Table 2). Although the specific reasons for the differences in the response mechanisms were not clear, our data suggest that there may be some factors that promote P uptake efficiency in corn grown in the CSGL rotation.

CONCLUSIONS

Our data show a beneficial effect of crop rotation on soil N and Fe fertility as well as on corn mineral nutrition. We still do not understand the scientific reasons for the beneficial crop rotation effect. A mechanistic understanding of this beneficial effect could be used as a basis to help design and evaluate more diverse crop rotations that sustain soil and crop productivity.

Table 1. Soil fertility levels in 0 to 1 foot soil samples taken on June 12, 1998 from the Input Plots at the Eastern South Dakota Soil and Water Research Farm. All samples were taken from the corn plots when the crop was at the V6 leaf development stage.

Previous crop	NO_3-nitrogen		Phosphorus		Iron		Soil water[§]	
	--------------- parts per million (ppm)				---------------		cm	
corn	7.8	b[†]	14.7	a	49.5	b	16.6	ns
soybean	10.4	ab	15.7	a	46.8	b	16.0	
alfalfa	15.4	a	11.3	b	67.9	a	15.6	
Probability > F	0.04[‡]		0.005		0.01		0.18	

[†] Means followed by the same letter are not significantly different (LSD test).
[‡] Values represent the probability associated with the F value generated in the ANOVA analysis.
[§] Soil water measurements (first to second foot depths) were taken on June 4, 1998.

Table 2. Leaf dry weight and mineral nutrient concentrations from corn (Pioneer brand corn hybrid '3751') plants sampled at the V6 leaf development stage on June 12, 1998.

Previous crop	Dry weight		Nitrogen		Phosphorus		Iron	
	g $plant^{-1}$		---------- percent		----------		ppm	
corn	2.7	a	4.6	b[†]	0.49	ns	485	b
soybean	2.1	b	4.7	b	0.50		596	ab
alfalfa	2.6	ab	4.9	a	0.52		664	a
Probability > F	0.08[‡]		0.03		0.76		0.07	

[†] Means followed by the same letter are not significantly different (LSD test).
[‡] Values represent the probability associated with the F value generated in the ANOVA analysis.

MICROBIAL ACTIVITY AND NITROGEN MINERALIZATION AFFECTED BY ROTATION AND FERTILIZATION

Lynne Carpenter-Boggs[2] and Joseph L. Pikul Jr.[3]

INTRODUCTION

Any nutrient or environmental factor can limit plant growth, but in the Midwestern corn belt nitrogen availability is one of the most critical factors in determining crop yield. Most of the N required by crops in the Midwest is supplied by mineral fertilization. Alternatively, a great deal of N can be supplied from natural sources such as legumes. Legumes, like all plant residues and organic material in the soil, release N via microbial activity. Legumes such as alfalfa and clover are particularly high in N because of their relationship with N-fixing bacteria, of the genus Rhizobium. Many producers use both mineral and plant sources of N, incorporating some legumes into the crop rotation (though they are often less effective N-fixers such as soybeans) as well as applying mineral fertilizer to ensure maximum yield.

Generally, recommendations for fertilizer N application consider the crop yield goal and level of nitrate available in the soil at planting. Also, an N credit should be allowed for any legume grown the previous year. Fertilizer recommendations have not yet addressed possible interactions between release of plant-derived N and the level of fertilization. Since release of N from legumes is a biological process, and mineral fertilization can affect biological processes, mineral fertilization could affect the level of N made available through legume rotation.

The objective of this study was to determine the effects of fertilization level on microbial activity and N mineralization under three rotations.

METHODS

Study plots are located on the Eastern South Dakota Soil and Water Research Farm at Brookings, SD. Soils are a Barnes clay loam (fine-loamy, mixed Udic Haploboroll) with nearly level topography. Plots have been managed under the current experimental design since 1990. The experimental design includes three crop rotations, continuous corn (CC), corn-soybean (CS), and corn-soybean-wheat/alfalfa-alfalfa (CSWA). Rotations are replicated three times in randomized complete blocks. Each rotation plot is split into three randomized subplots to test fertilization effects at 0 N application (0N), low N fertilization at 85 bu/acre yield goal (LN), and high fertilization at 135 bu/acre yield goal (HN). Nitrogen application for corn is determined by the formula 1.2 lbs/bu x yield goal (bu/acre) – soil test nitrate. Nitrogen was applied as starter and additional sidedressed urea. Starter was applied at 100 lb/acre 0-36-13 on 0N plots, 7-36-13 on LN, and 14-36-13 on HN. Soybean fertilization was starter only. Phosphorus and potassium fertilization was equal among 0N, LN, and HN; only N level differed among fertilizer treatments.

All plots receive the same herbicide and pesticide treatment, and typically are chisel plowed in the fall. The seedbed is prepared each spring using a tandem disk and field cultivator. Other management details are contained the paper by Pikul et al. in this farm report.

Nitrogen mineralization was tracked throughout the growing season. Disposable Falcon filtration units were filled with 30g dry weight soil plus 30g silica sand. Units were kept moist and incubated in a variable-temperature incubator that tracked the temperature in surface soil under a crop canopy. Filtration units were leached with 100 ml 0.025 M $CaCl_2$ every 2-3 weeks from 1 day prior to planting (April 29) through November 4, (day 189). Nitrate and ammonium were analyzed on a Lachat Instruments (Milwaukee, WI) autoanalyzer using the Cd reduction column procedure (Zellweger Analytics, 1992). Substrate-induced respiration was used to estimate soil microbial biomass (Anderson and Domsch, 1978). Soil samples are allowed to rest at room temperature for 2 weeks, then a nutrient broth was added and vials were capped (Smith et al., 1985). Addition of the nutrients stimulated microbial activity and respiration of carbon dioxide, which was measured with a gas chromatograph. The rate of respiration is dependent upon the initial microbial biomass. Dehydrogenase

[2] Microbiologist , USDA-ARS, located at Morris, MN, lcboggs@mail.mrsars.usda.gov
[3] Soil scientist, USDA-ARS, located at Brookings, SD, jpikul@ngirl.ars.usda.gov.

enzyme activity indicates the current level of microbial activity. A reduction-oxidation reaction catalyzed by dehydrogenase was measured using a Dynatech MR5000 microtiter plate-scanning spectrophotometer (Tabatabai, 1994). Ammonium oxidizing bacteria populations were estimated using a most-probable-number procedure. Serial dilutions of soil were supplied with ammonium. Ammonium oxidation to nitrite was evaluated with a color test (Schmidt and Belser, 1994).

Statistical analysis was completed using SYSTAT 7.0 General Linear Models. Because of the split-plot design and analysis, hypotheses of rotation effects were tested using whole plot effects (rotation x block) as the error term.

RESULTS AND DISCUSSION

Microbial biomass and activity were affected by level of fertilization. Measures of total microbial activity, biomass, and microbe-available substrate declined with increasing fertilizer application.

Dehydrogenase enzyme measurement indicates microbial intracellular oxidation activity. This measure of general microbial activity shows a significant decline in plots receiving the highest level of N fertilizer (Fig. 1). Dehydrogenase activity was not significantly affected by rotation. Total microbial biomass as measured by substrate-induced respiration was also significantly lower in the high-fertilizer plots (Fig. 2). Biomass was also not significantly affected by rotation.

It is often assumed that, within any given crop rotation, increasing crop biomass production will enhance microbial populations and activity. Higher levels of fertilization generally increase crop growth. Increased above-ground biomass is usually supported by increased below-ground biomass (root mass) and provides more residue, thereby increasing nutrient input to the soil. Microbial communities are strongly affected by readily available supplies of nutrients.

However, increasing fertilization can have other effects on the soil and crop besides increasing crop biomass. Since samples were taken in 1998 prior to planting and fertilization, the effects seen are the result of the previous 8 years of management rather than immediate effects of more or less fertilization. Fertilization can cause a "priming effect" that actually decreases the amount of available nutrients in the soil over the long term. Increasing the supply of available nutrients, especially N, causes a rise in microbial activity. In order to support this increased metabolism, other nutrients such as carbon and phosphorus are mineralized from the soil. Unfortunately, microbes are not very efficient in their use of carbon. For every one unit of N assimilated by microbes, they require twenty to thirty units of carbon, most of which is released to the atmosphere as carbon dioxide. Thereby, increasing microbial activity by adding N without additional carbon leads to a net decrease in the level of soil carbon, which is often the element most limiting to stable microbial populations. It is ironic that increasing short-term nutrients can decrease long-term nutrients, and increasing short-term microbial activity can decrease the soil's capacity to support microbial activity and biomass in the long term.

Initial nitrate in soil samples was not affected by level of fertilization (Fig. 3). Corn-soybean-wheat/alfalfa-alfalfa rotation contained significantly more nitrate than the other rotations overall. Level of nitrate in initial samples was determined primarily by crop rotation, population of ammonium-oxidizing bacteria, and soil C:N ratio (regression model r^2 = 0.810).

Nitrogen mineralized over the growing season, however, was affected by level of fertilization. Average N mineralized was greater in the 0N treatment than in the LN treatment, but not statistically greater than mineralization in the HN treatment (Fig. 4). In the 4-yr rotation, N mineralization was significantly greater than in the 2-yr and 1-yr rotations. Nitrogen mineralization is a microbial activity, dependent on the amount of readily degradable N-containing material and any other factors that may limit microbial activity. Regression analysis showed the most important factors in determining N mineralization to be initial nitrate (governed by crop rotation, ammonium-oxidizing bacteria, and soil C:N) and soil pH (r^2 = .849). The effects of source material, specific bacterial populations, and soil chemistry are evident in this model. Initial nitrate and pH were better predictors of total N mineralization in HN treatments (r^2 = 0.834) and LN treatments (r^2 = 0.945) than in 0N treatments (r^2 = 0.783).

CONCLUSIONS

Fertilization decreased overall microbial activity and biomass. Fertilization significantly affected N mineralization, but in a different pattern. Nitrogen mineralization is the result of microbial activity on available organic matter. The types of microbial activities and populations resulting in nitrogen mineralization may not significantly affect total microbial activity or biomass measures.

Soil spring nitrate was affected in this study primarily by rotation and ammonium-oxidizing bacteria, and was not affected by fertilization level. A model including initial nitrate and pH was overall a good predictor of seasonal N mineralization, but was less accurate predictor in 0N plots. Spring nitrate tests may be less accurate predictors of nitrogen availability on organically managed fields.

REFERENCES

Anderson, J.P.E., and K.H. Domsch. 1978. A physiological method for the quantitative measurement of microbial biomass in soils. Soil Biology and Biochemistry. 10:215-221.

Schmidt, E.L., and L.W. Belser. 1994. Autotrophic nitrifying bacteria. p. 159-177. *In* R.W. Weaver et al. (ed.) Methods of soil analysis: Part 2 Microbiological and biochemical properties. SSSA, Madison, WI.

Smith, J.L., B.L. McNeal, and H.H. Cheng. 1985. Estimation of soil microbial biomass: an analysis of the respiratory response of soils. Soil Biology and Biochemistry. 17:11-16.

Tabatabai, M.A. 1994. Soil Enzymes. p. 775-834. *In* R.W. Weaver et al. (ed.) Methods of soil analysis: Part 2 Microbiological and biochemical properties. SSSA, Madison, WI.

Zellweger Analytics. 1992. Nitrate in 2M KCl soil extracts. QuickChem method 12-107-04-1-B. Zellweger Analytics, Inc., Lachat Instruments Div., Milwaukee, WI.

Fig. 1.

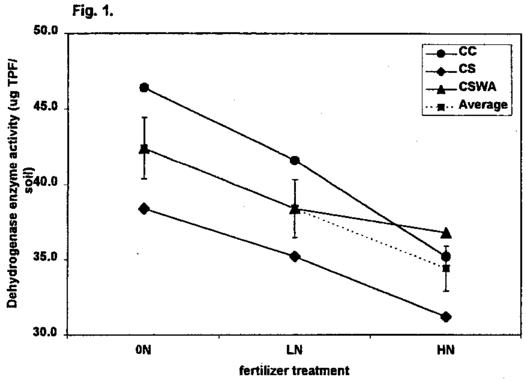


Fig. 2.

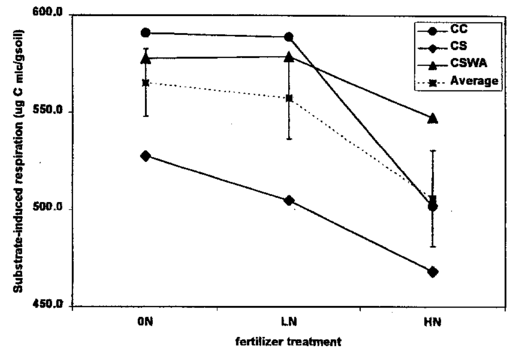


Fig. 3.

