Eastern South Dakota Soil and Water Research Farm

2000

Annual Report to the Board of Directors

March 21, 2001

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

ANNUAL REPORT

EASTERN SOUTH DAKOTA SOIL AND WATER RESEARCH FARM, INC.

Volume 12

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RESEARCH PARTNERS

The Eastern South Dakota Soil and Water Research 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 Experiment Station, Brookings SD, South Dakota State University, Brookings, SD, the Brookings County Conservation District, and the USDA Natural Resources Conservation Service have developed cooperative 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 solution to these important problems.

Research participants during 2000 were:

USDA-ARS Northern Grain Insects Research Laboratory, Brookings, SD

Dr. Randy Anderson, Research Leader
Dr. Michael M. Ellsbury, Research Entomologist
Dr. Wade French, Research Entomologist
Dr. Leslie Hammack, Research Entomologist
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Mr. David Schneider, Biological Science Technician
Mr. Cecil Tharp, Biological Science Technician
Ms. Rebecca White, Biological Science Technician

Ms. Jackie Zafft, Biological Aid
Ms. Erika Zink, Biological Science Technician

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

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Dr. David Archer, Research Economist
Dr. Lynne Carpenter-Boggs, Microbiologist
Dr. Michael Lindstrom, Soil Scientist

South Dakota Agricultural Experiment Station
Dr. Kevin Kephart, Director

South Dakota State University, Brookings, SD

Dr. Fred Cholick, Dean, College of Agricultural and Biological Sciences
Dr. Dale Gallenberg, Professor, Head of Plant Science Department
Dr. Thomas Schumacher, Professor, Plant Science
Dr. Sharon Clay, Professor, Plant Science
Dr. David Clay, Assoc. Professor, Plant Science
Dr. Ron Gelderman, Professor, Plant Science
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Dr. Arvid Boe, Professor, Plant Science
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Brookings, South Dakota Conservation District and USDA-NRCS Employees

Mr. Darrell Granbois, District Conservationist
Mr. Gary Kirschman, Soil Conservationist
Mr. Jamie Albertson, District Resources Conservationist
Ms. Joan Kreitlow, Brookings County Conservation District Office Manager
Mr. James Millar, Soil Conservationist
Mr. Wayne Bachman, Soil Conservationist

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

Sherry Brende
Steven Brende
Sarah Bulfer
Dan Weber

Other Cooperators

Dr. Robert Schroder, USDA-ARS, Beltsville, MD
Dr. Merle Vigil, USDA-ARS, Akron CO

A special thank you is extended to Kathy Reese (secretary), Sharon Telkamp (administrative officer), Douglas Nemitz (maintenance mechanic) and Megan Joachim 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.

2000 FARM MANAGER REPORT

Max Pravecek

Precipitation for year 2000 at the Eastern South Dakota Soil and Water Research Farm was 18.21 inches. A very wet May (5.8 inches), which delayed planting, was followed by a dry June (2.52 inches). This combination probably accounted for the lower yields on the farm. Corn averaged about 85 bushes per acre, soybeans averaged 30 bushes per acre and wheat averaged 27 bushels per acre.

Monthly Rainfall Totals								
Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
0.74	0.76	5.80	2.52	2.66	2.02	0.91	0.92	1.88

Field day was held September 7. One hundred twenty-five people enjoyed supper and a 1-hour riding field tour with speakers. Topics and presenters for the tour were: "Net Returns for Diversified Rotations", Dave Archer, ARS Economist; "Benefits and Obstacles to Crop Diversity", Tom Dobbs, SDSU Economist; "Alternative Crop Rotations", Shannon Osborne, ARS Agronomist; and "Grass Establishment for CRP", Jamie Albertson, NRCS Conservationist. Attendees of the field day were treated to a supper of pork sandwiches, potato salad, baked beans and dessert.

The Grass Phenotype Display along the northern border of the farm was seeded, and good stands of grass and forbes were established in all but 3 plots. These will be either reseeded this year or a new phenotype will be chosen. The Mixed Grass and Forced Management studies were seeded and will be evaluated in 2001 for plant diversity.

The northwest corner of the farm (a wetland) was squared off and some native grasses were planted into prepared soil. This year the established grasses in the untilled part will be burned off and seeded with native grasses also. Big bluestem and Indian grass were planted for seed production. This year little bluestem will be planted for seed production also. After a good stand is established, these plots will be harvested for seed to be planted at other sites. Brome grass will also be planted. An experiment to introduce plant diversity into an established brome grass monoculture will be conducted after a solid stand is obtained.

A 640' by 120' shelterbelt was planted north to south last year on the eastern edge of the farm. Tree species planted this year were amur maple, blue spruce, crabapple, black walnut, green ash, eastern red cedar, ponderosa pine, Hanson hedge rose, lilac, American plum, little leaf linden, hackberry, bur oak, high bush cranberry, Black Hills spruce, and apricot. An additional tree planting running east to west from the middle of the existing shelterbelt will be done this spring. This planting will be 3 rows wide and approximately 180 feet long.

This year, 5 new experiments by Louis Hesler, Shannon Osborne, Wade French, and Randy Olsen were started on the new land. All land on the new farm is assigned to a scientist, specific experiment or project. New alleys were established and more will be put in in 2001.

2000 GRASS, WILDFLOWER AND TREE REPORT

Jamie Albertson
Brookings Conservation District – NRCS

Grasses and Wildflowers Report

The beginning of the new millennium brought new projects and research in the form of grasses, wildflowers and trees at the ARS farm. With the addition of these new projects the emphasis is to gain information regarding these specialized activities and promote public awareness. Native grasses and wildflower plantings have increased due to requirements in the Conservation Reserve Program. The increased use of these species and the lack of information on ground preparation, seeding rates, planter needs, seeding dates, weed control and herbicide use has magnified concerns in stand establishment and maintenance.

Ground preparation is important in establishing grasses and wildflowers. Existing wheat stubble was fall chisled in 1999. In the spring of 2000 all plots were disced once with a harrow and followed by packing performed by a brillion drill. A firm seedbed is extremely important for many reasons. It ensures good soil to seed contact and conserves moisture in the soil. Seedbeds are adequately firm when less than a ½ inch footprint penetrates the soil. Prime conditions are no-tilling into soybean stubble.

Optimum planting dates for grasses and wildflowers is May 15 - June 15. Due to extreme dry conditions these dates were pushed back slightly. Individual demonstration plots were seeded May 22, 2000 with a prototype Trillion specialized grass drill. The Trillion is a broadcast seeder equipped with two packer wheels and a specialized seed box for fluffy native seeds. The remaining plots: mixed grasses, forced management and seed production was seeded with a Truax specialized grass drill on June 12. The Truax is a no-till drill with double disc openers and specialized native seed boxes. All seeding rates came from Table 1 Pasture and Hayland Planting S.D. Tech Guide Section IV Notice SD 69 January 99.

Post seeding weed control such as mechanical clipping or herbicide uses helps decrease competition for new seedlings and reduces canopy, thus increasing soil temperatures promoting seed germination. The first weed concerns throughout all the plots were sunflowers. To control these weeds and other broadleafs 1½ pints per acre of Buctril herbicide was applied over all plots on June 12. Good control of these broadleafs resulted from the chemical application.

The grasses and wildflowers began to emerge along with annual grassy weeds such as green / yellow foxtail. Mechanical weed control such as clipping was chosen for post plant weed control of these grassy weeds. Particular herbicides such as Plateau and Pursuit were not used due to their label restrictions for some of the grasses and the effects on certain wildflowers.

The first clipping of all plots was performed with a flail mower on July 11. A second clipping for weed control with the flail mower was done on July 24. A third growth of green / yellow foxtail came back and clipped with a stalk chopper just above newly seeded grasses on Aug. 23. In 2001 herbicide applications will be used to control grassy weeds and broadleafs if they present a problem.

Overall status of the grass and wildflower plots (56 out of 57 plots) are considered to have a good to excellent stand. The seed production and forced management plots will be put into action in 2001 with various research performed on these sites.

Tree Report

In 2000 the Brookings Conservation District planted sixteen different species of trees on two sites. These two sites will be used to show the difference of weed control methods and difference in tree species.

Conventional (tillage) and weed barrier fabric was used on the sites for weed control. Six-foot wide Geo textile fabric was laid which allows precipitation to enter and prevent weed growth. Each site was separated into halves using these two weed control methods.

The trees look really good, at least the ones that the jackrabbits didn't enjoy lunch on. In 2001 replacement trees will be planted and hopefully jackrabbits controlled and/or tree wraps used to prevent tree losses.

*We would like to thank Max Pravecek for all his time and devotion towards this project. Also a special thanks to all ARS employees who have helped get this project rolling.

RECOVERY OF WESTERN CORN ROOTWORM LARVAE FROM ROOT SYSTEMS IN RELATION TO INSECT DENSITY AND CROP DAMAGE

Leslie Hammack, Michael M. Ellsbury, and Joseph L. Pikul, Jr.

USDA-ARS Northern Grain Insects Research Laboratory

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, however, always practiced. In addition, 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 crops rotated with 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 subterranean and cause most crop damage. Standard larval monitoring techniques attempt to recover rootworms from large soil volumes but the methods are either of low efficiency or too tedious for routine applications, especially early in the infestation before significant root pruning has occurred. Attempts have been made to limit sampling to corn roots (Apple et al. 1969, Gould 1971), but this approach has not been widely adopted or validated despite its greater ease.

Here, we report preliminary results from 1999 and 2000 tests that examined larval recovery from corn root systems in relation to western corn rootworm egg numbers used to artificially infest the corn plants, root damage ratings, adult emergence, and crop yields.

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). A plot that had not been planted to corn in the previous two years was planted May 12, 1999 at the rate of 31,336 corn seeds (Pioneer 3751) per acre in 100-foot long rows spaced 30 inches apart and fertilized with 95.5 lbs 14-36-13 starter fertilizer. Within each of six randomized complete field blocks, every other row was artificially infested (Sutter and Branson 1986) on May 13, 1999 with one of eight doses of western corn rootworm eggs that ranged from 0 to 2400 viable eggs per foot of row length (viability was estimated in 6 samples of 50 eggs per sample). The eggs derived from a laboratory colony reared for about 15 generations on corn at the Northern Grain Insects Research Laboratory in Brookings. On June 23, 1999, corn was cultivated and nitrogen (N) fertilized with 106 lbs per acre of 46-0-0 at the time of cultivation. The test was repeated in 2000 on a similar adjacent plot except that 29,185 corn seeds per acre were planted May 13, 2000 and Pioneer 37H24, a hybrid similar to 3751, was used because sales of the latter were discontinued in 2000. Starter fertilizer was 100.5 lb per acre of 14-36-13 applied at planting. Infestation with WCR eggs was done May 14 in 2000. No additional cultivation or N application was done in 2000.

Rootworm larvae were sampled in root systems dug with a spade on June 15 and 22, 1999 when corn plants were predominantly in leaf stage 5-6 and 6-7, respectively. Similar samples were taken on June 27 and July 5, 2000 when corn plants were stage 6-8 and 8-10. Sample size was 6 plants per egg dose per block on each sample date. After surface soil was removed with a pressure hose, root systems were individually dried in open-bottomed containers positioned above water traps where larvae were collected for counting. The containers were made from two 24-oz. plastic drinking cups and standard window screen, as described by Fromm, E.A., Bernklau, E.J. and Bjostad, L.B. (http://www.colostate.edu/Depts/Entomology/posters/fromm981108.html). Briefly, a circle of screen was stretched between two stacked cups without bottoms to form a screen platform for drying each root system over a water trap made from the base section of one of the cups. The containers were held in the dark at room temperature for a 4-day, 1999 root drying period that was extended to 6-7 days in 2000. Larvae were removed from the water traps daily during the drying period, counted and stored frozen.

On July 15, 1999 and July 24, 2000, three corn root systems per treatment row were dug to assess root damage from corn rootworm feeding. We used Oleson's linear scale, which records the proportion of three nodes of roots that are pruned by feeding activity of the larvae. Zero on this scale indicates no feeding damage, whereas 3 indicates that 3 whole nodes were pruned to within 2 inches of the stalk. A coding system was used so that individuals doing the scoring were unaware of treatment designations.

Adult beetles were trapped as they emerged from the soil in three cages per treatment row. Each cage, 40" wide x 24" long, covered the roots of three corn plants and extended 20" to each side of a corn row. Beetles, which were 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.

Two 3.3-foot long sections of each treatment row were hand harvested on Sept. 23, 1999 and Sept. 28, 2000 for determination of yields of grain and stover (above ground tissues minus the grain). Grain and stover yields are reported as dry weights.

Significant numbers of northern corn rootworm adults were recovered in emergence cages in one block adjacent to the edge of the test plot in 1999, and all data from that block were disregarded.

RESULTS AND CONCLUSIONS

- ❑ The mean number of corn rootworm larvae recovered from root systems on June 15 and June 22, 1999 increased linearly with increasing dose of western corn rootworm eggs between 0 and 1000 eggs per foot length of row (Fig. 1; $y = 0.0062\,x + 0.56$, $r^2 = 0.93$, $P = 0.002$). No further increase in larval numbers beyond 6-7 per root system occurred as dose increased beyond 1000 eggs per foot of row. In 2000, when sampling was done June 27 and July 5, mean numbers of larvae increased with dose up to 600 eggs per foot length of row before leveling off just short of 2 larvae per root system (Fig. 1).

