2000 RESEARCH and CROPPING RESULTS
Area IV SCD/ARS Research Farm

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INTRODUCTION
AREA IV SCD/ARS RESEARCH FARM

The Area IV SCD/ARS Research Farm is the result of a specific cooperative agreement between USDA-ARS and the twelve Soil Conservation Districts (SCDs) that make up Area IV. This agreement was put in place in 1984. Through this agreement, the Area IV SCDs lease cropland from the Nelson estate for the Northern Great Plains Research Lab, USDA-ARS, to conduct cooperative research projects with the Area IV SCDs. Total cropland leased by AREA IV SCDs is 382 acres. In addition, USDA-ARS has leased 55 acres in sec. 17 and sec. 18 for soil and water conservation research for many years and another 26 acres in sec. 8 for tree plantings since 1989. Total acreage leased for research purposes is 463 acres. The Area IV Research Farm is located southwest of the USDA-ARS Northern Great Plains Research Laboratory, Mandan, ND (Figure 1). The general 2000 cropping plans are outlined on maps for the four field areas designated as F, G, H, and I (Figure 2). The precipitation pattern for the 2000 growing season and the total precipitation history (1984-2000) for the duration of the Area IV cooperative agreement is shown in Figure 3 and Figure 4.

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Site specific farming.

FIG. 1. LOCATION OF ARS AND AREA IV RESEARCH FARM LAND RESOURCES

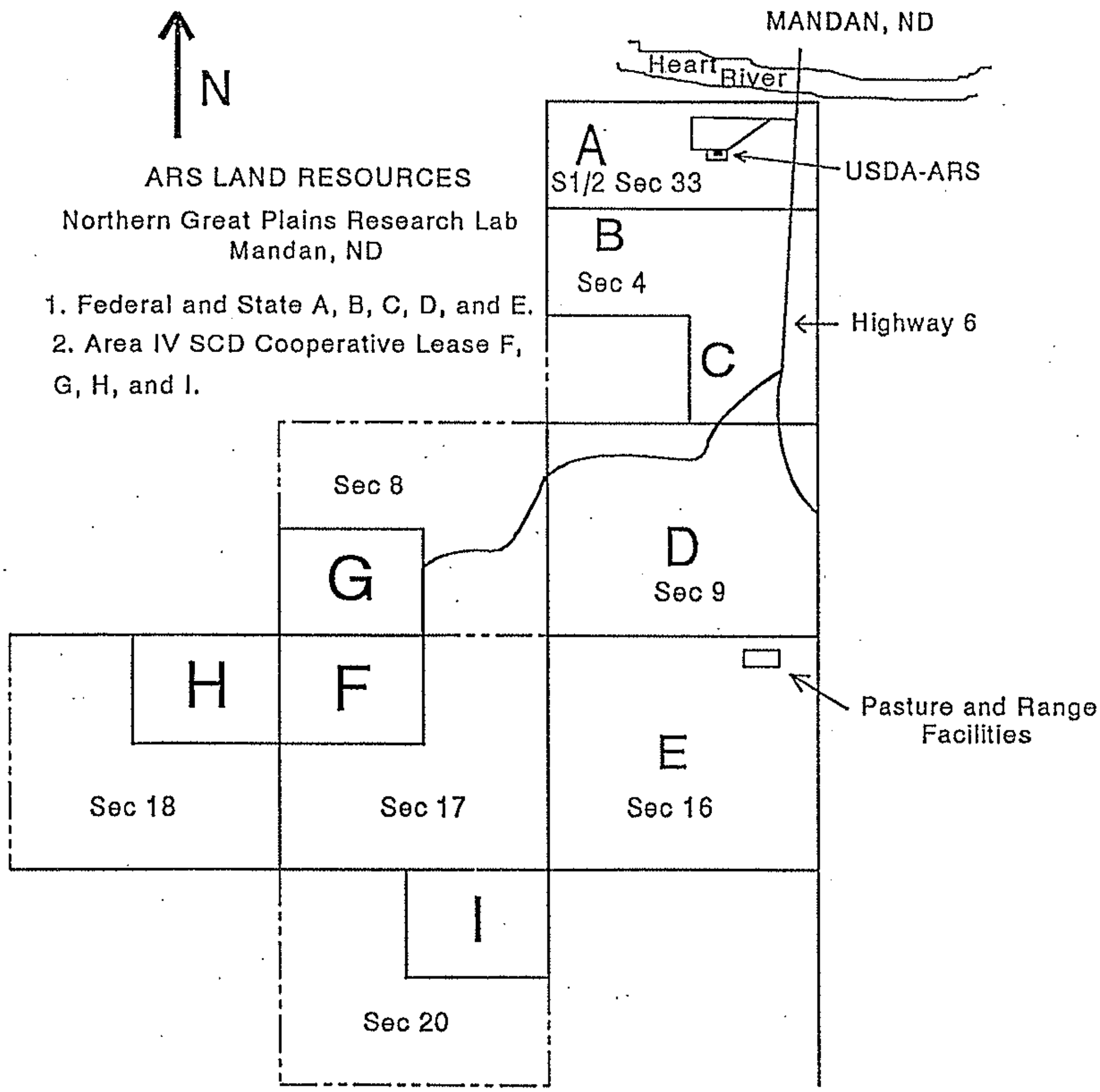
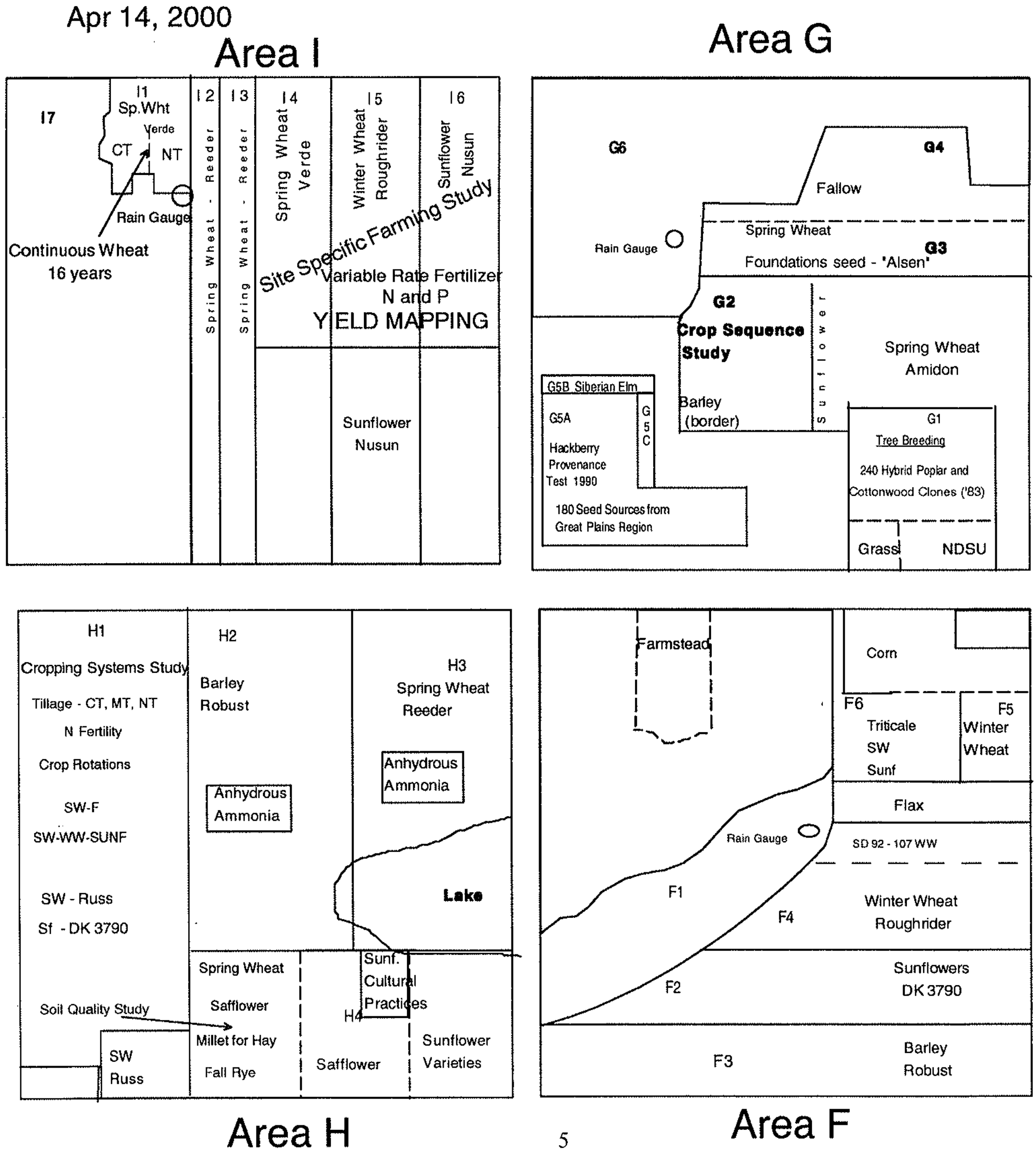


FIG. 2.

Area IV Research Farm Crop Plan - 2000.



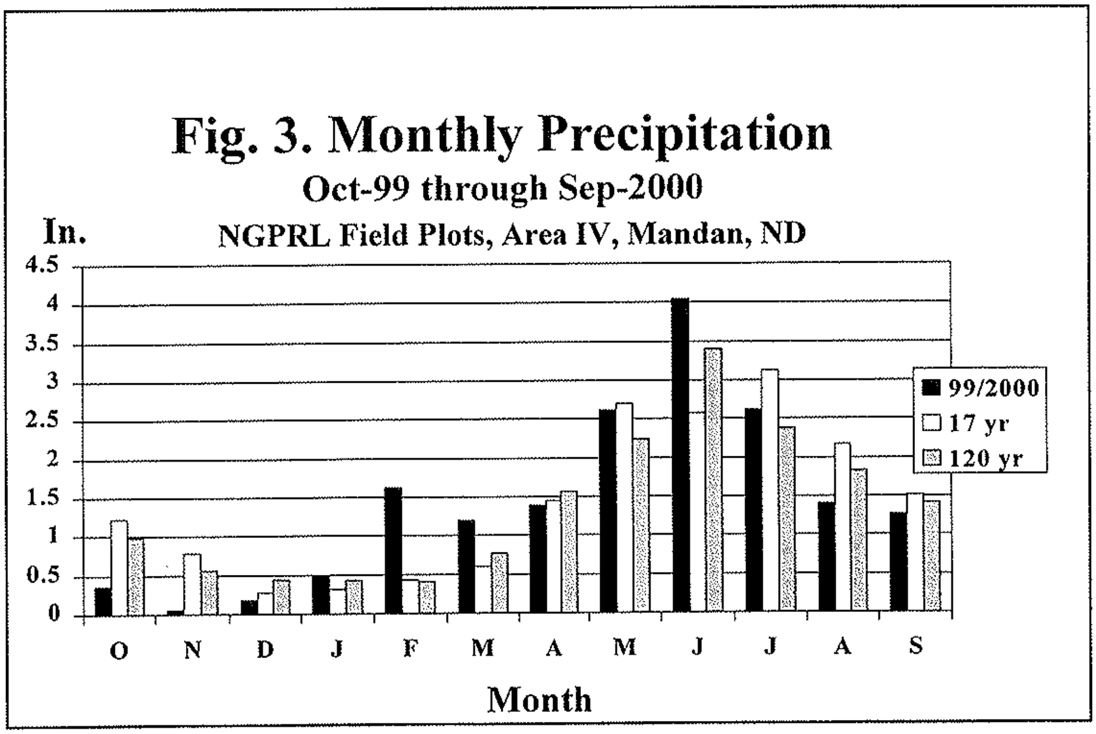


Fig. 3. Monthly Precipitation
Oct-99 through Sep-2000
In.
NGPRL Field Plots, Area IV, Mandan, ND
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
O
N
D
J
F
M
A
M
J
J
A
S
Month
99/2000
17 yr
120 yr

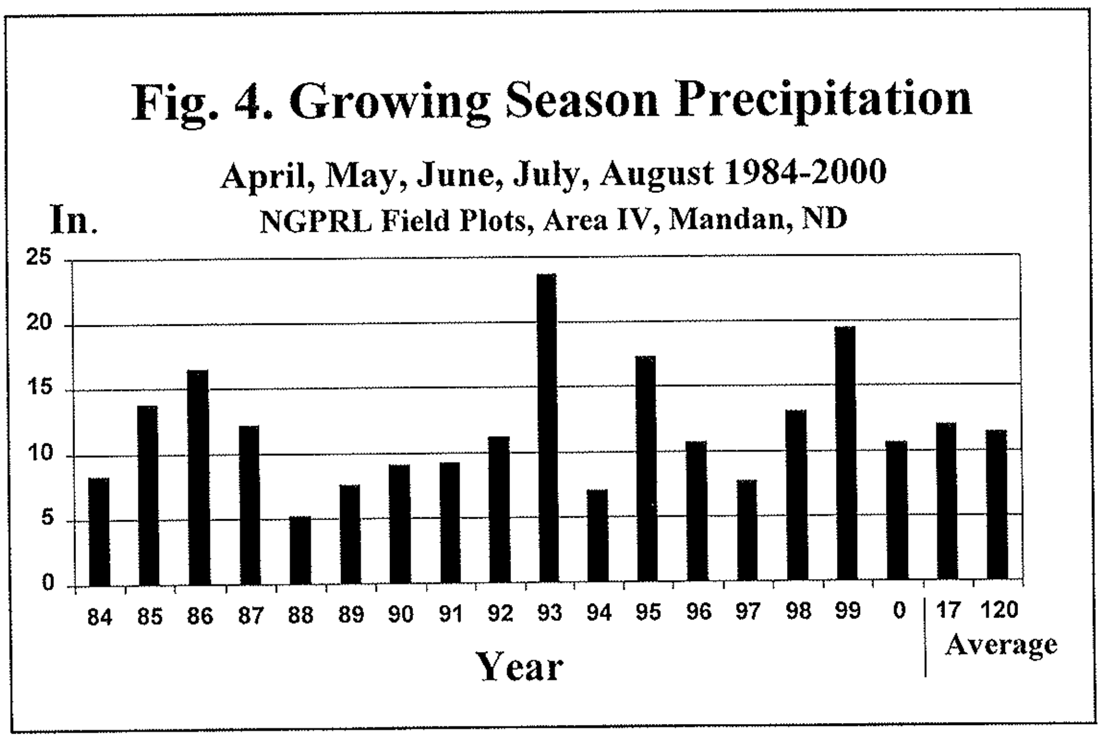


Fig. 4. Growing Season Precipitation
April, May, June, July, August 1984-2000
In.
NGPRL Field Plots, Area IV, Mandan, ND
25
20
15
10
5
0
84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 0
17 120
Average
Year

Figure 5. The crop X crop residue matrix used in the Early Season Crop Sequence Project to evaluate the influence of crop sequence. During the first year (1999), ten crops are no-till seeded into uniform cereal residue. During the second year (2000) the same crops are no-till seeded perpendicular over the residue of the previous year's crop.

1999 (dark band: 1999 crops)
2000 (shaded band: 2000 crops)

300' × 300' (each block); N ↑

VII

										1999
709	719	729	739	749	759	769	779	789	799	6
708	718	728	738	748	758	768	778	788	798	2
707	717	727	737	747	757	767	777	787	797	5
706	716	726	736	746	756	766	776	786	796	10
705	715	725	735	745	755	765	775	785	795	8
704	714	724	734	744	754	764	774	784	794	7
703	713	723	733	743	753	763	773	783	793	3
702	712	722	732	742	752	762	772	782	792	9
701	711	721	731	741	751	761	771	781	791	1
700	710	720	730	740	750	760	770	780	790	4
6	8	4	9	2	7	3	5	1	10	

2000 Crops

VIII

										1999
809	819	829	839	849	859	869	879	889	899	1
808	818	828	838	848	858	868	878	888	898	2
807	817	827	837	847	857	867	877	887	897	5
806	816	826	836	846	856	866	876	886	896	9
805	815	825	835	845	855	865	875	885	895	7
804	814	824	834	844	854	864	874	884	894	10
803	813	823	833	843	853	863	873	883	893	6
802	812	822	832	842	852	862	872	882	892	3
801	811	821	831	841	851	861	871	881	891	4
800	810	820	830	840	850	860	870	880	890	8
5	2	7	1	8	4	6	9	3	10	

2000 Crops

V

										1999
509	519	529	539	549	559	569	579	589	599	8
508	518	528	538	548	558	568	578	588	598	10
507	517	527	537	547	557	567	577	587	597	1
506	516	526	536	546	556	566	576	586	596	4
505	515	525	535	545	555	565	575	585	595	5
504	514	524	534	544	554	564	574	584	594	2
503	513	523	533	543	553	563	573	583	593	9
502	512	522	532	542	552	562	572	582	592	7
501	511	521	531	541	551	561	571	581	591	6
500	510	520	530	540	550	560	570	580	590	3
3	9	7	6	10	2	5	4	1	8	

2000 Crops

VI

										1999
609	619	629	639	649	659	669	679	689	699	7
608	618	628	638	648	658	668	678	688	698	8
607	617	627	637	647	657	667	677	687	697	10
606	616	626	636	646	656	666	676	686	696	5
605	615	625	635	645	655	665	675	685	695	1
604	614	624	634	644	654	664	674	684	694	9
603	613	623	633	643	653	663	673	683	693	4
602	612	622	632	642	652	662	672	682	692	3
601	611	621	631	641	651	661	671	681	691	6
600	610	620	630	640	650	660	670	680	690	2
9	1	2	10	3	6	8	4	5	7	

2000 Crops

Crops Seeded

1 **Canola** - Dynamite
2 **Crambe** - Meyer
3 **Dry Bean** - T-39 (1999), Shadow (2000)
4 **Dry Pea** - Profi
5 **Flax** - Omega
6 **Safflower** - Montola 2000
7 **Soybean** - Jim
8 **Sunflower** - Cenex 803
9 **Wheat** - Amidon
10 **Barley** - Stander

CROP SEQUENCE CALCULATOR[1]
A COMPUTER PROGRAM TO ASSIST PRODUCERS

USDA, Agriculture Research Service
Northern Great Plains Research Laboratory
Mandan, North Dakota 58554-0459 USA

A computer program entitled "Crop Sequence Calculator" is designed to help producers assess crop production and the potential returns of ten crops in a diverse cropping system. Expected crop prices and expected loan deficiency payments (LDP) can be input to provide rapid calculations of potential returns. The program contains information on crop production, plant diseases, weeds, crop water use, and surface soil properties to aid producers in their evaluation of management risks associated with different crop sequences. The user-friendly program runs directly from a CD-ROM eliminating the need for additional disk space or installation procedures. The program is designed for computers running Windows® (3.1/95/98/ME/NT/2000) and works best with a screen area of 800 X 600 pixels or greater.

The program can calculate the expected yield of ten crops (barley [*Hordeum vulgare*], bean [*Phaseolus vulgaris*], canola [*Brassica napus*], crambe [*Crambe abyssinica*], flax [*Linum usitatissimum*], pea [*Pisum sativum*], safflower [*Carthamus tinctorius*], soybean [*Glycine max*], sunflower [*Helianthus annuus*], and wheat [*Triticum aestivum*]) grown in any two-year combination. Crop production and other data was obtained from a crop by crop-residue matrix grown in 1999 on field plots located on the Area IV ARS/SCD Research Farm near the Northern Great Plains Research Laboratory, southwest of Mandan, North Dakota. Information is only applicable to the northern Great Plains with precipitation averaging less than 17 in (43 cm).

A field was divided into an east and west side in 1998 in order to provide two site years. On the east side in 1998, ten crops were seeded in an east-west direction with a JD 750 no-till drill in 9.1 m [30 ft] strips into wheat stubble in each of the four replications. The cultivars for each crop were: Montola 2000 safflower, Stander barley, Dynamite canola, Meyer crambe, Shadow Black Turtle dry bean, Profi dry pea, Omega flax, Jim soybean, Cenex 803 oilseed sunflower, and Amidon spring wheat. In 1999 all crops were again randomized and planted on the east side in a north-south direction, perpendicular to the 1998 crop, with a JD 750 no-till drill into stubble from the previous crops, allowing every crop to be planted on the residue of all the other crops (100 plots per replication). When planting perpendicular to the previous crop, the minimum plot size was 9.1 m (30 ft) by 9.1 m. In 1998, barley was uniformly planted on the west side. The west side was treated similarly to the east side. All crops were planted in an east-west direction in 1999 and in a north-south direction in 2000, again allowing every crop to be planted on the residue of the ten crops. Seeding rates, seeding dates, harvest dates, residue or straw production, and grain production are accessible on the program. Data from the crop by crop-residue matrix grown in 2000 on the west side will be included in the next release of the program along with suggested herbicide use for different crop sequences.