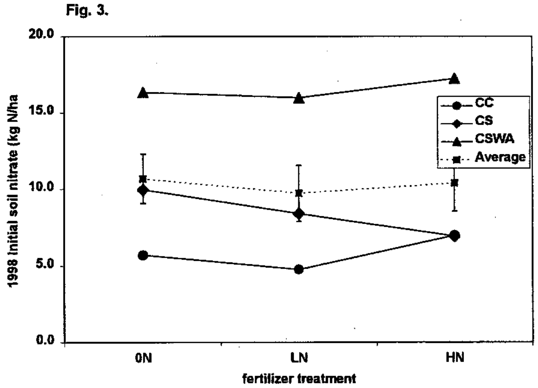
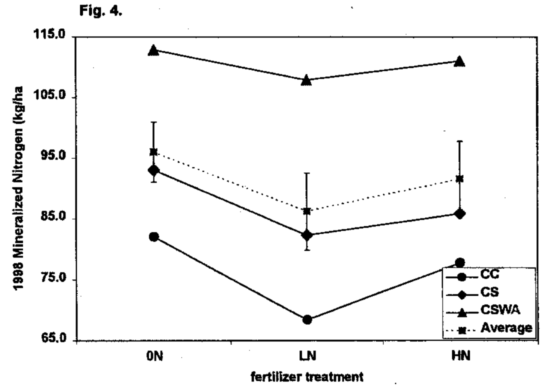


Fig. 4.



LARVAL AND ADULT CORN ROOTWORM SAMPLING BY CROP ROTATION AND NITROGEN FERTILIZATION LEVEL

Leslie Hammack, Jan J. Jackson*, and Joseph L. Pikul, Jr.
USDA-ARS Northern Grain Insects Research Laboratory
*Pioneer HiBred International

Crop rotation is a good defense against corn rootworm feeding damage because eggs laid in summer usually hatch the next spring to larvae needing corn to survive. Rotation is not always practiced, however, and some northern and western corn rootworm populations have adapted to survive 2-year rotations by, respectively, extending the egg stage for a second winter and by laying eggs in soybeans instead of corn. These adaptations may further increase pesticide applications for rootworms, which already account for nearly 20% of the insecticide applied to U.S. field crops. Better ways are needed to detect the existence and spread of these adaptations and to monitor rootworms where insecticides are now routinely applied without knowledge of pest populations.

The widespread prophylactic use of soil insecticides has undoubtedly developed because of difficulties associated with monitoring rootworm populations, especially the larval populations which are primarily responsible for crop damage. Standard larval monitoring techniques require the handling of large soil volumes, although a few early researchers focused on larval recovery from just the corn root system. The latter strategy is receiving renewed interest and, in addition to the above applications, could facilitate testing of transgenic corn lines for toxicity and palatability to rootworms.

Here, we report preliminary results from tests that were started in 1998 and that compared larval recovery from the corn root system with cumulative adult emergence data. Sampling was done on research plots that allowed determination of corn rootworm populations in relation to crop rotation and soil nitrogen levels.

MATERIALS AND METHODS

The study was conducted at the Eastern South Dakota Soil & Water Research Farm in Brookings, where the soil is a Barnes clay loam (fine-loamy, mixed Udic Haploboroll, formerly Vienna loam). Naturally occurring corn rootworm populations were sampled in 100' x 100' corn subplots that were part of a long-term crop rotation and nitrogen (N) fertilizer experiment. Rotation and nitrogen level treatments for this larger experiment were laid out in a split plot design with 3 replicates (blocks) and all crop phases present yearly since 1990. No soil insecticide was applied.

Rotation plots sampled for corn rootworm larvae and adults were 1) **continuous corn**, 2) **2-year** corn-soybean, and 3) **4-year** corn-soybean-wheat interseeded with alfalfa-alfalfa. Corn (Pioneer 3751) was planted April 30, 1998 at the rate of 29,620 seeds per acre in 30" wide rows.

Nitrogen subplots within each rotation were 1) **high N** fertilized to achieve a corn yield goal (YG) = 135 bu/acre, 2) **intermediate N** fertilized to achieve a corn yield of 85 bu/acre, and 3) **low N** without added N. The nitrogen prescription (NP) was calculated as 1.2(YG) - (N from soil nitrate), where soil nitrate was sampled to 4' in 1997 and 1998. Starter applications were 100 lb/acre 14-36-13 (high N subplot), 7-36-13 (intermediate) and 0-36-13 (low). A side dress of urea (46-0-0) was made June 25, 1998 to meet NP just before the second cultivation.

Rootworm larvae were sampled in root systems dug with a spade between May 28 and June 22, when the sampled corn plants were in leaf stage 2-4 to 6-8. Sample size was 12 and 4 plants/subplot/sample date for continuous and rotated corn, respectively. After soil was removed with a pressure hose, roots were dried in open-bottomed containers positioned above water traps where larvae were collected for counting. The containers were held in a greenhouse cooled below about 80°F. during drying. Two drying methods were used: one with small containers and heat from overhead light bulbs and the other with larger containers and no added heat. The first method was used in all tests and was compared with the second method in one experiment which sampled three continuous corn subplots.

Small containers were 1.5"-diam. x 1.75"-deep pots comprising 73-pot, black, polyethylene, growing trays (12" x 20", Growing Systems, Inc. Milwaukee, WI). Pots were positioned just above the water level in 37-ml (1.5 oz) Dixie portion cups. The large containers were 2.5"-diam x 10"-deep black plastic seedling pots (volume of 40 cu. in., Deepot™ supplied by Hummert, Earth City, MO), each with five bottom drainage holes. The larger pots were positioned over 5-oz. collecting cups that served as water traps. The water in collecting cups was about 0.5 inch deep, regardless of cup volume.

Larvae were collected daily from water traps until recovery ceased (2-4 days of drying). Head capsule widths were measured to determine larval stage. Larvae were stored frozen for species determination at a later time.

Adult beetles were trapped as they emerged from the soil in four cages per continuous corn subplot. Each cage, 24" long x 30" wide, covered the roots of three corn plants and extended 15" to each side of a corn row. Beetles, removed from cages every 3-4 days through peak emergence and every 6-8 days later in the season, were counted by species and sex.

Larval recovery and adult emergence data were transformed [ln(x+1)] to equalize variances before statistical scrutiny by analysis of variance.

RESULTS AND CONCLUSIONS

Northern corn rootworm (NCR) adults began to emerge from 1998 continuous corn subplots slightly earlier than did the western corn rootworm (WCR) and outnumbered the latter species by about 2 to 1 (Figs. 1-4). While this 2:1 ratio has persisted on the farm since 1996, total rootworm numbers were at least 2 or 3 times higher in 1998 than in 1996 or 1997 and sufficient to cause lodging and goose necking in all continuous corn subplots.

There was a tendency for higher WCR recovery with increased nitrogen level, that is, about 50% more WCR adults emerged from high than low nitrogen subplots (Fig. 1). Despite this tendency, the number of adults emerging from the soil did not vary enough with nitrogen level (or block) in either species that the variation could be attributed to factors other than chance alone (F = 0.94 and 1.22 for WCR and NCR, respectively, df = 8/35, P > 0.3).

Rootworm larvae were found in notable numbers only in continuous corn (Fig 5), where they increased steadily as corn developed from 3- to 7-leaf stage (Fig. 6). Thus, there was no evidence for adaptation to corn-soybean rotation, despite survival of NCR eggs for two winters in some South Dakota populations and WCR egg laying in soybeans in Illinois and Indiana where corn-soybean rotations are prevalent.

Nitrogen fertilization level did not significantly affect the number of rootworm larvae recovered from corn root systems (Fig. 7), but there was more variation in recovery among blocks than could be explained by chance alone (Fig. 8, F = 4.14, 7.51, 14.93, and 3.71 at Julian day 154, 160, 166 and 173, respectively, df = 2/103, P < 0.03). As already noted, this block effect in larval numbers was not reflected in cumulative adult emergence data (Fig 2). This discrepancy remains to be resolved. It might relate to earlier development in block 3, which sloped slightly to the south and may have produced warmer soil temperatures sooner in the season. This possibility is suggested by the plateau in larval numbers reached in block 3 but not blocks 1 or 2 during the course of the 1998 experiments. Soil temperature measurements will be taken in 1999 to examine this hypothesis.

Average number of larvae per plant root ±SE*

Subplot number	Small containers heat	Large containers no heat
101	3.2 ± 0.9	6.0 ± 1.6
316	6.3 ± 1.2	11.8 ± 1.8
318	4.7 ± 0.8	10.8 ± 2.1
Pooled	4.7 ± 0.4	9.5 ± 1.1

*based on 12 plants per subplot and recovery method dug June 22, 1998 (Julian day 173)

A comparison of the two root drying methods (below) indicated that the use of the larger containers without heat approximately doubled the number of larvae recovered from roots sampled when corn plants were in the 6- to 8-leaf vegetative stage. By this stage, roots totally filled the small containers. Additional tests are needed to optimize larval recovery.

One advantage of the root system method of sampling is the ability to recover relatively high proportions of 1st stage rootworm larvae from young corn plants (Figs. 9 and 10). These young larvae are too small to cause extensive root damage but indicate an imminent problem soon enough for rescue treatment, potentially avoiding the routine application of soil insecticide at planting without knowledge of rootworm populations. Sampling for rootworm larvae in the root system of corn plants is a relatively easy and potentially useful population monitoring technique, even though the technique can clearly be improved and methods to differentiate between species in the larval stage could facilitate data interpretation. Larvae were easy to count floating in the water traps, which collected little debris.

Before larval sampling from corn root systems can be recommended for population monitoring, it will be necessary to establish that larval recovery rates are consistently correlated with actual rootworm densities. Tests are planned in 1999 to examine the relationship between rates of infestation with WCR eggs and recovery of WCR larvae from root systems.

ACKNOWLEDGMENTS

We thank Sherri Brende, Janet Fergen, David Harris, Max Pravecek, and Nichole VandeWeerd for excellent technical assistance.

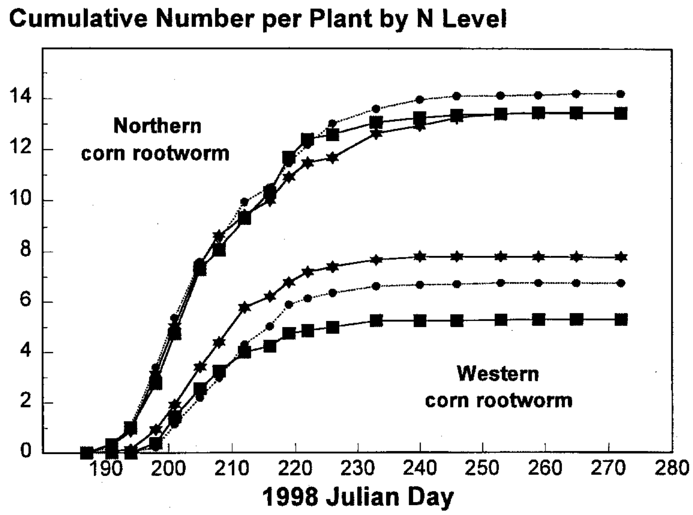
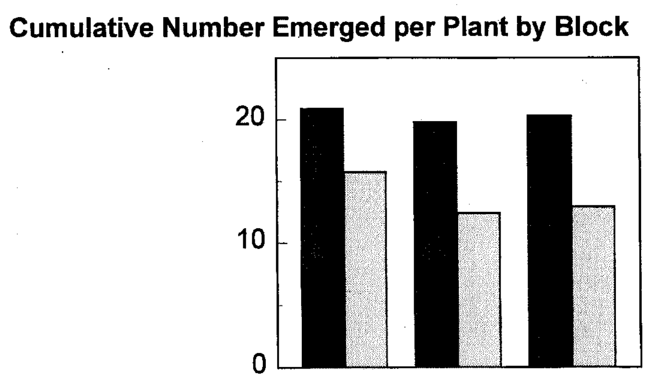


Fig. 1. Cumulative emergence by species of corn rootworm adults from continuous corn by nitrogen (N) fertilization level (■ low N, ● intermediate N, ✱ high N)



	Block 1	Block 2	Block 3
WCR and NCR ■	20.90	19.80	20.30
NCR □	15.75	12.39	12.92

Fig. 2. Seasonal emergence of northern (NCR) and western (WCR) corn rootworm beetles by block.