- ❑ Mean numbers of larvae recovered from root systems on June 15 and June 22, 1999 predicted root damage ratings occurring July 15 near the end of the larval feeding period (Fig. 2; $y = 0.400\,x + 0.1180$, $r^2 = 0.81$, $P = 0.002$). Mean number of larvae per root system on June 27 and July 5, 2000 was also highly correlated with root damage rating determined July 24 (Fig. 2; $y = 1.532\,x - 0.308$, $r^2 = 0.83$, $P = 0.002$). However, root damage ratings were just as high in 2000 as in 1999, despite the much lower larval recoveries in 2000.

- ❑ Cumulative seasonal adult emergence by species and western corn rootworm egg dose is shown by year in Fig. 3. Although adult numbers tended to be slightly lower in 2000 than in 1999, any difference was too small to correlate with the large difference between years in larval recoveries. Western corn rootworm adult emergence per plant increased from 2.2 to 27.1 in 1999 and from 1.2 to 15.5 in 2000 as egg dosage increased from 0 to 1000 eggs per foot of row. Adult numbers then tended to decline (1999) or level off (2000) with further increases in egg numbers. Branson et al. (1980) also found no increase in adult numbers at egg infestation rates above about 1200 eggs per foot of row. Northern corn rootworm emergence was unrelated to western corn rootworm egg dose and did not exceed 1.7 and 0.8 adults per plant in 1999 and 2000, respectively. Adult western corn rootworms were emerging by July 13 in both years; northern corn rootworms were first detected July 16-21.

- ❑ In both 1999 and 2000, crop yields varied inversely with western corn rootworm egg numbers used to artificially infest treatment plots (Fig. 4). Grain and stover dry weights recovered per acre both fell linearly as egg numbers increased from 0 to 2400 per foot of row. Although stover yields were very similar in 1999 and 2000 at each egg dose, grain yields in 2000 were only about 65% of those obtained in 1999. The lower N fertilization level in 2000 undoubtedly accounted for the lower grain yields. That dry matter accumulation in corn tissues comprising stover is largely finished before much accumulation occurs in grain (Ritchie et al., 1989) likely explains why stover yield varied little between years despite the large grain yield difference.

- The lower larval recovery in 2000 compared with 1999 was associated with use of a new corn variety (Pioneer 37H24) and with later sampling dates. The 37H24 variety yielded 6-10 mostly 1st instar larvae per root system in mid June 2000 at the higher doses in another study on the same plot and in an adjacent study with feral populations (see Hammack, Pikul and Roehrdanz, this volume). This suggests that larval recoveries from root systems may be higher during early instars and that the lower recoveries here in 2000 might have been due to the later sampling dates and not the new corn variety.

- It is conceivable that some rootworms had completed larval development and ceased feeding by the July 5, 2000 sampling date; however, this seems an unlikely explanation for the releatively low larval recoveries in 2000 because recoveries were actually somewhat higher on July 5 than June 27. Head capsule widths of larvae recovered in 1999 and 2000 are being measured to determine their stage of development. Preliminary measurements indicate a more mature population overall in 2000, but suggest that larvae sampled on the first 2000 date (June 27) were no more developed than those sampled on the second 1999 date (June 22).

- The discrepancy between years in the relationship between larval recoveries and root damage (Fig. 2) will certainly need to be explained before recovery of corn rootworms from root systems can be considered a useful technique for monitoring larval populations and their potential for crop damage.

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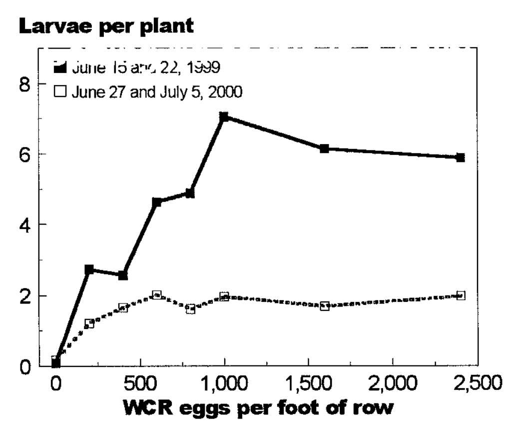

Fig. 1. Relationship between egg infestation level and mean larval recovery from roots for the western corn rootworm sampled on two dates in each of two years

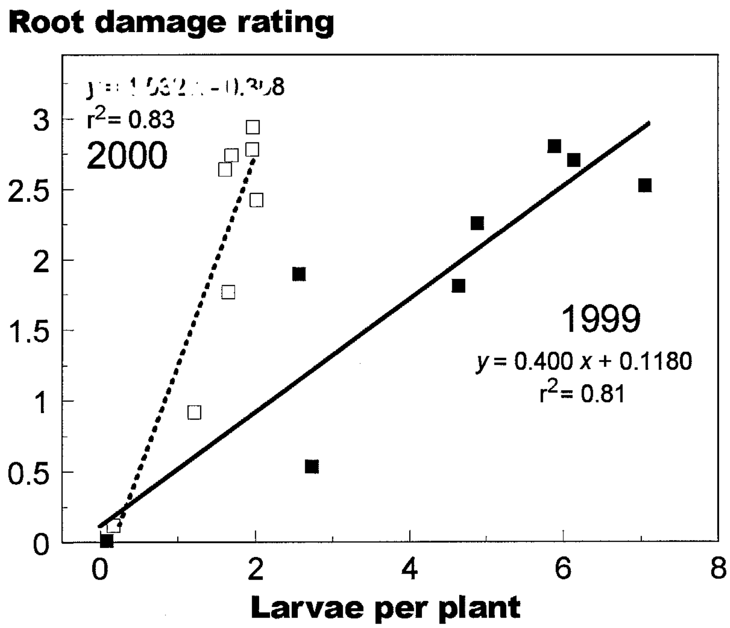

Fig. 2. Relationship between the number of corn rootworm larvae recovered per root system and subsequent damage rating on roots dug July 15, 1999 and July 24, 2000 on a 0-3 damage scale

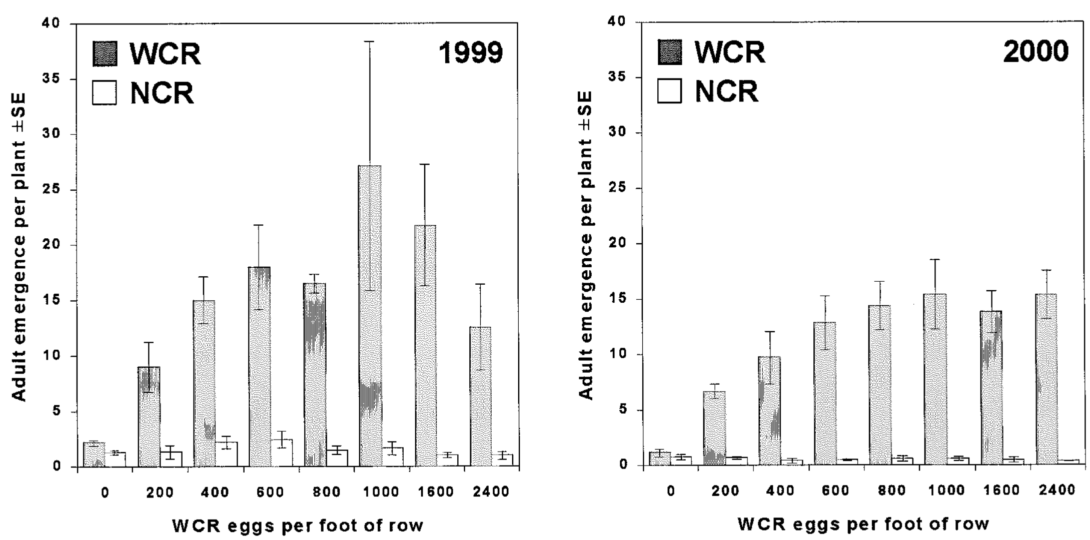

Fig. 3. Cumulative emergence of western (WCR) and northern corn rootworm (NCR) adults in 1999 and 2000 in relation to the number of WCR eggs used to artificially infest treatment plots

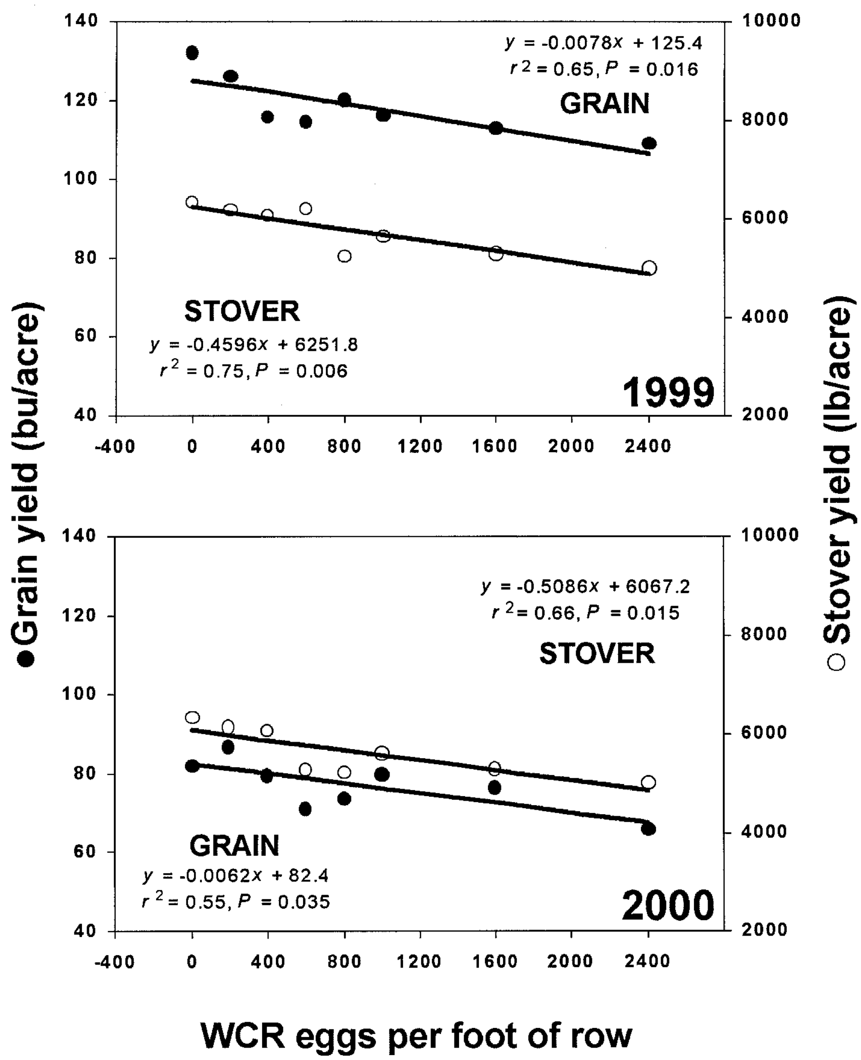

Fig. 4. Corn grain and stover yields in 1999 and 2000 in relation to the number of WCR eggs used to artificially infest treatment plots

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

Leslie Hammack, Joseph L. Pikul, Jr., and Richard L. Roehrdanz*

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*USDA-ARS Biosciences Research Laboratory, Fargo, ND

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 crops rotated with 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 results from 1999 and 2000 tests that compared larval recovery from the corn root system with cumulative adult emergence data. Sampling was done on both crop rotation and nitrogen fertilization research plots in an attempt to obtain a range of rootworm population densities from wild populations for evaluation.

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). Wild 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.

Rotation plots sampled for corn rootworm larvae and adults were **continuous corn** and **corn-soybeans** (corn rotated annually with soybeans). Corn was planted in 30" wide rows at the per acre rate of 31,336 seeds on May 12, 1999 and 29,185 seeds on May 3, 2000. No soil insecticide was applied. Pioneer 3751 was planted in 1999. Pioneer 37H24, a hybrid with characteristics similar to 3751, was planted in 2000 because sale of the latter was discontinued after 1999. No soil insecticide was applied.

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). Starter applications in 1999 and 2000, respectively, were 95.5 and 100.5 lb/acre 14-36-13 in high N subplots, 104.5 and 104.0 lb/acre 7-36-13 in intermediate subplots and 95.5 and 94 lbs/acre 0-36-13 in low input plots. A side dress of urea (46-0-0) was made June 21, 1999 and June 27, 2000 to meet the NP just before the second cultivation.

Rootworm larvae were sampled in root systems dug with a spade between June 3-21, 1999 and May 31-June 19, 2000 when the sampled corn plants were in leaf stage 2-4 to 5-8 and 2-4 to 5-7, respectively. Sample size was 12 plants/subplot/sample date. Once soil was removed with a pressure hose, the roots were dried in open-bottomed containers positioned above water traps where larvae were collected for counting. Each container was fashioned from two 24 oz. Solo® plastic cups and standard window screen as described by Fromm, E.A., Bernklau, E.J. and Bjostad, L.B. (http://www.colostate.edu/ Depts/Entomology/posters/from981108.htlm). Briefly, a circle of screen was stretched between two stacked cups without bottoms to form a screen platform for drying a root system over a water trap made from the base section of one of the cups. Water in the traps was about 0.5 in. deep. The cups were held in the dark at room temperature during drying.