Users are presented summary data on crop production, plant diseases, weeds, crop water use, and surface soil properties. By selecting the "More Info" buttons adjacent to each summary, graphs, photos, and additional information are easily accessed. For example, photographs of weeds are available to aid in their identification. Additional information concerning plant diseases includes an introduction to plant diseases, information on the plant disease triangle and management for plant disease risks, websites for plant disease information, and photographs of plant diseases to aid in their identification.

Copies of the **CROP SEQUENCE CALCULATOR** can be requested from:

Crop Sequence Calculator
Northern Great Plains Research Laboratory
Agricultural Research Service-USDA
Box 459
Mandan, North Dakota 58554-0459

Phone: 701-667-3000 or 701-667-3001
FAX: 701-667-3054

Or order from our website:
www.mandan.ars.usda.gov

Users of the program are encouraged to register their CD-ROM with the Northern Great Plains Research Laboratory. When a new version of the program is produced registered users will receive a copy of a CD-ROM with the new program.

ACKNOWLEDGEMENT

This program and the underlying data were generated with the support of the Area IV Soil Conservation District, The National Sunflower Association, The North Dakota Oilseed Council, and the Agricultural Research Service, U.S. Department of Agriculture.

[1] The crop sequence calculator program and CD are produced and distributed by the USDA-ARS, Northern Great Plains Research Laboratory, P.O. Box 459, 1701 10th Ave., S.W., Mandan, ND 58554. • No material in this CD may be copied and distributed in part or whole without permission of the research scientists involved and due credit given to the scientists. • Persons with disabilities who require alternative means for communication of program information (Braille, large print, audiotape, etc.) should contact USDA's TARGET Center at 202-720-2600 (voice and TDD). • The United States Department of Agriculture prohibits discrimination in all its programs and activities on the basis of race, color, national origin, gender, religion, age, disability, political beliefs, sexual orientation, and marital and family status. • To file a complaint of discrimination, write USDA, Director, Office of Civil Rights, Room 326-W, Whitten Building, 14th and Independence, S.W., Washington, DC 20250-9410 or call 202-720-5964 (voice or TDD). • USDA is an equal opportunity provider and employer. • Mention of trade or manufacturer names is provided for information only and does not constitute endorsement by USDA-ARS.

EARLY SEASON CROP SEQUENCE PROJECT

Phase II of the Diverse Cropping Systems Project

A multi-disciplinary team of scientists (J. Krupinsky, D. Tanaka, S. Merrill, R. Ries, J. Hendrickson, M. Liebig, J. Fehmi, S. Wright, and J. Hanson) is conducting a multi-phased project with early- and late-season grass and broad leaf crops to develop diverse cropping systems. The team is evaluating the components of crop production, crop residue, plant disease, weeds, root growth, crop-water use, soil quality, and economics to develop guidelines for long-term diversified crop production systems and to provide producers with a flexible method (management tools) for developing their own cropping systems.

INTRODUCTION

The Early Season Crop Sequence Project, Phase II of the Diverse Cropping Systems Project, was initiated in 1998 to determine the sequence crops should follow to take advantage of the previous crop and crop residues. Field plots were located on the Area IV ARS/SCD Research Farm located near the Northern Great Plains Research Laboratory, southwest of Mandan, North Dakota. A field was divided into an east and west side in order to provide two site years. On the east side in 1998, ten crops (barley [*Hordeum vulgare*], dry bean [*Phaseolus vulgaris*], canola [*Brassica napus*], crambe [*Crambe abyssinica*], flax [*Linum usitatissimum*], dry pea [*Pisum sativum*], safflower [*Carthamus tinctorius*], soybean [*Glycine max*], oil seed sunflower [*Helianthus annuus*], and wheat [*Triticum aestivum*]) were seeded in an east-west direction with a JD 750 no-till drill in 9.1 m [30 ft] strips into wheat stubble in each of four replications and 60 lb N/a and 10 lb P/a were applied at seeding. Roundup® was applied after seeding early season crops (canola, crambe, dry pea, flax, safflower, barley, and spring wheat) and before seeding late season crops (dry bean, sunflower, and soybean). The cultivars for each crop were: Montola 2000 safflower, Stander barley, Dynamite canola, Meyer crambe, Shadow Black Turtle dry bean, Profi dry pea, Omega flax, Jim soybean, Cenex 803 oilseed sunflower, and Amidon spring wheat. In 1999 all crops were again randomized and seeded into stubble from the previous crops on the east side in a north-south direction, perpendicular to the 1998 crop, with a JD 750 no-till drill. This allowed every crop to be seeded on the residue of all the other crops (100 treatments per replication). Seeding perpendicular to previous crops established a minimum plot size of 9.1 m by 9.1 m (30 X 30 ft). In 1998, barley was uniformly seeded on the west side. The west side was treated similarly to the east side. All crops were seeded in an east-west direction in 1999 and in a north-south direction in 2000, again allowing every crop to be seeded on the residue of the ten previous crops (Figure 5). Following the crop by crop-residue matrix, a uniform wheat crop will be grown on the east side in 2000 and on the west side in 2001 to determine how wheat performs after all crop sequences. After the wheat crop, a sunflower cultivar, susceptible to Sclerotinia, will be uniformly seeded over the crop by crop-residue matrix area on the eastside in 2001 and on the westside in 2002.

The sunflower crop will be used as an indicator crop to determine the amount of Sclerotinia present in plots following the various crop sequences.

CROP PRODUCTION AND CROP SEQUENCE

Dr. Donald Tanaka

All crops for the Early Season Crop Sequence Project (Figure 5) were seeded at the appropriate time for the particular crop in 2000. Early crops were seeded on May 2 and 3 while late crops were seeded on May 24. Previous crop and crop residues influenced seed yield of the ten no-till seeded crops (Figure 6). Because of harvest problems in 1999, early seeded crops where canola was grown produced a low yield where the volunteer canola could not be controlled. In general, two years of the same crop produced the lowest seed yield. One of the exceptions was soybean, which may be due to the inoculation of soybean since soybean was not previously grown in this field.

Spring wheat (cv. Amidon) was seeded on April 13, 2000 where the 1999 crop sequence project was located (eastside). Spring wheat production is shown in Figure 7. By planting a non-cereal crop in one year out of five, spring wheat yields were about 10% greater in 2000 than continuous spring wheat. Seeding two years of consecutive non-cereal crops increased spring wheat yields up to 40% in some instances.

PLANT DISEASES AND CROP SEQUENCE

Dr. Joe Krupinsky

Wheat and Barley Leaf Spot Diseases. Wheat leaves from the crop by crop-residue matrix of the Early Season Crop Sequence Project (Figure 5) were analyzed for plant pathogens present. Diseases found on wheat leaves include: Stagonospora nodorum blotch (*Stagonospora nodorum*), tan spot (*Pyrenophora tritici-repentis*), stagonospora avenae leaf blotch (*Stagonospora avenae f. sp. triticea*), septoria tritici blotch (*Septoria tritici*) and spot blotch (*Helminthosporium sativum*). Stagonospora nodorum blotch and tan spot were the most common diseases on wheat, followed by septoria tritici blotch, septoria avenae blotch and spot blotch. Thus, the leaf spot diseases on wheat were caused by a complex of fungi. Early in the season, leaf spot diseases on wheat were more severe following a wheat crop compared with the other nine crops.

Barley leaves from the crop by crop-residue matrix of the Early Season Crop Sequence Project (Figure 5) were analyzed for plant pathogens present. Diseases found on barley leaves include: net blotch (*Helminthosporium teres*), spot blotch (*Helminthosporium sativum*), stagonospora avenae leaf blotch (*Stagonospora avenae f. sp. triticea*), septoria speckled leaf blotch (*Septoria passerinii*), and stagonospora nodorum blotch. Net blotch was the most common disease on barley, followed by septoria speckled leaf blotch, stagonospora avenae leaf blotch, and spot blotch. These results also show that the leaf spot diseases on barley were caused by a complex of fungi. Early in the season, leaf spot

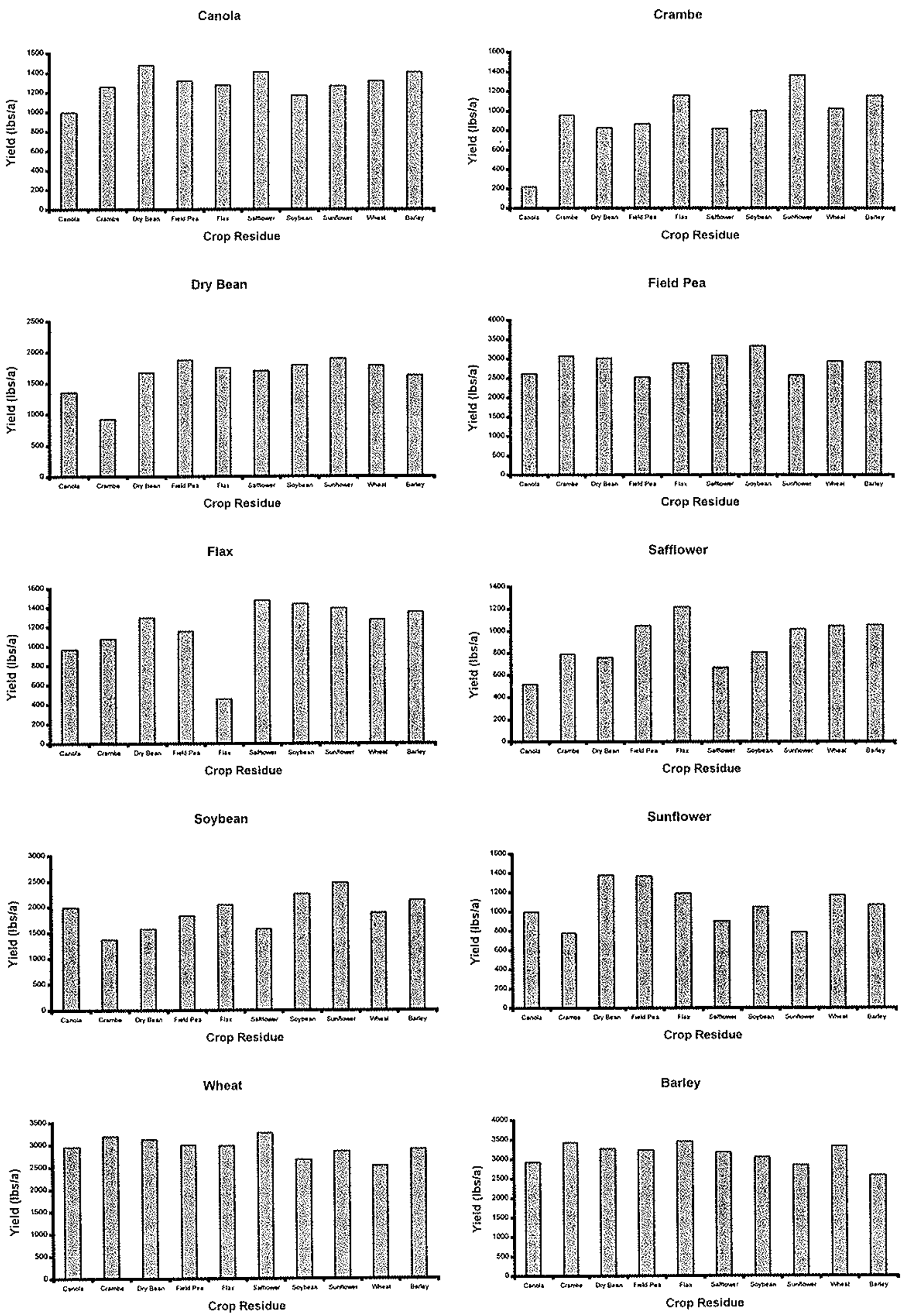


Figure 6. Seed yield of the ten crops as influenced by previous crop residue.

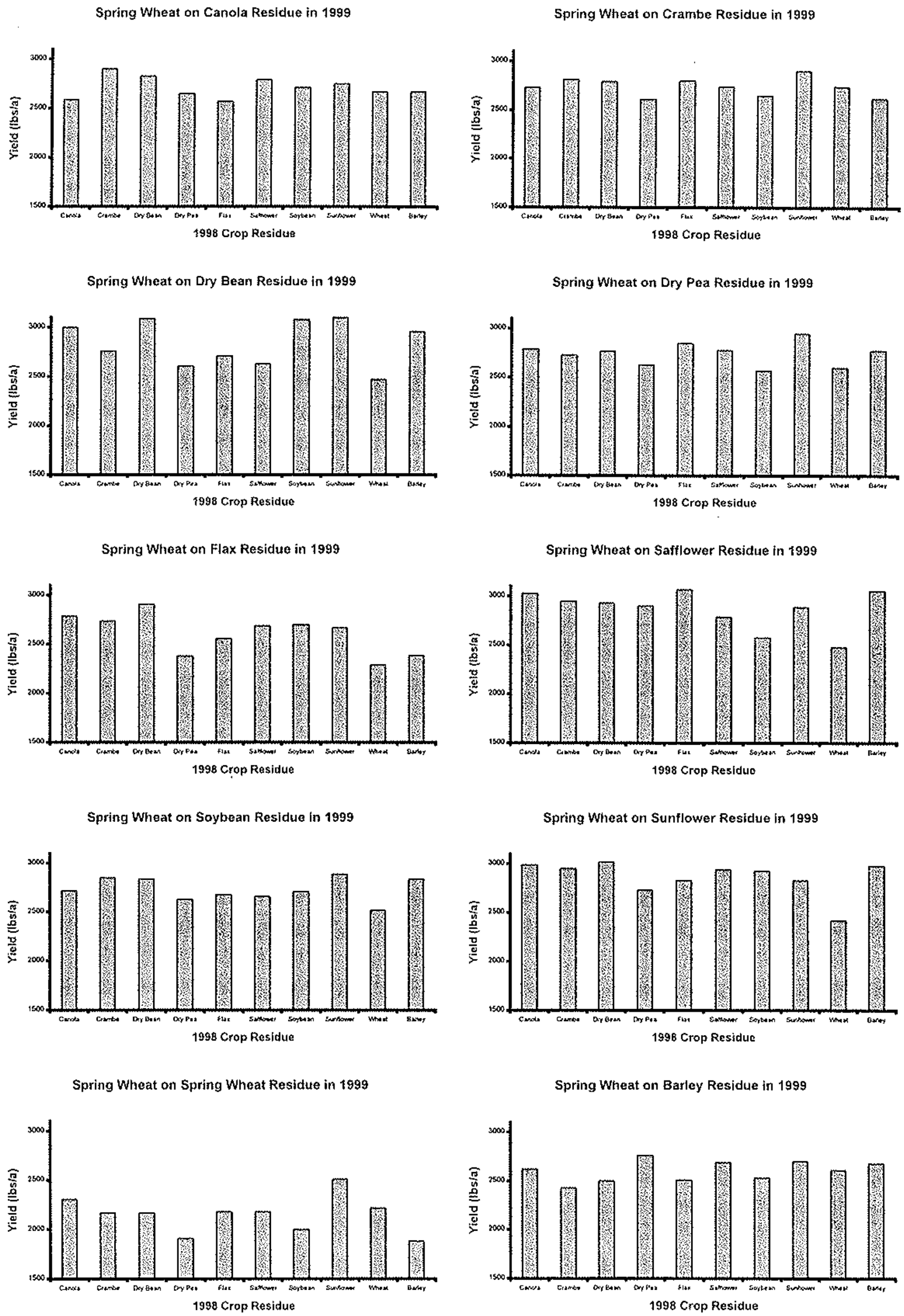


Figure 7. Spring wheat production in 2000 as influenced by previous crop and crop residue in 1998 and 1999.

diseases on barley were more severe following a barley crop compared with the other nine crops.

Sclerotinia (White Mold). Sclerotinia diseases of oilseed and pulse crops (i.e. white mold, stem rot, wilt, caused by *Sclerotinia sclerotiorum*) have the potential to cause substantial losses in yield. The fungus, *Sclerotinia sclerotiorum,* has a wide host range causing sclerotinia disease on broadleaf crops and weeds. The fungus causes sclerotinia stem rot on canola and crambe, sclerotinia stem rot and head rot (head blight) of safflower and sunflower. Sclerotia are hard fungal bodies that are produced in or on infected tissue and contaminate soil, stubble and harvested seed. Sclerotia can survive for 3-5 yr in the soil and pose a threat to subsequent susceptible crops. Although sclerotinia disease has a wide host range, it does not affect cereals and grasses. Crop diversification has increased the risk of sclerotinia diseases by bringing more broadleaf crops into traditional cereal-growing regions. Thus, it is important for producers to consider which crops to use in their rotations as well as the sequence in which they are grown. The use of a broadleaf crop with less susceptibility or one that produces fewer sclerotia may be important for the next broadleaf crop grown in the rotation.

The crop by crop-residue matrix of the Early Season Crop Sequence Project (Figure 5) was evaluated for sclerotinia disease of canola, crambe, safflower, and sunflower. Plants were randomly sampled and evaluated. Although disease incidence was low, sclerotinia head blight on safflower ranged from 0 to 3% in 1999 and from 0 to 2% in 2000 (Figure D1 and D2), with the highest level on crambe residue for both years. With canola, sclerotinia stem rot ranged from 0 to 6% in 1999 and from 1 to 5% in 2000 (Figure D3 and D4) with the highest level on safflower residue for both years. With crambe, sclerotinia stem rot ranged from 2 to 15% in 1999 and from 10 to 60% in 2000 (Figure D5 and D6) with the highest level on safflower residue for both years. Thus, the higher levels of Sclerotinia on canola and crambe followed a safflower crop for both years even though the incidence of Sclerotinia head blight on the previous safflower crop was rather low. Sunflower was rated for Sclerotinia stem rot but the data is not included because no diseased plants were identified in 1999 and very few infected plants were found in 2000.

Given the variation in disease incidence among plots, it was difficult to demonstrate significant differences among previous residue treatments. Even though there were some patterns in the incidence of Sclerotinia disease, one can speculate that the movement of ascospores among plots (interplot interference) or from other areas made it difficult to detect significant differences among the individual crop residue treatments. Crop rotation may be only partially effective because of the movement of wind-borne ascospores. Proper crop rotations will need to be combined with other management practices to reduce the severity of Sclerotinia.

Flax. Consistent with 1999 data, flax diseases were severe when flax was grown on flax residue in the Early Season Crop Sequence Project (Figure 5). This was supported by yield loss data. For example, flax grown on flax residue only yielded 32% of the flax yield from the top three crop by crop residue combinations. The diseases most evident on flax were Fusarium wilt (*Fusarium oxysporum f. sp. lini*) and Pasmo (*Mycosphaerella linicola*). The fungi causing these diseases can easily carry over on infested residue. Thus, the residue from the 1999 flax crop provided inoculum for the 2000 flax crop.

