Effect of a Multi-Crop Rotation on Soil Health, Spring Wheat and Rotation Crop Yields, and Cropping System Economics in Western North Dakota

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Abstract

A five-year cropping study (2011-2015) compared hard red spring wheat grown continuously (HRSW-C) with hard red spring wheat grown in a five-crop rotation (HRSW-R). Sequence of crops consisted of HRSW, dual crop of winter and spring cover crop, silage type corn, field pea-forage barley, and sunflower, and included cool- and warm-season crops. Because the research design included integrating beef cattle grazing into the cropping system, cover crop, corn and field pea-forage barley were grazed. This report focuses on the cropping system, soil organic matter influence on soil health, nitrogen fertility, and the effect of nutrient cycling on production.

Over the course of five years, the effect of improved soil health on HRSW production resulted in increased production and greater net return for HRSW-R grown in the rotation compared to HRSW-C grown continuously on the same land. Crop rotation diversity had a positive influence resulting in increasing production, during the five-year period, due to increased soil organic matter, nitrogen fertility, and nutrient cycling. Based on NDSU Soil Testing Laboratory fertilizer recommendations for 40-50 bu/ac spring wheat, the nitrogen fertilizer requirement for HRSW-R was eliminated after year two and after year three HRSW-C nitrogen fertilizer application was discontinued. Considering all crops grown in the rotation, increased soil health reduced the nitrogen fertilizer requirement.

Average five-year net return for HRSW-C was $70 per acre compared to $85 per acre for the HRSW-R. Moreover, when the continuous HRSW-C was compared, on an equal acre basis, to the combined total five-year net return of all crops in the rotation the total net return from the HRSW-R rotation was $2,035 compared to $1,514 for continuous HRSW-C.

Introduction

Multiple challenges have effected farming and ranching business profitability in western North Dakota with fluctuating commodity price, excessive precipitation and wheat falling numbers, hail, and drought. Environmental insults and unfavorable commodity price wreak havoc with agricultural businesses. The five principles of soil health include keeping the soil surface covered with foliage and/or residue, minimizing soil disturbance through no-till seeding and planting practices, increasing plant diversity using multi-crop rotations, keeping living roots in the soil as much as possible, and increasing systems' diversity with livestock grazing.

Improving farming and ranching profitability is not easy and there are no simple solutions. In most cases, changes often require more planning and management; however, the result is often favorable. Spring wheat is the most commonly grown crop in North Dakota. On a national basis, North Dakota farmers grow 50.4% of the spring wheat, 44.5% of the oil-type sunflowers, 3.4% of the corn for grain and 2.1% of the corn for silage, and raise 3.1% of the nation's beef cows with calves (ND Agric. Stat., 2017). Therefore, research that incorporates these crops plus beef cattle grazing into a fully integrated crop and livestock system (ICL), in which a significant amount of mechanically harvested feed is replaced with animal harvesting, has the potential to increase farm and ranch sustainability and profitability from input reduction.

The long-term research objective focused on comparing hard red spring wheat HRSW-C grown continuously on the same fields to HRSW-R grown in a five-crop rotation to determine the effect on spring wheat yield and quality, soil nitrogen fertility, fertilizer requirement change, rotation crop production, soil health, and cropping system economic analysis. Within the basic framework of the cropping system comparison, to study production methods and soil health, beef cattle grazing of annual forages grown in the rotation added grazing diversity. This report focuses on the system crop production, soil health, and nitrogen fertility change.

Materials and Methods

Prior to the initiation of the research in 2011, the cropping study area was previously seeded to HRSW. The cropping systems consisted of a continuous HRSW-C compared to HRSW-R grown in a multi-crop five-year rotation. The five-year rotation consisted of HRSW, cover crop (**CC** dual crop of winter triticale-hairy vetch harvested for hay in June and immediately reseeded to a 7-specie cover crop mix), forage corn (**CN**), field pea-forage barley (**PB**), and sunflower (**SF**). Each of the replicated study fields were 4.3 acres in size and the crops were replicated three times across soil type blocks (Figure 1). The order in which crops occurred in the rotation was based on information available through the USDA/ARS - Crop Sequence Calculator Version 2.25 (updated Version 3.1) (USDA/ARS, 2016).