Larvae were collected daily from water traps until recovery ceased (2-7 days of drying, depending on root system size). Head capsule widths were measured to determine larval stage. Larvae were stored frozen for eventual determination of species using methodology currently being developed in the Fargo laboratory.

Adult beetles were trapped as they emerged from the soil in four cages per subplot, although six damaged cages had to be disregarded (out of 36) in 1999. 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, which were 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 insure homogeneity of variances before statistical scrutiny by analysis of variance or regression techniques.

RESULTS AND CONCLUSIONS

- ❑ Larvae were recovered in very small numbers in 1999 when corn averaged leaf stage 2.7, but numbers increased steadily during the next 18 days as corn matured to leaf stage 6.4 (Fig 1). The 2000 pattern was similar, although corn matured a bit slower over the 19-day test period from leaf stage 3.0 to 5.8 (Fig. 1).

- ❑ Continuous corn plots yielded about five times more rootworm larvae than did corn rotated annually with soybeans in both 1999 and 2000 (Fig. 2).

- ❑ Towards the end of the 1999 and 2000 sampling periods in continuous corn plots, low N subplots were yielding only about 1/2 to 2/3rds as many larvae as were high N subplots (Fig. 3).

- ❑ The frequency distribution of larval stages varied significantly between continuous and rotated corn plots in 1999 (χ^2 = 13.66 calculated from a 3 x 2 contingency table, df = 2, P < 0.005), with relatively fewer 1st and more last stage larvae in the rotated plots (Fig. 4). A similar tendency arose in 2000 (Fig. 4), but was not statistically meaningful (χ^2 = 4.36, df = 2, P < 0.10 > 0.05).
- ❑ A comparison of frequency distributions of larval stages between 1999 and 2000 suggested that 6/12 and 6/19/2000 sample dates were more comparable to 6/9/1999 and 6/14/1999, respectively, than to 6/14 and 6/21/1999. This would be consistent with the somewhat slower development of corn plants in 1999 than in 2000 and would suggest that larval numbers increased considerably from 1999 to 2000.

- ❑ Continuous corn subplots without added N fertilizer yielded fewer adults (Fig. 5), as well as fewer larvae (Fig. 3), than did plots receiving medium or high N in both 1999 and 2000, although the considerable variability in high and medium N subplots may well render the difference statistically meaningless. Larger root systems and greater capacity for root regrowth in plants receiving N may explain these results.

- ❑ Emergence of corn rootworm adults in continuous and rotated, high N corn subplots was nearly equal in 1999 but differed by about 2-fold in 2000, with continuous corn producing more (Fig. 6). As expected, northern corn rootworm accounted for nearly all (97.7 %) adult emergence from the rotated plots in 1999 and 86.7% in 2000 (Fig. 7). This result, combined with the about 4-5 times lower recovery of larvae from rotated compared with continuous corn plots, led us last year to suggest that sampling root systems for northern corn rootworm larvae may be far less efficient than sampling for western corn rootworm. However, very preliminary results using PCR (polymerase chain reaction) molecular genetics methods with species specific primers to amplify sections of mitochondrial DNA and assign species to a subset of larvae collected in 1999 did not support this idea: northern corn rootworm appeared to be the predominant species recovered from both continuous (≥246/347) and rotated corn (≥69/87), although a sizable minority of larvae could not be assigned to species either because of sample condition or previously unrecognized variability at a primer binding site.

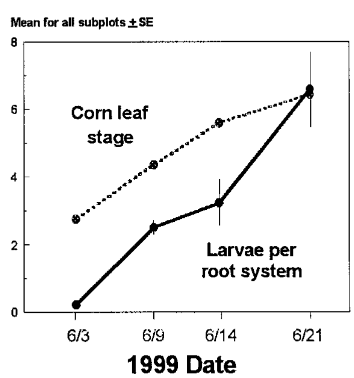
- ❑ If under sampling of northern compared with western corn rootworm from corn roots will not explain the relative paucity of larvae in rotated compared with continuous corn, then the possibility that a larger proportion of larvae survive to adulthood in rotated than in continuous corn warrants examination.

- ❑ In 2000 compared with 1999, numbers of emerging beetles rose about 30% in continuous corn but fell about 20% in rotated corn. The rise was confined to western corn rootworm, which jumped from 6.3 to 14.6 beetles per continuous corn plant and from 0.3 to 1.2 in corn rotated with soybeans. Northern corn rootworm numbers fell, in contrast, from 9.6 to 6.1 beetles per plant in continuous corn and from 13.0 to 9.3 in rotated corn from 1999 to 2000. Continuous corn subplots were severely lodged in 2000, but not in 1999, correlated with the rise in western corn rootworm populations.

- ❑ Sampling of rootworm larvae from root systems may yet prove to be an easy means to estimate larval numbers early in development before the final cultivation, when rescue treatment is still an option. It could also prove useful for monitoring development of resistence to corn modified genetically for corn rootworm control. Data from continuous and rotated corn will need separate interpretation, however, and simpler means than measurement of larval head capsule widths would facilitate determination of appropriate sample dates. Soil temperature data are available and will be examined in this regard.

ACKNOWLEDGMENTS

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



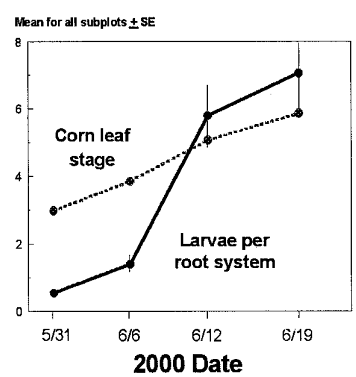


Fig. 1. Relationship between crop stage and recovery of corn rootworm larvae June 3-21, 1999 and May 31-June 19, 2000

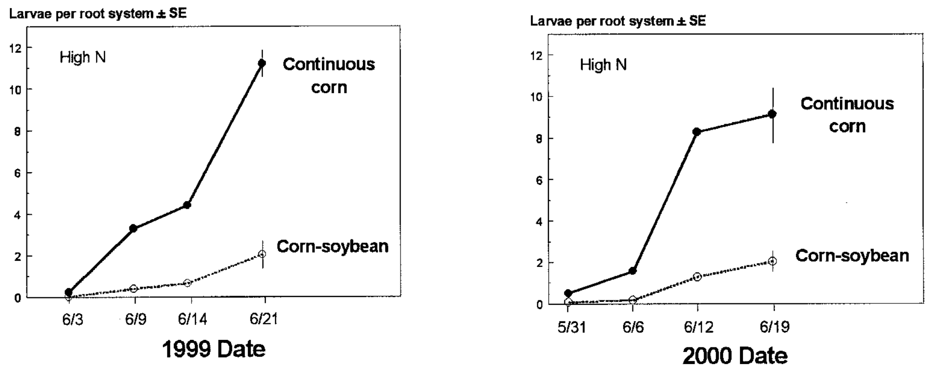


Fig. 2. Corn rootworm recovery compared between continuous and rotated corn in high nitrogen subplots in 1999 and 2000

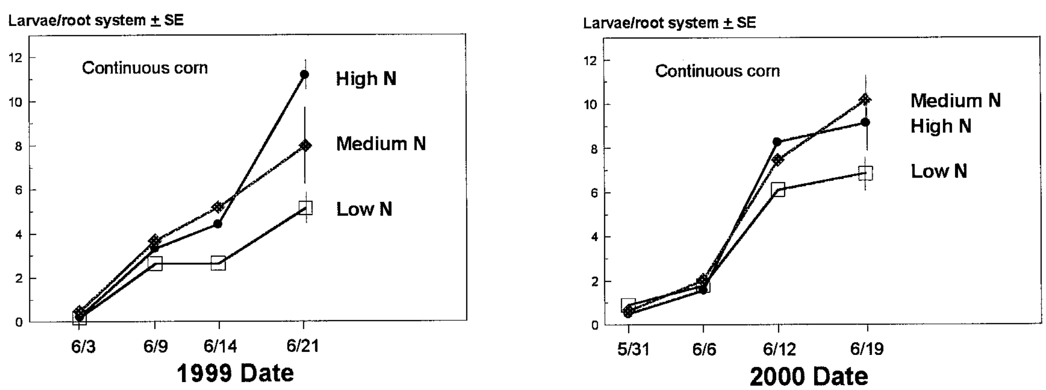


Fig. 3. Recovery of corn rootworm larvae from corn roots by nitrogen (N) level and year

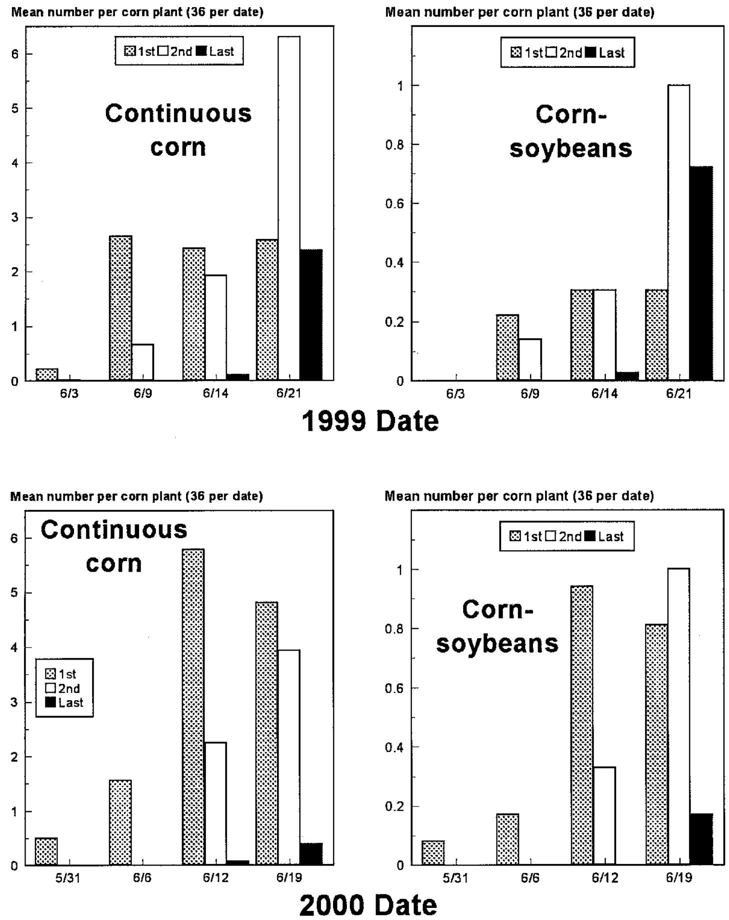


Fig 4. Frequency of corn rootworm larval stages by crop rotation, sampling date, and year in high nitrogen subplots

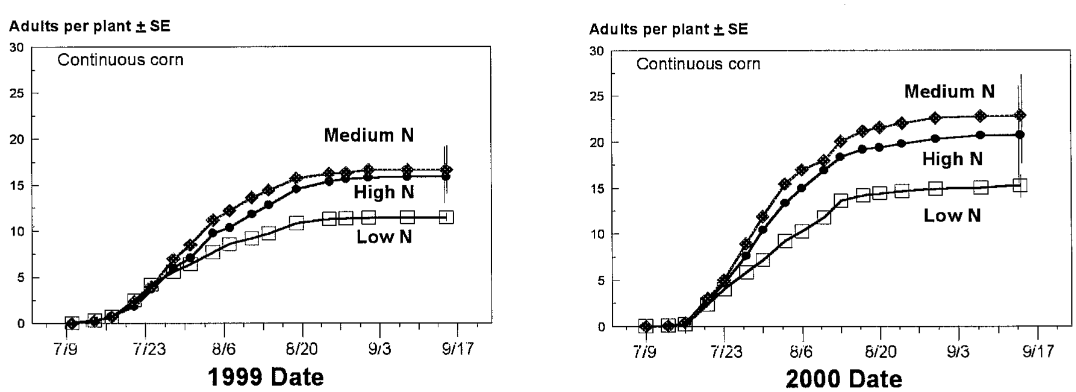


Fig. 5. Cumulative adult corn rootworm emergence in continuous corn by nitrogen fertilization level and year