Fig. D1. Safflower with Sclerotinia, 1999
Crop Sequence Project, NGPRL, Mandan, ND

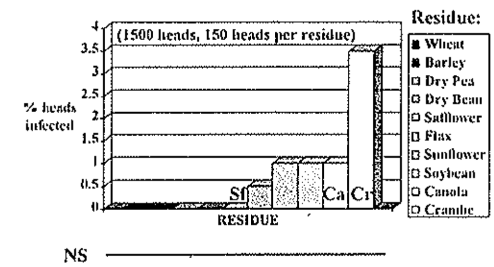


Fig. D2. Safflower with Sclerotinia, 2000
Crop Sequence Project, NGPRL, Mandan, ND

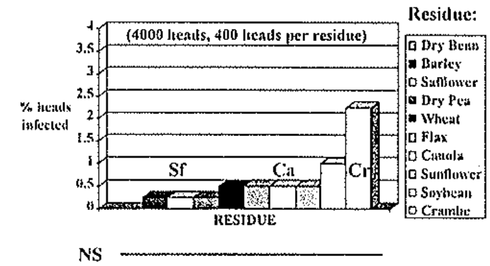


Fig. D3. Canola with Sclerotinia, 1999
Crop Sequence Project, NGPRL, Mandan, ND

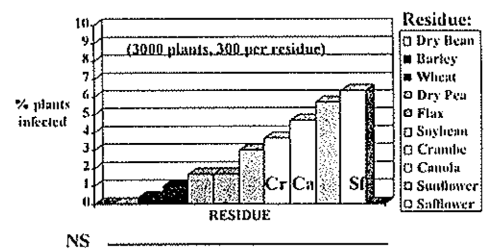


Fig. D4. Canola with Sclerotinia, 2000
Crop Sequence Project, NGPRL, Mandan, ND

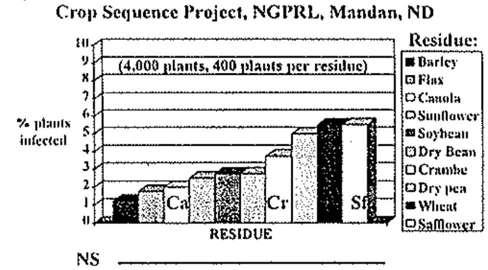


Fig. D5. Crambe with Sclerotinia, 1999
Crop Sequence Project, NGPRL, Mandan, ND

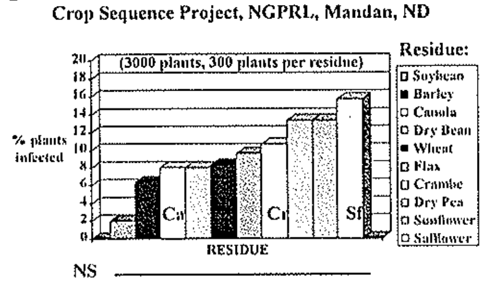
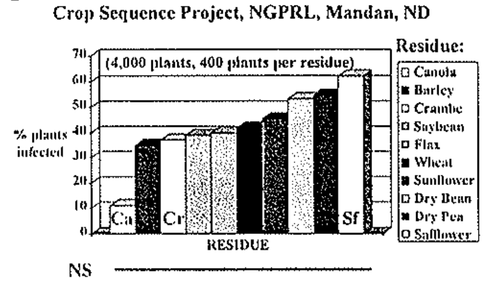


Fig. D6. Crambe with Sclerotinia, 2000
Crop Sequence Project, NGPRL, Mandan, ND



SOIL WATER AND CROP SEQUENCE – WATER USE OF CROPS

Dr. Steve Merrill

The neutron moisture meter technique was used for making repeated, nondestructive measurements of soil water content in the Early Season Crop Sequence Project (Figure 5). Soil water depletion was measured to a depth of eight feet. Comparative water use is defined as the sum of soil water depletion under a particular crop from harvest to seeding plus the total precipitation that fell on all crops between about mid May to mid August. Comparative water use figures for alternative crops grown in the Early Season Crop Sequence Project in 1999 and 2000 are shown in Figure A. The crops are placed in the same order on Figures A and B as the order of their observed root growth depths, from deepest (safflower) to most shallow (dry bean). Sunflower and safflower had the greatest water use in 1999 and 2000 with an average of 14.8 inches. The lowest water users in 1999 and 2000 were crambe, canola, and dry pea with average use of 11.8 inches. Water use was considerably higher in 1999, a wetter than average year, compared to 2000.

Another way to compare the crops is to look at their full season soil water depletion, which we measure as the difference between mid-May and mid-October soil water content (Figure B). Soil water depletions were higher in the year 2000 compared to those in wetter 1999. Sunflower had the largest depletions, followed by safflower. Both of these oilseed crops have greater ability to proliferate fine root growth in subsoil zones compared to other crops grown in our region. Soybean had the third greatest 2-year average soil water depletion. While soybean is relatively less deeply rooted than other, non-pulse type crops, it is tends to be indeterminate in our region and exhibits an extended growth season. Dry pea had the lowest average water depletion in 1999 and 2000, followed by the lower water-users barley and crambe.

WEEDS AND CROP SEQUENCE – WEED CONTROL IN SPRING WHEAT

Drs. John Hendrickson and Ron Ries

In 2000, weed density measurements were taken April 25, 2000 on an area that had been previously seeded to ten different crops in the Early Season Crop Sequence Project (Figure 5). The purpose of these density measurements was to determine if the previous crops influenced the density of weeds or volunteer plants in wheat the year following the alternative crops. No weed control was used before the April weed count. The maximum weed density was 51% of 1999 weed densities, which indicates the effectiveness of the previous year's weed control. Wheat following canola had the highest density of broadleaf weeds (32.3 plants ft^2) in 2000 while in 1999 wheat following sunflower had the highest density of broadleaf weeds (62.4 plants per ft^2). The primary broadleaf weed in canola was volunteer canola caused by shattering during harvest. Grassy weeds were also reduced considerably from the previous year and the species composition switched from primarily downy brome to volunteer wheat.

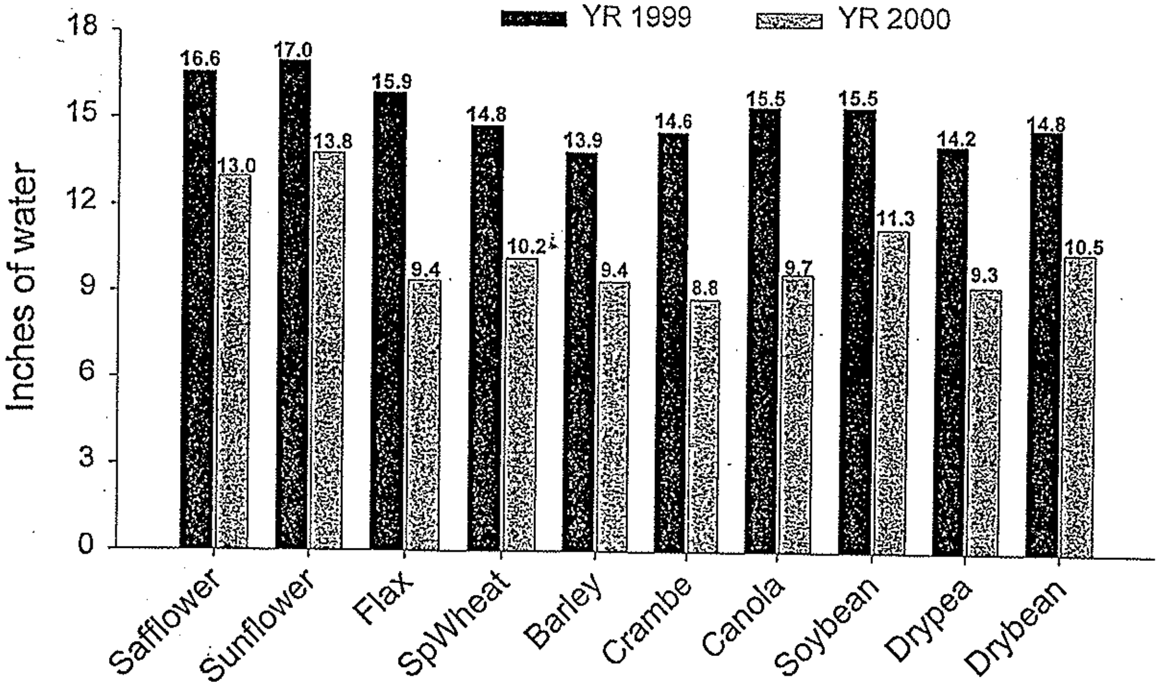


Figure A. Comparative water use of alternative crops with the soil water depletion component being measured by neutron moisture meter to a depth of 8 feet.

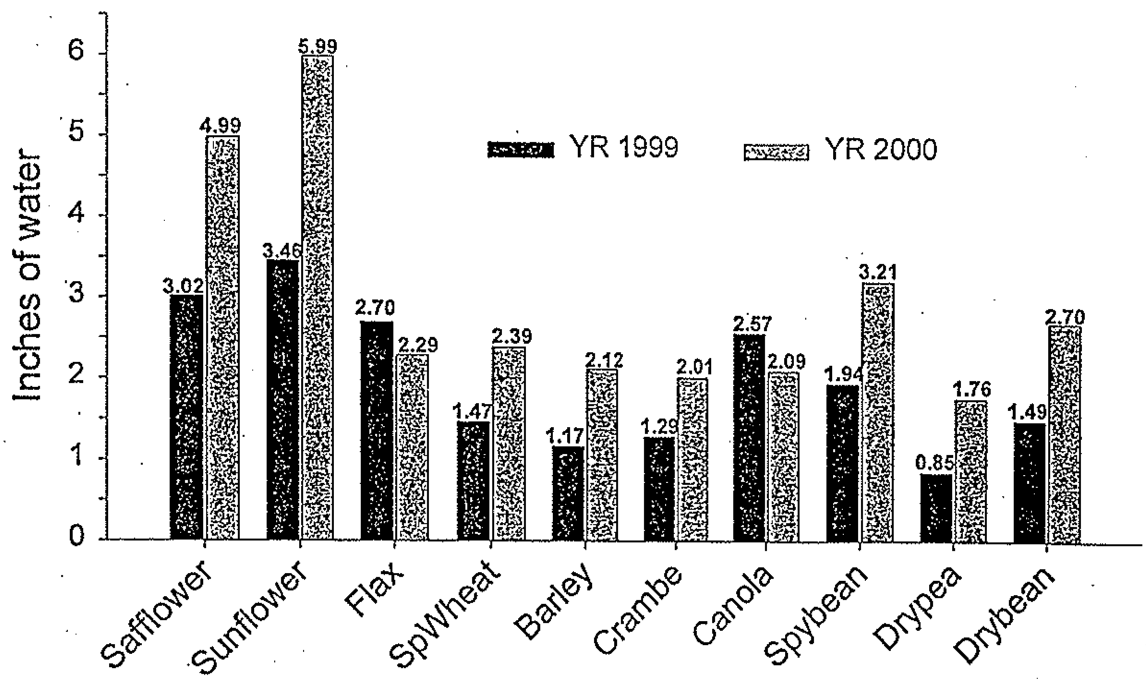


Figure B. Full season soil water depletion of alternative crops measured by neutron moisture meter to a depth of 8 feet.

SOIL QUALITY INDICATORS AND CROP SEQUENCE

Dr. Mark Liebig (USDA-ARS, Mandan, ND) and
Dr. Sara Wright (USDA-ARS, Beltsville, MD)

The effects of alternative crops on surface soil condition are largely unknown. In the spring of 2000, a study was initiated to determine the effects of ten crops on soil physical, chemical, and biological properties. Evaluations were limited to cropping sequences where the same crop had been planted in consecutive years (i.e., a 'stacked' sequence) in the crop by crop-residue matrix of the Early Season Crop Sequence Project. The hypothesis for this study was as follows: Crops belonging to the same botanic group (e.g., legume, mustard, grass, taproot, and linum) impact soil condition more similarly than crops belonging to different botanic groups.

Soil samples were collected prior to planting from 0-7.5 and 7.5-30.0 cm depths. Samples were analyzed for aggregate stability, aggregate-size distribution, electrical conductivity, soil pH, soil NO_3-N, organic carbon, total nitrogen, particulate organic matter, glomalin, potentially mineralizable nitrogen, and microbial biomass. To complement laboratory evaluations, infiltration rate was measured at the time of soil sampling.

Preliminary data from the 0-7.5 cm depth indicate cropping sequence did not affect the properties listed above. There was a trend, however, for higher levels of particulate organic matter, potentially mineralizable nitrogen, and total glomalin under flax. Tabulated data from this evaluation will be presented in 2002, after a second year of data has been collected.

ADDITIONAL RESEARCH ON AREA IV SCD/ARS FARM

CROP PRODUCTION ON POST-CRP LAND

Drs. Donald Tanaka, Steve Merrill, Joe Krupinsky, and Mark Liebig

In October 1994, a cooperative study was initiated to determine techniques for conversion of CRP land to crop production. Cooperators included NRCS, Consolidated Farm Service Agency, and the farm cooperators, Mr. Keith Boehm and Lyle Boehm. Treatments were: 1) hayed or nonhayed prior to tillage or spray operations; 2) residue management, conventional-till (<30% surface cover), minimum-till (30-60% surface cover) and no-till (>60% surface cover); and 3) nitrogen fertilizer, 0 and 60 lb N/a. Reference treatments included permanent hay (PH) and cover (PC). Plots were hayed on October 11, 1994 and tillage and spray operations were done on October 14, 1994.

The 2000 dry pea crop was seeded on April 20 and harvested on July 31. All treatments were sprayed for broadleaf and grassy weed control using Pursuit® (0.72 oz material/a) and Poast® (1 pt material/a) on June 2. Dry pea seed yields are shown in Figure 8. Removal of hay before residue management treatments were established decreased seed yield for CT and NT. Leaving all the residue in place when killing CRP permanent vegetation has a long-term impact on dry pea even though no difference could be determined for cereals in the rotation. The addition of 60 lb N/a did not increase pea seed yield and may have been detrimental for MT and NT. Addition of N fertilizer may not be a practice for sustainable dry pea production.

Hay production from CRP ranged from over 7000 lb/a to 1460 lb/a from 1995 through 2000 (Figure 9). Two cuttings were made in 2000 with very little increase in hay production from the additional fertilizer.

SOIL WATER EROSION ON POST-CRP LAND

Drs. Steve Merrill, Donald Tanaka, and Mark Liebig at NGPRL, Mandan, ND
Drs. Chihua Huang, Fenli Zheng, and Frederic Darboux at USDA-ARS National Soil Erosion Research Lab (NSERL), West Lafayette, IN

A team of scientists from the National Soil Erosion Research Lab (NSERL) cooperated with Mandan scientists on a soil erosion project at a local post-CRP site during the 2000 cropping season. The research was conducted in August and September after completion of two complete spring wheat - winter wheat - dry pea rotations. Precision rainfall simulation equipment was used on erosion plots 16 ft long by 5 ft wide set up on land with about 4% slope. Erosion plots were subjected to a rainfall program starting with one hour or longer at 2 in/hr followed without break by shorter rains at 1, 3, 4, and 5 in/hr. Measurements of runoff, eroded sediment, and other quantities were taken on plots set up on no-till (NT) and conventional-till (CT, disk tillage) cropped treatments, and the

2000 Dry Pea Yield

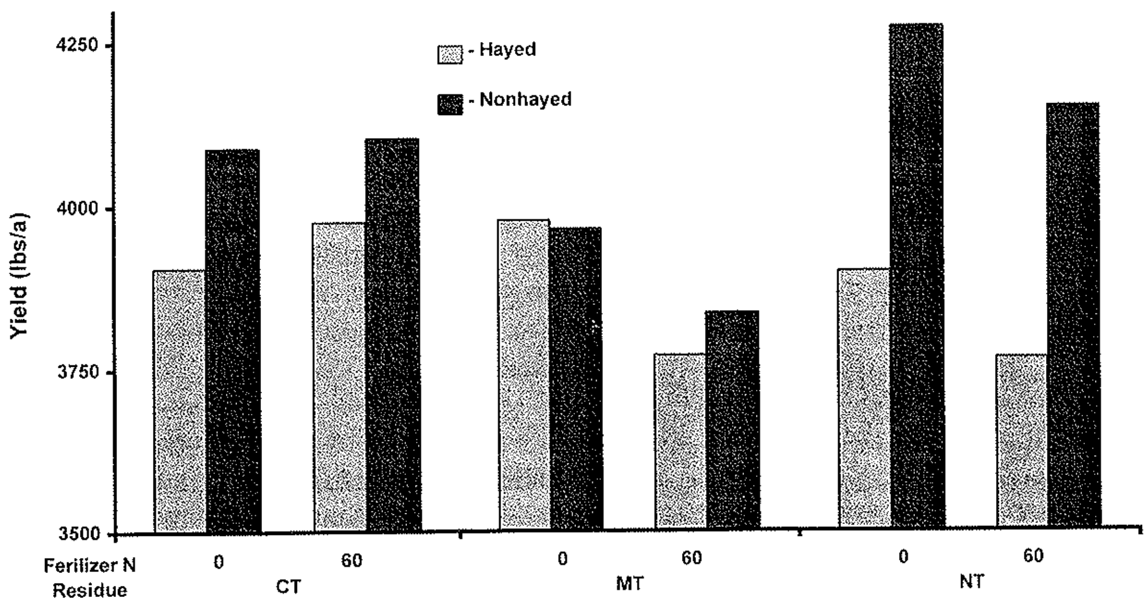


Figure 8. Dry pea seed yield as influenced by hay removal, nitrogen fertilizer, and conventional- (CT), minimum- (MT), and no-till (NT).

1995-2000 CRP Hay Yield

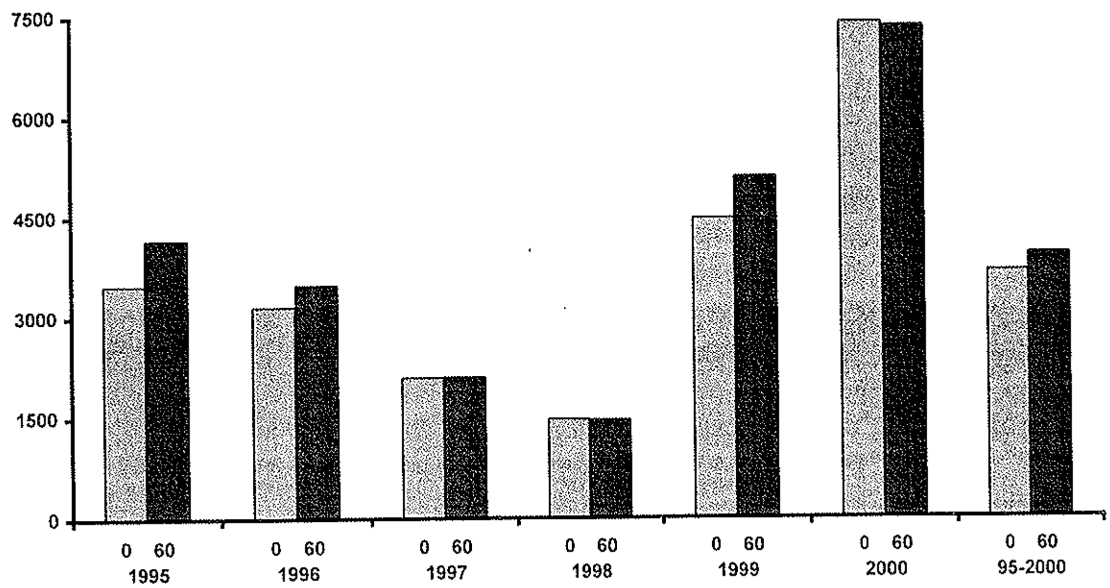


Figure 9. Hay production on CRP from 1995 through 2000 for 0 and 60 pounds of N per acre.

permanent hayland (PH) treatment. Hay was cut on PH plots immediately before erosion tests. Erodibility factor treatments were established on areas that were (a) unaltered – "As-Is"; (b) had residue thoroughly removed by hand, without raking; (c) rototilled after close mowing. There were 3 replications for erodibility treatments (a) and (b), and 4 replications for (c) at each agronomic treatment

Soil loss due to erosion was measured by sampling runoff waters emerging from erosion plots with subsequent precipitation of sediments. Runoff rates on the unaltered treatments at different rainfall intensities (Figure A) were lowest on CT at a given rainfall rate, intermediate for PH, and highest for NT. In general, the relative dryness of surface soil at the time of the study and good overall soil stability linked to near-surface coarse organic material apparently helped to boost overall infiltration rates and lower runoff. Greater tillage-induced soil surface roughness in CT probably helped to lower runoff in that treatment.

In contrast to the runoff results, erosion rates (Figure B) at the same rainfall rate on unaltered treatments were highest for CT, intermediate for NT, and lowest for PH. The erosion rate on CT at 3.9 in/hr rainfall was 80% greater than the erosion rate on PH. Erosion rates on NT differed but little from those on PH. The relative protective power of no-tillage was observable at the higher rainfall rates. At 3.9 in/hr rainfall, CT had an 110% greater erosion rate than NT, and at 4.9 in/hr rainfall, the erosion rate for CT was 173% greater than the rate for NT.

Removal of surface residue without soil disturbance had considerably greater effect on erosion rate for CT compared to NT (see Figure C). At 3.0 in/hr rainfall, the erosion rate on CT after residue removal was 4.7 times greater than that on NT with residue removed. Residue removal from PH resulted in an erosion rate that was 3 times greater than NT with residue removal. These results can be interpreted as showing that the NT appears to have erosion-protective residue and organic material in the surface soil layer. Complete tillage of agronomic treatments results in high soil loss rates, but the relative protective power of the greater root and near-surface herbage available to the PH treatment was evident. The erosion rate at 3.0 in/hr rainfall for NT after tillage was 1.8 times that of PH after tillage, while the erosion rate for tilled CT was 2.9 times greater than tilled PH.