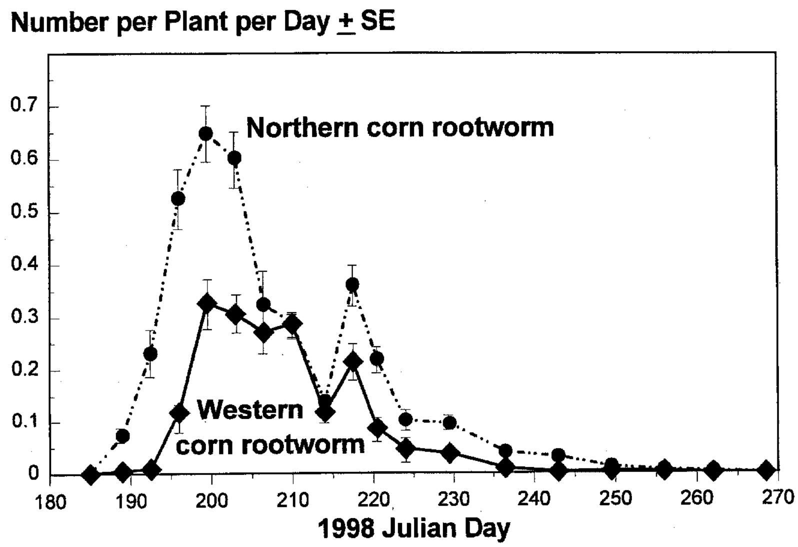


Fig. 3. Daily emergence by species of corn rootworm adults from continuous corn. [Julian days 185 and 230 = July 4 and August 18, respectively]

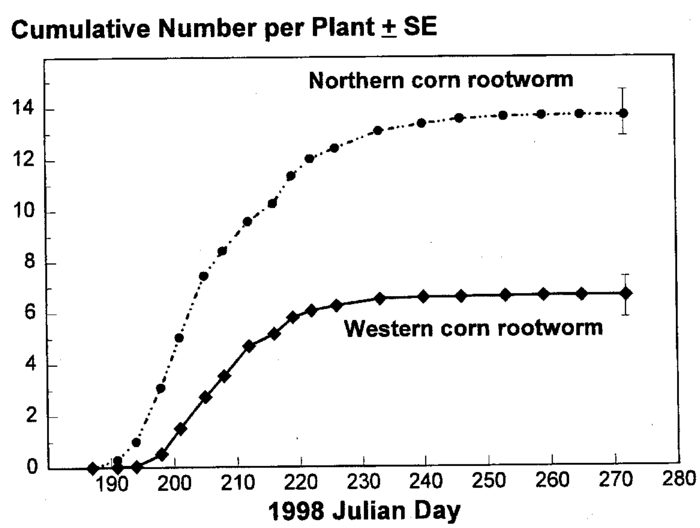


Fig. 4. Cumulative emergence by species of corn rootworm adults from continuous corn [Julian days 185, 230, and 272 = July 4, August 18, and September 29, respectively]

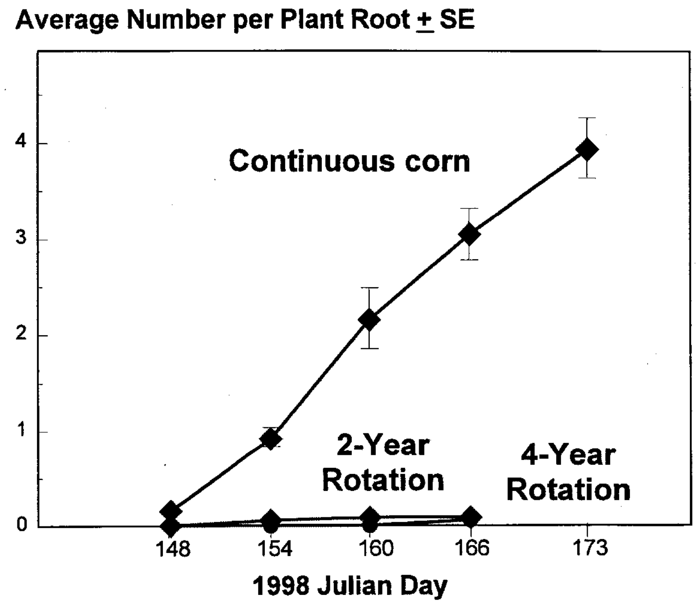


Fig. 5. Recovery of corn rootworm larvae from corn roots by crop rotation. [Julian days 148 and 173 = May 28 and June 22, respectively]

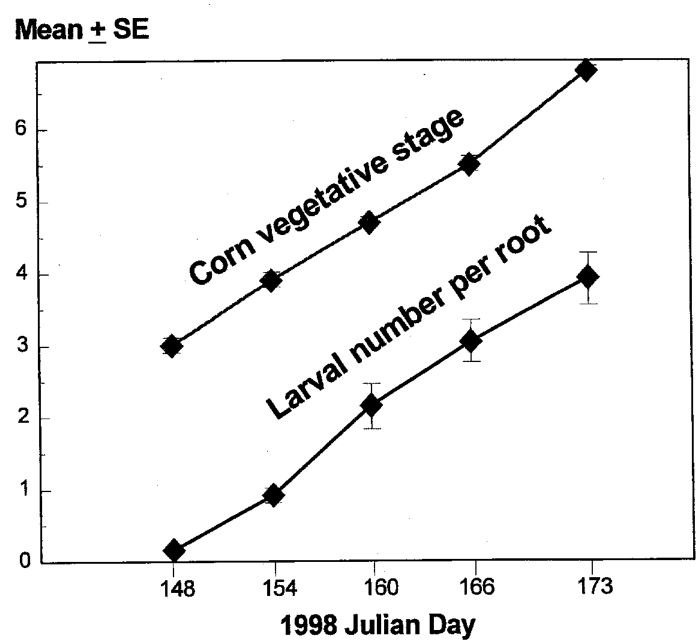


Fig 6. Relationship between continuous corn phenology (leaf number) and recovery of corn rootworm larvae. [Julian days 148 and 173 = May 28 and June 22, respectively]

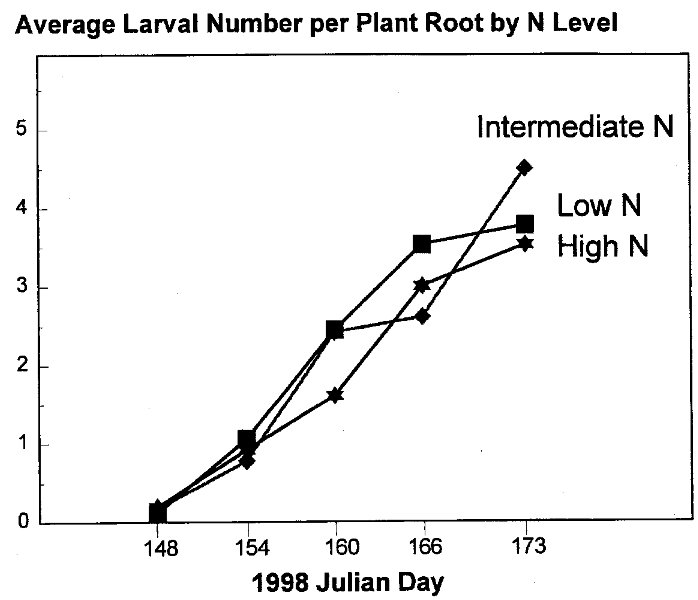


Fig. 7. Recovery of corn rootworm larvae by date and nitrogen (N) level [Julian days 148 and 173 = May 28 and June 22, respectively]

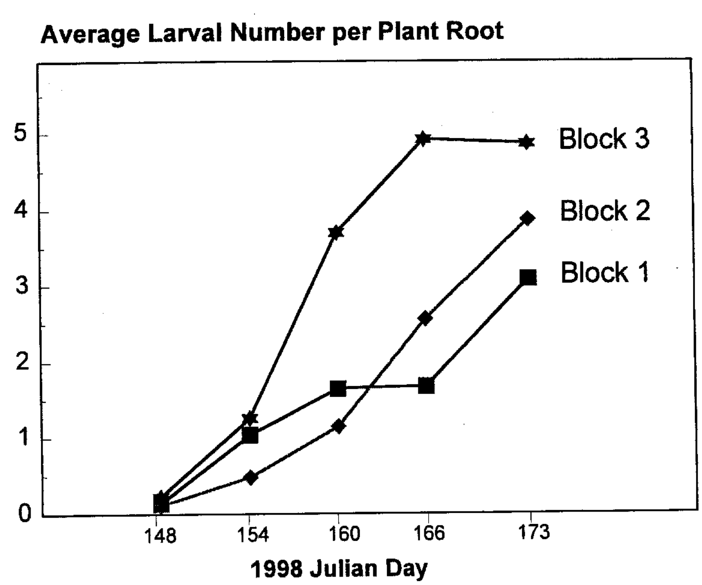


Fig. 8. Recovery of corn rootworm larvae by date and block. [Julian days 148 and 173 = May 28 and June 22, respectively]

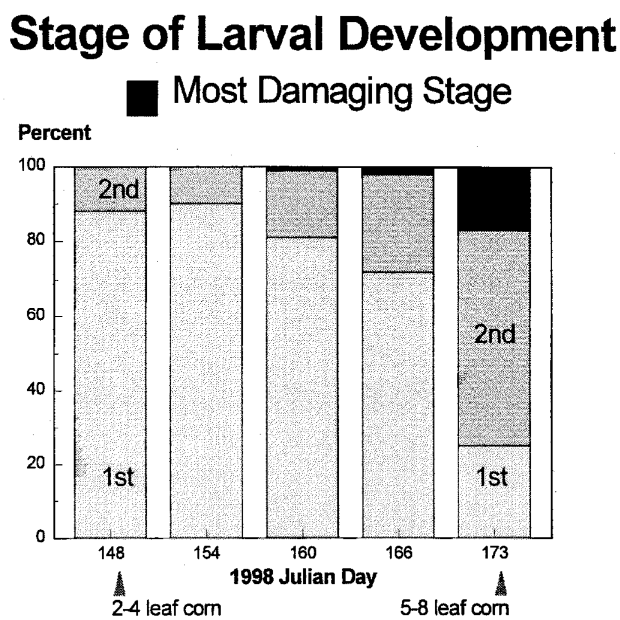


Fig. 9. Abundance of corn rootworm larval stages by sample date
[Julian days 148 and 173 = May 28 and June 22, respectively]

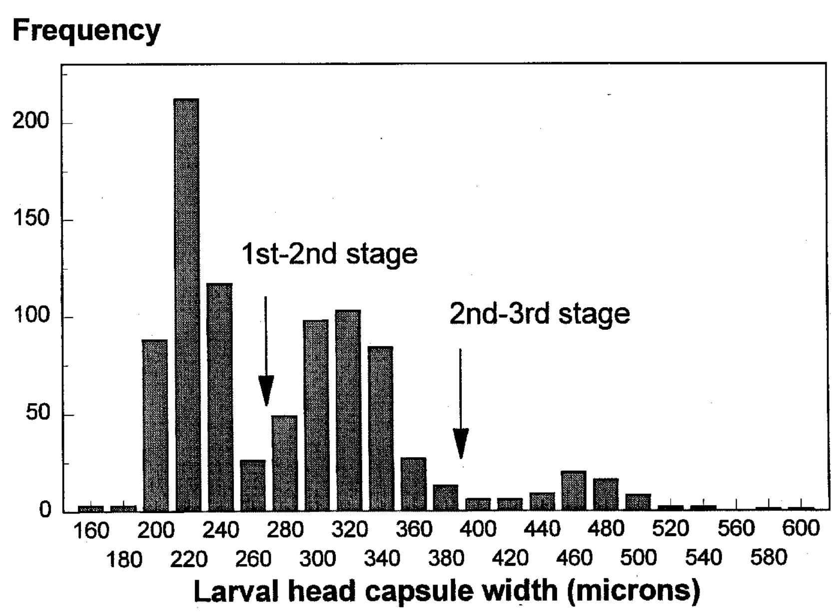


Fig. 10. Frequency distribution of head capsule widths among recovered corn rootworm larvae and dimensions used to differentiate between stages (arrow)
[1/64 inch =397 microns]

CORN ROOTWORM EGG NUMBERS BY NITROGEN FERTILIZATION LEVEL

Leslie Hammack, W. David Woodson, and David Beck
USDA-ARS Northern Grain Insects Research Laboratory

One research objective at the Eastern South Dakota Soil and Water Research Farm is to evaluate the influence of crop management practices on the abundance of insect populations. In common with many insect pests, corn rootworm population levels tend to fluctuate for reasons that are often poorly understood. Here, we present corn rootworm egg numbers recovered during three consecutive years in continuous corn treated with varying levels of nitrogen (N) fertilizer.

MATERIALS AND METHODS

The study was conducted at the Eastern South Dakota Soil & Water Research Farm in Brookings, where the soil is a Barnes clay loam (fine-loamy, mixed Udic Haploboroll, formerly Vienna loam). Naturally occurring corn rootworm populations were sampled in 100' x 100' corn subplots that were part of the long-term crop rotation and nitrogen (N) fertilizer experiment. Rotation and nitrogen level treatments for this larger experiment were laid out in a split plot design with 3 replicates and all crop phases present yearly since 1990. No soil insecticide was applied.

Each of three continuous corn plots was divided into subplots on the basis of nitrogen treatment. Nitrogen subplots were 1) high N fertilized to achieve a corn yield goal (YG) = 135 bu/acre, 2) intermediate N fertilized to achieve a corn yield of 85 bu/acre, and 3) low N without added N. The prescription for added N was calculated as 1.2(YG) - (N from soil nitrate).

Soil samples were taken from each subplot and examined for rootworm eggs in the spring and fall of 1996, 1997 and 1998 (May 20 and Oct 21, 1996; May 12 and October 22, 1997; and May 4 and September 21, 1998). On each sampling date, four 5"-deep soil cores were removed from each nitrogen subplot. The volume of each core was 1.1 liters (1.16 qts.) Fall samples were taken between plants within corn rows. Once washed from the soil, the eggs were identified as northern (NCR) or western corn rootworm (WCR) based on chorion ('egg shell') morphology.

Data are expressed as the total number of eggs recovered per nitrogen subplot (number in 4.4 liters of soil). The data were transformed [$\ln(x+1)$] to normalize variances before statistical examination with analysis of variance.