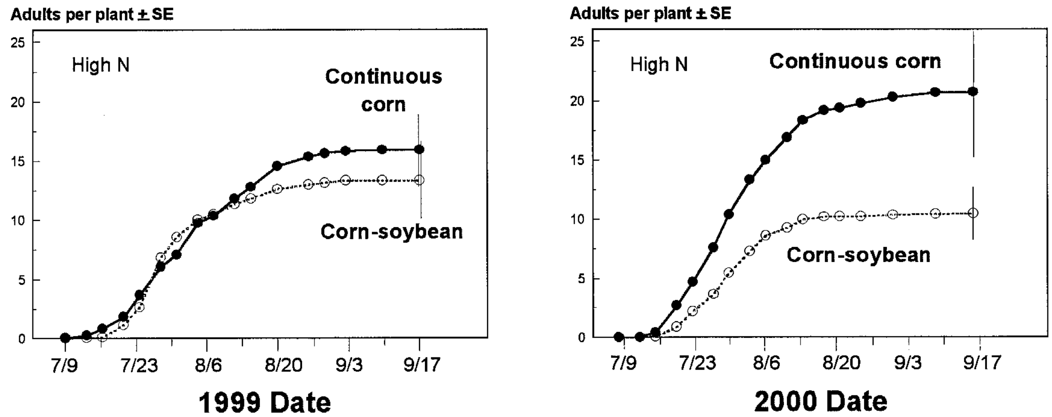


Fig. 6. Cumulative emergence of corn rootworm adults compared between continuous and rotated corn in high nitrogen subplots in 1999 and 2000

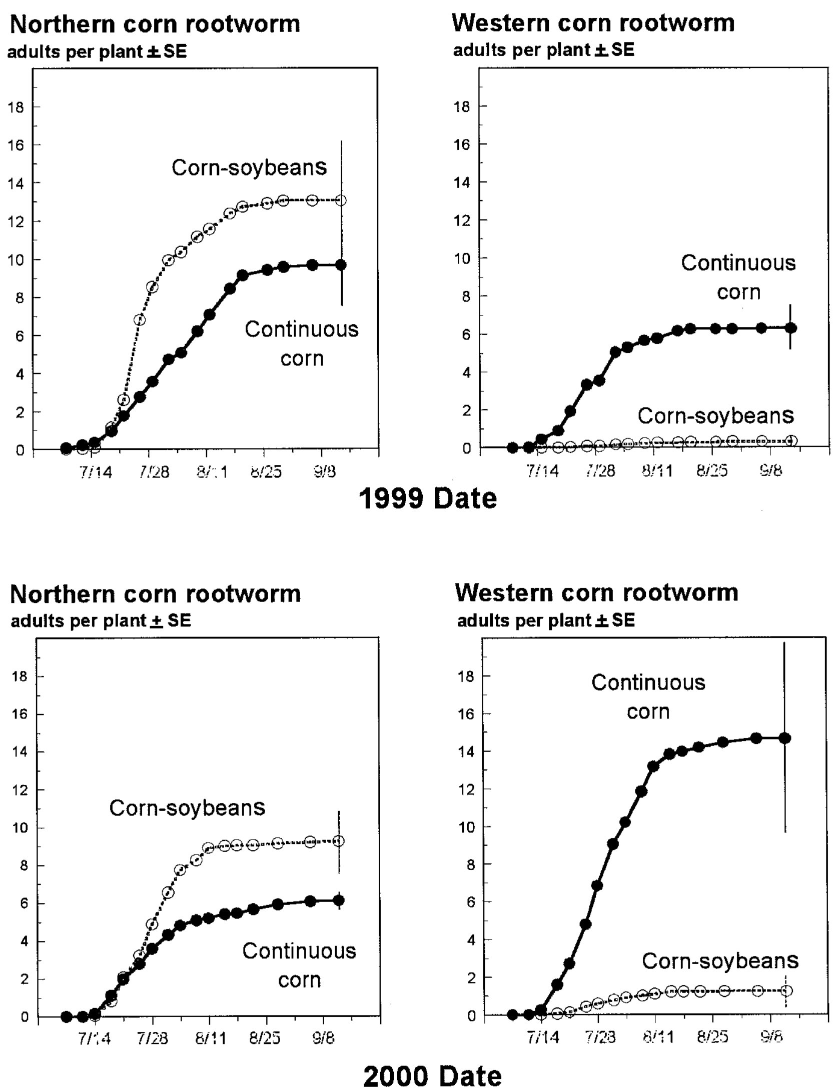


Fig. 7. Cumulative emergence of corn rootworm adults by species and crop rotation in high nitrogen subplots in 1999 and 2000

CORN ROOTWORM EGG NUMBERS BY NITROGEN FERTILIZATION LEVEL

Leslie Hammack, Ellsbury, M.M., Pikul, Joseph L., Jr., and W. David Woodson

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 five 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 yearly from 1996 to 2000 (May 20 and Oct 21, 1996; May 12 and October 22, 1997; May 4 and September 21, 1998, May 19 and October 13, 1999, and May 15 and October 19, 2000). 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. In 1999 and 2000, four additional cores were taken in each subplot. These were identical to the first four but were taken 15" to their side (midway between corn rows in the fall). 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 N subplot (number in 4.4 liters of soil). To ensure homogeneity of variances, data were transformed [$\ln(x+1)$] before statistical scrutiny with analysis of variance or linear regression techniques. A probability (P) $\leq$ 0.05 was considered statistically meaningful. Soil samples from the spring of 2000 have not yet been processed, and some statistical analyses have been delayed until these data become available.

RESULTS AND CONCLUSIONS

Mean recovery of eggs from the within-row samples taken in the three continuous corn plots from 1996 to 2000 is presented in Fig. 1 by N fertilization level and season (excepting spring 2000). There has been a trend over the last two years for higher egg recoveries from the high N subplots, although the considerable variability among replicates may well render any differences statistically meaningless.

Fig. 1 data averaged across nitrogen input levels are shown in Fig. 2. The obvious increase in numbers of both NCR and WCR eggs in the fall of 1999 indicated a potential for substantially increased larval populations in the spring of 2000, which was consistent with the considerable lodging that subsequently occurred in 2000. Fall egg numbers fell only slightly in 2000 compared with 1999. This pattern, combined with the early, deep snow cover this winter, again indicates the potential for substantial rootworm populations in 2001.

Fig. 2 clearly indicates that NCR eggs were recovered in higher numbers than were those of WCR, which is consistent with generally higher NCR adult populations typical of the last 4 years, 2000 excepted. Nevertheless, we recovered fewer NCR adults (or more WCR adults) than would be predicted from relative egg numbers. Although higher mortality of immature NCR compared with

WCR may account for much of this discrepancy, it is also 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 perhaps not in the spring after chisel plowing, because of the greater tendency of NCR than WCR to lay eggs within rows close to the base of corn plants (Hein et al. 1985; Ruesink, 1986).

Additional soil samples were therefore taken in 1999 and 2000 in the between-row position to try to overcome the above bias and to more accurately estimate numbers of rootworm eggs, which tend to be deposited in highly aggregated patterns. The tendency toward more NCR eggs within rows and more WCR eggs between rows detected in the fall of 1999 (Table 1) was repeated in the fall of 2000 (Table 2). Only the WCR difference, however, proved statistically meaningful when data from both years were analyzed using Wilcoxon's signed rank test (NCR, $S = -21.5$, $n = 18$, $P = 0.37$; WCR, $S = 48$, $n = 18$, $P = 0.02$)

Table 1. Recovery of northern (NCR) and western (WCR) corn rootworm eggs in fall 1999 soil samples by sampling site within or between corn rows.

Row site	N[a]	Mean number/subplot ± SE	
		NCR	WCR
Within	9	221.3 ± 47.2	27.7 ± 11.9
Between	9	186.8 ± 51.1	59.6 ± 15.2

[a]Number of subplots sampled

Table 2. Recovery of northern (NCR) and western (WCR) corn rootworm eggs in fall 2000 soil samples by sampling site within or between corn rows.

Row site	N[a]	Mean number/subplot ± SE	
		NCR	WCR
Within	9	138.8 ± 39.0	12.2 ± 3.9
Between	9	79.3 ± 22.1	71.1 ± 30.7

[a]Number of subplots sampled

Despite the high variability and tendency for more WCR egg laying between than within rows, linear regression analysis of data from all five years nevertheless revealed a highly significant positive correlation between the presence of NCR and WCR eggs ($F = 150.68$, df = 1/430, $P < 0.0001$, $r^2 = 0.26$). In other words, if an individual soil core contained more eggs of one rootworm species then there was an increased probability that it also contained more eggs of the second species. This most likely reflects the necessity in both species of laying eggs within existing soil cracks or burrows made in the soil by other organisms such as earthworms (Kirk 1981). Neither species will lay in dry soil or has the ability to make its own burrows.

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We are grateful to David Beck, Janet Fergen, Dave Harris, Sharon Nichols, and Max Pravecek for their excellent technical assistance.

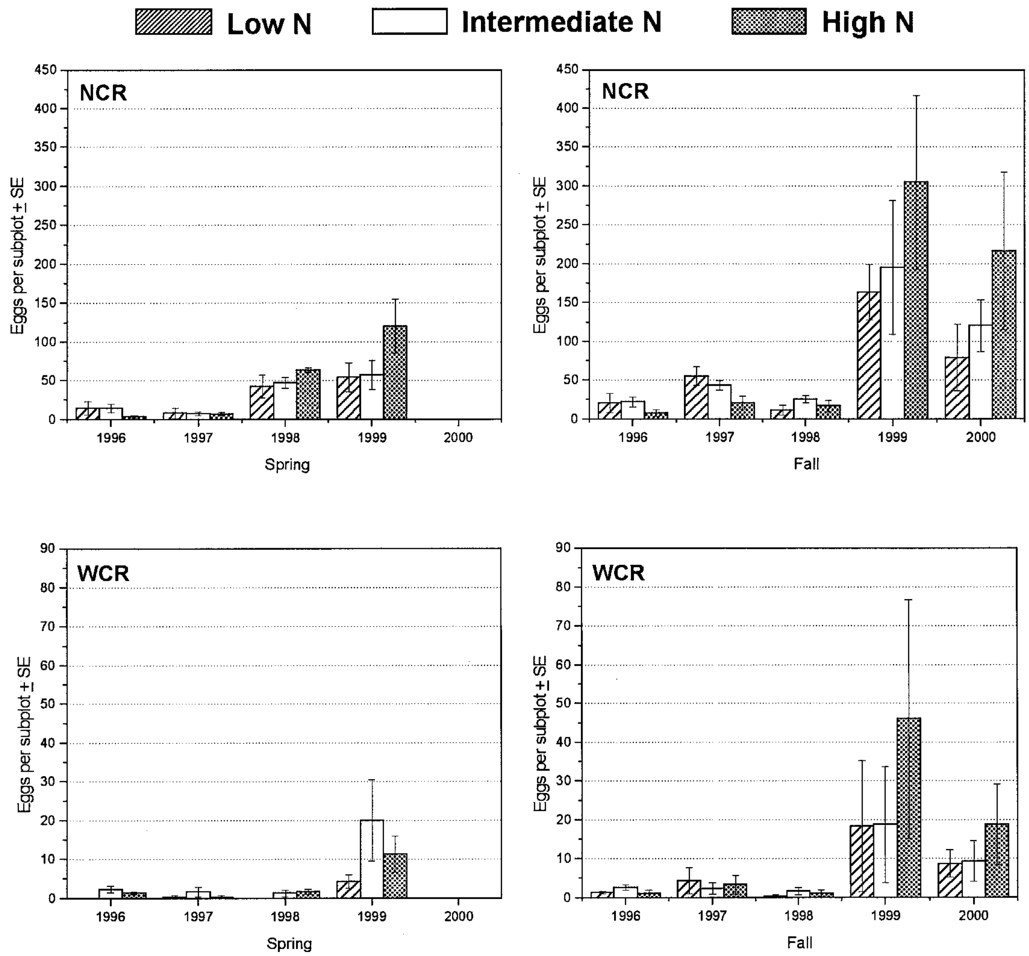

Figure 1. Recovery of northern (NCR) and western (WCR) corn rootworm eggs in four within-row soil samples per subplot by subplot nitrogen (N) level, season and year

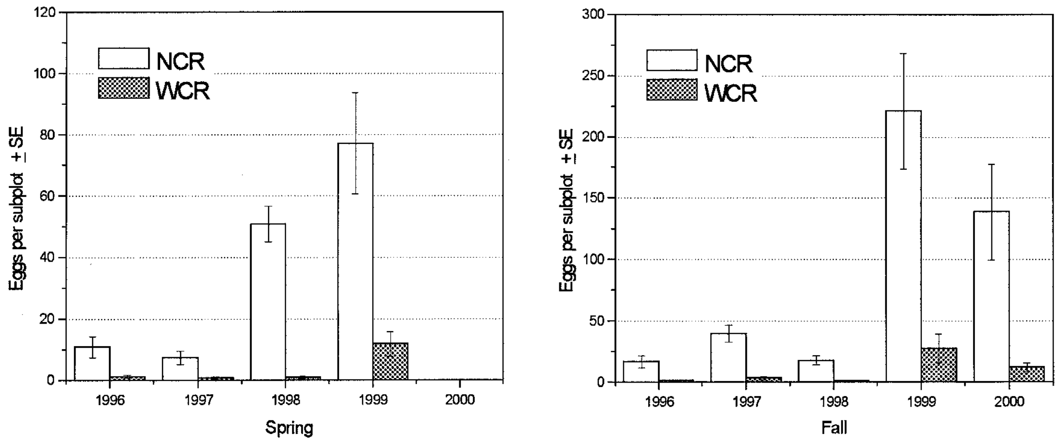

Figure 2. Recovery of northern (NCR) and western (WCR) corn rootworm eggs in four within-row soil samples per subplot by season and year. Data are averaged across nitrogen fertilization levels (N=9 subplots per season and year)

INFLUENCE OF PLANTING DATE ON INSECT INFESTATIONS, VIRAL DISEASE, PLANT GROWTH AND YIELD OF SPRING WHEAT, 2000

Louis Hesler[1], Walt Riedell[1], and Marie Langham[2]

Summary

1. Cereal aphid populations in all plots were relatively low. Populations peaked on May 22 with averages of 0.75, 3.75, and 6.75 aphids per 25 tillers in the early, middle and late plantings, respectively.