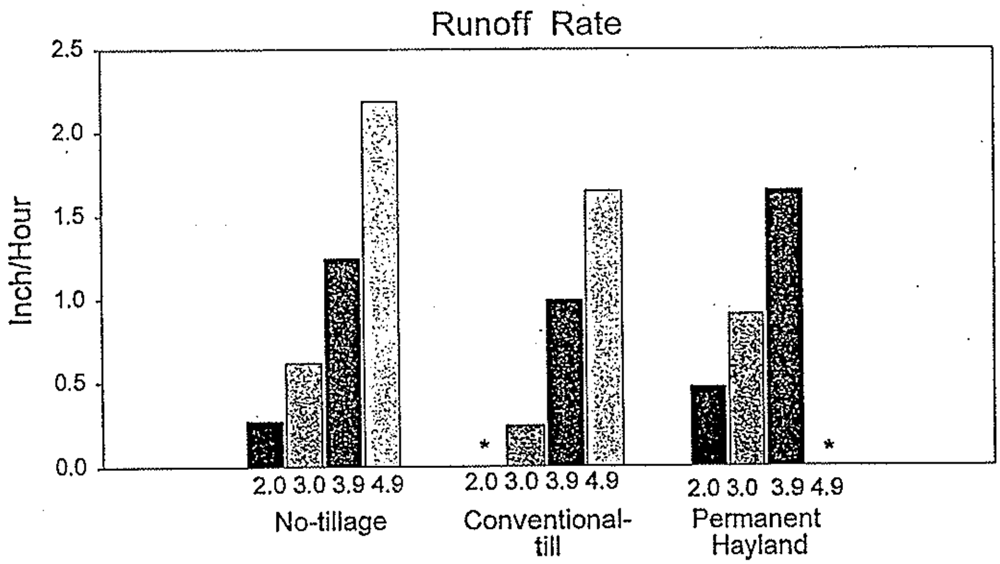
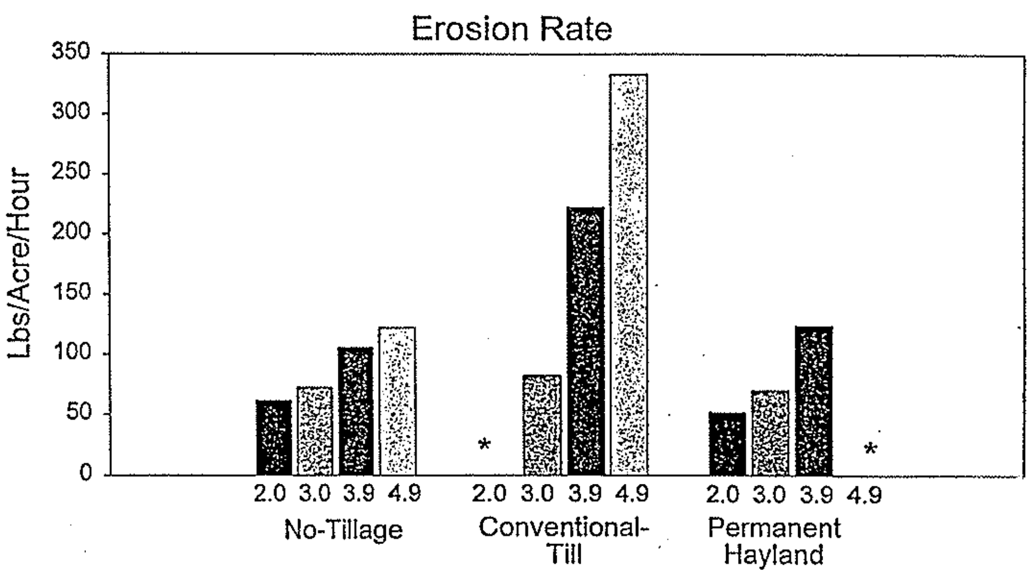


Figure A. Runoff rates measured for agronomic treatments at different rainfall rates, which are given in inches/hour. Asterisks indicate treatment-rainfall rate combinations for which insufficient data exists.

Figure B. Soil erosion rates measured for agronomic treatments at different rainfall rates, which are given in inches/hour. Asterisks indicate treatment-rainfall rate combinations for which insufficient data exists.



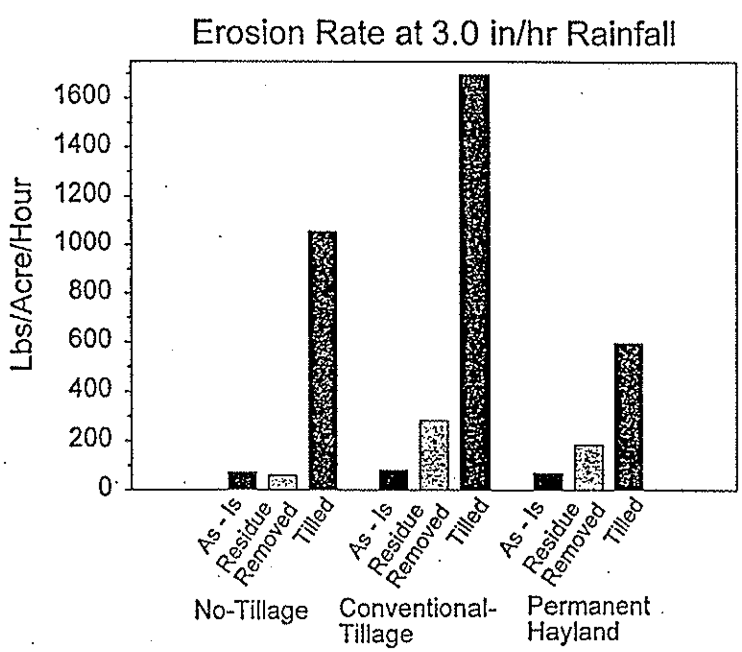


Figure C. Soil erosion rates measured at 3.0 in/hr rainfall on agronomic treatments subjected to various operations so that soil erodibility factors could be assessed.

MANAGEMENT STRATEGIES FOR SOIL QUALITY

Drs. Donald Tanaka, Steve Merrill, Mark Liebig, and Joe Krupinsky

A long-term study was initiated in the spring of 1993 to evaluate the influences of residue management and crop rotations on soil quality. Tillage, crops, and crop residues were all in the appropriate places in 1994. Treatments for the 2000 crop included minimum- and no-till for the following crop rotations:

1. Continuous spring wheat (CSW+); straw chopped and spread
2. Continuous spring wheat (CSW-); stubble left in place, straw removed
3. Spring wheat – millet for hay (SW-M)
4. Spring wheat – safflower – fallow (SW-S-F)
5. Spring wheat – safflower – rye (partial fallow, cover crop) (SW-S-R)
6. Spring wheat – fallow (SW-F)

Spring wheat (cv. Russ) was seeded on April 28 at 1.3 million viable seeds per acre. Safflower (cv. Montola 2000) was seeded on May 2 at 200,000 viable seeds per acre. Millet was seeded at 4 million viable seeds per acre on June 7. All no-till plots were sprayed with Roundup® (0.375 lb ai/a) prior to seeding while minimum-till plots were tilled with an undercutter prior to seeding. Spring wheat, safflower, and millet were seeded with a JD 750 no-till drill with N fertilizer banded and phosphorus applied with the seed at seeding. Recrop plots received 60 lb N/a and 10 lb P/a while fallow or partial fallow plots received 30 lb N/a and 10 lb P/a at seeding. Rye was seeded on September 29, 1999 at 1.3 million viable seeds per acre with a Haybuster 8000.

Above-average precipitation in May and June resulted in good rye and millet dry matter production (Figure 10). The above-average May, June, and July was detrimental to safflower seed production (Figure 11). Spring wheat seed production was greatest for the two three-year rotations (SW-S-F and SW-S-R) and lowest for SW-M (Figure 12).

Few cropping system studies in the Great Plains have investigated the impact of including annual forages and cover crops for partial fallow on long-term changes in soil quality. In the spring of 2000, an evaluation was initiated to determine the impact of annual forages and cover crops on soil quality indicators for a cropping systems experiment started in 1993. The experiment has six cropping sequences (continuous spring wheat – w/ residue; continuous spring wheat – w/o residue; spring wheat-millet; spring wheat-safflower-fallow; spring wheat-safflower-rye; spring wheat-fallow) under minimum- and no-till treatments. The hypothesis for this evaluation was as follows: In no-till treatments, inclusion of annual forages and cover crops in cropping sequences improve the status of soil quality indicators compared to cropping sequences without annual forages or cover crops.

Soil samples were collected prior to planting from 0-7.6, 7.6-15.2, and 15.2-30.5 cm depths. Samples were analyzed for electrical conductivity, soil pH, soil NO_3-N, organic

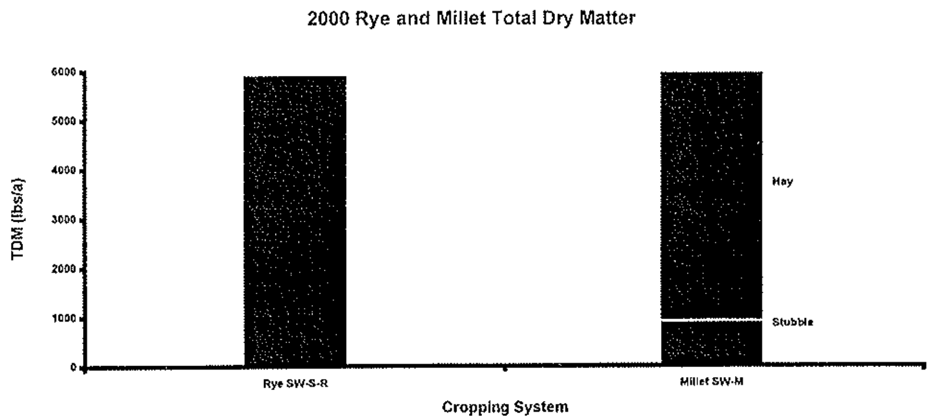


Figure 10. Total dry matter production for rye used as a partial fallow and siberian millet used for hay

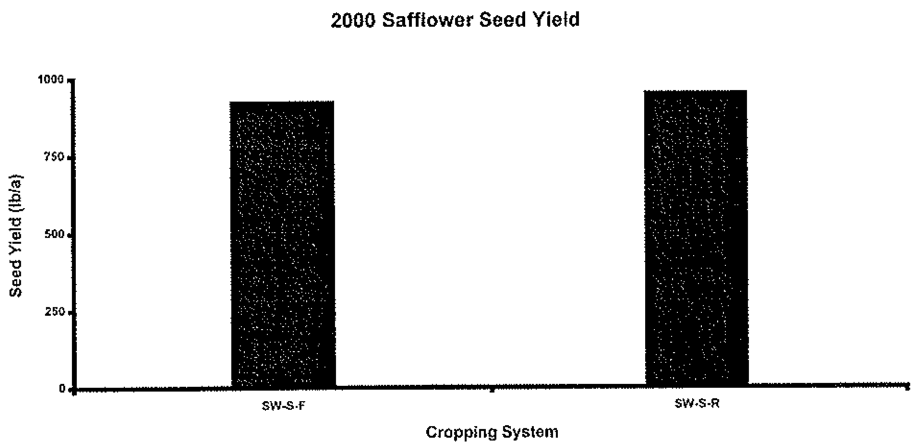


Figure 11. Safflower seed yield as influenced by crop rotation. Yields are the average of minimum- and no-till.

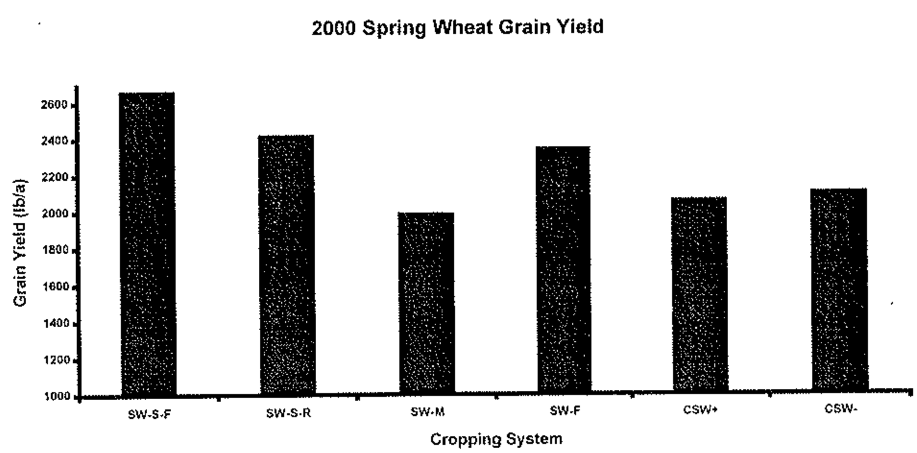


Figure 12. Spring wheat grain yields as influenced by crop production. Yields are the average of minimum- and no-till.

carbon, total nitrogen, particulate organic matter, potentially mineralizable nitrogen, and microbial biomass.

Preliminary data indicate treatments under no-till have higher soil bulk density, organic carbon, and total nitrogen. Cropping sequence was found to rarely affect the properties listed above, though there was a distinct trend for higher levels of large fraction particulate organic matter (0.5-2.0 mm) in continuous spring wheat. Tabulated data will be presented in 2002, after a second year of data has been collected.

SUNFLOWER CULTIVARS AND SCLEROTINIA DISEASE

Drs. Joe Krupinsky and Donald Tanaka

The fungus, *Sclerotinia sclerotiorum,* has a wide host range causing wilt and rot Sclerotinia disease on broadleaf crops and weeds. The fungus causes Sclerotinia stem rot (wilt) and head rot (head blight) on sunflower. Sclerotinia disease is reported worldwide and can cause serious yield and quality losses on sunflower. Yield losses can range from 30 to 70% depending on the stage of development when the wilt occurs. Sclerotinia also has the ability to produce sclerotia, which are hard fungal bodies that may survive for at least 3-5 years in the soil. Thus, the fungus can pose a disease risk for a number of years.

Sunflower cultivars were seeded in strips (60 ft by 665 ft) in a field naturally infected with Sclerotinia for observation. The six cultivars (Croplan 803, DK 29-99, DK 31-01 NS, DK 3790, DK 3868, Pioneer 63A81) were seeded in 76 cm (30 in) rows with a JD Maximerge planter at 62,000 viable seeds per hectare (25,000 viable seeds per acre). Because Sclerotinia stem rot (wilt) naturally developed in the field, cultivars were evaluated for the disease three times (Aug. 25; Sept. 7; and Sept. 20) during the growing season. Two hundred plants were rated for each cultivar in each of the three evaluations. The incidence of Sclerotinia stalk rot was confirmed by the presence of sclerotia inside split stems.

The incidence of Sclerotinia stalk rot increased throughout the growing season when six sunflower cultivars were grown in a high disease-risk field. The incidence of disease ranged from 9%-67% (September 20). The incidence of Sclerotinia stalk rot was low for two cultivars (DK 29-99 [9%] and Croplan 803 [11%]) compared to the other four cultivars (Pioneer 63A81 [35%], DK 31-01 NS [42%], DK 3790 [43%], and DK 3868 [67%]). The percentage of sclerotia harvested with the combine varied (DK 29-99 [0.08%], DK 31-01 NS [0.3%], Pioneer 63A81 [0.3%], Croplan 803 [0.7%], DK 3790 [0.7%], and DK 3868 [0.9%]). When comparing the high disease potential area, north side of field, with the low disease potential area, south side of field, yield losses ranged from 7% to 11%. These results show the importance of cultivar selection, particularly when planting into a high-disease risk field. An additional disadvantage of using highly susceptible cultivars is the production of sclerotia that will carryover in the field. Higher inoculum levels (sclerotia) will increase disease risk for a number of years, particularly when environmental conditions are favorable for disease development.

Sunflower seed yield and test weight for varieties grown in 2000 at Mandan, ND.

Variety	Yield (lbs/a)	TW (lbs/bu)
DeKalb 3790	2130	36.25
DeKalb 3868	2123	34.85
DeKalb 31-01 NS	2137	36.25
Pioneer 63A81	1718	31.10
Croplan 803	2097	36.30
DeKalb 29-99 NS	1903	35.90

Seeding Date = 5-25-00
Harvest Date = 10-18-00

WEED SEEDBANK POPULATIONS IN SPRING WHEAT/FALLOW ROTATIONS

Drs. Ron Ries and Donald Tanaka

Weed seeds in the soil seedbank provide a source of seed that cause weed infestations in crops grown in the northern Great Plains. The purpose of this field research was to quantify the weed seed populations in no-till/fallow, no-till/spring wheat, undercut/ fallow, undercut/spring wheat, conventional till/fallow, and conventional till/ spring wheat tillages and rotations. Samples were taken where no nitrogen fertilizer was applied. Seedbank samples were taken in the spring and fall 1996, 1997, and 1998.

Three soil cores containing seeds were taken in the field at depths of 0-1, 1-2, 2-4, and 4-6 inches. Cores were 2 inches in diameter and were 1 inch in length for a total of 3.14 cubic inches. Each sample contained 3 cores for a total 9.42 cubic inches for 1 inch cores. These samples were air dried and later mulched over steam-heat-treated soil in trays in the greenhouse. Trays were watered with distilled water as needed to keep the soil in the trays moist and the number and species of plants germinating and emerging from the seed in the cores were counted over an 8 week period. This period was chosen after a trial of trays observed for 10 - 12 weeks with a drying and rewatering period did not result in significantly more observed germinated and emerged seedlings. The total number and species of seeds in each sample were averaged. Data were analyzed by analysis of variance with treatment and sample dates. Treatment and date means with significant F tests were separated with a Waller Kration =100 means separation test.

Tables 1 and 2 present weed seeds observed in the top inch and top 6 inches of soil under three tillages and spring wheat/fallow conditions. No significant differences could be found between treatments. Broadleaf weeds were many times more abundant that grassy weeds. The top inch of soil contained more than 50% of the total and broadleaf weed seeds observed to a total depth of 6 inches for the no-till fallow or no-till spring wheat areas (Table 1). This is explained by the fact that no tillage was used on these areas leaving the weed seeds near the soil surface. Less than 40% of the total and broadleaf weed seeds were observed in the top inch where under cutting was used as a tillage practice, indicating deeper soil burial of seeds than with no-tillage. Only 25% of the total and broadleaf weed seeds were found in the top inch where conventional tillage was used. After conventional tillage and spring wheat harvest, 36 -37% of the total and broadleaf weeds were found in the top inch of soil. Conventional tillage moved more of the weeds seeds deeper into the soil. About 93% of the broadleaf weed seeds observed were those of fairy candelabra, a small, short-lived annual. Another 2% of the weed seeds were prostrate spurge, another annual. Fourteen other broadleaf weedy species made up the remaining 5% composition of the weed seeds observed. None of the broadleaf weed species observed represent much of a problem for crop production. About 52% of the grassy weed seeds observed were green and yellow foxtail. This weedy grass can be an important competitor with cereal grain crops. About 16% of the weedy grass seeds were also Downy brome, a winter annual that can be very competitive with cereal grains. Volunteer wheat made up 28% of the grassy seeds and can also be competitive in cereal grain fields. The remaining 4% composition of the grassy weed seeds were made up of 3 other grassy weed species.

Total weed seeds in the top inch of soil averaged across tillage and rotation were most abundant in the soil cores collected in the spring of 1996, 34 seeds/9.42 cubic inches of soil (Table 3). This corresponded to 202% normal precipitation received during the summer of 1995 which resulted in late summer and early fall weed and seed production. Precipitation in the fall of 1995 was drier at 74% of normal, so many seeds produced after the rains of the summer of 1995 were still in the top inch of the soil seedbank in the spring of 1996. Total weed seeds to 6 inches were not significantly different for any of the 6 core collection dates (Table 4). Total, broadleaf, and grassy weed seeds counted in the top inch of soil over an acre were high. No-till fallow or spring wheat had the most total and broadleaf weed seeds, about 13.3 to 18.6 million. Undercut fallow or spring wheat had 6.0 to 8.7 million seeds in the top inch of soil across an acre. Conventional till fallow or spring wheat had 5.3 to 10.7 million total and broadleaf weed seeds in the top inch over an acre.

Table 1. Weed seed numbers in soil under 3 tillages in fallow/spring wheat rotation.