RESULTS AND CONCLUSIONS

Mean recovery of eggs from the three continuous corn plots is presented in Fig. 1 by nitrogen fertilization level for spring and fall samples. N fertilization level did not significantly influence NCR egg numbers in either the spring or fall soil samples (respectively, $F =$ 0.49 and 2.46, $P = 0.62$ and 0.11, df = 2/18). In the WCR, a statistically meaningful effect of N fertilization level on egg numbers occurred in the spring but not the fall ($F = 7.21$ and 0.48, $P = 0.005$ and 0.63 for spring and fall, respectively, df = 2/18).

In the WCR spring samples, egg numbers tended to be depressed in the low N subplots, compared with the intermediate and high N subplots; indeed, WCR eggs were detected in the low N subplots in only one of the three test years (1997, Fig. 1). This WCR spring egg pattern is consistent with the tendency, not always statistically significant, for lower WCR adult emergence from low N subplots, a tendency noted in other annual farm reports for this and past years. Although relatively few WCR eggs were detected in low N subplots in the fall of 1998, the fall egg data for 1996 and 1997 do not support the conclusion that low spring egg numbers in low N subplots were caused by reduced egg laying in these subplots the previous summer/fall. Instead, the data suggest that eggs initially present in the fall tended to be lost over the winter months at a greater rate from the low than from the intermediate and high N subplots.

Egg numbers varied significantly among years in both the spring and fall for NCR (respectively, $F =$ 22.66 and 3.83, $P < 0.0001$ and = 0.04, df = 2/18), but not for WCR in either season ($F \leq 1.46$, $P \geq 0.26$, df = 2/18). In neither species nor season was there any indication of interaction between year and N fertilizer level, so these factors operated independently of one another ($F \leq 1.48$, $P \geq 0.5$, df = 4/18).

It is interesting to note that the large increase in NCR egg load seen during the course of these tests occurred between the spring and fall of 1997, suggesting that the increase was not related to overwinter survival. NCR spring egg loads were similar in 1996 and 1997 (Fig. 1) but, because adult emergence was about twice as high in 1997 as 1996 (see Woodson et al. 1997 farm report), conditions during the spring of 1997 appear to have been especially favorable for NCR larval/pupal survival.

High NCR egg numbers and adult emergence in the spring of 1998 suggest that the fall 1998 drop in NCR egg numbers resulted from reduced adult reproduction (or NCR migration to other sites for reproduction). These data would predict that rootworm numbers will likely decline in 1999 compared with 1998.

Data are pooled across N fertilizer levels in Fig. 2 to better contrast NCR with WCR egg numbers. NCR eggs were clearly recovered in higher numbers, which is consistent with higher NCR adult populations typical of the last 3 years. Nevertheless, for each egg recovered, more adult WCR than NCR emerged. For example, the species egg ratio was about 1 WCR/50 NCR in the spring of 1998, but the adult emergence ratio approximated 1 WCR/2 NCR. Thus, we recovered many fewer NCR adults (or many more WCR adults) than would be predicted from relative egg numbers. Although very high mortality of immature NCR compared with WCR could explain this discrepancy, it is more likely that our egg sampling procedures favored recovery of NCR eggs. This bias would be expected in the fall when soil samples were taken within corn rows, although not in the spring after chisel plowing, because of the greater tendency of NCR than WCR to lay their eggs very close to the base of corn plants (Ruesink, 1986).

REFERENCES

Ruesink, W.G. 1986. Egg sampling techniques, pp. 83-99. *In*: Methods for the study of pest *Diabrotica*, J.L. Krysan and T.A. Miller (eds.). Springer-Verlag, New York.

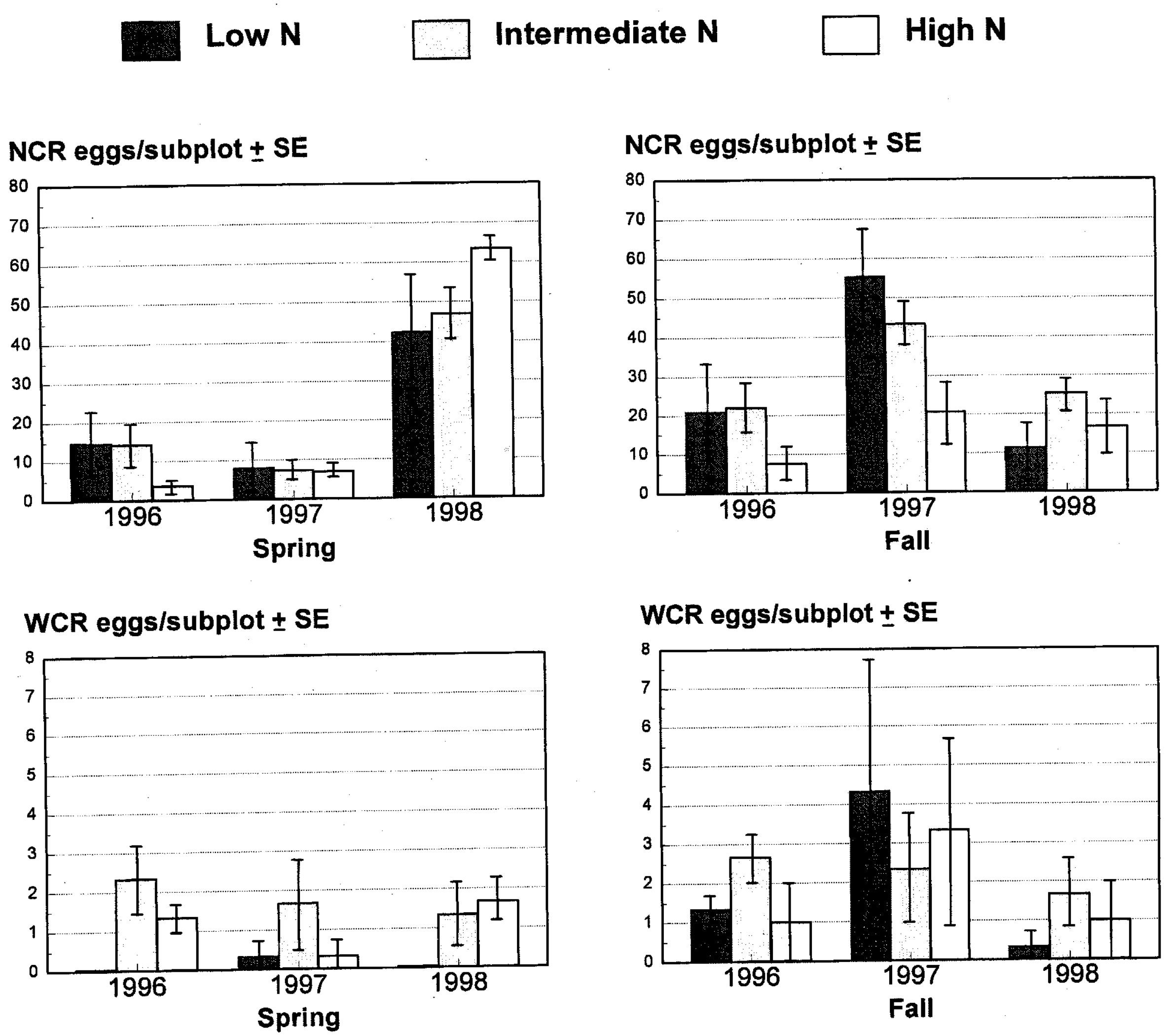


Fig. 1. Recovery of northern (NCR) and western (WCR) corn rootworm eggs in four samples per subplot by subplot nitrogen (N) level, season, and year

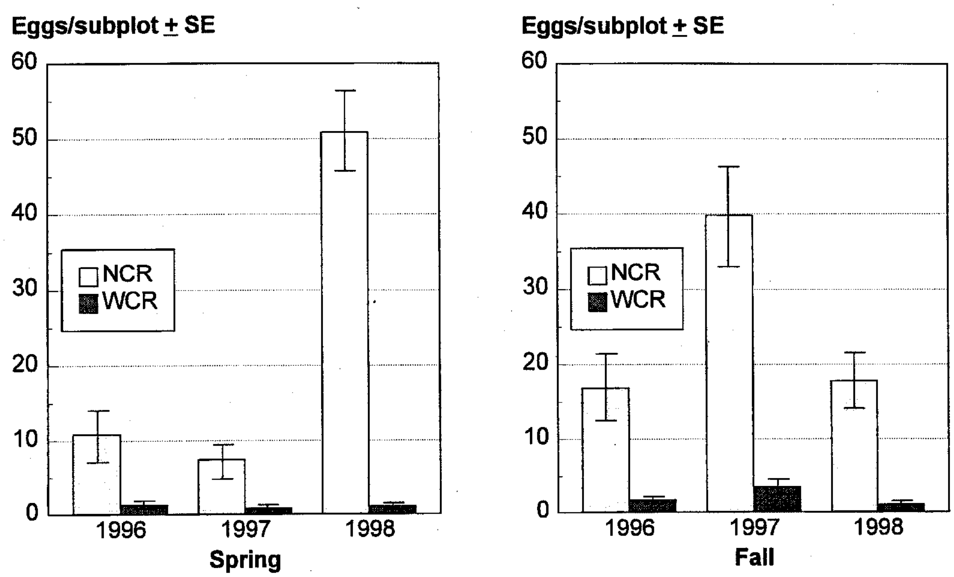


Fig. 2. Recovery of northern (NCR) and western (WCR) corn rootworm eggs in four samples per subplot by season and year. Data are averaged across nitrogen fertilization levels (N = 9 subplots per year and season).

BEAN LEAF BEETLE AND NORTHERN CORN ROOTWORM POPULATIONS IN ROTATED SOYBEANS -1998

Larry Chandler, Research Entomologist
USDA-ARS, Northern Grain Insects Research Laboratory

There are numerous species of insects that can be found inhabiting South Dakota soybean fields. Many of these insects feed on foliage, flowers, and pods throughout the growing season. Fortunately, large numbers of these pests must be present before economic losses occur. Economic losses rarely occur in South Dakota. A common insect pest found on soybean in our area is the bean leaf beetle, *Cerotoma trifurcata.* This small (1/4 inch long) reddish brown to pale yellow beetle can attack soybeans at any plant growth stage. Early season bean leaf beetle infestations sometimes cause significant stand loss in many midwestern states. Leaf feeding by these insects in later plant growth stages can cause some defoliation, resulting in plant stress and possible yield loss.

Another insect that is commonly found on soybeans during the latter part of the growing season is the northern corn rootworm, *Diabrotica barberi.* This small green beetle is primarily a pest of corn but can be seen frequently feeding on soybean flowers. Little damage is caused by this pest on soybeans. However, the fact that the insect is found in the crop needs to be better documented so that a basis of understanding of it's complex ecological behavior can be developed. It could be possible that northern corn rootworms feeding in soybean may also lay eggs in the crop. These eggs could hatch in the following growing season when corn is planted in the same field.

The purpose of this study was to determine the seasonal population dynamics of bean leaf beetles and northern corn rootworm adults on soybean grown in rotation with other crops. Effects of fertilizer level, tillage method, or crop rotation on insect populations were evaluated.

METHODS

Soybean grown in a crop rotation/nitrogen fertilizer experiment were sampled weekly beginning on 17 July and continuing through 24 August 1998. The soybeans were grown in a corn-soybean rotation using either ridge or chisel plow tillage methods or in a corn-soybean-alfalfa-wheat rotation using chisel plow ground preparation. Three levels of fertilizer inputs were applied to the rotations. Starter fertilizer was placed on all plots at planting as follows: 100.7 lbs./ac 14-36-13 for high input; 100.8 lbs./ac 7-36-13 for intermediate input; and 98.9 lbs/ac 0-36-13 for low input. All soybean plots were treated with Broadstrike and Dual herbicide. In addition, ridge till plots were treated with Roundup. Bean leaf beetles and northern corn rootworm adults were sampled in each plot (27 total plots) using an insect sweep net. Sixty total sweeps per plot in two subsamples (30 sweeps/subsample) were made and the total number of adults of the two species collected in the net counted. Appropriate statistical analyses were used to evaluate the results.

RESULTS

Bean leaf beetles were collected throughout the 6 weeks of sampling. Populations slowly increased through July and early August. Beetle populations peaked between 7 and 24 August, and were more numerous in 1998 than in 1997 or 1996.

Table 1 shows the effects of crop rotational patterns on beetle populations throughout the sampling period. In general, significantly greater numbers of beetles were collected from soybean in the soybean/corn/chisel plow rotational plots during August compared to other rotations. These results are different than those observed in 1997 when greater numbers of beetles were observed in the soybean/corn ridge till plots, but were similar to data gathered in 1996. Beetles populations in 1996 were more similar in number to those observed in 1998 than those observed in 1997. Perhaps rotational effects are more dramatic in years when bean leaf beetle populations are high.

Fertilizer input level had a significant effect on bean leaf beetle numbers in 1998 (Table 1). In 1996 beetle numbers on soybean appeared to be affected by the amount of nitrogen fertilizer present in each plot, with the lowest nitrogen level having the greatest number of insects. Similar results were obtained in 1998. The results from 1997, however, did not support this observation. In 1997 no fertilizer effects were observed. Again, it is possible that high populations of beetles may be more affected by rotational or fertilizer strategies than lower populations. Obviously, a combination of factors, including rotational patterns, plant nutrition, and soil type must be considered when developing a more thorough understanding of the population dynamics of this insect.