2. Numbers of wheat stem maggots and grasshoppers were low in all plots and did not pose a risk to spring wheat. Wheat stem maggot infestation was low in all plots, with means of 1.3, 0.9 and 1.5 percent infested heads in the early, middle and late plantings, respectively.

3. The late planting had a greater percentage (4.3) of wheat plants with wheat streak mosaic virus infection than the early planting (1.3 percent). The middle planting had an intermediate level of plants with WSMV (2.1 percent).

4. Spring wheat had low but similar infection levels of barley yellow dwarf virus across the three plantings. The incidence of BYDV-infected plants ranged from 2.3 to 3.0 percent among plantings (Table 2).

5. Measurement of leaf area showed that late-planted wheat had the thinnest canopy, whereas the early planting had the thickest canopy.

6. Early planted wheat yielded most, had the greatest number of total seeds per foot of row and the greatest number of heads per foot of row.

Introduction

Infestation of spring wheat by cereal insect pests can reduce yield. Cereal aphids can infect wheat with barley yellow dwarf virus. Severity of aphid infestation is generally affected by planting date, but specific differences in infestation levels have not been determined for various planting dates. The objective of our study was to measure insect and viral disease levels and plant growth and yield of spring wheat planted at three different dates.

Methods

'Ember' spring wheat was sown at three different planting dates ("early", Apr 13; "middle", Apr 24; and "late" May 5, 2000) at the Eastern South Dakota Soil and Water Research Farm near Brookings. Planting-date treatment plots (32 by 60 ft) were arranged in a randomized complete block design with 4 replicates. Seed was sown using a JD 750 drill roughly 1-in. Deep in furrows 7.5 in. Apart. Fertilizer was applied at planting.

Cereal aphids. Spring wheat was sampled for ahid infestations over 6 sampling dates: May 2 (only plots of early and middle planting dates), and May 12, May 22, May 31, Jun 8 and Jun 19. On each sampling date, we sampled 25 tillers (from five groups fo five plants) per plot and counted the number of cereal aphids per tiller.

Wheat stem maggot. Spring wheat was sampled for wheat stem maggot infestation by counting the number of heads within each of 10, 0.09 m^2-quadrats per plot. Grain heads were sampled during the milk to soft dough stages (Jun 27 for early and middle plantings, Jul 5 for late planting). White heads within each quadrat were examined for the presence of maggot infestation. The ratio of maggot-infested heads to total grain heads were quadrat was expressed as a percentage.

Grasshoppers. We sampled for grasshoppers by walking along a 20-m transect within each plot during the milk to soft dough stages (Jun 27 for early and middle plantings, Jul 6 for late planting). Grasshoppers seen moving into or out of an approximately 2-ft. Wide swath along each transect were counted..

Viral diseases. We sampled for the

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incidence of viral diseases in wheat by walking through plots in a W-pattern and classifying 200 randomly selected plants per plot as either having or not having symptoms of barley yellow dwarf virus (BYDV) or wheat streak mosaic virus (WSMV). Plots were sampled for WSMV and for BYDV on Jul 3, 2000.

Leaf area measurements. The ratio of wheat-leaf area to the ground area upon which the wheat was grown was measured using the leaf-area index (LAI) feature of the LAI-2000 crop canopy analyzer on May 26, 2000. An above-canopy reference measurement was used as a benchmark for 4 within canopy measurements per plot. Data were averaged across treatments and standard deviation of data means calculated using Excel spreadsheet software.

Yield data. Plots were harvested by hand and by using a Massey-Ferguson 8XP combine on Aug 1. Hand-harvest yield data was derived by taking three, 1-foot sections of row per plot. Plants were cut at the ground level using scissors. Leaves, stems, and grain heads were placed into paper bags and dried to ambient humidity in a greenhouse. The number of heads was determined, and the grain manually separated from the chaff. Total grain weight and 100-kernel weight was then measured. Data for grain yield in bushels per acre was extrapolated from the 1-foot grain-harvest samples. Test weight and moisture content of grain combined over date of planting treatments were measured using a Dickey-John seed tester.

Combine yield was taken from two, 6-ft-wide combine strips within each plot; exact measurements of strips were made immediately after each combine pass. Moisture was measured for each combine strip sample, and yield data was adjusted to the equivalent weight at 13.5 percent moisture. Test weight and moisture content of grain combined over date of planting treatments were measured using a Dickey-John seed tester.

Results

Aphids. Cereal aphid populations in all plots were relatively low. Populations peaked on May 22 with averages of 0.8, 3l.8, and 6.8 aphids per 25 tillers in the early, middle and late plantings, respectively. Plants were tillered in the early and middle plantings, and in the 3-to 5-leaf stages in the late planting.

Wheat stem maggots. Wheat stem maggots were found in low numbers in all plots. They infested a mean of 1.3, 0.9 and 1.5 percent of heads sampled in the early, middle and late plantings, respectively.

Grasshoppers. Grasshoppers were sparse in all plots. We detected a mean of 0.3, 0.6 and 0.3 grasshoppers per 20-m transect in the early, middle and late plantings, respectively.

Viral diseases. The late planting had a greater percentage (4.3) of wheat plants with WSMV infection than the early planting (1.3 percent) (Table 1). The middle planting had an intermediate level of plants with WSMV (2.1 percent). Spring wheat had low but similar levels of BYDV infection across the three plantings. The incidence of BYDV-infected plants ranged from 2.3 to 3.0 percent among plantings (Table 1).

Leaf area. Leaf area index measurements show that late-planted wheat had the thinnest canopy, whereas the early planting had the thickest canopy (Table 2). The middle planting had crop canopy characteristics that were intermediate between the early and late plantings.

Results from the combine harvest samples (Table 3) showed that yields for early and middle plantings were similar, and that yield for the late planting was considerably less than the yield of early and middle plantings. Test weights were comparable among the three plantings.

A comparison between hand and combine harvest results showed some similarities and some differences. Both methods indicated that early plantings yielded the most grain, and that the middle planting had a yield intermediate to that of early and late plantings.

Results from the two harvest methods differed in that hand harvest results gave higher estimates of yield than combine harvest results. Hand harvest also indicated that the difference in yield between early and middle plantings was greater than that of middle and late plantings. In contrast, combine harvest indicated a greater similarity between early and middle plantings. Finally, hand harvest indicated that test weight for the late planting was substantially less than either the early or middle plantings, whereas combine harvest results showed test weights to be similar among plantings.

Table 1. Percentage of spring wheat plants showing symptoms of wheat streak mosaic (WSM) and percentage showing symptoms of barley yellow dwarf (BYD), year 2000, Eastern South Dakota Soil and Water Research Farm, near Brookings.

Planting	Plants with WSMV symptoms (percent)	Plants with BYDV symptoms (percent)
Early	1.3 (0.3)	2.3 (0.6)
Middle	2.1 (0.5)	3.0 (0.5)
Late	4.3 (0.9)	2.3 (0.3)

Values represent an average (± standard error) for 4 replicates per planting of spring wheat (early = Apr 13, middle = Apr 24, and late = May 5, 2000). Plants sampled for WSM and BYD on Jul 3, 2000.

Table 2. Leaf area measurements and hand-harvest yield results for 'Ember' spring wheat, year 2000, Eastern South Dakota Soil and Water Research Farm, near Brookings.

Planting	Crop canopy[a]	Total head	Total seeds	Seed weight	Yield[c]
	(LAI)	(per foot of row)		(g per 100 seeds)	(bu acre^{-1})
Early	5.5 (0.2)[b]	52 (5)	1281 (125)	2.39 (0.05)	81 (6)
Mid	4.7 (0.1)	43 (50	1005 (134)	2.57 (0.06)	67 (8)
Late	4.0 (0.4)	37 (2)	872 (29)	2.41 (0.05)	59 (3)

[a] Values represent average (± standard deviation) for 4 replicates per planting of spring wheat (early = Apr 13, middle = Apr 24, and late = May 5, 2000).

[b] Crop canopy characteristics were measured with a LAI-2000 leaf area index (LAI) meter during boot stage: June 12, June 15 and June 23 for early, middle and late plantings, respectively.

[c] Data were obtained on Aug 1 by hand harvest. Test weights were 59.7, 60.2, and 55.9 lbs bu^{-1} for early, middle, and late plantings, respectively.

Table 3. Yield results from combine harvest of 'Ember' spring wheat, Aug 1, 2000, Eastern South Dakota Soil and Water Research Farm, near Brookings.

Planting	Yield (bu acre^{-1})	Test weight (lb bu^{-1})
Early	44.7 (0.8)	60.3 (0.1)
Middle	42.9 (1.0)	60.4 (0.4)
Late	39.0 (0.6)	59.5 (0.3)

Values represent an average (± standard error) for 4 replicates per planting of spring wheat (early = Apr 13, middle = Apr 24, and late = May 5, 2000).

Acknowledgments

Max Pravecek established and combine-harvested the spring wheat plots. Dave Schneider, Kurt Dagel, Erika Zink, Megan Johnson and Rebecca White assisted in spring sampling.

INFLUENCE OF PLANTING DATE ON INSECT INFESTATIONS IN WINTER WHEAT, 1999-2000

Louis Hesler[1], Walt Riedell[1] and Marie Langham[2]

Summary

1. Autumn infestations of cereal aphids in winter wheat peaked at 190 per 25 tillers in the early planting (Oct 28), 110 in the middle planting (Nov 18), and 69 in the late planting (Nov 18 and (Dec 7). Corn leaf aphids predominated on the first three sampling dates, whereas bird cherry-oat aphids predominated later in the autumn.

2. More grasshoppers were found in early versus middle or late plantings of wheat.

3. The incidence of damage from chewing herbivores peaked at 40% on Sep 20 in the early planting, at 36% on Sep 30 in the middle planting, and 11% on Nov 8 in the late planting. Overall, we estimated that less than 5 percent of the leaf area of wheat seedlings was defoliated.

4. The early planting of winter wheat had the highest percentage of plants with symptoms of barley yellow dwarf virus (BYDV), the middle planting had an intermediate level, and the late planting had the lowest percentage of plants iwth BYDV symptoms. The percentage of plants with wheat streak mosaic virus was ≤ 2.4 percent.

5. Early-planted wheat had the thinnest canopy, whereas the middle-planted wheat had the thickest canopy, according to leaf-area indices. Late-planted wheat had crop canopy characteristics intermediate to early and middle plantings.

6. The late planting yielded most, whereas the early planting yielded least. Hand harvesting showed yield in the middle planting was comparable to that of the early planting, whereas combine harvesting showed that yield of the middle planting was comparable to that of the late planting. Test weight estimates and trends among treatments were similar for both hand and combine harvesting.

Introduction

Infestation of seedling winter wheat by cereal aphids, grasshoppers, and other arthropod pests can reduce yield. Also, aphids can infect wheat with barley yellow dwarf virus, and wheat curl mites can transmit wheat streak mosaic virus. Severity of aphid, grasshopper, and mite infestation is generally affected by planting date, but specific differences in infestation levels have not been determined for various planting dates. The objective of our study was to measure insect, plant damage, and viral disease levels in winter wheat planted at three different dates and to determine plant growth and yield across the three planting dates.

Methods

'Roughrider' winter wheat was sown at three different planting dates ("early", Aug 31; "middle", Sep 10; and "late" Sep 20, 1999) at the Eastern South Dakota Soil and Water Research Farm near Brookings. Planting-date treatment plots (32 by 115 ft) were arranged in a randomized complete block design with 6 replicates. Seed was sown using a JD 750 drill roughly 1-in. Deep in furrows 7.5 in. Apart. All seed was treated with fungicides (mixture of 17% Al carboxin and 17% Al thiram, 3.5 fl oz (product)/cwt) to prevent seed- and soi-borne diseases of wheat. Fertilizer was applied at planting (14-36-13, N-P-K, 100 lb/ac) and in early spring just before the wheat broke dormancy (46-0-0 (N-P-K), 300 lb/ac).

Aphid counts and damage by chewing herbivores. Seedling wheat was sampled for aphid infestations and chewing insect damage over 8 sampling dates in the autumn and once the following spring. On each sampling date, we sampled 25 tillers (from five groups of five plants) per plot. For each 25-tiller sample, we

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counted the number of cereal aphids per tiller and the number of plants damaged by herbivores with chewing mouthparts (i.e., insects such as grasshoppers, wireworms and cutworms, or small mammals).