Tillage/Rotation[1/]	Total Seeds		Broadleaf Seeds		Grassy Seeds	
	----------------seeds/9.42 cubic inches of soil----------------					
No-till/Fallow	28a	61[2/]	20a	53[2/]	8a	100[2/]
No-till/Spring wheat	21a	52	20a	51	1a	100
Undercut/Fallow	10a	37	9a	35	1a	100
Undercut/Spring wheat	13a	39	12a	38	1a	100
Conventional-till/Fallow	8a	25	8a	26	0a	0
Conventional-till/Spring wheat	16a	37	15a	36	1a	50

[1/] From non-fertilized area averaged across 6 spring/fall collection dates – top inch of soil profile.
[2/] Percent (%) of total seeds from 0-6 inches found in top inch.

Table 2. Weed seed numbers in soil under 3 tillages in fallow/spring wheat rotation.

Tillage/Rotation[1/]	Total Seeds	Broadleaf Seeds	Grassy Seeds
	---------------seeds/56.52 cubic inches of soil----------------		
No-till/Fallow	46a	38a	8a
No-till/Spring wheat	40a	39a	1a
Undercut/Fallow	27a	26a	1a
Undercut/Spring wheat	33a	32a	1a
Conventional-till/Fallow	32a	31a	1a
Conventional-till/Spring wheat	43a	41a	2a

[1/] From non-fertilized area averaged across 6 spring/fall collection dates – top 6 inches of soil profile.

Table 3. Weed seed numbers in soil under 3 tillages in fallow/spring wheat rotation.

Tillage/Rotation[1/]	Total Seeds	Broadleaf Seeds	Grassy Seeds
	----------------seeds/9.42 cubic inches of soil----------------		
Spring '96	34a	25a	9a
Fall '96	9b	8a	1a
Spring '97	12b	12a	Ta
Fall '97	14b	14a	Ta
Spring '98	14b	14a	Ta
Fall '98	13b	12a	1a

[1/] From non-fertilized area averaged across 6 tillage/rotation treatments – top inch of soil profile.

Table 4. Weed seed numbers in soil under 3 tillages in fallow/spring wheat rotation.

Tillage/Rotation[1/]	Total Seeds	Broadleaf Seeds	Grassy Seeds
	----------------seeds/56.52 cubic inches of soil---------------		
Spring '96	59a	50a	9a
Fall '96	24a	22a	2a
Spring '97	27a	26a	1a
Fall '97	41a	40a	1a
Spring '98	43a	42a	1a
Fall '98	26a	24a	2a

[1/] From non-fertilized area averaged across 6 tillage/rotation treatments – top 6 inches of soil profile.

Table 5. Weed seed numbers in soil under 3 tillages in fallow/spring wheat rotation.

Tillage/Rotation[1/]	Total Seeds	Broadleaf Seeds	Grassy Seeds
	------------seeds (millions)/acre cubic inch of soil----------		
No-till/Fallow	18.6	13.3	5.3
No-till/Spring wheat	14.0	13.3	0.7
Undercut/Fallow	6.7	6.0	0.7
Undercut/Spring wheat	8.7	8.0	0.7
Conventional-till/Fallow	5.3	5.3	0.0
Conventional-till/Spring wheat	10.7	10.0	0.7

[1/] From non-fertilized area averaged across 6 spring/fall collection dates – top inch of soil profile.

DATES FOR HARVESTING ANNUAL FORAGE CROP HAY

Drs. Ron Ries, Donald Tanaka, and Jim Karn

Integrated forage/crop/livestock operations in the Northern Great Plains often rely on hay as winter feed for livestock and/or a cash crop. The objective of our study was to determine the appropriate time to cut and cure annual forage crops for maximum hay quantity and quality based on phenological development stage. During 1996, quadrats of annual forage crops (lentil, sudan grass, millet, and annual alfalfa seeded into both spring wheat and sunflower residue and oat/pea, vine pea, and semi-leafless pea seeded into only spring wheat residue) were clipped, oven dried, and weighed at the phenological stage recommended for hay harvest. To evaluate the change in quantity and quality of hay over time, each annual forage crop was also harvest 2 weeks before, 1 week before, and 2 weeks after the recommended harvest date as determined by phenological development stage. Hay samples were later analyzed for crude protein (CP), phosphorus (P), and in vitro dry matter digestibility (IVDMD).

Weather conditions during the 1996 growing season are presented in Table 1. Total precipitation during the growing season months of May through August was 10.51 inches, 1.02 inches more than average which is 111% of normal. Soil water at the start of the season was 11.5 inches to a depth of 4 feet in spring wheat residue and 10 inches to a depth of 4 feet in sunflower residue. Temperatures during these months averaged 64 °F, 2.5 °F cooler than average or 96% of normal. Free water evaporation for this growing season was 28.10 inches, 3.46 inches below average or 89% of normal. Weather conditions experienced in 1996 are not all that unusual for the Mandan, ND area.

Oat/pea grown in spring wheat stubble yielded 3271 lb/a and in vitro digestible dry matter (IVDDM) was 2271 lb/a at the time the oat was in late boot (Table 2). Crude protein was 12.7% and phosphorus was 0.22%. One week before oat was in the late boot stage, IVDDM was 2289 lb/a, the same as for oat at the late boot stage, but crude protein and phosphorus were higher at 15.8% and 0.28%, respectively.

Vine pea yield at first flower, the plant stage considered to be best for maximum yield and quality, was 3995 lb/a and IVDDM was 2814 lb/a with crude protein at 10.2% and phosphorus at 0.17% (Table 3). When harvested for hay 1 week before first flower, IVDDM was statistically the same, while there was 13.7% crude protein and 0.26% phosphorus. Vine pea IVDDM remained the same from 1 week before first flower through 2 weeks after (Table 3).

Semi-leafless pea yield at first flower was 2901 lb/a and 2089 lb/a IVDDM with 10.8% protein and 0.18% phosphorus (Table 4). A week earlier, yield was 2002 lb/a and 1471 lb/a IVDDM with 12.5% crude protein and 0.25% phosphorus. By giving up 618 lb/a IVDDM by harvesting semi-leafless pea hay 1 week before first flower, crude protein and phosphorus content could be increased to 12.5 and 0.25%, respectively.

Annual alfalfa was seeded after both spring wheat and sunflowers, however, only a 75% stand was obtained on the area after sunflower. The difficulty with establishing this annual alfalfa is believed to be related to the later seeding date due to wet/cold early spring weather conditions. The data presented in Table 5 for the harvested annual alfalfa was lower than could be achieved with a full stand, 989 lb/a at 1/10 bloom. At this stage, the quality and digestibility of this annual alfalfa was similar to that of perennial alfalfa hay harvested at past bloom.

Lentil yield was less after sunflowers than after spring wheat as shown in Table 6. There was more soil water at planting in spring wheat residue compared to sunflower residue because of the deeper soil water use by sunflowers the previous crop year. Lentil grown in spring wheat stubble had a yield of 1990 lb/a (IVDDM = 1493 lb/a) at first flower which is the recommended phenological stage considered to provide for maximum yield and quality. Lentil hay at first flower had 9.4% crude protein and 0.24% phosphorus. Lentil hay harvested one week before first flower, had a IVDDM the same, but with a crude protein content 12.0%. Crude protein levels in hay at first flower were equal to levels in hay harvested 2 weeks later. Lentil yield at first flower after sunflowers was 1837 lb/a (IVDDM = 1362 lb/a) with 8.8% crude protein and 0.21% phosphorus.

Sudan grass grown after spring wheat had a yield of 5374 lb/a and a total of 3339 lb/a IVDDM when it was 91-122 cm high, the recommended stage considered best for high quality and yield (Table 7). At this time, sudan had 5.9% crude protein and 0.14% phosphorus. Sudan grass harvested 1 week earlier, had yield equal, but with higher protein and phosphorus content. Yield of sudan grass grown after sunflowers was 4641 lb/a (3160 lb/a IVDDM) with 7.6% crude protein and 0.12% phosphorus. When sudan grass was harvested 2 weeks after reaching 91-122 cm high, yield and IVDDM were more while crude protein and phosphorus content were equal to that of hay harvested at the earlier stage.

Millet yield was also less after sunflowers than after spring wheat and is related to less stored soil water at planting (Table 8). Millet yield in spring wheat stubble at the start of heading was 4318 lb/a (2786 lb/a IVDDM) with 8.6% crude protein and 0.15% phosphorus. Yield and IVDDM were equal 1 week earlier with increased protein content. Millet hay grown in sunflower stubble at the start of heading yielded 3810 lb/a (2666 lb/a IVDDM) with 11% crude protein and 0.15% phosphorus (Table 8).

Close monitoring of harvest date through plant phenological stage can help customize hay quantities and qualities for the specific needs of the farm/ranch operation. Our data show that earlier and later harvest of the various annual forage crops for hay results in different yields and quality for the hay. In general, early harvested hay results in high quality (IVDDM, protein, and phosphorus) at the expense of yield. This may be a reasonable time to harvest hay if quantities of other lower quality feeds are available as part of the farm/ranch operation. If quantity of hay is the most important, later harvest allows for the greatest yield of reasonable quality hay.

Table 1. Weather conditions during the 1996 growing season.

Weather parameter	May	Jun	Jul	Aug
Precipitation (in.)	2.40 (+0.16)[1/]	2.36 (-0.59)	4.02 (+1.65)	1.73 (-0.20)
Temperature (°F)	51.8 (-2.9)	65.8 (+1.2)	67.5 (-3.2)	70.9 (+2.4)
Evaporation (in.)	4.68 (-2.12)	7.60 (-0.08)	7.44 (-1.61)	8.38 (+0.35)

[1/] Deviation from monthly average.

Table 2. Production and quality of oat/pea mixture grown for hay.

Crop		Harvest Date 26 Jun	2 Jul	9 Jul**	23 Jul	$LSD_{.05}$
		after wheat				
Oat/Pea	*Prod. (lb/a)	1662c	2858b	3271b	5571a	848
	*Prot. (%)	20.3a	15.8b	12.7c	10.1d	1.2
	*P (%)	0.34a	0.28b	0.22c	0.16d	0.03
	*IVDMD (%)	87.5a	80.0b	69.4c	63.0d	2.0
	*IVDDM (lb/a)	1456c	2289b	2271b	3505a	563

** Recommended harvest date – oat/pea with oat at late boot stage. Means within rows with same letters are statistically equal and means are compared by $LSD_{.05}$ with the mean at recommended harvest date.

Table 3. Production and quality of vine pea grown for hay.

Crop		Harvest Date 2 Jul	 9 Jul	 15 Jul** after wheat	 30 Jul	 $LSD_{.05}$
Vine Pea	*Prod. (lb/a)	2266c	3813b	3995ab	4345a	418
	*Prot. (%)	17.1a	13.7b	10.2c	10.2c	1.4
	*P (%)	0.29a	0.26a	0.17b	0.20b	0.04
	*IVDMD (%)	74.7a	74.7a	70.5b	69.0b	3.0
	*IVDDM (lb/a)	1692b	2849a	2814a	3000a	389

** Recommended harvest date – vine pea at first flower. Means within rows with same letters are statistically equal and means are compared by $LSD_{.05}$ with the mean at recommended harvest date.

Table 4. Production and quality of semi-leafless peas grown for hay.

Crop		Harvest date 2 Jul	 9 Jul	 15 Jul** after wheat	 30 Jul	 $LSD_{.05}$
Leafless pea	*Prod. (lb/a)	1208c	2002bc	2901b	4118a	984
	*Prot. (%)	16.2a	12.5b	10.8c	8.7d	1.6
	*P (%)	0.29a	0.25a	0.18b	0.17b	0.05
	*IVDMD (%)	72.5a	73.4a	72.1a	64.3b	3.7
	*IVDDM (lb/a)	877c	1471bc	2089ab	2653a	659

** Recommended harvest date – semi-leafless pea at first flower. Means within rows with same letters are statistically equal and means are compared by $LSD_{.05}$ with the mean at recommended harvest date.

Table 5. Production and quality of annual alfalfa grown for hay.

Crop		Harvest Date 26 Jun	2 Jul	9 Jul**	23 Jul	$LSD_{.05}$
				after sunflower		
Annual Alfalfa	*Prod. (lb/a)	396b	963b	989b	2032a	600
	*Prot. (%)	24.3a	17.4b	12.6c	8.0d	2.6
	P (%)	0.31a	0.30a	0.19b	0.15b	0.08
	*IVDMD (%)	86.5a	77.6b	70.3c	52.8d	3.8
	*IVDDM (lb/a)	342b	744ab	696ab	1072a	404

** Recommended harvest date – alfalfa at 1/10 bloom. Means within rows with same letters are statistically equal and means are compared by $LSD_{.05}$ with the mean at recommended harvest date.

Table 6. Production and quality of lentil grown for hay.

Crop		Harvest Date 9 Jul	15 Jul	23 Jul**	6 Aug	$LSD_{.05}$
				after wheat		
Lentil	* Prod. (lb/a)	1208c	1728bc	1990b	3082a	738
	* Prot. (%)	13.8a	12.0a	9.4b	9.3b	2.2
	* P (%)	0.31a	0.26a	0.24ab	0.18b	0.07
	* IVDMD (%)	78.3a	77.2a	72.2b	66.5c	2.6
	* IVDDM (lb/a)	940b	1339b	1493ab	2044a	630
				after sunflower		
Lentil	NS Prod. (lb/a)	1542a	2591a	1837a	2890a	NS
	* Prot. (%)	13.4a	10.7b	8.8c	7.7c	1.7
	* P (%)	0.28a	0.23b	0.21bc	0.18c	0.04
	* IVDMD (%)	79.1a	79.5a	74.1b	67.6c	3.9
	NS IVDDM (lb/a)	1221a	2070a	1362a	1940a	NS

** Recommended harvest date – lentil at first flower. Means within rows with same letters are statistically equal and means are compared by $LSD_{.05}$ with the mean at recommended harvest date.

Table 7. Production and quality of sudan grass grown for hay.

Crop		Harvest Date 23 Jun	30 Jul	6 Aug**	20 Aug	$LSD_{.05}$
				after wheat		
Sudan Grass	*Prod. (lb/a)	3782c	5301b	5374b	7710a	1406
	*Prot. (%)	9.9a	7.3b	5.9bc	5.0c	1.5
	*P (%)	0.18a	0.16b	0.14c	0.14c	0.01
	*IVDMD (%)	71.5a	67.9b	62.2c	62.3c	1.4
	*IVDDM (lb/a)	2702b	3598b	3339b	4808a	947
				after sunflower		
Sudan Grass	*Prod. (lb/a)	3222b	4592b	4641b	7032a	1444
	*Prot. (%)	12.3a	9.4b	7.6bc	6.5c	2.2
	*P (%)	0.17a	0.14ab	0.12b	0.12b	0.04
	*IVDMD (%)	75.0a	71.5ab	68.1bc	65.0c	4.2
	*IVDDM (lb/a)	2401b	3268b	3160b	4574a	1049

** Recommended harvest date – sudan grass 91-122 cm high. Means within rows with same letters are statistically equal and means are compared by $LSD_{.05}$ with the mean at recommended harvest date.

Table 8. Production and quality of millet grown for hay.

Crop		Harvest Date 15 Jul	23 Jul	30 Jul**	13 Aug	$LSD_{.05}$
				after wheat		
Millet	*Prod. (lb/a)	2184c	3877b	4318b	7436a	1134
	*Prot. (%)	13.2a	10.6b	8.6c	5.2d	1.5
	*P (%)	0.21a	0.18ab	0.15bc	0.13c	0.04
	*IVDMD (%)	76.2a	73.6a	64.6b	59.8c	3.8
	*IVDDM (lb/a)	1670c	2849b	2786b	4445a	675
				after sunflower		
Millet	*Prod. (lb/a)	1499d	2736c	3810b	6752a	822
	*Prot. (%)	19.3a	16.0b	11.0c	7.0d	1.5
	*P (%)	0.20a	0.19a	0.15b	0.11c	0.02
	*IVDMD (%)	82.4a	78.0b	70.0c	66.2d	3.4
	*IVDDM (lb/a)	1235d	2134c	2666b	4460a	410

** Recommended harvest date – millet starting to head. Means within rows with same letters are statistically equal and means are compared by $LSD_{.05}$ with the mean at recommended harvest date.

SITE-SPECIFIC FARMING IN WESTERN N.D. - 2000

Mr. Vern Hofman, Extension Ag Engineer
Dr. Dave Franzen, Extension Soil Specialist
Mr. Lowell Disrud, Ag Engineer
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Introduction:

The site-specific farming project being conducted in cooperation with Area IV SCD and USDA-ARS - Mandan has conducted intensive soil sampling, variable rate fertilizer application, yield monitoring and map interpretation on 3 of the I fields. These fields previously contained about 76 acres but this year they were reduced in size as USDA-ARS needed some land for other research projects. Currently, the 3 fields contain about 47 acres which is split into fields containing about 12.5, 16. 5 and 18 acres.

The project objective is to demonstrate site-specific farming techniques and to gather data to support soil sampling techniques, profitability and changes in soil test levels through a cropping rotation. Another objective is to monitor N movement through the soil profile to determine if fertilizer N may pose a hazard to underground water supplies.

Previous work has shown that topography base soil sampling provides as good or better soil nutrient information than dense grid sampling at a fraction of the samples (cost) needed to determine filed nutrient levels. Profitability of variable - rate fertilizer application has been erratic. Sunflower and wheat production data did show a net increase in return for topography directed fertilizer application over a uniform application and a grid based application. This occurred in some years and not in others.

Data is showing that sunflower is recycling fertilizer nutrients from deeper soil (2 to 6 ft.) depths. This is being found in lower N tests for sunflower as compared to soil N tests under a wheat crop. Nutrients are deposited on the soil surface in residue from the previous crop. Soil tests taken after harvest is showing low nitrates in the soil but after breakdown during the next growing season, nutrients are becoming available for the next years crop near the soil surface.

Variable-rate studies from the previous years have shown that for profitable returns from variable-rate application, N levels in the top 24 inches of the soil need to vary by more than 30 lbs/acre over fairly large areas. If yields are low due to environmental factors, variable-rate application will probably not be cost effective. Variable-rate application will be most effective when high variability of a nutrient is present, the nutrient is variable within a zone where adjustment impacts crop yield and environmental conditions allow yields to achieve those considered in yield goals based on nutrient requirement predictions.

Year 2000 Methods

In 1999 deep soil sampling down to 6 feet deep was started. This project is designed to demonstrate the reduction of N fertilizer movement through the soil profile by variable rate application. During previous years studies, variable rate application was showing reduced amounts of N fertilizer remaining in the top 24 inches of the soil profile. This project is intended to show this concept in deeper soil levels. In western ND high nitrates have been found in underground water supplies. Variable-rate fertilizer application may help reduce the nitrates getting into water supplies. This past cropping year, a uniform fertilizer application was applied to all three fields. After soil testing, it was found that little variation in fertility levels was occurring in the field. Fertilizer was applied to the winter wheat field (I5) in the fall of 1999 at the rate of 170 lbs of N (Urea) and 50 lbs/acre (11-52-0 material) at planting time. The spring wheat field (I4) had 125 lbs of N per acre (Urea) and 50 lbs/acre of (11-52-0 material) at planting time. The sunflower field (I6) had 125 lbs of N per acre broadcast prior to planting. Rainfall during the growing season (March through September) was 14.5 inches, which is above the normal 13.7 inches for the same period.

Results:

The 2000 crop year contour maps for the 3-I fields are shown in figure 1. The spring wheat (I4 field) averaged 56 bu/acre, the winter wheat (I5 field) averaged 57.3 bu/acre and the sunflower (I6 field) averaged 2217 lbs/acre. The I4 field shows a majority of the field producing a 40 to 55 bu/ac yield and another large section producing a 55 to 70 bu/acre yield.

The I5 field has a large section producing 55 to 70 bu/acre with some smaller areas producing 40 to 55 bu/acre. The white areas in both I4 and I5 fields are low yielding areas due to wet spots or field ends. The I6 field shows sunflower with a large area producing 18 to 26 cwt/acre. The south end of the field shows a fairly large white area producing 10 to 18 cwt/acre. The north end has a small area yielding very high with 26 to 34 cwt/acre.