For beef cattle integration, yearling crossbred steers raised at the Dickinson Research Extension Center (DREC) grazed native range (NR) until crop rotation annual forages were suitable for grazing. Field pea-barley is the earliest maturing annual forage grown and was the first crop grazed followed by grazing of the unharvested corn. Beef cows grazed cover crop fields and crop residues after weaning.

Cereal grains, CC, and PB were seeded using a JD 1590 no-till drill, 7.5-inch row spacing, and seed depth of 1.0 inch. Plant population for cereal grains was 1.25 million plants/ac. Row crops were planted using a JD 7000 no-till planter, 30.0-inch row spacing, and seed depth of 2.0 inches. Plant population for the row crops was 19-20,000 plants/ac. Weed control included a pre-plant burndown and post-emergence application of approved chemicals and rates. Field pea-barley and cover crop plantings received a pre-plant burndown only. Nitrogen fertilizer application, for spring wheat, was based NDSU Soil Testing Laboratory recommendations and adjustments (previous crop N credit, no-till credit, western ND region) for a 40-50 bu/ac yield (Franzen, 2016).

Soil fertility was evaluated during the 2014 and 2015 crop years. Root restriction zones, created using 8” x 24” aluminum irrigation pipe, were pressed into the soil using a large industrial front-end loader. Soil samples were collected using a hand-held soil sampler from inside and outside of the root restriction zones.

For the economic analysis, Region-4, ND Farm and Ranch Business Management Education program crop budgets served as the basis for economic analysis and actual expenses incurred for seed, chemical, fertilizer, and crop insurance were entered into the budgets (ND Farm and Ranch Bus. Mgmt. Ed., 2011, 2012, 2013, 2014, 2015). Budgets for each individual year crop expense, gross return and net return were also calculated. From the individual year budgets, five-year average budget results were calculated. Cover crop, CN, and PB forages were valued at $65.00/Ton of dry matter. Spring wheat and SF price was the price listed in the ND Farm and Ranch Bus. Mgmt. crop budgets.

Results and Discussion

Design for this research project focused on comparing HRSW-C grown continuously to HRSW-R grown as part of a five-crop rotation in which yearling crossbred steers grazed PB and CN, and beef cows grazed CC and crop residues (CN and SF residue) after weaning. From a practical perspective, connecting the potential for soil health improvement with crop production, accelerated with beef cattle grazing, was a design set forth to document an approach that would reduce mechanical harvesting, increase soil nutrient cycling, reduce fuel and fertilizer input, and add value to yearling steers grazing annual forages before feedlot entry. Addressing multiple aspects of the project, required separate investigations to evaluate spring wheat and rotation crop production, soil nitrogen fertility (Cihacek et al., 2015, 2016), birth to slaughter beef production (Senturklu et al., 2016), and cow winter grazing of CC and annual forage residues (Senturklu and Landblom, 2016).

Annual crop yield for HRSW-C and HRSW-R, as well as rotation crop yields, and economic summaries are shown in Table 1.

The five-year average HRSW yield (HRSW-C: 42.1 vs. HRSW-R: 42.5 bu/ac; P=0.30), protein (HRSW-C: 13.9 vs. HRSW-R: 13.3%; P=0.47), and test weight (HRSW-C: 61.8 vs. HRSW-R: 62.0 lb/bu; P=0.76) did not differ between management treatments for grain yield and test weight. There was a trend for higher grain protein in the HRSW-C. Average spring wheat yield (HRSW-C vs. HRSW-R) does not explain the soil health influence on yield. Comparing multiple-year yield data, increasing and decreasing yield trends became evident. Observing the yearly yield data, yields were the same year 1, but in year 2, HRSW-C wheat yield was 23.5% higher than HRSW-R wheat (55.7 vs. 45.1 bu/ac). Although difficult to detect initially, soil nutrient cycling became evident in year three, when the yield margin between the two management practices narrowed, but remained 19.4% higher for the HRSW-C (46.8 vs. 39.2 bu/ac). Yield reversal became fully evident by year 4, when HRSW-R wheat yield was 8.4% higher (44.2 vs. 47.9 bu/ac), and for the fifth crop year, HRSW-R wheat yield was 32.6% higher than the HRSW-C wheat yield (35.6 vs. 50.0 bu/ac).