Grasshoppers and crickets. We sampled for grasshoppers and crickets both within and along the margins of treatment plots on Sep 27 and Oct 12. We counted the number of grasshoppers and crickets seen as a sampler walked along a 20-m transect within each plot on each sampling date. Grasshoppers and crickets seen moving into or out of an approximately 2-ft. Wide swath along each transect were counted. We sampled for grasshoppers and crickets along field margins (i.e. grass alleys) on each sampling date by making 40 pendular sweeps with a 15-inch (diam.) Net along a transect parallel to and approximately 15 feet from the east, west, north and south margins of the research plots.

Viral diseases. We sampled for the incidence of viral diseases in wheat by walking through plots in a W-pattern and classifying 200 randomly selected plants per plot as either having or not having symptoms of barley yellow dwarf virus (BYDV) or wheat streak mosaic virus (WSMV). Plots were sampled for WSMV on May 19 and for BYDV on Jun 9.

Leaf area measurements. The ratio of wheat-leaf area to the ground area upon which the wheat was grown was measured using the leaf-area index (LAI) feature of the LAI-2000 crop canopy analyzer on May 26, 2000. An above-canopy reference measurement was used as a benchmark for 4 within canopy measurements per plot. Data were averaged across treatments, and standard deviations and means were calculated using Excel spreadsheet software.

Yield data. Plots were harvested by hand on 11 Jul 00 and by using a Massey-Ferguson 8XP combine on Jul 13. Hand-harvest yield data was derived by taking three, 1-foot sections of row per plot. Plants were cut at the ground level using scissors. Leaves, stems, and grain heads were placed into paper bags and dried to ambient humidity in a greenhouse. The number of heads was determined, and the grain manually separated from the chaff. Total grain weight and 100-kernel weight was then measured. Data for grain yield in bushels per acre was extrapolated from the 1-foot grain-harvest samples. Test weight and moisture content of grain combined over date of planting treatments and were measured using a Dickey-John seed tester.

Combine yield was taken from two, 6-ft-wide combine strips within each plot; exact measurements of strips were made immediately after each combine pass. Moisture was measured for each combine strip sample, and yield data was adjusted to the equivalent weight at 13.5 percent moisture. Test weight and moisture content of grain combined over date of planting treatments were measured using a Dickey-John seed tester.

Results

Aphids. Cereal aphid populations in plots of the early and middle planting dates rose, peaked and then gradually declined during the fall sampling period (Fig. 1). The population in the early planting peaked at nearly 200 aphids per 25 tillers on Oct 28. Aphids peaked at about 150 per tiller on Nov 18 in the middle planting. Populations in the late-planted wheat peaked at about 65 aphids per tiller on Nov 18 and remained at that level on the final sampling date (Dec 7). Leaf yellowing was quite noticeable on plants in the early and middle plots by mid-November, but did not appear in the late-planted plots. Corn leaf aphids predominated on the first three sampling dates, whereas bird cherry-oat aphids predominated later in the autumn.

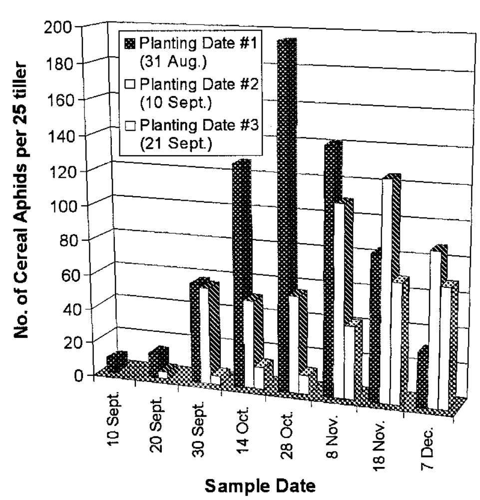

Fig. 1. Number of cereal aphids

Aphid infestations were light (≤ 1.4 aphids per 25 tillers) when sampled winter wheat was sampled the following spring (May 19, 2000) during the late joint to boot stages.

Grasshoppers. The number of grasshoppers was consistently greater in plots of the early versus the middle or late plantings of wheat. An average peak of 8.5 grasshoppers per 20-m transect occurred on Oct 14 in the early plots. However, the numbers of grasshoppers were well below economic threshold in all plots.

Damage by chewing herbivores. The incidence of damage from chewing herbivores peaked at 40% on Sep 20 in the early planting, at 36% on Sep 30 in the middle planting, and 11% on Nov 8 in the late planting. The range in the amount of defoliation was great, but most damage consisted of leaves with their tips or margins having uneven edges, irregular-shaped holes, or tillers that had been severed near the ground. Overall, we estimated that less than 5 percent of the leaf area of wheat seedlings was defoliated.

Viral diseases. The percentage of plants with WSMV symptoms was low, ranging from 1.1 percent in the early planting to 2.4 percent in the late planting (Table 1). In the middle planting, 1.9 percent of plants showed WSMV symptoms. These results are atypical, as earlier plantings usually have higher rates of infection.

The late planting of winter wheat had the lowest percentage of plants with BYDV symptoms (Table 1). The middle planting had an intermediate level of symptoms, and the early planting had the highest percentage of plants with BYDV symptoms.

Table 1. Percentage of winter wheat plants showing symptoms of wheat streak mosaic (WSM) and percentage showing symptoms of barley yellow dwarf (BYD), Eastern South Dakota Soil and Water Research Farm, near Brookings.

Planting	Plants with WSM Symptoms	Plants with BYD Symptoms
	(percent)	(percent)
Early	1.1 (0.1)	83.5 (4.5)
Middle	1.9 (0.4)	68.0 (5.8)
Late	2.4 (0.4)	41.3 (8.3)

Leaf area. At the time of leaf-area measurements, wheat in the early-, middle-, and late-planted treatments was in the anthesis (flowering), heading and boot/early heading stages of development, respectively. The early planting had the thinnest canopy whereas the middle planting had the thickest canopy (Table 2). The late-planted wheat had crop canopy characteristics that were intermediate to the early and middle plantings.

Table 2. Leaf area and yield results from hand harvest of 'Roughrider' winter wheat, Eastern South Dakota Soil and Water Research Farm, near Brookings

Planting[a]	Crop Canopy[b]	Total Heads	Total Seeds	Seed Weight	Yield[c]
	(LAI)	(per foot of row)		(g per 100 seeds)	(bu $acre^{-1}$)
Early	3.4 (0.3)	80 (2)	856 (138)	2.6 (0.1)	59 (11)
Middle	5.0 (0.4)	72 (11)	847 (132)	2.7 (0.1)	59 (7)
Late	4.8 (0.6)	68 (8)	1055 (72)	2.6 (0.1)	70 (4)

[a] Values represent average (± standard deviation) for 4 replicates per planting of winter wheat (early = Aug 31, middle = Sep 10, and late = Sep 20, 1999).

[b] Crop canopy characteristics were measured with a LAI-2000 leaf area index (LAI) meter on May 26, 2000.

[c] Data were obtained on Jul 11, 2000, by hand harvest. Test weights were 60.8, 61.5, and 60.6 lbs bu^{-1} for early, middle, and late planting dates, respectively.

STARTER FERTILIZER EFFECTS ON SOYBEAN YIELD AND QUALITY IN THE NORTHERN GREAT PLAINS

S.L. Osborne, W.E Riedell, and J.L. Pikul Jr.

INTRODUCTION

The concept of fertilizing soybeans (Glycine max (L.) Merrill) is not new. For several years scientist have investigated the effect of nitrogen (N) fertilizer on yield and quality of soybeans. Results from this work have found mixed conclusions. Brevedan et al. (1978) reported a 28 to 33 % yield increase under field conditions if N was applied between initial bloom (R1) to the end of bloom (R3). Terman (1977) found that applied-N increased early vegetative growth by 20%, but that it had no subsequent effect on yield. Sorenson and Penas (1978) concluded that a number of factors affect soybean response to applied-N including soil temperature, moisture and pH. The objectives of this experiment were to determine the effect of starter fertilizer N sources and rates on soybean yield, protein, and oil content, and to determine the effect of applied N on N fixation in the cool, moist soils of the Northern Great Plains.

METHODS

A field experiment was established in the spring of 2000 at the Eastern South Dakota Soil and Water Research Farm near Brookings, SD on a Barnes clay loam. The experiment was established within a two-year corn (*Zea mays* L.)-soybean rotation. Pioneer variety 91B01 soybeans were seeded at a rate of 235,000 seeds ac^{-1}. Planting occurred on 22 May 2000 with an 8 row JD 7200 planter. The experimental design was a split-plot design with four replications. Whole plots were no-till and conventional tillage and the split plots were fertilizer (source x rate) treatments. Starter fertilizer treatments were a 2 x 4 factorial arrangement of treatments with two N sources either ammonium nitrate (AN) or urea (UR) each at four rates (0, 7, 14, and 21 lb N ac^{-1}). Phosphorus (P) and potassium (K) were applied as 100 lb ac^{-1} of 0-36-13 (N-P_2O_5-K_2O). All starter fertilizer was applied at planting in a 2 X 2 band application. Plots were 20 X 50 ft with 30 in row spacing. Phenology data according to Ritchie et al. (1996) were recorded weekly from the first of June until the end of August.

Aboveground biomass sampling was performed at growth stage R1 (6 June 2000) and R7 (25 Aug 2000) along 3 ft of row. Samples were weighed, oven dried at 125^{0}F, and then reweighed to obtain total dry matter production. Samples were ground with a Wiley Mill to pass a 0.079-inch sieve. Nitrogen concentration was determined on all samples using dry combustion (Schepers et al., 1989) and ureide concentration as described by Young and Conway (1942). Grain yield was estimated by harvesting 50 ft of the two middle rows from each plot. Grain moisture and test weights were determined using a Dickey-John seed tester. Grain samples were oven dried at 125^{0}F, ground, and analyzed for N concentration as described above for biomass samples. Data analysis was performed using the GLM procedure in SAS (SAS, 1988).

RESULTS AND DISCUSSION

Only results of yield and biomass production will be discussed in the report. Biomass at R1 growth stage showed no significant difference among no-till plots. In the conventional tillage only the 7 lb N ac^{-1} AN treatment was significantly lower than other treatments, with biomass reduced by 22 % compared to the average of the other treatments (Fig. 1).

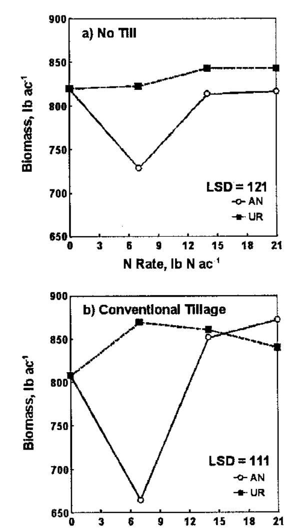

Figure 1. Soybean biomass production by treatment, R1 growth stage, 6 July 2000.

Results of the R7 sampling were similar to those of R1 stage, except for the 14 lb N ac^{-1} UR conventional tillage treatment. This treatment had significantly more biomass than the other treatments (Fig 2).

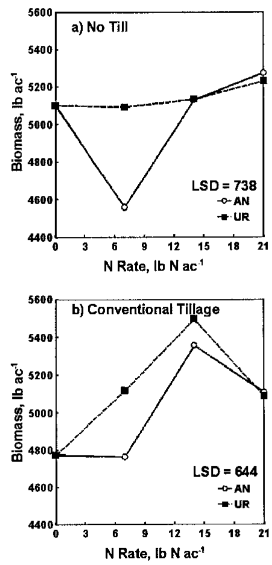

Figure 2. Soybean biomass production by treatment, R7 growth stage, 25 Aug 2000.

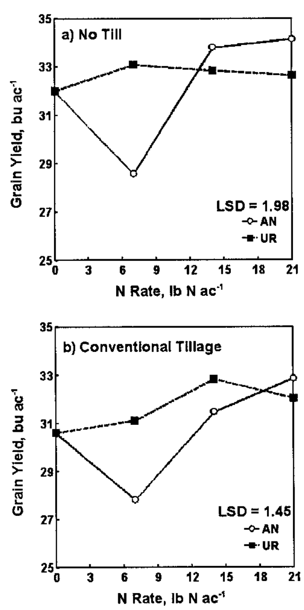

Figure 3. Soybean grain yield by treatment, 18 Sept, 2000.

Grain yield data was generally reflective of biomass data. The 7 lb N ac^{-1} AN treatment resulted in decreased yields, while maximum yield occurred at the 21 lb N ac^{-1} AN treatment (Fig 3). Overall grain yield was less for the conventional tillage compared to the no-till plots.

In all biomass and grain yield sampling, the 7 lb N ac^{-1} AN decreased production. This could be due to a decrease in nodulation in the early growth stages and subsequent decrease in N fixation. Perhaps the 14 and 21 lb treatments may have provided enough soil N to overcome a delay in nodulation. Ureide and N content (yet to be determined) information could strengthen this conclusion. Although differences in yield and biomass production are small, it is important to know that yield increased when N was applied at planting. Effect on soybean quality (such as protein and oil content) is needed to determine if starter fertilizer is economical.