Figure 2 is a profit/loss contour map of the 3 fields. Determining a profit/loss for all parts of a field can be extremely helpful in estimating net returns from all parts of the field. A computer spreadsheet is needed where yield and coordinates for each yield data pont is identified. A gross return (price per bu plus LDP payment) is figured for each yield point, a crop cost per acre is determined which is subtracted from the gross return/acre, which gives a net return. This can help a producer decide if certain places in a field are making him money or costing him money. If places in a field are consistently losing money over a number of years, can anything be done to change the loss into a profit. Quite often wet spots or extremely poor soil show up as losing money. Then a producer can determine if a wet spot should or could be drained to make it more profitable or, if nothing can be done at an reasonable cost, maybe the area should be taken out of production and grassed. This will reduce input production costs such as seed, fertilizer and pesticides being applied to unproductive areas.

This year, most areas of the fields produced enough yield to show a profit. The I5 field shows 2 areas (white spots which were too wet) that did not produce enough crop to show a profit. These two areas show up in figure 1 as well. If the LDP payment was subtracted from these returns, larger areas of these fields show up as losing money. If yields were lower due to dry weather, this economic analysis is an excellent way to determine returns. Looking at fields in this manner may help determine what needs to be done to show a profit.

Deep soil sampling was completed after harvest on all three fields. The residual nitrogen left in the soil in the top 24 inches is shown in Figure 3. Figure 4 indicates the nitrogen in the top 48 inches of the soil profile. This information was obtained by sampling every ½ acre in the I4 and I5 field and sampling every ¼ acre on field I6. The I4 field indicates an average of 27.5 lbs of N per acre in the top 24 inches of the soil profile. The residual N in the top 48 inches averaged 41.5 lbs. The majority (about 2/3) of the residual N was found in the top 2 ft. The amount of residual N in the 48 to 72 inch soil section averaged another 20.6 lbs/acre. In the top 6 ft. of the soil profile, an average of a little more than 60 lbs/acre of N was found. The majority of the applied N in the spring was used in producing the crop. The yield times 2.5 lbs per bushel (56 bu/acre X 2.5 lbs N/bu= 140 lbs N/acre) caused about 140 lbs of N to be removed from the field in the harvested crop. Only marginal variability occurred in this field and a uniform fertilizer rate was applied when the winter wheat was planted in September 2000.

Field I5 contains considerably more residual N in the top 24 inches than the I4 and I6 fields. This was due to the higher fertilizer rate applied to the winter wheat when planted in September 1999. Some places in field I5 indicate residual N exceeding 120 lbs per acre. A large part of the field indicates residual N in the 30 to 90 lb/acre range. This variability indicates that variable fertilizer application should be done on this field when planting the sunflower crop next season. The average residual nitrogen in the top 2 ft. of field I5 was 66.4 lbs/acre, in the top 4 ft. was 83.8 lbs/acre and 118.4 lbs/acre in the top 6 ft. Again, the majority of the residual N was found in the top 2 ft. Sunflower will be planted on this field in 2001 and should be helpful in utilizing the N in the top 4 to 6 ft. due to the plants tap root.

Fertilizer prices are predicted to be higher this spring. The residual fertilizer left in the I5 field was purchased at a cheaper cost last year and will be available to produce a crop next season reducing the amount of fertilizer that will be needed next season.

Figure 3 indicates less than 30 lbs/acre of N in the top 2 ft. of field I6. Figure 4 indicates very low residual N in the top 4 ft. of field I6. The average amount of N in the top 2 ft. of I6 was 20.3 lbs/acre and only 33 lbs/acre in the top 4 ft. The total average amount of N in the top 6 ft. of field I6 was only 51.2 lbs/acre. This is lower than the other 2 fields and is due to sunflower removing about 110 lbs of N per acre with 2217 lbs/acre yield. The tap root of the sunflower removed an average of about 10 to 20 lbs per acre more N than the wheat crops.

Again, like past years, sunflower removed N from deeper soil depths and tends to recycle the N from the 2 –6 ft. depths and place it in crop yield and in residue that will break down for future year crop production.

Conclusion:

Crop yields in 2000 on the I fields on the Area IV farm near Mandan were very good. Above normal rainfall, significant fertilizer applications and a good growing season produced very good yields.

An economic analysis of all yield data points is an excellent way to determine profitable and unprofitable areas of fields. If a portion of a field shows a loss over several years, the producer must determine the reason for the loss, what to do about it or to discontinue farming that area. If production costs are applied to unproductive areas, it is reducing the profit margin on the profitable parts of the field.

The deep soil sampling is again showing the capability of sunflower to remove residual N from soil depths below wheat rooting zones. Typically, sunflower plants are recycling about 10 to 20 lbs/acre more N from the 2 – 6 ft. soil profile than a wheat crop.

Sunflower is an excellent crop at recycling N from the 2 – 6 ft. depths. This helps reduce the potential of N leaching below crop rooting zones and the possibility of it getting into ground water.

Figure 1
I4, I5, & I6 Fields
Crop Yields
Year 2000

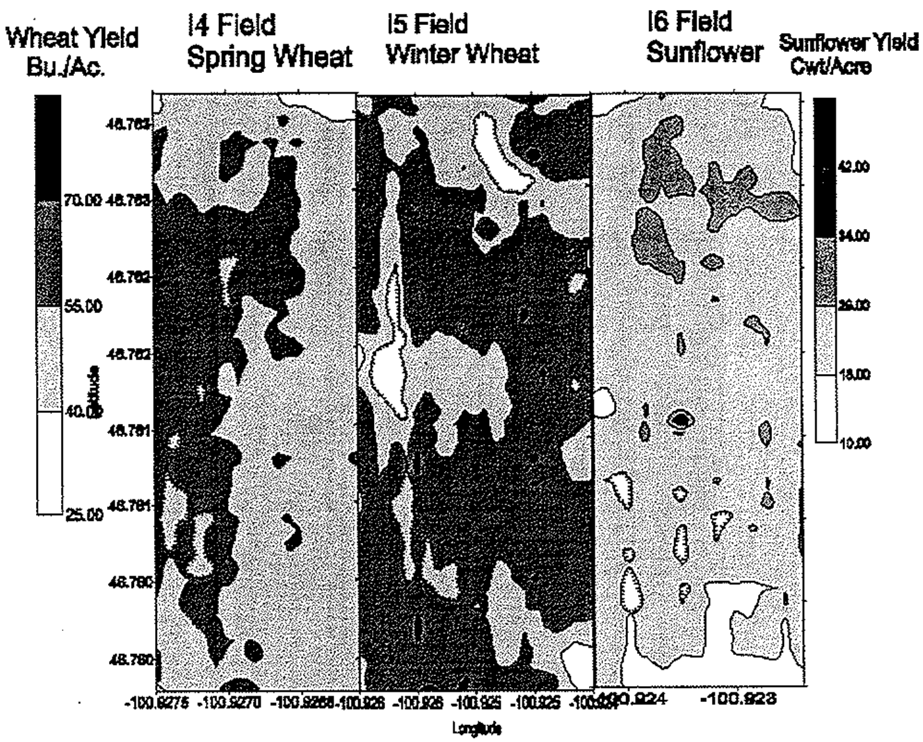


Figure 2
I4, I5 & I6 Fields
Profit/Loss $/Ac
Year 2000

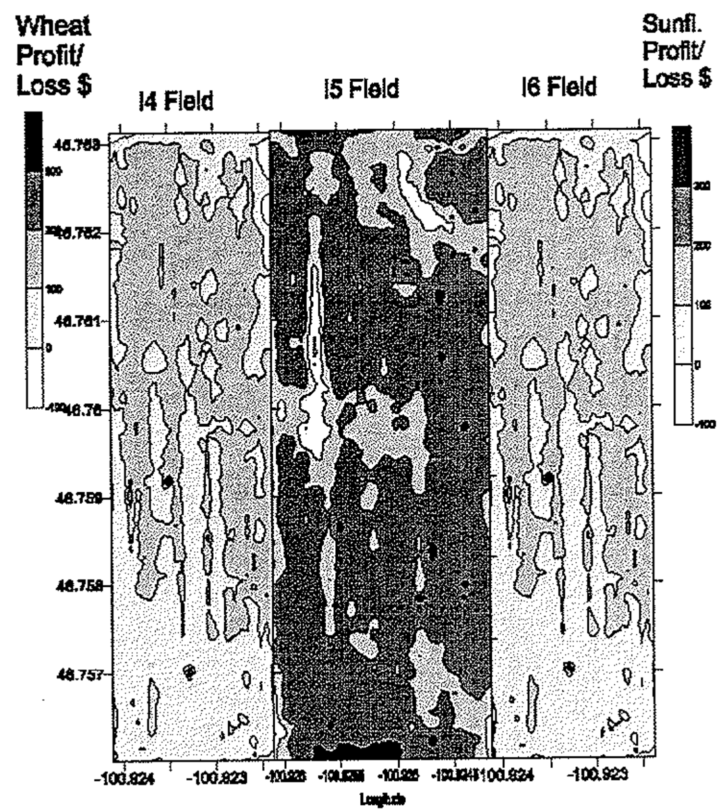


Figure 3
I4, I5 & I6 Fields
Residual Nitrogen
0 To 24inches
Year 2000

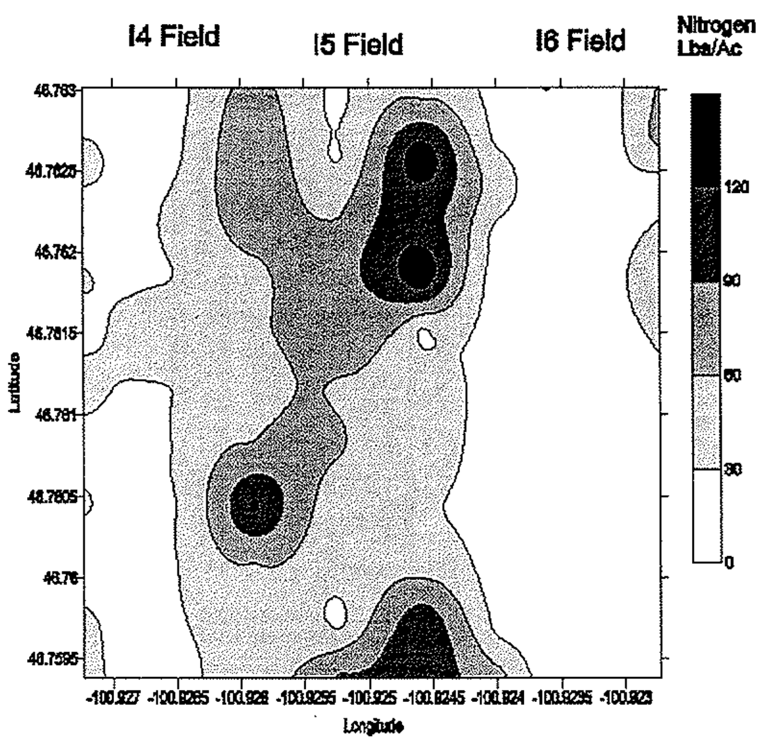
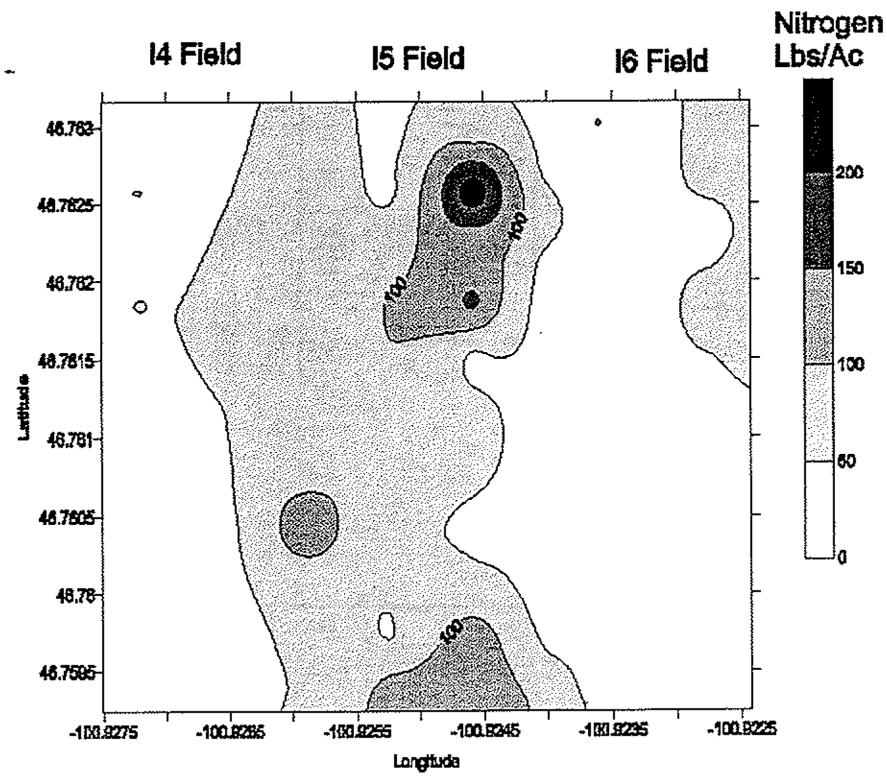


Figure 4
I4, I5 & I6 Fields
Residual Nitrogen
0 to 48 inches
Year 2000



SMALL GRAIN VARIETY EVALUATIONS – 2000

Mr. Eric Eriksmoen, NDSU, Hettinger, ND

2000 Hard Red Spring Wheat - Continuously Cropped No-till **Mandan**

Variety	Plant Height	Test Weight	Protein	Grain Yield 1998	Grain Yield 1999	Grain Yield 2000	Average Yield 2 year	Average Yield 3 year
	inches	lbs/bu	%	bu/ac				
2375	40	62.4	14.5	55.2	39.2	53.6	46.4	49.3
Oxen	39	58.6	14.2	52.6	36.0	59.1	47.6	49.2
2398	37	58.6	12.9	58.8	38.5	47.7	43.1	48.3
Keene	47	59.8	16.1	50.4	39.8	48.6	44.2	46.3
Grandin	39	58.6	15.5	45.2	23.4	41.7	32.6	36.8
Reeder	41	60.5	16.3		46.9	60.3	53.6	
Parshall	45	61.9	16.9		42.9	54.1	48.5	
Ivan	36	59.9	12.1			59.7		
Norpro	38	58.9	13.5			57.4		
Ember	40	61.7	14.8			50.9		
Alsen	39	61.4	16.2			50.2		
Ingot	40	62.6	13.0			48.9		
Trial Mean	40	60.4	14.7	50.2	39.3	52.7	--	--
C.V. %	3.4	1.1	--	7.0	12.5	9.5	--	--
LSD .05	3	1.0	--	6.0	8.3	7.2	--	--
LSD .01	4	1.3	--	8.0	11.3	9.6	--	--

Planting Date: April 13, 2000
Harvest Date: August 10, 2000
Seeding rate: 1.1 million live seeds/A (approx. 1.6 bu/A).
Previous Crop: 1998 = HRSW
1999 = Rye
2000 = Barley

2000 Durum - Continuously Cropped No-till **Mandan**

Variety	Plant Height	Test Weight	Protein	-------- Grain Yield -------- 1998	1999	2000	Average Yield 2 year	3 year
	inches	lbs/bu	%	----------	----------	bu/ac	----------	----------
Mountrail	42	59.1	14.7	57.0	60.5	66.1	63.3	61.2
Ben	43	59.4	14.9	53.6	59.0	62.0	60.5	58.2
Maier	41	58.9	15.4	54.6	51.9	63.5	57.7	56.7
Lebsock	41	60.6	14.4		55.0	66.4	60.7	
Plaza	31	54.9	14.7		45.3	42.2	43.8	
Trial Mean	40	58.9	14.7	52.3	54.4	61.3	--	--
C.V. %	1.9	1.9	--	5.2	8.9	14.4	--	--
LSD .05	2	1.6	--	NS	8.6	13.2	--	--
LSD .01	3	2.3	--	NS	NS	18.1	--	--

Planting Date: April 13, 2000 Harvest Date: August 10, 2000
Seeding rate: 1.25 million live seeds/A (approx. 2.2 bu/A).
Previous Crop: 1998 = HRSW, 1999 = Rye, 2000 = Barley
NS = no statistical difference between varieties.

2000 Oats - Continuously Cropped No-till	Mandan

Variety	Plant Height	Test Weight	Grain Yield 1998	Grain Yield 1999	Grain Yield 2000	Average Yield 2 year	Average Yield 3 year
	inches	lbs/bu	bu/ac				
Jud	52	34.5	112.9	91.0	97.0	94.0	100.3
Jerry	47	34.6	125.2	58.7	89.4	74.0	91.1
Paul*	56	41.3	93.3	48.3	66.4	57.4	69.3
Ebeltoft	46	33.9		99.2	110.2	104.7	
Youngs	53	34.1		84.1	110.0	97.0	
Killdeer	45	33.7			121.1		
Loyal	53	36.5			97.2		
Trial Mean	50	35.5	116.9	76.3	98.8	--	--
C.V. %	2.1	1.9	7.8	5.9	10.4	--	--
LSD .05	3	1.0	13.6	8.3	15.2	--	--
LSD .01	4	1.4	18.7	11.9	20.7	--	--

Planting Date: April 13, 2000
Harvest Date: August 10, 2000
Seeding rate: 750,000 live seeds/A (approx. 1.7 bu/A).
Previous Crop: 1998 = HRSW
1999 = Rye
2000 = Barley
* Naked (hulless) type.

NOTE: For more information on yields of small cereal grains for Western North Dakota, contact:

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MANAGEMENT PRACTICES, 2000
AREA IV SCD/ARS RESEARCH FARM

AREA-F FIELD OPERATIONS, NW 1/4 Section 17 (Figure 2, page 5)

Field F1. This conservation bench terrace area has been excluded from the total acreage leased by AREA IV SCDs since 1987.

Field F2. DeKalb 3790 sunflower. The previous crop (1999) was Roughrider winter wheat (44 bu/a; 14% protein). On April 5, 2000, anhydrous ammonia was contract applied at 60 lb N/a. Sonalan® (1 lb ai/a) was applied with a Gandy air applicator mounted to a Haybuster undercutter on April 20, 2000. Second incorporation of Sonalan® was done with a JD Mulchmaster on May 22, 2000. On May 23, 2000, DeKalb 3790 sunflower was seeded with a JD Maxemerge II planter (25,000 seeds/a planted in 30 inch rows). Crop was sprayed with Assert® (12 oz/a) on June 29, 2000 and with Poast® (24 oz/a) on June 30, 2000. Asana XL® (5.6 oz product/a) was contract sprayed on August 11, 2000. Crop was combined on October 12, 2000, yield of 1851 lb/a.

Field F3. Robust barley. The previous crop was Cenex 803 and DeKalb's Nusun with yields of 1690 lb/a. On April 5, 2000 anhydrous ammonia was contract applied at 70 lb N/a. The field was reduced tilled with a JD Mulchmater on April 28, 2000. Robust barley was seeded with a Haybuster 1000 disk drill on May 4, 2000. The seeding rate was 90 lb/a and 11-52-0 was applied with the seed at 50 lb/a. On May 30, 2000, the field was sprayed with Bronate® (1 pt/a) plus Puma® (0.33 pt/a). The crop was swathed on July 27, 2000 and combined on August 9, 2000 with a yield of 78.4 bu/a. The south half of the field was seeded to Necota winter wheat, a South Dakota winter wheat variety, on September 26, 2000. The north half of the field was seed to Roughrider winter wheat on September 27, 2000. Both varieties were seeded with a Haybuster 8000 hoe drill at a rate of 1.3 m seeds/a. Fertilizer (11-52-0) was applied with the seed at 50 lb material/a. The drill has a row space of 10 inches. Field was sprayed with Roundup Ultra® (24 oz material/a) on October 2, 2000.

Field F4. Roughrider winter wheat. The previous crop (1999) was Amidon spring wheat (30.8 bu/a yield). The field was sprayed with Roundup Ultra® (24 oz product/a) on September 15, 1999. The north side of the field was seeded to Harding a new hard red winter wheat (SD 92-107) released by South Dakota State University and the south side was seeded to Roughrider winter wheat on September 24, 1999. All of the seeding was performed with a Haybuster 8000 hoe drill (10-inch row space). The planting rate was 1.3 million seeds/a and fertilizer (11-52-0) was applied with the seed at 50 lb/a. On March 17, 2000, urea (46-0-0) was contract bulk spread at 70 lb N/a. On May 10, 2000, the field was sprayed with Bronate® at 24 oz product/a. The crop was straight combined on August 1, 2000. The Roughrider yield was 41 bu/a and the SD92-107 yield was 45 bu/a (13.9% protein). Field was sprayed with Roundup Ultra® (24 oz material/a) on September 27, 2000.