Northern corn rootworm adults were found in all soybean plots throughout the sampling period (Table 2). Adults numbers remained low until the week of 7 August and increased through the remainder of the period. Crop rotation patterns and fertility levels did not appear to affect total number of adults collected throughout the period.

CONCLUSIONS

Information gathered on bean leaf beetle population dynamics over the last three years appears to support a general idea that soybean/corn/chisel plow rotations and low fertility inputs may support increased numbers of beetles feeding on soybean in years of high populations. Although this pattern was not obvious in 1997 when populations were low, there were indications that beetles preferred low fertilizer input plots prior to 22 August. Additional information is needed to fully understand the ecology/biology of this insect in South Dakota. We do know, however, that beetle populations peak in late season and are more likely to damage crops at that time than at planting.

Northern corn rootworms were not affected by crop rotational patterns and fertility levels during the last two growing seasons. These insects are unlikely to become a soybean pest since the larval stages cannot survive on soybean roots. There is value, however, in learning more about their preferential feeding sites and the components that attract them to those sites. If behavioral adaptations occur and northern corn rootworms move into soybean in large numbers late in the growing season, changes in the manner in which we manage these pests could occur. Large numbers of rootworm adults inhabiting soybean in late August and September could lay substantial numbers of eggs which could result in damage to the following year's corn crop. A better understanding of the mechanisms governing rootworm movement into soybean could provide for the development of long term management strategies to prevent or minimize possible adaptations.

ACKNOWLEDGMENT

Cecil Tharp is acknowledged for his effort in data management and analysis. Special thanks are also extended to Max Pravecek and Dave Harris for plot management.

Table 1. Average number of bean leaf beetles per 30 sweeps on date indicated.

	July 17	July 24	Aug 1	Aug 7	Aug 14	Aug 24
Soybean/Corn/Chisel Plow	1.4	14.7 B	30.5 A	45.7A	30.5 A	47.4 A
Soybean/Corn/Ridge Till	1.4	12.3 B	20.9 B	35.3 AB	26.2 B	34.9 B
Soybean/Wheat/Alfalfa/Corn	2.4 N.S.	20.6 A	25.5 AB	30.2 B	20.1 C	24.9B
High Fertilizer Input	1.2	9.4 B	15.4 C	22.6 B	17.0 C	27.9 B
Intermediate Fertilizer Input	1.9	16.8 A	26.2 B	35.3 B	25.6 B	36.0 AB
Low Fertilizer Input	2.3 N.S.	21.3 A	35.3 A	53.3 A	34.2 A	43.3 A

Means in a column per rotation or fertilizer input level followed by the same letter are not significantly different ($\underline{P} \leq 0.05$, Tukey's HSD Test). N.S. indicates no significant differences.

Table 2. Average number of northern corn rootworm adults per 30 sweeps on date indicated.

	July 17	July 24	Aug 1	Aug 7	Aug 14	Aug 24
Soybean/Corn/Chisel Plow	0.5	0.2	1.4	1.1 B	4.2	6.9
Soybean/Corn/Ridge Till	0.6	0.2	1.1	1.5 AB	4.7	6.5
Soybean/Wheat/Alfalfa/Corn	0.5 N.S.	0.4 N.S.	0.8 N.S.	3.7 A	3.3 N.S.	6.9 N.S.
High Fertilizer Input	0.4	0.2	1.1	1.4	4.9	6.0
Intermediate Fertilizer Input	0.4	0.4	0.9	2.0	3.4	7.1
Low Fertilizer Input	0.7 N.S.	0.2 N.S.	1.3 N.S.	2.9 N.S.	3.9 N.S.	7.2 N.S.

Means in a column per rotation or fertilizer input level followed by the same letter are not significantly different ($\underline{P} \leq 0.05$, Tukey's HSD Test). N.S. indicates no significant differences.

EUROPEAN CORN BORER AND CORN ROOTWORM DAMAGE TO CORN GROWN UNDER VARIOUS ROTATIONAL SCHEMES - 1999 RESULTS

Larry Chandler, Research Entomologist
USDA-ARS, Northern Grain Insects Research Laboratory

European corn borer, *Ostrinia nubilalis*, northern corn rootworm, *Diabrotica barberi*, and western corn rootworm, *Diabrotica virgifera virgifera*, are important pests of field corn throughout the United States corn belt. These insects account for millions of dollars in yield loss and control costs each year. To more thoroughly understand the biology/ecology of these pests, field observations are needed to determine if infestation patterns in corn are affected by rotational schemes, tillage methods, or fertilizer use. Therefore, this study was conducted to investigate the occurrence of physical damage symptoms inflicted by European corn borer, northern corn rootworm and western corn rootworm larvae as indicators of the crop production method that most influences the severity of the infestation.

METHODS

Corn grown in a crop rotation/nitrogen fertilizer experiment was sampled for visual signs of European corn borer and corn rootworm (both species combined) damage on 29 September. The corn was grown in four rotational schemes: 1) soybean/wheat/ alfalfa/corn using chisel plow ground preparation; 2) soybean/corn using ridge till ground preparation; 3) soybean/corn using chisel plow ground preparation; and 4) corn following corn using chisel plow ground preparation. Three levels of fertilizer inputs were applied to the rotations. Starter fertilizer was placed on all plots at planting as follows: 100.7 lbs/ac 14-36-13 for high input; 100.6 lbs/ac 7-36-13 for intermediate input; and 98.9 lbs/ac 0-36-13 for low input. A sidedress fertilizer application was applied at 118.5, 66, and 0 lbs/ac of 46-0-0 for high, intermediate, and low input plots, respectively. All plots received herbicide treatments consisting of 3.8 qts/ac Lasso and 2 pts/ac Buctril. Ridgetill plots were also treated with Roundup at 2 qts/ac. In the center two rows of each plot (12 treatments replicated 3 times) 25 plants/row were evaluated for signs of corn borer and corn rootworm damage. Corn borer damage consisted of signs of stalk breakage (with tunneling apparent) and larval exit holes. Corn rootworm damage was evaluated as goosenecked or lodged plants. Data were then subjected to appropriate statistical analyses.

RESULTS

European corn borer damage at the Eastern South Dakota Soil and Water Farm during 1998 was approximately 1/3 the severity in total plants damaged compared to observations made in 1997. Percentage of damaged plants ranged from 6.8 to 17.2% and from 11.2 to 13.2% depending on crop rotational pattern and fertilizer input level, respectively (Table 1). Significantly fewer plants were damaged in the corn/soybean/wheat/alfalfa rotation compared to those in corn/soybean rotations. Fertilizer level did not appear to influence infestations. These results contrast to those observed in 1997 where damage was significantly less in the continual corn and low fertilizer input plots.

Corn rootworm damage was primarily observed in corn on corn plots (Table 2). The percent of goosenecked plants ranged from 0 to 73.6% and from 16.8 to 21.2% depending on crop rotational pattern and fertilizer input level, respectively. The number of goosenecked plants observed in the corn on corn plots was significantly greater than those noted in the other rotations. No differences in the number of corn rootworm damaged plants were noted among fertilizer input levels.

CONCLUSIONS

Many published reports have suggested that European corn borer moths are attracted to taller more mature plants for egg laying during the early growing season. In 1997 the low input fertilizer plants did not grow as quickly or as tall as those in the high and intermediate fertilizer plots. Thus, these plants were probably not as attractive for early season infestations. Since no attempt was made to separate early (1st generation) from late (2nd generation) season damage it is difficult to tell how much damage in low input plots can be attributed to the lack of plant growth and maturity. Populations of European corn borer in 1998 were not as numerous as those of 1997 and did not appear to be affected by plant fertility. Further study is needed to determine the exact influence corn rotational and fertility practices have on the severity of corn borer infestations.

It was not surprising that the continual corn rotational plots had high levels of corn rootworm damage. Western and northern corn rootworm both thrive in corn on corn conditions if they are not managed. In 1997 substantial amounts of damage were observed in corn/soybean rotations. The same physical damage symptoms were not readily apparent in the corn/soybean rotation plots in 1998. At present it appears that rotational patterns have a greater influence on the severity of corn rootworm damage than does fertility.

ACKNOWLEDGMENT

I thank Cecil Tharp for his assistance in data management and analysis. Thanks are also extended to Max Pravecek and Dave Harris for field management of the experiment.

Table 1. Average number of European corn borer damaged plants (out of 25) per rotation or fertilizer level.

	Avg. Number Damaged	%
Corn/Soybean/Wheat/Alfalfa	1.7 B	6.8
Corn/Soybean/Ridge Till	4.3 A	17.2
Corn/Soybean/Chisel Plow	3.9 A	15.6
Corn on Corn	2.6 AB	10.4
High Fertilizer Input	3.3	13.2
Intermediate Fertilizer Input	3.2	12.8
Low Fertilizer Input	2.8 N.S.	11.2

Means in a column per rotation or fertilizer input level followed by the same letter are not significantly different ($\underline{P} \leq 0.05$, Tukey's HSD Test). N.S. indicates non-significance.

Table 2. Average number of corn rootworm damaged (goosenecked or lodged) plants (out of 25) per rotation or fertilizer level.

	Avg. Number Damaged	%
Corn/Soybean/Wheat/Alfalfa	0.3 B	1.2
Corn/Soybean/Ridge Till	0.1 B	0.4
Corn/Soybean/Chisel Plow	0.0 B	0.0
Corn on Corn	18.4 A	73.6
High Fertilizer Input	4.2	16.8
Intermediate Fertilizer Input	5.3	21.2
Low Fertilizer Input	4.7 N.S.	18.8

Means in a column per rotation or fertilizer input level followed by the same letter are not significantly different ($\underline{P} \leq 0.05$, Tukey's HSD Test). N.S. indicates non-significance.

CRIMSON CLOVER INTERSEEDED WITH CORN AND SOYBEAN

T.E. Schumacher, A.A. Boe, W. E. Riedell, and J.L. Pikul Jr.

Introduction

Cover crops can be a useful soil management tool under specific situations where there are problems with soil erosion, water runoff, excess soil nitrate, or excessively wet soils. The choice of cover crop depends on the type of soil problem and the level of competition occurring with the companion crop. Competition is dependent largely on the growth and development patterns of the cover crop and the companion crop.

Originally we planned to examine the characteristics of strawberry clover (*Trifolium fragiferum* L.) because of its ability to form a tight mat of stolons at the soil surface. Strawberry clover has a high tolerance of wet conditions and a tolerance to salinity. We felt that strawberry clover would have characteristics that would make it useful for increasing the bearing strength of small areas in the field that tend to stay wet late into the spring. We have identified a selection of strawberry clover that is winter hardy in South Dakota and has growth characteristics that may limit competition with row crops. However we do not have enough seed for testing at this time. We secured strawberry clover seed from Oregon as an alternative. The clover was seeded in the fall of 1997. The clover grew well but did not survive the winter. We are currently in the process of increasing seed of the South Dakota selection.

We chose to select another clover species to test in the plot area in 1998. Crimson clover (*Trifolium incarnatum* L.) is adapted to warmer climates than South Dakota and is not winter hardy. However it grows quickly in the spring and tends to stop growing during hot dry periods. We felt that these characteristics would make this species useful as ground cover prior to canopy closure of row crops in areas where there is a high potential for soil erosion. While the effect of warmer weather after canopy closure would limit competition with a row crop like corn, competition should be more severe with another legume like soybean. A study was conducted to evaluate the effects of interseeding crimson clover with corn and soybean.

Materials and Methods

Crimson clover was seeded at a rate of 10 lbs/acre. Soybean (*Glycine Max* L.) (Pioneer 9172) was planted at the rate of 198,000 seeds per acre. Corn (*Zea mays* L.) (Pioneer 3883) was planted at 30,000 seeds per acre. Both soybean and corn were planted in 30 inch rows. Fertilizer (14-36-13) was applied at the time of planting at the rate of 100 lbs per acre. The plot area was chisel plowed and disked prior to planting. A half-pint of Fusion was applied on June 22 to the soybean and clover plots. This selectively killed grass weeds that were exceptionally abundant in replication 3 without damage to the crimson clover. Accent was applied to the corn at a rate of 0.67 oz per acre on June 22.

The study was laid out in a randomized complete block design with three replications. Treatments consisted of crimson clover, corn, soybean, clover interseeded with corn, and clover interseeded with soybean. Each plot area had dimensions of forty feet wide and forty feet long. Plots were visually evaluated every week during the growing season. Notes were taken of the progress of the crops and digital photos were taken to document the observed progress of each treatment.

All plots were harvested for biomass on September 16, 1998 by selecting an eight square foot area and removing all above ground biomass in the selected area. A two square foot area was used to evaluate soybean biomass. These samples were also used to determine yield components for the soybean and corn crops. Two subsamples were taken for each treatment-replication combination. A plot combine was used to harvest the soybean and corn plots for grain yield.