Nitrate-N fertilizer application amounts for crops grown in the study are shown in Figure. 2. Paralleling yield changes, the NDSU Soil Testing Laboratory did not recommend nitrogen (N) fertilizer application to the HRSW-R after the second year of the five-year rotation. However, chlorine was low. Thirty to 55 lbs/ac were applied each year to the HRSW-C and HRSW-R treatments.

Based on 2014 and 2015 seasonal mineral N values, the data suggests that N levels were adequate to meet the 40 bu/ac yield goal. In 2015, the HRSW-R yield goal was exceeded by 10.0 bu/ac whereas the HRSW-C yield goal of 40 bu/ac was not achieved indicating that the multi-crop rotation collectively enhanced organic matter input and diversity, and increased nutrient cycling resulting in improved N availability within the rotation management system. A primary factor that facilitates enhanced soil nutrient cycling is the supply of soil organic matter (SOM) available for microbial decomposition. Soil OM in the experimental fields ranged from 2.8 to 6.0% by the end of the first five-year rotation (Cihacek, et al., 2015). Regression analysis contrasting soil mineral N with SOM indicates a trend such that as SOM increases there is a corresponding increase in plant available mineralized N (Figure. 3).

The five-year average input cost, gross return, and net return for the HRSW-C, and rotation crops (Table 2) show input cost for HRSW-C to be $18.30 more per acre compared to the HRSW-R ($196.40 vs. $178.10/ac) and a narrower gross return margin per acre (HRSW-C $266.80 vs. HRSW-R $263.10/ac). Net return for the HRSW-C was $14.60 less per acre than the HRSW-R. Five-year average net returns for CC, CN, PB, and SF forages were 61.80, 77.30, 98.50, $151.00/ac, respectively. When HRSW-C and rotation crop (HRSW-R, CC, CN, PB, and SF) net returns are combined, on an equal acre basis, net return for the HRSW-C was $1,514 compared to $2,036 for the rotation crops; a difference of $522.00 more from the crop rotation system. Results suggest that growing continuous HRSW-C is less intensive, but also 34.5% less profitable.

Implication

Improved crop production is the result of many factors, which are often difficult to explain. In general, when the principals of soil health are applied in a diverse crop rotation that includes cool- and warm-season crop types coupled with cover crops, soil health improves. Soil organic matter content is a leading indicator of soil health. As SOM increases, soil microbial decomposition increases nutrient cycling and nutrients available for plant growth and production. Ultimately, N fertilizer additions can be significantly reduced, or eliminated.

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Figure 1. Crop rotation and major soil type map (Graphic by Jon Stika**)**