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CARBON SEQUESTRATION IN SOIL UNDER TWO CROPPING SYSTEMS

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INTRODUCTION

With increased interest in global climate change, there is a new awareness of the potential for using innovative soil and crop management to capture (sequester) atmospheric carbon (C). Agriculture plays a major role in and benefits directly from removing C from the atmosphere. Carbon sequestration in soil is a complex process that starts when C is removed from the atmosphere by plants. Plant materials, both above and below ground, that remain in the field following harvest are subsequently decomposed. Decomposition products contain C and these products are generally called soil organic matter. Soil organic matter is continuously being decomposed and replenished resulting in a diverse array of compounds. These compounds have significant and positive effects on soil behavior. In moderation, organic matter is good for soil quality and sustained agricultural production.

Loss of soil organic matter (SOM) has been associated with increased tillage intensity. But, SOM loss from tillage can be expected to be a function of soil type, climate, and cropping practice (Lal et al., 1998). Increased intensity of tillage can increase short-term CO_2 flux from soils of semi-arid (Ellert and Janzen, 1999) and sub-humid (Reicosky and Lindstrom, 1993) agricultural production systems. The impact of these tillage-induced fluxes of CO_2 on atmospheric CO_2 concentration or soil C retention is uncertain. Ellert and Janzen (1999) suggest that the short-term influence of soil tillage on the transfer of soil C to atmospheric CO_2 is small. Based on cropping studies established in the 1930s in the semi-arid Pacific Northwest, USA, Rasmussen et al. (1998) concluded that loss of SOM was related to excessive oxidation and absence of C input during fallow. Decreasing tillage intensity reduced SOM loss, but cropping practice, especially avoiding bare fallow, had a more dramatic effect on SOM status. Similarly, Doran et al. (1998) concluded, from long-term studies on the Central Great Plains, USA, that decline of SOM could be slowed by a more intensive cropping system.

In the current popular press there is much publicity about the potential benefits of sequestering carbon from the atmosphere. Carbon dioxide is a green house gas and there is no question about the need to reduce emissions of green house gasses to the atmosphere. However, there are unresolved issues concerning the quantity of carbon that can actually be sequestered in soil and the time frame involved in that sequestration. This progress report provides preliminary information on soil carbon budget affected by crop rotation. Our objectives were to ascertain effect of cropping system on soil carbon sequestration.

METHODS

Our study was located on the Eastern SD Soil and Water Research Farm at Brookings, South Dakota 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 rotations discussed in this report are continuous corn (CC) and corn grown in rotation with

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soybean, spring wheat, and alfalfa hay (4-year rotation). Rotations in the experiment were arranged as a randomized complete block. Plots were 100 ft by 100 ft. All crops in the 4-year rotation were present every year. Therefore, there were 4 identical 4-year rotations each being in a different crop phase. Rotations were started in corn, soybean, wheat, or alfalfa in 1990. The present report is based on soils and crops data from the 4-year rotation that was started as alfalfa in 1990 and rotated into corn in 1991.

Continuous corn plots were fertilized with N to achieve a yield goal of 135 bu/acre. Fertilizer N prescription follows the Fertilizer Recommendations Guide, SDSU (Gerwing and Gelderman, 1996). Samples for soil nitrate-N were collected in the fall or spring, depending on weather conditions. Nitrogen prescription was met by applying starter fertilizer with the seed and sidedressing appropriate amounts of urea (46-0-0). Urea-N was broadcast on CC immediately before the 2nd cultivation. The 4-year rotation was not fertilized with inorganic N.

With the start of the 1996 crop year, 100 lb/acre of starter fertilizer as 14-36-13 and 0-36-13 (N- P_2O_5- K_2O) have been used on CC and the 4-year rotation, respectively. Soil P levels were rebuilt prior to spring fieldwork in 1996 with an application of 395 lb/acre of triple super phosphate (45% P_2O_5) on all plots (Equivalent to 80 lb/acre of elemental P).

Moldboard plow or chisel plow in the fall of the year has been the primary tillage, except in 1995 and 1996 when wet weather conditions precluded fall tillage. Primary tillage since 1996 has been chisel plow. Seedbeds for corn, soybean and wheat were prepared using a tandem disk and field cultivator. All corn and soybean plots were cultivated twice during the early growing season. Total tillage operations for a 4-year time interval are shown in Table1.

Corn seeding dates and rates (30,000 seeds/acre) were the same for both treatments in a given year. Soybean was planted at 225,000 seeds/acre. Row spacing was 30 inches for corn and soybean. Wheat was planted at 1,000,000 seeds/acre in 7.5-inch rows. Alfalfa was companion seeded (12 lb/acre) with spring wheat by broadcast seeding at the time of wheat planting.

Relationships between plant materials removed from the plots and plant C returned to the soil were developed for corn, soybean, wheat, and alfalfa. Samples were taken to measure quantity of C in plant materials (grain, crop residue, and hay) in 1996, 1997, 1998, and 1999. Carbon content of plant materials was measured using a Carlo Erba NA 1500 C-N analyzer. Corn stover/grain ratio was 0.96. Carbon content of stover was 44.1%. Wheat straw/grain was 1.27. Carbon content of straw was 44.7%. Soybean plant/grain was 2.03. Plant carbon was 44.9% and grain C was 49.8%. We estimated that 20% of alfalfa hay crop remained in the field. Carbon content of alfalfa was 44.6%.

In 1989, prior to establishment of this study, the experimental farm was sampled on a 100-ft. by 100-ft. grid (Maursetter, 1992). Samples were taken in August after a wheat crop. Intact soil cores 2 inches in diameter were taken from the Ap (plow depth) layer for determination of soil bulk density and soil organic C. Soil organic matter was determined by loss on ignition (360 °C for 2 hr). Organic C was estimated by assuming organic matter of soil contains 56% organic C. Analytical results on samples from grid locations that match to the location of present day rotation plots were used to calculate change in organic C between 1989 and present day.

In 1999, all plots were soil sampled for bulk density and organic C at three dates corresponding to before seeding, at corn tassel stage, and at harvest. At each sampling date, 20 cores were collected from the 0- to 3-inch and 3- to 6- inch depth. Five of the twenty cores were taken from row positions and fifteen of the twenty cores were taken from between-the-row positions. Samples were processed and organic C measured by complete combustion using a Carlo Erba NA 1500 C-N analyzer. Soil C results for 1999 were presented as an average of sampling date and depth.

Mass of C/area/depth was calculated as the product of C concentration, bulk density and core length for soil samples collected in 1989 and 1999. Carbon sequestered in the top 6 inches of soil was determined by calculating the difference in soil C between 1999 and 1989. For this report, only one crop rotation sequence for the 4-year rotation was shown and that was for the plot series starting as corn in 1991.

RESULTS AND DISCUSSION

These field trials cover one of the wettest and coolest periods in the South Dakota climate record beginning 1890 (Alan Bender, South Dakota State Climatologist, Brookings, SD). Precipitation totals from 1991-1995 were the greatest in more than 100 years and the 1992 and 1993 summers were the coolest consecutive summer seasons.

From 1990-1999, total corn grain harvested from CC plots was 1122 bu/acre (Table 2). Available N (fertilizer N and soil nitrate N) for this yield was 1634 lb N/acre resulting in a N-use-efficiency (NUE) factor of 0.7 bu corn/lb N (Fertilizer guides for SD and MN suggest 0.8 bu corn/lb N). During the same length of time, total corn grain yield was 321 bu/acre from the 4-year rotation (Table 2, 1991, 1995, 1999). Soil nitrate N was 182 lb N/acre resulting in a NUE factor of 1.8 bu corn/lb N. Comparison of NUE's for CC and the 4-year rotation can be misleading because the values suggest that corn grown in a 4-year rotation is more efficient at converting N to corn grain. This is not the case because N taken up by corn in the 4-year rotation is derived through the biological conversion of soil organic nitrogen (contained in soil organic matter) to inorganic N.

Soil improvement is a slow process and crop yield is a valuable indicator of soil condition because the plant integrates across many biological, chemical, and physical soil properties. Corn grain yield from the 4-year rotation plots in 1999 was 125 bu/acre without additional fertilizer N. Corn yield was 86 bu/acre under CC. For comparison, corn yield was 105 bu/acre under a corn-soybean rotation fertilized with N at the same rate as the CC rotation (data not shown). In 1999, the 4-year rotation had been through 2 complete 4-year rotations with 2 crop-years of alfalfa hay. We have found that alfalfa plowed-down can supply at least 50 lb N/acre more than CC (Carpenter-Boggs, et al., 2000).

It is difficult to judge soil condition by quantity of soil C alone. There are many soil properties, acting together, that ultimately affect how a soil will function. Soil quality factors may be affected by tillage, crop practice and fertilizer additions. For the present report, we have focused on soil organic C. In the past 10 years, total corn grain yield from CC plots was 1,122 bu/acre (31.4-ton grain/acre). This production level produced 30.1-ton stover/acre, or 13.3 ton C/acre, that was returned to the soil. Our estimates are for aboveground plant material only. We can only account for a gain of 0.821-ton C/acre (6% of the C returned as stover) in the top 6 inches of soil (Figure 1). On the 4-year rotation, 5.7 ton C/acre was returned to the soil. On these plots we have measured a loss of 0.17-ton C/acre from the top 6 inches (Figure 1). There was about 35% less tillage used on the 4-year rotation compared with CC.

Research in the northern corn belt suggests that the balance of C in soil depends on crop yield. Larson et al. (1972) showed that corn, under conventional tillage, provided a net addition to soil organic C when the amount of corn stalk dry matter returned to the soil exceeded 2.7 ton/acre (Larson et al., 1972). Depending upon the ratio of corn stover/corn grain, this equates to about a grain yield of 100 bu/acre. Our results on soil organic C accumulation were in general agreement with Larson et al. (1972) because our corn yield averaged 112 bu/acre and we measured only a small increase in soil organic C under continuous corn.

CONCLUSION

Corn captured significant amounts of C. But, only a small fraction of plant C was retained in the soil. Continuous corn returned 2.3 times as much C to the soil as the 4-year rotation. Under conventional tillage methods, the rate of loss of soil organic C was nearly the same as the rate of C return from plant materials. The net result after 10 years was a small gain of soil organic C under continuous corn and a slight loss of organic C under a 4-year rotation. Soil productivity is related to both quantity of soil organic C and quality of soil organic matter as well as other factors. The good yield of corn on the unfertilized 4-year rotation in 1999 may reflect soil-improvement on this rotation regardless of soil C status.

Our findings are applicable to other production areas in SD as a guide to estimate reasonable rates of soil organic C accumulation or loss. In respect to corn production, our trials represent average corn production in South Dakota. Average corn grain yield for 1995-1999 was 107.8 bu/acre for Brookings County and 103.2 bu/acre for South Dakota (Hamlin and Noyes, 2000). Yield from our plots for 1995-1999 was 108.8 bu/acre. Therefore, the quantity of corn residue returned to the soil of our research plots under CC was representative of an average condition for South Dakota. Sustainability questions aside, continuous corn may appear as a viable way to sequester carbon because of the large amount of organic material returned to the soil under corn. However, within a corn production system using conventional tillage and producing only 100 bu/acre of corn grain per year we found limited gains in soil C after 10 years. Our current effort is to evaluate both N fertilizer and crop rotation on soil C storage.

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Table 1. Comparison of tillage operations during 4 years in continuous corn and a 4-year crop rotation.

Crop system	Primary tillage moldboard or chisel	Seedbed preparation disk and cultivate	Row cultivation twice per season	Total operations
Continuous corn				
Corn	1	2	2	5
Corn	1	2	2	5
Corn	1	2	2	5
Corn	1	2	2	5
Total	4	8	8	20
4-year rotation				
Corn	1	2	2	5
Soybean	1	2	2	5
Wheat - alfalfa	0	2	0	2
Alfalfa hay	1	0	0	1
Total	3	6	4	13

Table 2. Crop yield on plots in continuous corn and in a 4-year rotation of corn, soybean, wheat, and alfalfa.