Results

Noticeable differences between interseeded and non-interseeded crops were not apparent until the second week in July. At that time there were noticeable differences in row crop height and an apparent nitrogen deficiency in the interseeded treatments. Hot dry weather in July did not seem to reduce the growth of the crimson clover as expected. Significant leaf rolling of the interseeded corn was observed starting the second week in July. Although leaf rolling also occurred on the corn grown alone it was not as severe in duration as the interseeded corn. Crimson clover reduced growth in the corn during August and there was very little evidence of the clover under the corn by the end of August.

Grain yield for corn and soybean are given in Table 1. There is strong evidence of competition between the crimson clover and both crops. However yield reduction appears to be more severe in soybean compared to corn.

Yield components for soybean are given in Table 2. There is considerable effect of crimson clover on all aspects of soybean yield components. A simple evaluation of the yield components in soybean indicate that the greatest effect of crimson clover on soybean yield occurred as a result of a reduction in the number of pods per plant. The effect of crimson clover on corn yield components was less pronounced (Table 3). The primary effect of competition from crimson clover in corn was a reduction in the number of kernels per ear.

Biomass was similar between the soybeans grown alone, the crimson clover grown alone, and crimson clover interseeded soybean treatments (Table 4). Although the interseeding treatment reduced both crimson clover and soybean growth, the total amount of biomass produced on these plots was similar to the amount of biomass produced on the soybean and clover plots. Interseeding with crimson clover reduced corn biomass. The higher amount of biomass on corn plots reflects the advantages of C4 metabolism and a non-nitrogen fixing plant on carbon fixation and utilization.

There appeared to be a severe nitrogen deficiency on the corn in the interseeded treatment. It is likely that a nitrogen deficiency was a primary contributor to reduced yields in interseeded corn. Future work will need to account for nitrogen needs of the cover crop. Although the cover crop was a legume, nitrogen fixed by the crop was not available to the companion crop during the critical part of the growing season. Further evaluation of the interaction between crops would be improved if the cover crop could be selectively removed during the growing season at selected times. We plan to use Round-up ready corn and soybean in a future experiment to facilitate this type of measurement.

Acknowledgments

The authors thank Max Pravecek for his excellent technical support.

Table 1. Grain Yield (bu/a)

Crop	Without Clover	With Clover	P> F *
Corn	117	77	0.012
Soybean	33	17	0.001

* P>F represents the probability that means are not different from each other.

Table 2. Soybean Yield Components

Treatment	Pods/plant	Seeds/pod	100 seed weight
	#/plant	#/pod	lbs/100 seeds
Soybean	23	2.3	0.033
Soybean/Clover	16	2.2	0.032
P>F *	0.001	0.002	0.09

* P>F represents the probability that means are not different from each other.

Table 3. Corn Yield Components

Treatment	Plant Population	Ear length/plant	Kernels/ear	Ears/plant	100 seed wt.
	plants/acre	in	#/ear	#/plant	lbs/100 seed
Corn	28,400	6.3	485	0.94	0.050
Corn/Clover	27,900	5.5	333	0.90	0.049
P>F *	0.84	0.15	0.07	0.59	0.63

* P>F represents the probability that means are not different from each other.

Table 4. Above Ground Biomass

Treatment	Clover Biomass	Corn Biomass	Soybean Biomass	Total Biomass
	lbs/acre			
Corn	-	12,263	-	12,263
Corn + Clover	602	8500	-	9124
Soybean	-	-	3267	3267
Soybean + Clover	1167	-	1893	3127
Clover	3529	-	-	3529
P>F *	0.0001	0.029	0.0001	0.0001
$LSD_{.05}$	561	-	-	2631

* P>F represents the probability that means are not different from each other.

INSECT PESTS IN SPRING SMALL GRAINS

Louis S. Hesler, Research Entomologist
USDA-ARS, Northern Grain Insects Research Laboratory

INTRODUCTION

A variety of insect pests can infest small grain fields in South Dakota and cause direct yield loss. Little is known of how tillage practices may affect levels of these pests. The purpose of our research was to compare population levels of cereal aphids and grasshoppers in spring barley plots under conventional versus conservation tillage. Surveys for wheat stem maggot, orange wheat blossom midge, and cereal leaf beetle were also conducted in spring small grains.

METHODS

Cereal aphids were counted in conventionally tilled (CT) and conservation tillage / non-tilled plots (NT) of barley. Tillage treatment plots within each rotation were replicated two times. Twenty-five stems (tillers) were sampled per replication every 3 to 4 days from April 28 through May 29, 1999. The mean number of cereal aphids per plot was calculated for each tillage treatment in each rotation study. The cumulative number of aphid days was tallied and compared by *t*-test between tillage treatments.

Grasshoppers were sampled in barley plots on June 29 by counting the number of adults and nymphs within a square yard area. Grasshoppers were counted in four areas per plot.

Surveys were conducted in spring grains for wheat stem maggot on June 24, and for orange wheat blossom midge and cereal leaf beetle on June 29.

RESULTS

Counts of cereal aphids per plot (mean ± standard error) in the tillage treatments are shown in Table 1. The number of cereal aphids counted per stem generally increased as sampling progressed through the season, but the numbers of cereal aphids in both plots were far below the economic threshold. Despite rather large differences in the mean cumulative aphid-days per plot in the NT treatment (107.0) versus those of the CT plots (273.5), they did not differ significantly ($P > 0.05$) in this measure.

The average number of grasshoppers per square yard equaled or exceeded the action threshold of 20 grasshoppers for field margins (this threshold can be used for small fields like the research plots) in both conventional and non-tillage plots. Barley plots were treated with malathion for grasshoppers on July 1.

Wheat stem maggots infested 5.38% of spring wheat plants but only 0.25% of barley plants at the ESDS&W Farm. Orange wheat blossom midge and cereal leaf beetle were not detected in spring grain plots at the ESDS&W Farm.

Table 1. Mean number of cereal aphids per spring barley plot, Eastern SD Soil & Water Farm, 1998.

Date	Mean no. aphids per 25 plants (x ± SE)	
	Non-tilled	Conventionally tilled
29 Apr	0.5 ± 0.5	0.6 ± 0.8
May 1	0.0	0.0
May 5	0.0	0.0
May 8	0.0	0.5 ± 0.5
May 12	1.5 ± 1.5	1.5 ± 1.5
May 15	9.0 ± 2.0	1.5 ± 1.5
May 19	3.5 ± 1.5	1.0 ± 0.0
May 22	5.5 ± 5.5	3.0 ± 0.0
May 26	24.5 ± 10.5	10.5 ± 2.5
May 29	35.0 ± 11.0	13.0 ± 8.0

FIELD-CAGE STUDIES OF *BEAUVERIA BASSIANA* FOR THE SUPPRESSION OF ADULT WESTERN CORN ROOTWORM

Barbara S. Mulock, Research Entomologist
USDA-ARS, Northern Grains Insect Research Laboratory

INTRODUCTION

The entomopathogenic fungus, *Beauveria bassiana* (Balsamo) Vuillemin, infects several economically important agricultural pests. *B. bassiana*-infected cadavers of adult western corn rootworm have been observed in the field, however, the fungus has never been evaluated as a possible adulticide. This study aimed to evaluate the potential of *B. bassiana* as a potential microbial control agent for adult western corn rootworm. Studies were conducted in walk-in field cages due to the time required for *B. bassiana* to kill a host insect (7-10 days) and beetle movement in the field. The objectives were to assess foliar applications of *B. bassiana* on beetle populations at variable rates and over time.

The mode of fungal infection in insects is via direct exposure and/or through contact with contaminated surfaces. In assessing potential of a microbial pesticide it is necessary to understand how the infection is initiated in the field environment. Conidia of *B. bassiana* are known to be susceptible to UV degradation and have limited persistence particularly on exposed foliage. A second field study aimed to compare beetle mortality due to direct exposure to a fungal application with mortality resulting from the secondary exposure of beetles to contaminated plant surfaces.

METHODS

The *B. bassiana* isolate selected for use was originally obtained from infected adult *D. virgifera virgifera* collected from corn in Illinois. Conidia were produced by suspending individual cadavers above Sabourand dextrose agar plus 2% yeast extract medium (SDAY). Plates were incubated at 28°C for 10-14 days; dry conidia were harvested by scraping the media surface and stored in desiccation chambers at 4°C. Additional plates were inoculated with conidia as required. Field preparations were prepared by suspending dry conidia in a wetting agent, 0.04% Silwet L-77 (polyalkyleneoxide heptamethyltrisiloxane) (OSi Specialties, Inc. Greenwich CT). The concentration (conidia/ml) was measured using a hemocytometer and adjusted by the addition of wetting agent.

Field trials were conducted on a short inbred line (» 2 m height) of field corn, TR311 (Thurstan Genetics Inc, Olivia, MN). Sequential plantings were made at two-week intervals beginning May 4, 1998. Walk-in field cages (2 m high, 3 by 3m) constructed of plastic mesh supported by metal frames were placed over corn at anthesis. Each cage covered approximately 16 plants in two rows of planting. The base of each frame was secured to the ground by a layer of soil. Naturally occurring *Diabrotica* species and potential corn rootworm predators were collected and removed from cages prior to each study with motorized vacuum pump.

Rate of Application. Into each cage, 300 WCR adults (1:2 male/female, aged 1-2 wk) were released. Corn plants inside the cages were sprayed 24 h later with a suspension of *B. bassiana* at a volume equivalent of 300 liters/ha (100 ml/cage). All applications were made at dusk with a compressed CO_2 (40 PSI) sprayer (R&D Sprayers, Opelousas, LA). Treatments were comprised of: 1) a single application of *B. bassiana* at the rate equivalent of 7 ´ 10^{12} conidia/ha, 2) two applications, 48 h apart, each at the rate equivalent of 2 ´ 10^{13} conidia/ha, 3) a single application at the rate equivalent of 5 ´ 10^{13} conidia/ha, and, 4) control cages treated with wetting agent (0.04% Silwet) only. Each treatment was replicated three times. At day-3 and day-5 post-application, approximately 100 beetles were aspirated with a motorized vacuum pump from each cage. Collected beetles were returned to the laboratory, placed in plastic cages (8 cm high by 8.5 cm diameter; 10 beetles/cage) with diet and water agar, and maintained at 27 ± 2°C, 50-60% RH and 16:8 (L: D) h. Laboratory cages were inspected daily for 15 days and mortality recorded. Dead beetles were placed on moist filter paper in petri dishes. The development of mycelial growth over the cadaver within 3 days was confirmation of infection by *B. bassiana*.

Persistence. Cages were repositioned over new corn in an unused area of the field. Foliar applications at the rate equivalent of 5 ´ 10^{13} conidia/ha and volume equivalent of 300L/ha were made as described above to corn inside: 1) cages into which 300 beetles had been released 24 h previously, and 2) cages into which beetles were released 24 h post-application. Control cages were treated with wetting agent only either 24 h before or 24 h after release of beetles. All treatments were replicated three times. Beetles (100) were collected from all cages five days following the date of beetle release and maintained in the laboratory as described above. Mortality in beetles directly exposed to the application of *B. bassiana* was compared with mortality in beetles released into cages of plants treated 24 h previously. Concurrently, leaf samples were taken plants from each of the treatments. Samples (» 30 cm^2) were removed from the tips of ten leaves from each cage and placed in individual plastic bags. Five samples were collected from the lower half of the plants and five samples from the upper canopy. Samples were collected immediately following application, (H_0) and at 12, 24, and 72 h following application. All samples were returned to the laboratory and a disk (15 cm^2) was removed from each leaf. Each disk was placed in a petri dish on moist filter paper and 10 beetles were added to each dish. After 24 h the beetles were removed and placed in cages with diet and agar water. Beetles were observed daily and mortality due to *B. bassiana* recorded.

RESULTS

Rate of Application. Laboratory mortality due to *B. bassiana* in adult western corn rootworm collected from field cages is presented in Table 1. Beetle mortality increased significantly with increasing rates of application. A cumulative mortality of 48.6% was obtained at the highest rate of application based on the combined results from both collection dates. There was no significant difference in mortality of beetles collected at day-3 post-application compared with day-5 at any of the rates tested. At the highest application rate, on both collection dates, beetle mortality in the laboratory was initially observed on day-6 post-application and was 75% complete by day-10. The onset of mortality was delayed at lower rates reaching peak mortality by day 14 (Fig. 1). Fungal infection in the control remained below 5% for both collection dates.

Persistence. Significantly higher mortality due to *B. bassiana* occurred in beetles collected from cages in which beetles were present during the application than in beetles which had been released into the cages 24 h following application. (Table 2). As observed in the previous study, there was no statistical difference between mortality of beetles collected on day-3 compared with day-5 for either beetle release date.

The highest mortality in leaf assays occurred when beetles were fed samples taken immediately following the application (H_o) (Table 3). Beetle mortality declined significantly with increasing time from application in leaf assays conducted with samples collected from inside the ($F = 5.00$; df = 3,23; $P = 0.0095$) and outside of cages ($F = 10.35$; df = 3,23; $P = 0.0003$). Approximately a 90% reduction in activity occurred over the 3 day period. No significant differences were observed in mortalities between beetles fed leaf samples collected from plants inside field cages compared with material from plants outside the cages at any of the sampling time intervals suggesting that the cages do not interfere with the degradation of the conidia on leaf surfaces. There was no difference in assay mortality between leaf samples taken from the upper levels of the plant compared with the lower levels with the exception of non-caged plants immediately following the application (H_o).