Field F5. Corn cultivars. The previous crop (1999) was Robust barley (56.5 bu/a). On March 17, 2000, urea (46-0-0) was contract bulk spread at 70 lb N/a. On April 5, 2000, anhydrous ammonia was contract applied at 70 lb N/a. Results follow:

Corn grain yield test weight and harvest moisture for varieties grown in 2000 at Mandan

Variety	Days to Maturity	*Yield (bu/a)	TW (lbs/bu)	% Moisture at Harvest
SS 90	85	81	51.50	16.9
2184	84	78	51.05	15.3
DKC26	75	97	53.30	15.2
2175	75	106	55.95	16.8
DK 334 BTY	83	104	51.60	16.5
2183	84	105	52.65	15.0
Pioneer 39A46	87	106	55.05	15.7
DK 626 RR	112	68	43.25	54.7
2177	77	107	55.20	18.0

Seeding Date = 5-19-00
Harvest Date = 10-24-00 *Reflects 14% Moisture

AREA-G FIELD OPERATIONS, SW 1/4 Section 8 (Figure 2, page 5)

Field G1. Forage Grass Breeding and Genetics. The southwest corner of field G1 is being used as a holding nursery for approximately 300 parent clones of crested wheatgrass. Progenies of these clones, which were tested for forage yield in the past, are currently undergoing laboratory tests for forage quality. Based on these tests, the most promising of the 300 clones will be selected for inclusion in improved experimental strains of crested wheatgrass. Preliminary results indicate that forage digestibility of crested wheatgrass can be improved. Contact Dr. John Berdahl for additional information (refer to scientific staff listing).

Field G1. Hybrid Poplar Clonal Test. The north side of field G1 is a plantation of 240 hybrid poplar and cottonwood clones. Clones were evaluated for drought and cold hardy as well as resistant to damage from insects and diseases. One variety, CANAM poplar, has been identified and released. For additional information contact Dr. Richard Cunningham, retired, NGPRL.

Field G1. NDSU Small Grain Cultivar Evaluations. For information on NDSU cultivar evaluation check Eric Eriksmoen's report starting on page 44.

Field G2. Early Season Crop Sequence Project, Phase II of the Diverse Cropping

Systems Project. Information on the crop sequence project starts on page 10.

Field G3. Alsen spring wheat. This field was fallow during the 1999 season. On May 1, 2000, Alsen spring wheat was seeded with a Concord air seeder. The seeding rate was 1.3 million seeds/a and fertilizer (11-52-0) was applied with the seed. Due to a mechanical problem no nitrogen was applied at seeding. On May 17, 2000, urea (46-0-0) was broadcast at 60 lb N/a. The crop was sprayed with Bronate® (1 pt/a) plus Puma® (0.33 pt/a) on May 30, 2000. The crop was swathed on August 9, 2000 and combined on August 17, 2000 with a yield of 50.5 bu/acre (13.5% protein).

Field G4. Fallow. The field was sprayed with Roundup® (16 oz product/a) and 2-4D (16 oz product/a) on May 23, 2000. Fallowmaster® (32 oz product/a) was used on June 30, 200 and on August 17, 2000.

<u>AREA-H FIELD OPERATIONS</u>, NE 1/4 Section 18 (Figure 2, page 5)

Field H1. Long-term cropping systems study, 65A study.

A long-term cropping systems—conservation tillage and nitrogen study was initiated in field H1 in 1984. This study involves two cropping systems: spring wheat [SWF]-fallow and spring wheat [SWC]-winter wheat [WWC]-sunflower [SUC] with three tillage treatments (conventional-till [CT or T1], minimum-till [MT or T2] and no-till [NT or T3]), and three nitrogen fertilizer levels (0, 20, and 40 lb N/a for spring wheat-fallow, and 30, 60, and 90 lb N/a for the 3-yr annual crop rotation) and two varieties of each crop from 1985 through 1996. This study also includes a no-residue spring wheat-fallow treatment [T4] to serve as a check plot for assessing wind erodibility and plant diseases. In 1997, only one cultivar was used in each of the rotations. In 1997, peas and corn were substituted for one of the cultivar treatments, thus in 1998 spring wheat was grown on pea ground in addition to the regular fallow (two-yr rotation) and sunflower ground (three-year rotation). In 1998 through 2000, only spring wheat, winter wheat, and sunflower crops were grown. In 1999 and 2000, only one fertility level was applied, 60 lb/a for the continuous cropping system and 20 lb/a for the crop-fallow system.

09/14/99	Sprayed WWC plots with Roundup Ultra® (24 oz product/a).
09/22/99	Tilled T-1, with the mulchmaster and T-2 with the undercutter. Seeded Roughrider winter wheat with a Haybuster 8000 hoe drill (10-inch row space) at 1.3 million seeds/a. Fertilizer (0-44-0) was applied (50 lb/a) with the seed.
04/19/00	Urea (46-0-0) was bulk spread on the winter wheat blocks at 60 lb N/a.
04/28/00	Tilled SWC and SWF T2 plots with Haybuster undercutter.
05/02/00	Sonalan® was applied to the SUC T1 and T2 plots with a Gandy air applicator mounted to a Haybuster undercutter. The rate was 1 lb ai/a.
05/03/00	Tilled SWC and SWF T1 plots with JD mulchmaster.

05/05/00	Seeded Russ spring wheat. The SWC plots were seeded with a Haybuster 107 disk drill and the SWF and NR plots were seeded with a Haybuster 1000 disk drill. Fertilizer (0-44-0) was applied at 50 lb/a. The seeding rate was 1.3 million seeds/a.
05/16/00	Sprayed WWC plots with Bronate® (24 oz product/a) after seeding.
05/22/00	Sprayed SUC plots with Spartan® (2 oz ai/a) before seeding.
05/26/00	Seeded DeKalb's 3790 sunflower with JD 750 no-till disk drill. The row spacing was 15 inches.
06/28/00	Tilled conventional till fallow plots and T4 plots with JD Mulchmaster.
06/30/00	Sprayed minimum till and no till fallow plots with Fallowmaster® (48 oz product/a).
08/01/00	Sampled WWC plots for yield with plot combine.
08/02/00	Cleaned up the winter wheat plots with the combine.
08/11/00	Contract sprayed the sunflower plots with Asana XL® (5.6 oz product/a).
08/16/00	Sampled the spring wheat plots for yield with plot combine.
08/21/00	Sprayed all fallow plots with Roundup® (24 oz product/a).
08/25/00	Cleaned up the spring wheat plots with the combines.
09/25/00	Sprayed with Roundup Ultra® (24 oz material/a)
09/21/00	Harvested plots for sunflower yield
10/13/00	Cleaned up the sunflower plots.

Table 1. Year 2000 combine grain yields for two-year crop rotation in long-term cropping systems study, NGPRL, Mandan.

	---------- N-rate (lb/ac) ----------			
Tillage	0	20	40	Mean
	Spring wheat (Russ) after fallow, bu/ac			
CT	40.4	45.7	42.3	42.8 a
MT	38.1	39.5	36.6	38.1 b
NT	35.6	37.6	32.3	35.2 b
Mean	38.0 y	41.0 x	37.1 y	
No residue	43.7	45.5	44.9	

Table 2. Year 2000 combine grain yields for three-year crop rotation in long-term cropping systems study, NGPRL, Mandan.

	N-rate (lb/ac)			
Tillage	30	60	90	Mean
	Winter wheat (Roughrider) after spring wheat, bu/ac			
CT	47.6	46.4	50.9	48.3 a
MT	38.6	42.0	47.8	42.8 a
NT	44.5	46.9	46.2	45.9 a
Mean	43.6 x	45.1 x	48.3 x	
	Sunflower (DeKalb 3790) after winter wheat, lb/ac			
CT	1853	1889	1591	1777 a
MT	2102	1787	2345	2078 a
NT	1670	2181	1778	1877 a
Mean	1875 x	1952 x	1905 x	
	Spring wheat (Russ) after sunflower, bu/ac			
CT	43.2	48.6	46.3	46.0 a
MT	47.8	48.1	49.2	48.4 a
NT	42.1	47.0	48.6	45.9 a
Mean	44.4 y	47.9 x	48.0 x	

Field H2. Robust barley. Previous crop (1999) was Amidon Spring wheat (20 bu/a). On April 5, 2000, anhydrous ammonia was contract applied at 60 lb N/a. On May 1, 2000, Robust barley was seeded at 90 lb/a with a JD-750 no-till drill. Fertilizer (11-52-0) was applied 50 lb material/a with the seed. Bronate® (1 pt/a) plus Puma® (0.33 pt/a) were sprayed on the crop on May 30, 2000. The crop was swathed on July 28, 2000 and combined on August 9, 2000 with a yield of 77.6 bu/a. Roundup Ultra® (24 oz material/a) was sprayed on the field on September 26, 2000. Roughrider winter wheat was seeded with a Haybuster 8000 hoe drill with a 10" row space on September 28, 2000. The seeding rate was 1.3 m seeds/a and fertilizer (11-52-0) was applied with the seed at 50 lb material/a.

Field H3. Reeder spring wheat. Sunflower (DeKalb's 3790) was present in this field (yield 1990 lb/a) in 1999. Anhydrous ammonia was contract applied at 70 lb N/a on April 5, 2000. The field was reduced tilled with a JD Mulchmaster on April 24, 2000. Reeder spring wheat was planted with a Haybubster 107 disk drill on April 24, 2000. The seeding rate was 1.3 million seeds/a and fertilizer (11-52-0) was placed with the seed at 50 lb material/a. Due to wet weather conditions, seeding was completed on April 28, 2000. Bronate® (1 pt/a) plus Puma® (0.33 pt/a) was sprayed on the crop on May 30, 2000. The crop was straight combined on August 15, 2000.with a yield of 50.5 bu/a (13.6 % protein). Roundup Ultra® (24 oz material/a) was sprayed on the field on August 18, 2000 and September 27, 2000.

Field H4. Soil Quality Study. A long-term study was initiated in the spring of 1993 to evaluate the influence of tillage and crop rotations on soil quality factors. For additional information see 'Management Strategies for Soil Quality' on page 23.

Field H4. Sunflower cultivars. This area was planted to sunflower cultivars. For more information see 'Sunflower cultivars' on page 25.

<u>**AREA-I FIELD OPERATIONS**</u>, NE 1/4 Section 20 (Figure 2, page 5)

Field I1. Spring wheat Verde. This continuous spring wheat field provides a location for monitoring wheat diseases. Spring wheat 2375 (29 bu/a) was present in 1999. Anhydrous ammonia was contract applied at 70 lb N/a on April 5, 2000. Verde spring wheat was seeded with a Concord air seeder on May 3, 2000. The seeding rate was 1.3 million seeds/a and fertilizer (11-52-0) was applied at 50 lb/a. Bronate® (1 pt/a) plus Puma® (0.33 pt/a) was sprayed on the crop on May 30, 2000. The crop was swathed on August 9, 2000 and combined on August 14, 2000 with a yield of 47 bu/a (13% protein). On September 20, 2000 it was contract sprayed with Roundup Ultra® (24 oz material/a).

Field I2. Reeder spring wheat. Robust barley (76.7 bu/a) was present in 1999. Anhydrous ammonia was contract applied at 60 lb N/a on April 5, 2000. Reeder spring wheat was seeded with a Concord air seeder at 1.3 million seeds/a on April 28, 2000. Fertilizer (11-52-0) was applied with the seed at 50 lb/a. Bronate® (1 pt/a) plus Puma® (0.33 pt/a) was sprayed on the crop on May 25, 2000. The crop was swathed on August 3, 2000 and combined on August 11, 2000 with a yield of 45.9 bu/a (13.5% protein). Roundup Ultra® (24 oz material/a) was contract sprayed on September 20, 2000. Roughrider winter wheat was seeded with a Concord air seeder with hoe openers and a 10-inch row space on September 27, 2000. The seeding rate was 1.3 million seeds/a and fertilizer (11-52-0) was applied at 50 lb/a between the split seed row.

Field I3. Reeder spring wheat. Jerry oat (92.7 bu/a) was present in 1999. Anhydrous ammonia was contract applied at 70 lb N/a on April 5, 2000. Reeder spring wheat was seeded with a Concord air seeder at 1.3 million seeds/a on April 26, 2000. Fertilizer (11-52-0) was applied with the seed at 50 lb/a. Bronate® (1 pt/a) plus Puma® (0.33 pt/a) was sprayed on the crop on May 25, 2000. The crop was swathed on August 3, 2000 and combined on August 11, 2000 with a yield of 48.5 bu/a (13.5% protein). Roundup Ultra® (24 oz material/a) was contract sprayed on September 20, 2000. Roughrider winter wheat was seeded with a Concord air seeder with hoe openers and a 10-inch row space on September 27, 2000. The seeding rate was 1.3 million seeds/a and fertilizer (11-52-0) was applied at 50 lb/a between the split seed row.

Field I4. Site-Specific Farming Project, Verde spring wheat. Sunflower (DeKalb's 3790 with 2230 lb/a) was present in 1999. Verde spring wheat was seeded with a Concord air seeder at 1.3 million seeds/a on May 2, 2000. Fertilizer (urea N) was applied at 125 lb N/a and 11-52-0 was applied at 50 lb material/a between the split seed row. Bronate® (1 pt/a) plus Puma® (0.33 pt/a) was sprayed on the crop on May 30, 2000. The crop was combined on August 10, 2000 with a yield of 56 bu/a (14.5% protein). Roundup Ultra® (24 oz material/a) was contract sprayed on September 20, 2000. Roughrider winter wheat was seeded with a Concord air seeder with hoe openers and a 10-inch row space on September 26, 2000. The seeding rate was 1.3 million seeds/a. Fertilizer (11-52-0) was applied at 50 lb/a between the split seed row. For additional information on site-specific farming see the report 'Site-Specific Farming Project' on page 38.

Field I5. Site-Specific Farming Project, Roughrider winter wheat. Verde spring wheat (51.8 bu/a) was present in 1999. Roundup Ultra® (24 oz material/a) was sprayed on September 10, 1999. Roughrider winter wheat was seeded with a Concord air seeder at 1.3 million seeds/a on September 23, 1999. Fertilizer (urea N) was applied at 180 lb N/a and 11-52-0 was applied at 50 lb material/a between the split seed row. Roundup Ultra® (24 oz material/a) was sprayed on September 28, 1999. Bronate (24 oz product/a) was sprayed on the crop on May 15, 2000. The crop was straight combined on August 3, 2000 with a yield of 57.3 bu/a (13.9% protein). Roundup Ultra® (24 oz material/a) was contract sprayed on September 20, 2000. For additional information on site-specific farming see the report 'Site-Specific Farming Project' on page 38.

Field I6. Site-Specific Farming Study, sunflower. Roughrider winter wheat (37 bu/a) was present in 1999. Sonalan® was applied (1 lb ai/a) with a Gandy air applicator mounted on a Haybuster undercutter on April 24, 2000. Urea N (46-0-0) was broadcast at 125 lb /a on May 17, 2000. The second incorporation of the Sonalan® was done with a JD Mulchmaster on May 23, 2000. DeKalb's Nusun sunflower was planted on May 24, 2000 with a JD Maxemerge II planter. The seed population was 25,000 seeds/a in 30-inch rows. The field was contract sprayed with Asana XL® (5.6 oz product/a) on August 11, 2000. The crop was combined on October 18, 2000 with a yield of 2217 lb/a. For additional information on site-specific farming see the report 'Site-Specific Farming Project' on page 38.

Field I7 (South 1200 ft of fields I4, I5, and I6). Nusun sunflower. Urea (46-0-0) was bulk spread to south 1200 ft of fields I4 and I6 at 60 lb N/a on April 19, 2000. Sonalan® was applied (1 lb ai/a) with a Gandy air applicator mounted on a Haybuster undercutter on April 24, 2000. The second incorporation of the Sonalan® was done with a JD Mulchmaster on May 23, 2000. DeKalb's Nusun sunflower was planted on May 24, 2000 with a JD Maxemerge II planter. The seed population was 25,000 seeds/a in 30-inch rows. The field was contract sprayed with Asana XL® (5.6 oz product/a) on August 11, 2000. The crop was combined on October 19, 2000 with a yield of 2217 lb/a.

ADDITIONAL NGPRL RESEARCH

WINTERING BEEF COWS ON SWATHED FORAGES

Drs. Jim Karn, Donald Tanaka, Ron Ries, and Jon Hanson

A three year integrated crop/livestock project was initiated in the spring of 1999. Initial results of the crops portion of the project was reported in the Area IV report for 2000. The animal portion of the project involved wintering 4-6 year-old dry bred Hereford cows on rotationally grazed triticale straw, oat/pea straw and swathed drilled corn. Triticale and oat/pea crops were harvested for grain with the straw spreader removed from the combine to leave the crop residue in swaths for winter grazing. Drilled corn was swathed with a haybine in mid-September. In the first year of the experiment, cows grazed on triticale straw for 25 days, oat/pea straw for 21 days and swathed drilled corn for 51 days, for a total of 97 days. The experiment was initiated on November 12, 1999 and terminated on February 17, 2000. Each of the 3 treatments included 2 replications of 10 cows, or 20 cows per treatment with a total of 60 cows on the experiment. Cows grazing the crop residue and drilled corn were also provided a daily supplement averaging 4 lbs/cow/day. The supplement consisted of a 50-50 mix of oat/pea and triticale grain previously harvested from the fields used for winter grazing. The grain mixture contained 17.2 % crude protein and 0.44 % phosphorus.

Cows were weighed and condition scored following an overnight stand without feed or water at the beginning and end of the experiment. Intermediate weights were taken following 25 days of grazing on triticale straw, and 21 days of grazing on oat/pea straw. Fresh forage was provided daily to swath grazing cows by moving a portable electric fence. The area of swathed forage provided each day was dependent on the cow's appearance, and how well the previous days feed had been cleaned up. Weekly samples of hay bales were collected using a coring device powered by an electric drill. Random samples of swathed forages were also collected on a weekly basis. All forage samples were analyzed for crude protein, in vitro digestible dry matter (IVDDM), neutral detergent fiber (NDF) and phosphorus.

Results and Conclusions

Weight gains (Fig. 1) and condition scores (Fig. 2) were significantly higher at the end of the experiment for cows grazing crop residue and drilled corn compared to cows grazing swathed western wheatgrass, or cows fed hay in a drylot. This was no doubt due to a mild winter and the supplemental grain fed to this group. Our goal was for cows on swathed forages to perform comparable to drylot cows.

Crude protein in triticale and oat/pea straw as well as the drilled corn was below beef cow requirements, and lower than swathed western wheatgrass or baled hay (Fig.3). Phosphorus was marginal for dry bred beef cows in swathed western wheatgrass, adequate in drilled corn, and clearly deficient in oat/pea straw. In vitro dry matter digestibility (IVDDM) was highest in drilled corn, next highest in hay, and lowest in oat/pea and triticale straw. Swathed western wheatgrass had slightly lower IVDDM than hay.

First year results suggest that dry bred cows can be successfully wintered on swathed forages, if they are properly supplemented. Cows will graze swaths through several inches of snow (Fig. 4), but crusting and icing can be a problem, which may necessitate a mechanical treatment to break the crust. Advantages of swath grazing include lower winter feed costs, and no manure concentration or handling problems.

We currently are in the second year of this 3 year swath grazing experiment. Temperatures in December of 2000 were below normal, compared to above normal temperatures during the entire 1999-2000 experimental period. Weather conditions during the 2000-2001 experiment necessitated additional supplementation, but results still seem encouraging. We expect to record calving and reproductive data to determine if swath grazing has any longer term effect cow performance.