		Continuous corn		4-year rotation			
Year	Crop	Yield Bu/acre	Residue C (ton/acre)	Crop	Yield Bu/acre	Yield (ton/acre)	Residue C (ton/acre)
1990	Corn	137.6	1.631	Alfalfa		1.00	0.089
1991	Corn	158.1	1.874	Corn	124.8		1.479
1992	Corn	93.5	1.108	Soy	19.9		0.246
1993	Corn	53.5	0.634	Wheat	5.3		0.090
1994	Corn	134.8	1.598	Alfalfa		2.46	0.219
1995	Corn	98.0	1.162	Corn	71.6		0.849
1996	Corn	146.2	1.733	Soy	37.8		0.468
1997	Corn	100.5	1.191	Wheat	34		0.578
1998	Corn	113.5	1.345	Alfalfa		1.93	0.172
1999	Corn	85.9	1.018	Corn	124.7		1.478
Total		1121.6	13.30				5.67

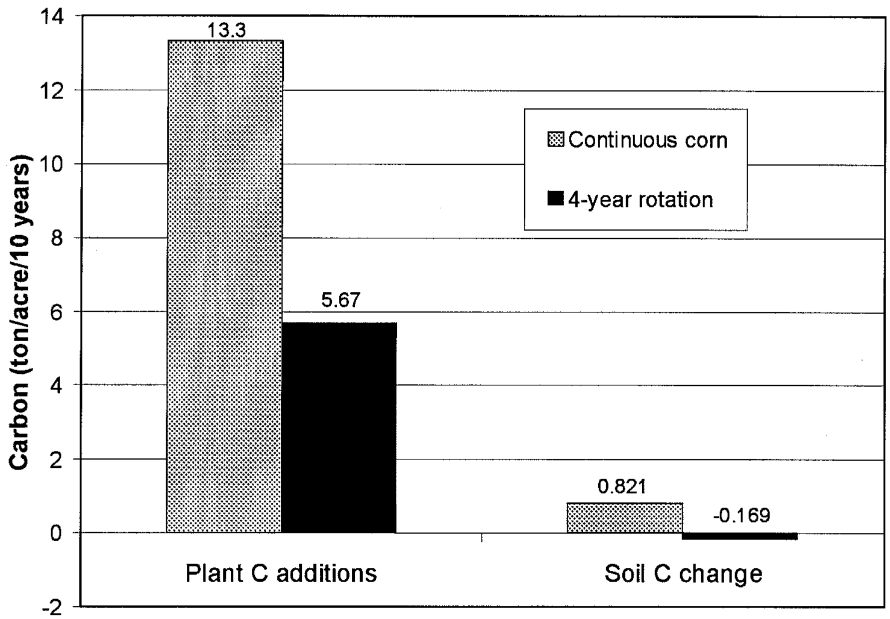

Figure 1. Aboveground plant carbon (Plant C additions) returned to the soil during 1990-1999 for continuous corn and a 4-year rotation of corn-soybean-wheat/alfalfa-alfalfa hay. Change in soil carbon (Soil C change) in the top 6 inches of soil under continuous corn and the 4-year rotation from 1989 to 1999.

NO-TILL FARMING PRACTICES FOR CORN?

Walt Riedell, Kurt Dagel, Dave Schneider, Louis Hesler, Shannon Osborne

INTRODUCTION

No-till farming practices are important components of sustainable agriculture systems. Research has shown that many of the advantages associated with no-till farming are derived from the residue mulch that remains on the soil surface after crop harvest. The residue mulch protects the soil from wind and water erosion, smothers weeds, reduces evaporation from the soil surface, and helps increase soil organic matter. Research conducted in Minnesota and North Dakota has shown that the residue mulch also delays soil warming in the spring which causes slower seed germination and less vigorous early crop growth. These contrasting characteristics of no-till farming practices add extra dimensions of complexity and uncertainty to sustainable agriculture, causing some producers to view no-till farming as a risky practice in the northern corn growing regions.

Our overall research goals are to understand the potential complexity that no-till farming practices introduces to sustainable agriculture systems, and to develop crop production systems that reduce the risk associated with no-till farming practices. With the research reported here we document how soil temperatures are affected by no-till farming practices and how these differences in soil temperature affect corn crop growth and yield.

MATERIALS AND METHODS

No-till and conventional tillage (fall chisel/spring disk) plots were established at the Eastern South Dakota Soil and Water Research Farm near Brookings SD in 1997. Plots received a soybean (1997), barley (1998), winter wheat (fall 1998 and 1999), and corn (2000) rotation. Data presented in this report came from the year 2000 growing season with the corn phase of the rotation. Corn (Golden Harvest H7476RR, 99 day relative maturity) was planted at a rate of 32000 kernels acre^{-1} on 3 May 2000 using an 8-row JD7200 corn planter. Corn production practices common to eastern South Dakota were used in this study.

ARS technicians Erika Beste-Zink and Kurt Dagel install soil temperature and moisture probes in no-till corn plots (following wheat) at the Eastern South Dakota Soil and Water Research Farm.

Recording thermometers (Boxcar, Onset Inc.) were placed at a 2 inch depth in the plots on 17 May 2000 (DOY 138) and were removed on 15 September 2000 (DOY 259). Soil heat unit accumulation (GDD, growing degree day, base 50 F) also was calculated. Corn leaf development was measured by counting the number of leaves per stem that produced a collar (ligule). These measurements were started on 16 June 2000 (DOY 168) and ended when the corn crop reached the tassel development stage on 26 July 2000 (DOY 208) in the conventional tillage plots and on 4 August 2000 (DOY 217) in the no-till plots. Corn yield was estimated from hand harvests (30 feet of row per plot) conducted on 7 December 2000. Grain test weights were determined with a Dickey-John seed tester.

RESULTS AND DISCUSSION

In contrast to the conventional tillage plots that had no surface residue present, no-till plots had a substantial amount of small grain residue spread evenly over the soil surface at corn planting. During the early portion of the growing season (DOY 138 to 164), soil temperature under conventional tillage was dramatically greater than that under no-till (Fig. 1). Later in the growing season

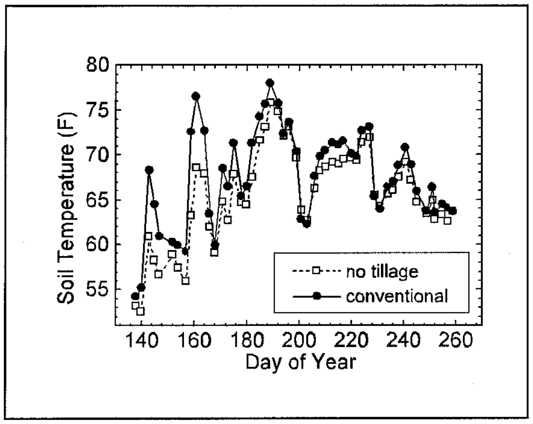

Fig. 1. Soil temperature under conventional tillage and no-till farming practices from 17 May to 16 September 2000.

(beyond DOY 168), soil under conventional tillage continued to be warmer than under no-till but the differences between tillage types were smaller (Fig. 1).

Soil heat unit accumulation rates (Fig. 2) were linear for both conventional and no-till farming practices from DOY 168 to 220. The Y intercept at DOY 166 was about 120 GDD units greater under conventional tillage than under no-till (Fig. 2). The slope of the line that describes soil heat unit accumulation under conventional tillage was slightly

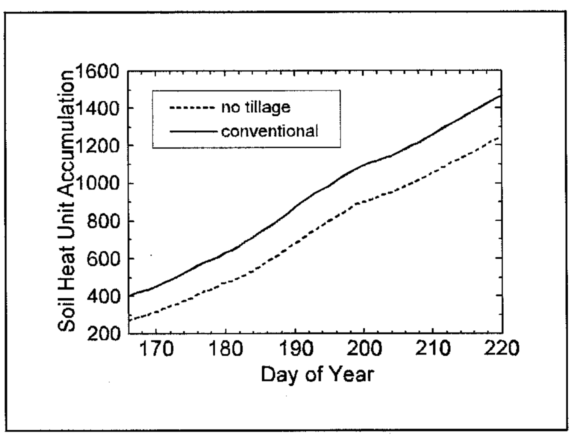

Fig. 2. Soil heat unit accumulation (growing degree days, base 50 F) under conventional tillage and no-till farming practices from 16 June to 7 August 2000.

greater than that seen under no-till. Soil under no-till management required an additional 10 days to reach 400 GDD units and an additional 12 days to reach 1200 GDD units when compared with conventional tillage (Fig. 2).

Corn leaf development rates (Fig. 3) also were linear for both conventional tillage and no-till from DOY 168 to 220. The Y intercept at DOY 168 was about 1 leaf unit greater under conventional tillage when compared with no-till (Fig. 2). The slope of the line that describes corn leaf development under conventional tillage appears to be slightly greater than that seen under no-till. Corn grown under no-till took an additional 6 days to reach the 6th leaf stage and an additional 10 days to reach 20th leaf stage when compared with corn grown under conventional tillage (Fig. 3).

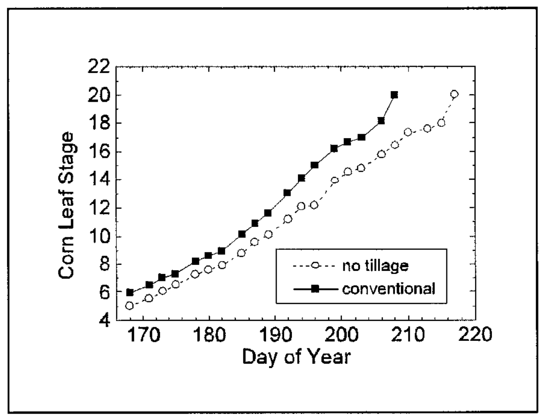

Fig. 3. Corn leaf development (leaves with ligule) under conventional tillage and no-till farming practices from 16 June to 7 August 2000.

Attempts were made to harvest the experimental plots with a plot combine in late September. At this time, grain moisture levels in corn grown under no-till exceeded 30 percent while corn grown under conventional tillage had 15 to 18 percent. It was decided to delay harvest. Wet soil and an early snowstorm prevented us from using a combine to harvest the corn plots. Hand harvest data is shown in Table 1. Grain yields and test weight were significantly greater (α = 0.1) with under conventional tillage than with no-till.

Table 1. Effect of no-tillage and conventional tillage on corn test weight and grain yield.

Tillage	Test weight	Grain yield
	(lbs/bushel)	(bushel/acre)
No-Till	51	137
Conventional	54	150
Prob. > *F*	0.10	0.06

CONCLUSION

Our results document the negative effects of soil surface residue on soil warming in the spring and on soil heat unit accumulation during the growing season in eastern South Dakota. By early August, soil heat unit accumulation and corn leaf development were delayed about 12 and 10 days, respectively, under no-till when compared with conventional tillage. The difference in corn development prevented us from combining corn in a timely manner. The delayed development of corn grown with no-till farming practices may be partially responsible for the reduced grain test weight and yield seen under these experimental conditions. Additional research with the goal of reducing the delay in corn development associated with no-till appears warranted.

CORN AND SOYBEAN INTERSEEDED WITH CRIMSON CLOVER

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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.

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. Crimson clover could also be useful to help remove excess water in the spring through transpiration. If used in conjunction with Roundup-Ready (RR) crops, soil moisture could be monitored and the clover killed at a critical soil moisture content based on the probability of a dry or wet spring. 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. A fall dormant seeding on November 18, 1999 was made. However in the spring of 2000 there was no evidence of germination. Therefore on May 25, 2000 all plots were sprayed with 2 quarts of roundup. The crimson clover was reseeded on all plots on May 26, 2000 with a JD 750 drill. Soybean (*Glycine Max* L.) (1800 –4 RR Stine, late maturity group 1) was planted at the rate of 235,000 seeds per acre (95% germination). Corn (*Zea mays* L.) (Golden Harvest H-7476RR, 99-day relative maturity) was planted at 29,000 seeds per acre (95% germination). Both soybean and corn were planted in 30-inch rows on May 26, 2000 with a JD 7200 planter. Prior to planting 105 Lbs. of actual N was broadcast applied as 46-0-0. Fertilizer (14-36-13) was applied at the time of planting at the rate of 100 lbs per acre. The plot area for the chisel plow/disk study was tilled prior to planting. The no-till study was last tilled in the spring of 1999. All treatments were sprayed with Glyphosate (Roundup – Ultra) on July 17, 2000 with 2 quarts on the soybeans and 1 quart on the corn. This killed grass and broadleaf weeds and substantially slowed the growth of the crimson clover.

The chisel plow/disk study was laid out in a randomized complete block design with four replications. Treatments consisted of crimson clover, corn, soybean, clover interseeded with corn, and clover interseeded with soybean. The no-till study was laid out in an identical randomized complete block design. Each plot had dimensions of twenty feet wide and one hundred twenty feet long. Plots were visually evaluated during the growing season. Digital photos were taken to document the progress of each treatment.

Soybean plots were harvested for yield on September 29, 2000 using a plot combine. Corn plots were harvested October 25, 2000. The middle four rows were harvested for yield.

RESULTS

Grain yield for corn and soybean on the chisel plow/disk study are given in Table 1. There was no significant difference in yield between the crops that had a vigorous growth of crimson clover in the inter-row prior to July 17 when Roundup was applied and crops with no inter-seeding of crimson clover. The crimson clover turned yellow-green when sprayed with Roundup and essentially stopped growing for several weeks but was not completely killed. This reduced competition but maintained ground cover. The crimson clover eventually disappeared from the interseeded areas but continued to survive and began to regrow in monoculture as also observed in 1999.

The grain yield for corn and soybean are given in Table 2 for the no-till study. There was a significant 6-bu/a yield reduction in soybean when clover was interseeded with the soybean. The significant effect of clover on reducing soybean yield in the no-till study may be related to early competition between the two legumes. However the lack of a similar response in the chisel plow/disk study suggests an additional factor related to soil disturbance is responsible for the lower yield in the no-till soybean - clover treatment.

Table 1. Grain Yield (bu/a) - Chisel Plowed and Disked Study

Crop	Without Clover	With Clover	P> F *
Corn	108	116	0.22
Soybean	29	28	0.80

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

Table 2. Grain Yield (bu/a) - No-till Study

Crop	Without Clover	With Clover	P>F *
Corn	85	90	0.53
Soybean	35	29	0.001

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