CONCLUSIONS

Application of *B. bassiana* within field cages initiated a fungal epizootic that caused adult population of western corn rootworm to decline by approximately 50% at the highest rate of application. The initial contact between the target insect and application material was of primary importance in ensuring the establishment of a lethal infection. Until the persistence of field applications can be extended through the addition of adjuvants and/or formulation modifications, insect contact with plant material previously treated with the fungus provides a minor source of infection.

Table 1. Mean percentage mortality due to *Beauveria bassiana* in adult western corn rootworm collected from treated field cages.

Rate of application (conidia/ha)	% mortality ± SD (n)[a]	
	Collection day (post-application)	
	Day-3	Day-5
5 ′ 10^{13}	46.7 ± 14.7 a (315)	50.7 ± 29.6 a (272)
2 ′ 10^{13}	24.9 ± 7.3 b (327)	34.5 ± 10.4 ab (303)
7 ′ 10^{12}	10.1 ± 3.0 bc (328)	10.6 ± 7.1 bc (298)
Control	2.2 ± 1.4 c (314)	1.7 ± 1.5 c (289)

Means within column followed by the same letter are not significantly different (P > 0.05, LSD test)
[a]n, number of beetles collected

Table 2. Mean mortality due to *B. bassiana* in adult western corn rootworm released into field cages prior to and 24 h following application.

Time of beetle release	% mortality ± SD (n)	
	Collection day (Post – beetle release)	
	Day -3	Day-5
24 h prior to application	48.6 ± 8.7 a (321)	57.9 ± 18.3 a (215)
24 h post-application	21.1 ± 7.9 b (311)	26.8 ± 0.6 b (326)

Day-3: $F = 16.27$; df = 1,5; $P = 0.016$; Day-5: $F = 8.74$; df = 1,5; $P = 0.041$

Table 3. Mean percentage mortality due to *B. bassiana* in *D. virgifera virgifera* exposed to corn samples collected at increasing time intervals from application and plant heights within and outside of field cages.

Time (h) post-application	Canopy height position of sample	Within cage	Outside cage
H_0	Upper	16.4 ± 11.5	17.8 ± 3.4
	Lower	7.0 ± 2.8	6.9 ± 2.4
H_{12}	Upper	6.7 ± 4.7	8.0 ± 4.2
	Lower	3.7 ± 3.4	9.1 ± 3.1
H_{24}	Upper	2.1 ± 3.8	1.4 ± 2.5
	Lower	1.4 ± 2.4	2.7 ± 1.2
H_{72}	Upper	2.6 ± 2.5	1.3 ± 1.1
	Lower	0	2.8 ± 1.2

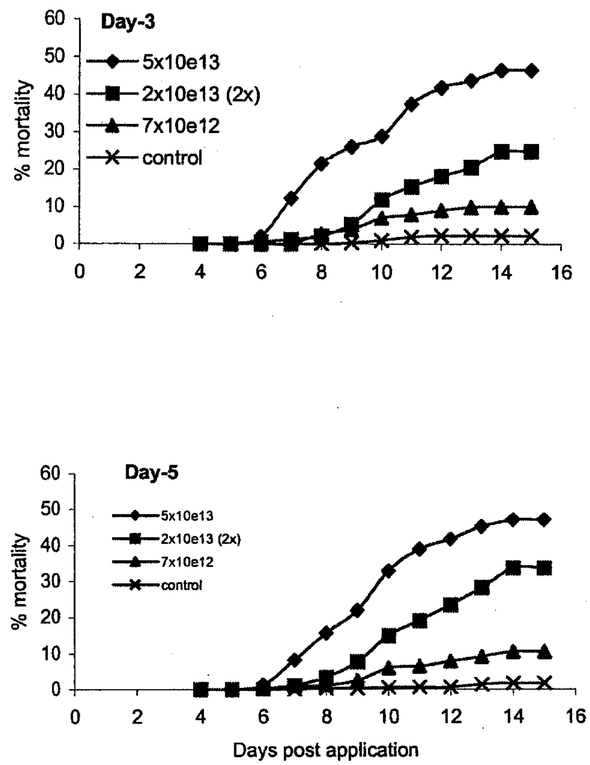


Figure 1. Cumulative mortality (%) of western corn rootworm adults collected at day-3 and day-5 following application with *B. bassiana*.

CORN ROOTWORM SURVIVAL AND FEEDING DAMAGE ON VALUE-ADDED CORN VARIETIES

Larry Chandler and Deb Hartman
USDA-ARS, Northern Grain Insects Research Laboratory

In recent years development of corn (*Zea mays* L.) varieties with agronomic traits that have the potential to add increased value at harvest to producer income has received increased attention within federal and state agencies, universities, and private industry. Two groups of corn that are being increasingly evaluated for use in the Northern Great Plains are high-oil content and white grain varieties. Both of these types can be grown throughout the region, although the maturity lengths for white grain varieties are still most adapted for the more southern portions of the corn belt. Most of the varieties categorized as "high-oil" or "white" come from known genetic backgrounds. Corn rootworm "resistance" to larval feeding within corn hybrids may occur at low levels and is generally not expressed well enough within roots to offer significant protection from feeding damage. Regardless of variety grown, producers must develop some type of rootworm management program based either on chemical or cultural control. Since high-oil and white varieties have had little attention given them to determine degree of rootworm feeding resistance/tolerance, this study was conducted to evaluate some candidate hybrids adapted to the Northern Great Plains to determine the effects of corn rootworm larval feeding on root damage and grain yield. Information on rootworm survival to adulthood was also gathered. This information can then be used by producers to determine the type and degree of rootworm management most profitable for their production system.

METHODS

Three high oil content, three white, and three standard yellow corn varieties somewhat adapted to northern Great Plains growing conditions were evaluated to compare larval western corn rootworm (*Diabrotica virgifera virgifera* LeConte) feeding damage and survival to adulthood. Corn was planted on 5 May 1998 at the Eastern South Dakota Soil and Water Research Farm in Brookings County, SD. The field had been planted in soybean during 1997. For each corn variety western corn rootworm eggs were artificially placed into the seed bed on 21 May at the rate of either 0, 600, or 1800 per linear foot of row. Plots were 2 rows (30 inch) wide and 20 ft. in length. One row was used for egg infestations and the other row used as a buffer between plots. Northern corn rootworm (*Diabrotica barberi* Smith and Lawrence) were not artificially placed into the field; however, naturally occurring extended diapause populations were present. Each variety and infestation rate was replicated four times. A single 1.2 yd^2 metal screen adult corn rootworm emergence capture cage was placed into each plot on 10 July. Cages were checked a minimum of two times per week through 14 September. Adults were collected, returned to the lab, sexed and enumerated by species (northern vs western corn rootworm). On 6 August five randomly selected corn roots per plot were dug to determine rootworm larval feeding damage. Damage was based on the Iowa 1 to 6 scale, where ratings of 3 or above are considered to result in economic damage. Five corn plants per plot were randomly harvested for yield determination on 8 October. Grain weight (converted to bushels per acre) and percent moisture were recorded. Means and square root transformations were calculated for all data. An ANOVA with mean separation using Fisher's LSD test was conducted for adult emergence (sexes combined) by species, root ratings, and bushels per acre standardized to 13% moisture.

RESULTS AND DISCUSSION

Northern and western corn rootworm adult emergence occurred in all plots regardless of whether or not the plots were artificially infested. Western corn rootworm emergence from plots that did not receive artificial infestation was surprising. Total numbers of western corn rootworm emerging from non-infested plots ranged from 0.4 to 15.6 per cage (Table 1). These data could indicate the occurrence of behavioral variants, such as extended diapause, within the population. Northern corn rootworm were prevalent in all plots and adults emerged in fairly high numbers per cage (3.3 to 24.1) across infestation rates. Western corn rootworm infestation rates did not appear to significantly affect numbers of adult northern corn rootworm emerging in each plot. As expected, western corn rootworm adult emergence was greater in plots infested with 1800 eggs per row ft (average of 115 adults/cage) compared to 600 eggs per row ft (average of 60 adults/cage) and 0 eggs per row ft (average of 6 adults/cage). Few pair wise comparison differences were observed in the number of emerged western and northern corn rootworm adults among varieties. The number of western corn rootworm adults that emerged from the standard corn variety, DeKalb 8766, was generally higher than the number emerging from the high oil variety DeKalb 8660TC3. Numerically greater numbers of northern corn rootworm adults were observed emerging from white corn variety DeKalb 8527 compared to high oil content variety AgriPro 326HO. In general, however, emergence was similar across all varieties and all infestation rates.

Root ratings in all 1800 eggs per linear foot plots averaged 4.0 compared to 3.4 in 600 eggs per linear foot and 1.3 in 0 eggs per linear foot plots. No differences in root ratings among varieties were observed for 600 and 1800 eggs per foot plots (Table 2). Some rootworm larval feeding damage (mean root ratings ≤ 1.6) was noted on roots in the non-infested plots which indicated that naturally occurring northen and western corn rootworm populations were low in number and did not greatly damage the root systems.

Yield averaged between 75.1 and 102.6 bushels per acre depending upon variety and infestation rate (Table 2). Yield was negatively affected by the egg infestation rate, with numerically higher yields achieved in 0 eggs per linear foot plots (average of 97 bushels per acre for all varieties) compared to 1800 eggs per linear foot plots (average of 88 bushels per acre). Dry conditions during portions of the growing season also affected corn yields. In general, it appears that the evaluated added value and standard corn varieties currently marketed in the northern Great Plains were similarly susceptible to both northern and western corn rootworm.

ACKNOWLEDGMENT

The authors would like to acknowledge the assistance of Max Pravecek (egg infestation and crop maintenance), Chad Nielson, Rae Jean Gee, and Terry Hall (egg production), Walt Riedell and Dave Schneider (assistance with varietal selection), Cecil Tharp (data analysis), and Travis Trudeau, Lora Kluis, Cara Wulf, Bryon van Ballegooyen, Jeremy Brady, Nate Hofstadter, Justin Haugen, and Tom Schroeder (field and lab data collection).

Table 1. Adult northern and western corn rootworm emergence from value-added corn varieties grown in Brookings Co., SD, 1998.

			Avg. Adult Emergence/Cage[1]							
			0 Eggs/Ft		600 Eggs/Ft		1800 Eggs/Ft		Avg. Number[a]	
Variety	Corn Type	Maturity Length (days)	NCR	WCR	NCR	WCR	NCR	WCR	NCR	WCR
AgriPro 326HO	High Oil	100	10.2	0.9 BC	6.4 AB	86.4 A	15.3	125.7	10.9 B	71.0 AB
DeKalb 8660TC3	High Oil	105	14.3	3.6 ABC	3.3 B	25.9 B	15.9	133.3	11.2 AB	54.3 B
Pioneer 73H97	High Oil	97	26.8	9.4 ABC	8.6 AB	42.6 AB	8.1	123.9	14.5 AB	58.6 AB
AgriPro 543W	White	112	7.7	13.9 AB	18.6 AB	56.3 AB	8.1	98.0	11.5 AB	56.0 AB
DeKalb 8527	White	108	24.6	0.7 BC	24.1 A	65.9 A	15.1	113.1	21.3 A	59.9 AB
Pioneer 3443W	White	109	21.5	1.8 ABC	10.4 AB	56.2 AB	13.0	104.3	14.9 AB	54.1 AB
AgriPro 9230	Typical	98	10.9	0.4 C	13.8 AB	57.2 AB	10.9	117.9	11.9 AB	58.5 AB
DeKalb 8766	Typical	97	19.3	15.6 A	18.7 AB	85.2 A	14.3	137.1	17.4 AB	79.3 A
Pioneer 3730	Typical	98	18.1	3.9 ABC	22.3 A	59.9 AB	13.4	79.9	17.9 AB	47.9 B
			N.S.				N.S.	N.S.		

[1]Means in a column followed by the same letter do not differ when pairwise comparisons are made (Fisher's LSD, p>0.05). N.S. = not significant.
[a]Summed over infestations.

Table 2. Corn rootworm larval root damage ratings and estimated yield from value-added corn varieties grown in Brookings Co., SD, 1998.

Variety	Corn Type	Maturity Length (days)	Root Ratings[1] 0 Eggs/Ft	600 Eggs/Ft	1800 Eggs/Ft	Avg. Rating[a]	Yield in Bushels/Ac
AgriPro 326H0	High Oil	100	1.2 AB	3.2	4.0	2.8 AB	99.8 A
DeKalb 8660TC3	High Oil	105	1.2 AB	3.5	4.4	3.0 AB	88.0 AB
Pioneer 73H97	High Oil	97	1.1 B	3.6	4.1	2.9 AB	99.5 A
AgriPro 543W	White	112	1.6 A	3.5	3.8	3.0 AB	75.1 B
DeKalb 8527	White	108	1.5 AB	3.6	4.6	3.2 A	96.4 A
Pioneer 3443W	White	109	1.1 B	3.4	4.2	2.9 AB	91.0 A
AgriPro 9230	Typical	98	1.3 AB	3.3	4.0	2.9 AB	102.6 A
DeKalb 8766	Typical	97	1.2 AB	3.0	3.6	2.6 B	88.9 AB
Pioneer 3730	Typical	98	1.4 AB	3.3	3.9	2.9 AB	97.6 A
				N.S.	N.S.		