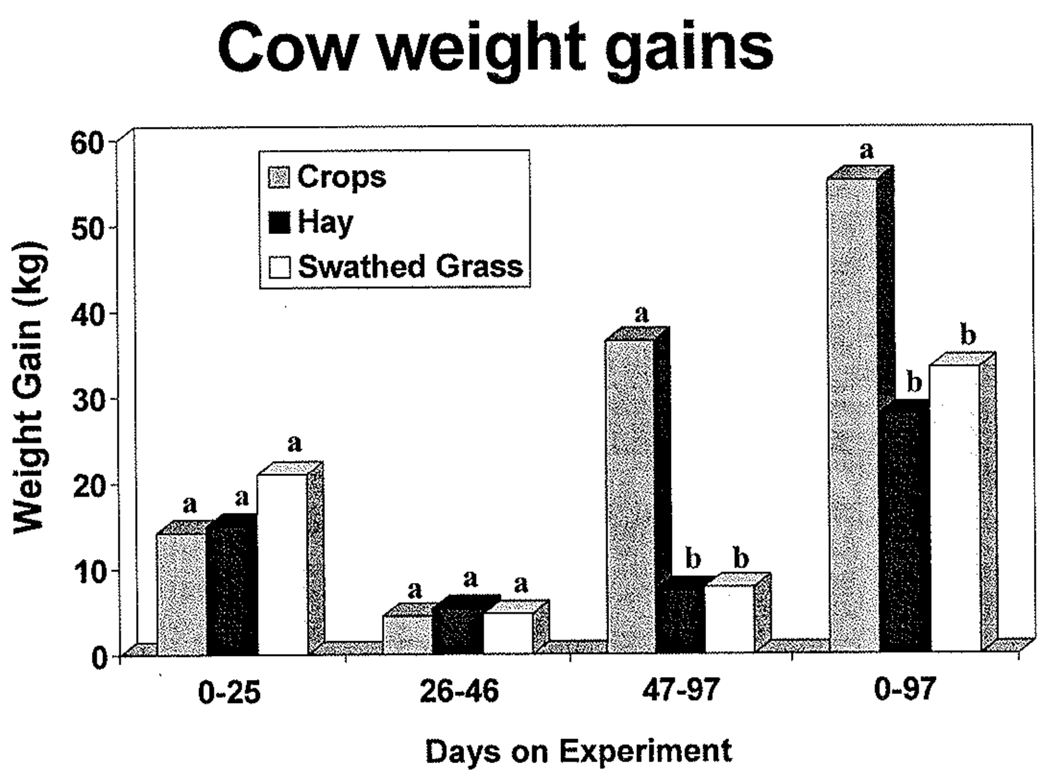

Fig. 1. Cows on the crops treatment had higher weight gains while grazing drilled corn (47-97days) and for the entire wintering period, compared to cows on the other treatments.

Cow condition scores

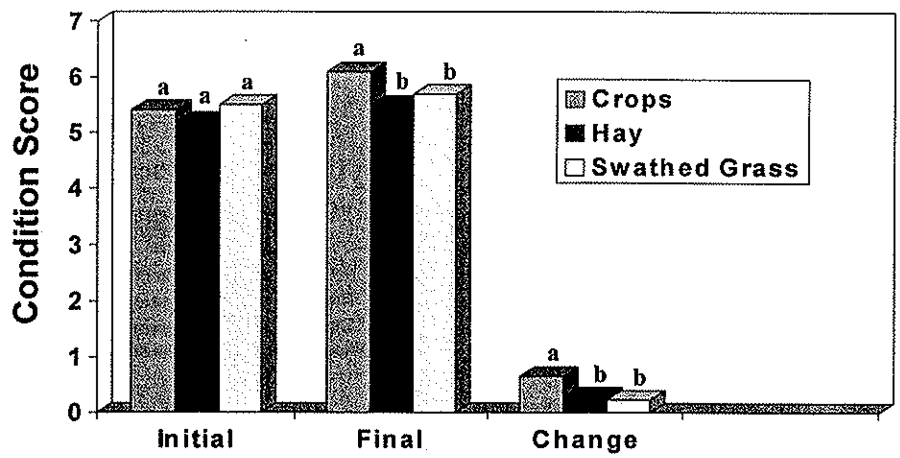

Fig. 2. Cow condition scores increased more for cows on the crops treatment than for cows on either of the other treatments.

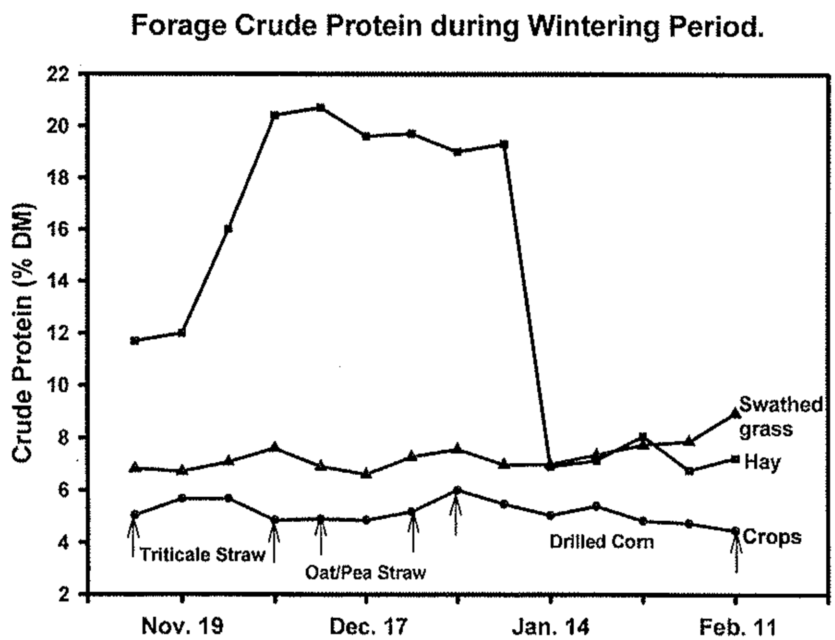

Fig. 3. Crude protein in crop residue and drilled corn was below beef cow requirements, while crude protein levels were adequate in both swathed grass and hay.

Fig. 4. Cows digging through snow to graze drilled corn.

FORAGE BREEDING RESEARCH

Dr. John Berdahl

The objective of our forage breeding research is to develop dependable perennial forage cultivars that will complement our native grasslands and provide additional management options for integrated forage-crop-livestock production systems. Our efforts are focused on development of Russian wildrye cultivars with improved seedling vigor and alfalfa cultivars that are adapted for use as dryland pasture and hay. We have doubled the normal chromosome number of Russian wildrye, and experimental populations have had greatly improved seedling vigor as well as increased dry matter production under drought stress. Seedling establishment of this tetraploid Russian wildrye was similar to crested wheatgrass in regional field tests in North Dakota, Montana, Nebraska, and Utah. Seed of four experimental populations of grazing-type alfalfa was harvested in 2000, and will be increased for regional tests that will be initiated in 2002 or 2003. The alfalfa populations have broad, deep-set crowns, fine stems, and high levels of drought and winter survival. We believe that these grazing-type alfalfas will be useful in grass-alfalfa mixtures for pasture and hay in the sub-humid to semi-arid environments of the Northern Great Plains.

CARBON SEQUESTRATION IN NORTHERN GREAT PLAINS GRASSLANDS

Dr. Al Frank

It is anticipated that future climate change will impact both grassland and cultivated agricultural ecosystems. Currently atmospheric carbon dioxide is increasing at about 0.4% per year due to burning of fossil fuels and land use changes. Scientists have been unable to balance the global carbon cycle as a substantial sink for atmospheric carbon dioxide cannot be identified. It has been suggested that grasslands may be sequestering more atmospheric carbon dioxide than is commonly assumed. Grasslands in poor condition contribute to atmospheric carbon dioxide, whereas, those in good condition either sequester carbon dioxide or are carbon dioxide neutral. At Mandan we are currently involved with the ARS Rangeland Carbon Dioxide Flux Project, a multi location effort to investigate the role grasslands have in the global carbon cycle. We have measured carbon dioxide fluxes over grazed, seeded, and nongrazed pastures since 1995. Dormant season soil carbon dioxide fluxes have also been measured. On average, a mixed prairie pasture sequesters about 3000 lb carbon dioxide during the growing season. However, during the dormant or winter season our estimated indicate that about 2700 lb carbon dioxide/acre is lost back to the atmosphere. The difference is a net annual sequestration of about 300 lb carbon dioxide/ac /yr. This would translate into about 2.5 ton of carbon per section of land being returned to the soil each year These results suggest that properly managed Northern Great Plains mixed prairie grasslands can provide a small sink for atmospheric carbon dioxide, but overall the carbon cycle for grassland is probably near equilibrium. It is anticipated that application of proper management to degraded grasslands will provide the best opportunity for increasing carbon storage in grassland soils.

EVALUATING AND IMPROVING SWITCHGRASS BIOMASS PRODUCTION FOR THE NORTHERN GREAT PLAINS

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The use of energy crops as a source of renewable fuels is a concept with great relevance to current ecological and economic issues at both national and global scales. Development of a significant national capacity to use perennial forage crops, such as switchgrass (*Panicum virgatum* L.), as biofuels could benefit our agricultural economy by providing an important new source of income for farmers. In addition energy production from perennial cropping systems, which are compatible with conventional farming practices, would help reduce degradation of agricultural soils, lower national dependence on foreign oil supplies, and reduce emissions of greenhouse gases and toxic pollutants to the atmosphere (McLaughlin et al., 1999[†]). As part of the program "Evaluating and Improving Switchgrass Biomass Production for the Northern Great Plains," scientists at the Northern Great Plains Research Laboratory have several objectives:

1. Assess the potential biomass yield of switchgrass cultivars in North Dakota.
2. Determine the carbon budget of varieties of switchgrass cultivars in North Dakota.
3. Evaluate the efficiency and extent of soil carbon storage in established switchgrass stands throughout ND, SD, and MN to determine the potential effects of switchgrass on soil health.
4. Evaluate carbon sequestration capacity of switchgrass in on-farm plantings.
5. Determine the effect of nitrogen and calcium fertilization and water stress on switchgrass net primary-production, carbon allocation, and carbon storage. Evaluate disease resistance of switchgrass.
6. Evaluate disease resistance of switchgrass.

Switchgrass Trials

Eight switchgrass cultivars were seeded two sites at Mandan, ND seeded in 1999, one site seeded in 1999 and another seeded in 2000 at Streeter, ND, and one site seeded in 1999 and reseeded in 2000 at Dickinson, ND. Biomass was collected in a two-harvest

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[†] McLaughlin, S.B., J. Bouton, D. Bransby, B. Conger, W. Occumpaught, D. Parrish, C. Talliaferro, K. Vogel, and S. Wullschleger. 1999. pp. 282-299. *In:* J. Janick (ed.), Developing Switchgrass as a Bioenergy Crop. Proc. Fourth National New Crops Symposium.

system during August and September. Based on data from one sample year, there were no significant differences in the biomass yields between harvest dates. (see Appendix Table for a summary of results). Sunburst was the most productive entry at the Mandan location and averaged about 9600 kg ha^{-1} (Table 1). ND 3743 was the least productive averaging only about 5900 kg ha^{-1}. Stand counts were generally high for all entries except for Summer. It had an average count of 30.5 (Table 2). Stand counts were measured using methods described by Vogel. The method provides a conservative measure of plant density, but does provide good relative comparisons. Heading dates were early for the northern varieties and increased markedly for the southern varieties. The Summer variety was, however the tallest of those tested and averaged about 145 cm in height. Dacotah and ND 3743 were significantly shorter (Table 3). Finally, the northern varieties tended to have a greater percentage of dry matter (Table. 4).

Table 1. Dry-matter yield of eight switchgrass cultivars and strains from single-cut harvests in mid-August and mid-September, 2000 at two sites near Mandan, ND.

	Site 1[1/]		Site 2[2/]	
Entry	Aug	Sept	Aug	Sept
	kg ha^{-1}			
Dacotah	5221	5322	7819	7389
ND 3743	5214	5470	6766	6135
Summer	7002	5629	9929	9739
Sunburst	9114	8507	10395	10554
Trailblazer	7986	8647	10932	9453
Shawnee	7554	7623	10600	9561
OK NU 2	5660	6400	8948	9786
Cave-In-Rock	7808	8024	9321	9835
$lsd_{0.05}$	1474	1172	1531	1505
CV (%)	14.5	11.4	12.6	12.8

[1/] Site 1 = Main station, sandy-loam soil
[2/] Site 2 = South unit, silt-loam soil

Table 2. Stand counts of eight switchgrass cultivars and experimental strains measured on 27 October 2000 and averaged over two harvest treatments at two sites near Mandan, ND. Heading date at one site.

	Stand counts		Heading date
Entry	Site 1[1/]	Site 1[2/]	Site 2
	---Plants m^{-2}---		DOY
Dacotah	39	39	186
ND 3743	38	38	186
Summer	31	30	206
Sunburst	40	40	213
Trailblazer	39	39	227
Shawnee	39	39	227
OK NU 2	36	38	252
Cave-In-Rock	39	39	233
$lsd_{0.05}$	2	2	
CV (%)	4.3	4.8	

[1/] Site 1 = Main station, sandy-loam soil Note: Maximum stand count = 40 plants m^{-2}
[2/] Site 2 = South unit, silt-loam soil

Table 3. Plant height of eight switchgrass cultivars in mid-August and mid-September, 2000 at two sites near Mandan, ND.

	Site 1[1/]		Site 2[2/]	
Entry	Aug	Sept	Aug	Sept
	---cm---			
Dacotah	122	125	114	112
ND 3743	120	126	118	118
Summer	138	144	147	153
Sunburst	141	145	140	140
Trailblazer	135	145	131	138
Shawnee	135	147	135	142
OK NU 2	129	139	134	142
Cave-In-Rock	133	148	139	146
$lsd_{0.05}$	8	8	6	9
CV (%)	4.4	4.1	3.2	4.9

[1/] Site 1 = Main station, sandy-loam soil
[2/] Site 2 = South unit, silt-loam soil

Table 4. Dry-matter percentage of biomass from eight switchgrass cultivars and strains from single-cut harvests in mid-August and mid-September, 2000 at two sites near Mandan, ND.

Entry	Site 1[1/]		Site 2[2/]	
	Aug	Sept	Aug	Sept
	%			
Dacotah	47	57	45	56
ND 3743	49	56	42	55
Summer	45	53	45	54
Sunburst	48	53	41	53
Trailblazer	43	49	39	50
Shawnee	42	48	41	45
OK NU 2	40	47	37	46
Cave-In-Rock	42	48	41	47
$lsd_{0.05}$	4	3	4	4
CV (%)	5.2	4.2	5.5	5.4

[1/] Site 1 = Main station, sandy-loam soil
[2/] Site 2 = South unit, silt-loam soil

Carbon Budget

Dakota and Sunburst plots were sampled during year 2000 in Mandan at both sites. Two replications were performed per plot. Eight collections of biomass data were acquired from May through September. Green leaves, dead leaves, stem and litter were collected and will be analyzed for carbon content. Soil sample collections to determine root biomass were taken six times May through October. Soil samples were taken to a 30 cm depth with the July sample collected to a depth of 110 cm. Soil respiration was determined by measuring carbon dioxide flux from the soil on nine dates May through October. Soil water loss from the profile was measured down to 180 cm to determine soil water use. Soil water was measured on ten dates May through October. Carbon budget work will continue through 2001. Samples are currently being analyzed.

Carbon Storage

Sampling was initiated to establish a soil carbon baseline and to assess total soil carbon in the Northern Great Plains. The NRCS in Bismarck helped identify established switchgrass stands paired next to adjacent cultivated fields in 11 counties across the North Dakota, South Dakota, and Minnesota tri-state region. Eight soil cores were taken to a depth of 120 cm on each site (cultivated and switchgrass). These cores are being analyzed for organic carbon, inorganic carbon, total N, particulate organic matter (POM), soil pH, electrical conductivity, soil nitrate and ammonium, and soil bulk density. Soil sampling will resume in the spring of 2001.

Carbon Sequestration
Sites at Dickinson and Streeter were reseeded due to poor seedling establishment in the original plots. Soil cores were collected to a depth of 120 cm from separate duplicate plots of the Dakota and Sunburst cultivars at the three locations (Mandan, Dickinson, and Streeter). Carbon storage will be evaluated for the two cultivars. Soil will be analyzed for organic carbon, inorganic carbon, total N, POM, soil pH, electrical conductivity, soil nitrate and ammonium, and soil bulk density.

The Northern Great Plains Research Laboratory initiated laboratory analyses of soil samples collected from four on-farm trials in Nebraska. Samples were collected in conjunction with ARS-NE to depths of 120 cm. Samples were analyzed for organic carbon, inorganic carbon, total nitrogen, particulate organic matter, soil pH, electrical conductivity, and soil bulk density. The National Soil Survey Laboratory (USDA-NRCS) in Lincoln, NE, will conduct particle-size analysis, cation exchange capacity, and exchangeable Ca, Mg, K, and Na for these samples. Sampling of farms in SD and ND will occur in 2001.

Nutrient Interactions
A factoral experiment with eight varieties of switchgrass, grown at five temperatures, and nine levels of pH was replicated ten times in germination chambers at Mandan to determine the interactive effects of temperature and pH on the germination rate for switchgrass varieties. All main effects and first order interactions were significant (Table 5). To determine the quality of germination, a germination index was developed that considered the rate and success of germination (percentage germination). Dacotah, Sunburst, and ND 3743 displayed the best germination across temperature and pH. All had germination indices over 20 (Table 6). The optimum temperature for germination was 25 °C (Table 7) and the optimum pH was 6.0 (Table 8). Switchgrass appears to be severely restricted at pH levels below 5 and above 8.

Table 5. Switchgrass germination AOV table.

Source	df	MS	F
Variety (V)	7	36383.9	600.2
Temp (T)	4	55971.5	932.3
V*T	28	4481.8	73.9
pH (p)	8	49150.0	810.8
V*p	56	3252.0	53.7
T*p	32	5179.7	85.5
V*T*p	224	494.7	8.2

Table 6. Germination index based on variety. The germination index is a value that considers the speed and success of germination. Treatments followed by the same letter are not significantly different.

Variety	Index Value	Treatment Significance Value
Dacotah	22.0	A
Sunburst	21.6	A
ND 3743	21.0	A
Cave-In-Rock	16.5	B
OK NU 2	9.5	C
Trailblazer	3.7	D
Shawnee	2.9	D
Summer	1.3	E

Table 7. Germination index based on temperature. Germination index is a value that considers the speed and success of germination. Treatments followed by the same letter are not significantly different.

Temperature	Index Value	Treatment Significance Value
5	0.0	E
15	8.5	D
25	22.4	A
35	18.8	B
40	11.9	C

Table 8. Germination index based on pH. The germination index is a value that considers the speed and success of germination. Treatments followed by the same letter are not significantly different.

PH	Index Value	Treatment Significance Value
4.0	.2	E
4.6	0.0	E
5.0	21.7	B
6.0	28.1	A
7.0	19.0	C
7.4	17.8	D
8.0	19.8	C
9.0	4.2	E
10.0	.1	E

Work was also initiated at the Mandan Laboratory to determine the importance of calcium on switchgrass development. Trailblazer was chosen as the test cultivar in an experiment to determine the calcium budget for switchgrass. Twelve repetitions were grown under five levels of calcium (0 ppm, 25 ppm, 75 ppm, 150 ppm, 400 ppm). Plants received 300 milliliter/day of nutrient solution. All elements except for calcium were kept constant. Biomass was separated into above- and belowground portions. Samples are being prepared and analyzed.

NGPRL has also renovated a greenhouse bay to investigate other nutritional requirements and limitations of switchgrass. Equipment has been designed to simultaneously fertigate 18 different nutrient levels. The greenhouse has space for 300 pots in the fully automated systems. We are currently determining the appropriate concentrations of nitrogen and calcium to use. A small trial was initiated to test nutrient levels before beginning the large-scale project. The full project will include nine different nutrient levels (3 levels of nitrogen and 3 levels of calcium), two switchgrass cultivars, and one cool season species for comparison. The experiment will be replicated 10 times.

Plant Disease

Foliar and root diseases within the switchgrass plantings at Mandan, Streeter, and Dickinson continue to be monitored. Collections of naturally diseased switchgrass leaves were obtained from local established plantings of switchgrass in 1999. One hundred and seventy-one infected leaves from 26 collections were processed for fungi present. Fifty-one fungal isolates were isolated and stored for testing. Eight varieties of switchgrass were inoculated with fungal isolates to determine which fungi are pathogenic on switchgrass. With additional inoculations, several fungi were confirmed as causing severe leaf spot disease damage (browning of leaves and loss of photosynthetic area) on switchgrass. Naturally diseased switchgrass leaves were again obtained in 2000: 67 local collections; 11 collections from NRCS plantings in North Dakota; and 48 collections from 10 field locations in Minnesota. Disease infected leaves are currently being processed for plant pathogens. Additional inoculations are planned to identify potential pathogens of switchgrass.

Appendix Table. Summary of stand performance at Mandan, ND.

Variety	Maximum Yield	% of Sunburst	Heading Date
Sunburst	10554	100	213
Trailblazer	10932	96	227
Shawnee	10600	92	227
Cave-In-Rock	9835	91	233
Summer	9929	84	206
OK NU 2	8948	80	252
Dacotah	7819	67	186
ND 3743	6766	61	186