[1]Means in a column followed by the same letter do not differ when pairwise comparisons are made (Fisher's LSD, $p>0.050$. n.s.= not significant.

[a]Summed over infestations.

OAT, WHEAT, AND CORN RESEARCH FACILITATED BY THE EASTERN SOUTH DAKOTA SOIL AND WATER RESEARCH FARM

Walter Riedell, Tracy Blackmer, Louis Hesler, Marie Langham, Shannon Osborne, Scott Haley, Neil Reese

INTRODUCTION

World grain harvests, which have doubled since 1960, have kept pace with the huge population increases that have taken place recently (*Science* 283:310, 1999). Thus, the global boom in agricultural production is one of the century's greatest technological achievements. By 2020, global demand for cereal crops (rice, wheat, and corn) will increase 40 percent. Crop producers will face the challenges of producing enough crops to feed the world now and in the future, preserving the natural resource base upon which all human life depends, and doing this in an economically sustainable fashion. Agricultural research is needed to help meet these challenges.

In eastern South Dakota, yields of oats, wheat, and corn can be affected by weather, soil fertility, weed and insect pests, and disease. Scientists from the Agricultural Research Service (Northern Grain Insects Research Laboratory in Brookings and the Soil and Water Conservation Research Unit at Lincoln NE), South Dakota State University (Plant Science and Biology/Microbiology Departments), and the University of Nebraska (Agronomy Department) are working together to evaluate the influence of root feeding insects, cereal aphids, and disease on yield, yield components, and cereal crop characteristics. The objectives of this research are to understand the mechanisms that cause yield loss to these stress agents, and to develop and investigate new crop production methods that improve crop tolerance to these stress agents. This report details the cooperative research being conducted on these important cereal crops as facilitated by the Eastern South Dakota Soil and Water Research Farm.

MATERIALS AND METHODS

Much of the agricultural cooperative research being performed involves the use of specialized research equipment. Image analysis of crop canopies and root systems involves the use of spectroradiometers, LAI meters, digital cameras, minirhizotrons, infrared temperature sensors, and computer-aided image analysis. Crop dry matter and grain yields are determined using hand sampling and plot combines. Yield components are determined using seed counters. Equipment being used is demonstrated on the next page.

RESULTS

Leaf reflectance in the 625 to 635 nm and 680 to 695 nm ranges, as well as the normalized total pigment to chlorophyll a ratio index, were correlated with total chlorophyll concentrations in both greenbug and Russian wheat aphid damaged plants (Fig. 1).

Early in the pre-vernalization period, BCO treatments (alone or in combination with BYDV) reduced plant height to about 55 % of control. During the post-vernalization period, plant heights attained about 80 % of control in BCO treatments and about 75 % in BYDV treatments (Fig. 2).

When given NH_4 nutrient solutions treatments, BYDV infection significantly reduced individual kernel weight in oat and primary tiller height in wheat. These same measures were not affected by BYDV infection in the NO_3 or NH_4NO_3 nutrient solution treatments (Fig. 3).

When corn rootworm larvae were damaging root systems or when specific roots were mechanically cut, leaf CO_2 assimilation was less in root damaged plants than in undamaged plants (Fig. 4).

CONCLUSIONS

Advances in understanding crop physiological stress mechanisms and grain yield responses to corn rootworm larval feeding damage in corn and cereal aphid infestation and disease in oats and wheat have been made. This information forms the starting point for the development of integrated pest and crop management strategies that improve crop tolerance to insect pests and disease, decrease crop production costs, and protect the environment.

Recommendations for corn and wheat best management practices, based upon the above scientific advances, have been developed. When adapted by farmers, these recommendations will improve cereal crop tolerance to stress caused by insect feeding and crop disease, reduce grain yield loss to these pests, and improve the probability that farmers will accept IPM insect management strategies.

These findings have been communicated to farmers, industry scientists, extension personnel, and other scientists through peer review publications, invited talks and seminars, direct meeting with farmers, and popular publications.

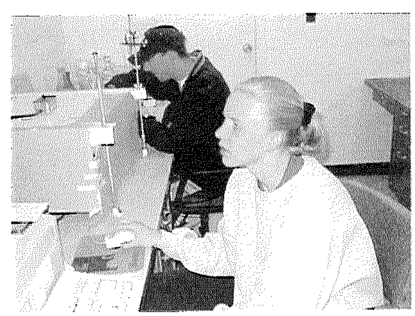
ARS technicians Eric Beckendorf and Dave Schneider install minirhizotron tubes into a wheat field. During the experiment, insects which carry crop disease are introduced into the cage at the left.

ARS technician Erika Beste demonstrates the proper use of a leaf area index (LAI) meter, which measures the crop canopy density.

A hand held infrared thermometer is used to measure the temperature of crop canopies. Crop stress caused by insect feeding is usually accompanied by increased canopy temperature

A portable spectroradiometer is used to measure the wavelength and intensity of solar radiation reflected from crop canopies. Knowledge of reflected energy from crop canopies damaged by insects may help farmers target their insecticide applications to those portions of the field actually infested with bugs.

Images of root systems within the soil profile are captured using a remote camera attached to a video recording system. In this photo, Erika and Eric are gathering images for later computer assisted analysis of root system characteristics.



A considerable portion of laboratory time during the winter months is spent performing computer-assisted image analysis of data taken during the growing season. In this photo, Eric is arranging root segments on a scanner while Erika operates the image analysis computer.

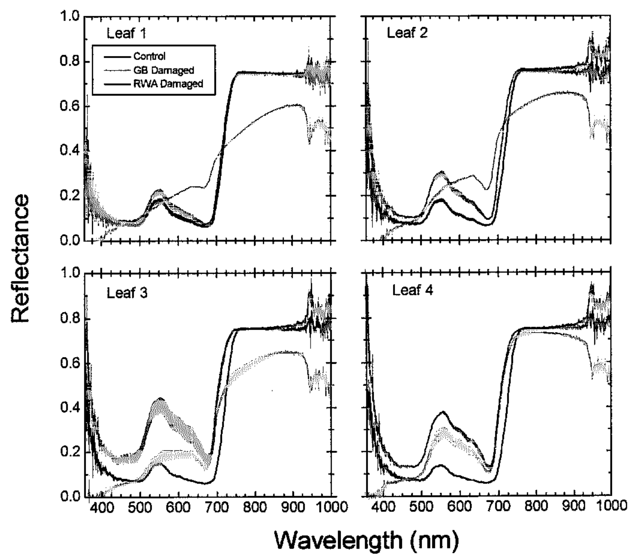


Fig. 1. Leaf reflectance spectra relative to a barium sulfate standard for plants damaged by greenbugs or Russian wheat aphids. Values represent mean and standard deviation for four replicates per treatment.

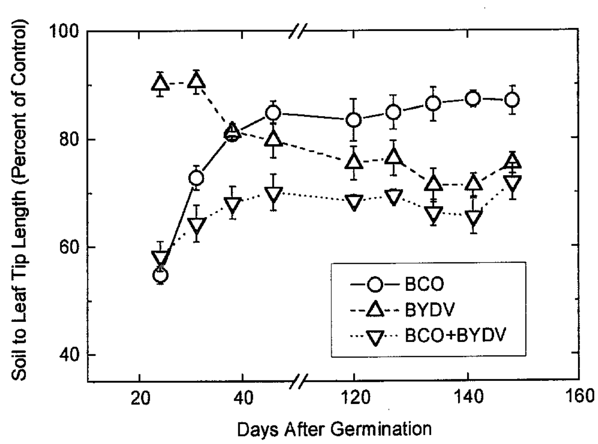


Fig. 2. Plant height (soil to tip of tallest leaf) plotted as a percent of the control treatments. Data points represent means combined by treatment across the four winter wheat varieties and the two runs of the experiment (n=32 for each treatment). Treatments are: *R. padi* treatment [bird cherry-oat aphid infestation (300 aphid d)], BYDV treatment [barley yellow dwarf virus infection (transmitted from viruliferous bird cherry-oat aphids for 48 hours)], *R. padi*+BYDV treatment [viruliferous bird cherry-oat aphid infestation (300 aphid d)].

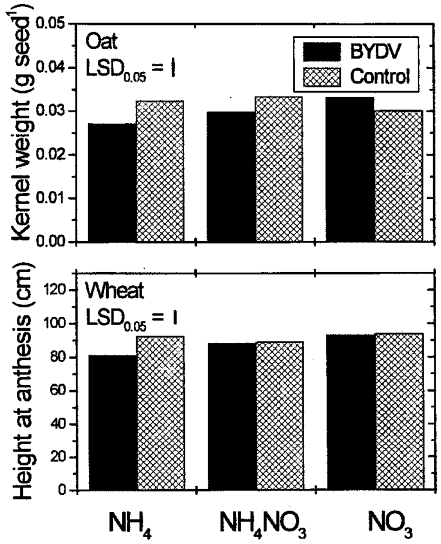


Fig. 3. Influence of nutrient solution N form treatments and BYDV infection on wheat primary tiller height at harvest. Nutrient solution treatment are: all nutrient solution N in the NH_4 form, the NH_4NO_3 form, or the NO_3 form. Values represent means for six replications per treatment. Error bar is the LSD value for comparing BYDV treatment effects within nutrient solution treatments.

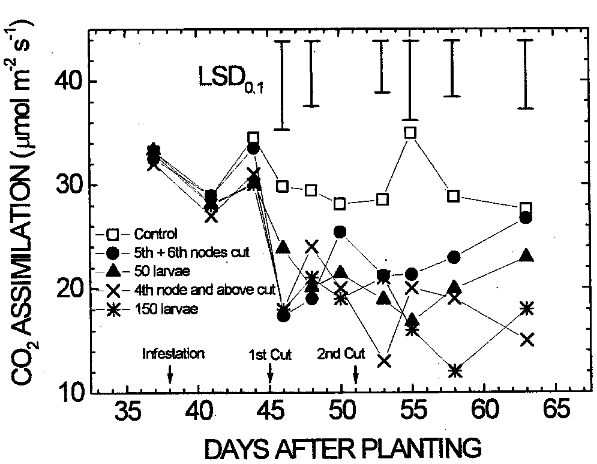


Fig. 4. CO_2 assimilation of the youngest leaf with a ligule in maize plants with root system damage caused by corn rootworm larval feeding or by mechanical cutting. Pots were infested 38 d after planting (V7 leaf stage). Late 3rd stage larvae and pupae were found 49 d after planting (V10 leaf stage). Mechanical damage to the 4th and/or 5th root nodes was performed 45 d after planting (V9 leaf stage) and again on the 6th node 51 d after planting (V11 leaf stage). Data points represent means for 4 replicate measurements per treatment. Upon obtaining a significant ANOVA for data within dates, LSD values represented by error bars were calculated.

Table 1. Yield and yield components of 'Jerry' oats which were treated with different cereal aphid infestations or barley yellow dwarf virus at the 3 leaf stage.

Treatment	Grain yield†				Seed number ‡			
	1997		1998		1997		1998	
	(bushel per acre)				(per foot of row)			
Control	121	a §	146	a	532	a	813	a
Bird cherry oat aphids	104	a	140	a	503	a	808	a
Greenbugs	112	a	107	b	509	a	620	b
Russian wheat aphids	106	a	138	a	476	a	800	b
Barley yellow dwarf virus	66	b	86	b	337	b	557	a

† 32 lbs per bushel
‡ Number of seeds per foot of row
§ Values followed by the same letter are not significantly different (LSD test, P=0.05)

Table 2. Yield and yield components of 'Sharp' spring wheat which were treated with different cereal aphid infestations or barley yellow dwarf virus at the 3 leaf stage.

Treatment	Grain yield†				Seed number ‡			
	1997		1998		1997		1998	
	(bushel per acre)				(per foot of row)			
Control	58	a §	65	a	530	a	666	a
Bird cherry oat aphids	37	b	52	b	374	b	577	ab
Greenbugs	51	a	53	b	483	a	537	b
Russian wheat aphids	35	b	47	b	388	b	606	b
Barley yellow dwarf virus	27	c	29	c	294	c	397	c

† 60 lbs per bushel
‡ Number of seeds per foot of row
§ Values followed by the same letter are not significantly different (LSD test, P=0.05)

Table 3. Correlation coefficients for days to anthesis, primary tiller height, yield components, and grain yield among four winter wheat varieties under control, *R. padi*, BYDV, and *R. padi*+BYDV treatments for both runs of the experiment (n=128).

Treatment	Days to anthesis	Primary Tiller Height	Fertile heads $plant^{-1}$	Spikelets $head^{-1}$	Kernels $plant^{-1}$	Kernel weight
Primary tiller height	0.39**					
Fertile heads $plant^{-1}$	0.05	-0.01				
Spikelets $head^{-1}$	0.01	0.58**	0.08			
Kernels $plant^{-1}$	-0.22*	0.50**	0.39**	0.68**		
Kernel weight	-0.34**	0.22*	-0.12	0.10	0.19*	
Grain Yield	-0.33**	0.51**	0.28**	0.62**	0.92**	0.53**

*, ** Significant at 0.05 and 0.01 levels of probability, respectively.