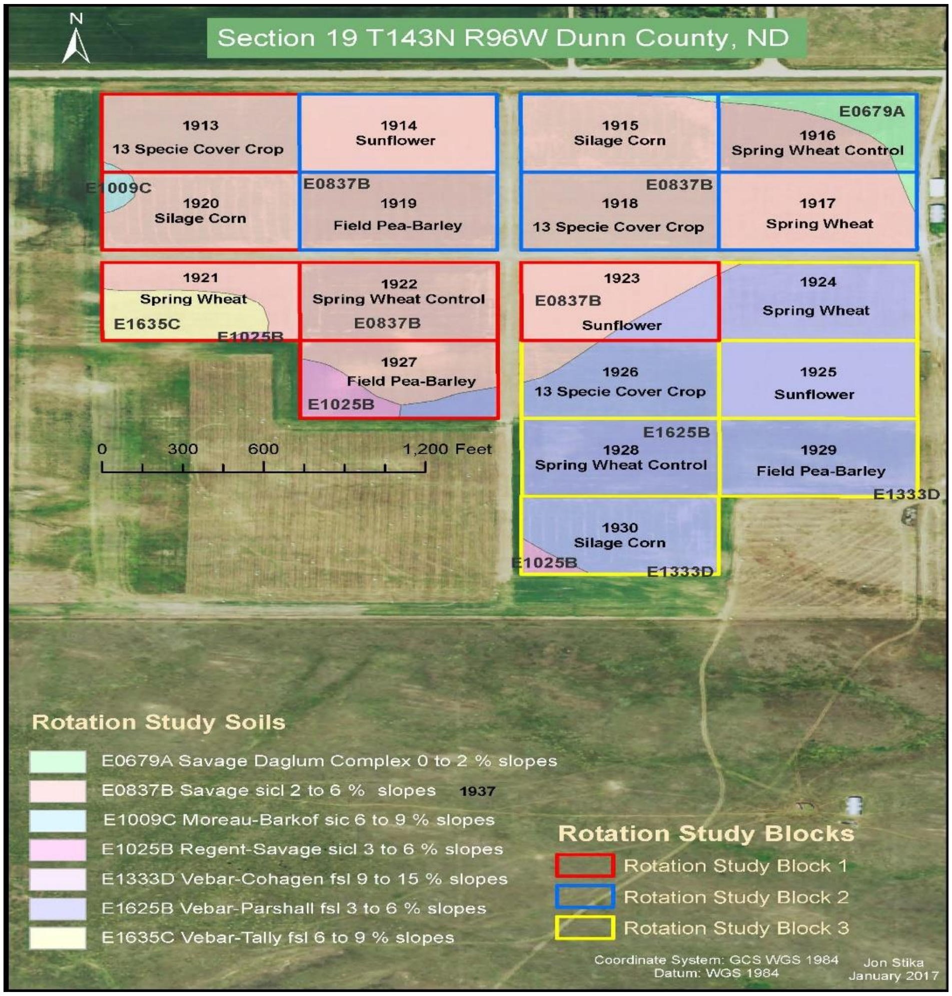

Table 1. Crop Yields and Economic Summary (2011-2015)

YEAR	HRSW CON[1] (bu/ac)	HRSW ROT[1] (bu/ac)	WT-HV &CC [1] (T/Ac)	CORN SILAGE[2] (T/Ac)	PEA BARLEY (T/Ac)	SUN-FLOWER (Lb/Ac)
2011	28.0	30.1	2.71 / 0 [a]	1.65	19 Bu Pea	891
2012	55.7	45.1	1.59 / 4.25	3.66	3.11	1590
2013	46.8	39.2	0.0 [b] / 3.25	4.59	4.53	1959
2014	44.2	47.9	0.66 / 0.62	3.50	3.75	1060
2015	35.6	50.0	1.41 / 2.92	5.81	3.53	1856
5-Yr Avg[1], (*P*=0.30)	**42.1**	**42.5**	**1.65 / 2.76**	**3.84**	**3.73**	**1471.2**
Test Wt., lb, (*P*=0.76)	60.1	62.0				
Protein, %, (*P*=0.47)	13.9	13.3				
5-Yr Avg Economic Analysis						
Total Input Cost/Ac, $	196.4	178.1	170.2	185.2	127.7	174.5
Gross Return/Ac, $	266.8	263.1	232.0	262.5	226.2	325.5
Net Return/Ac, $	70.4	85.0	61.8	77.3	98.5	151.0
System Net Return, $[3]	1,514			2,035		

[1] **HRSW-CON:** Hard Red Spring Wheat – Control**; HRSW- ROT:** Hard Red Spring Wheat – Rotation; **WT-HV&CC;** Winter Triticale - Hairy Vetch & 7-Specie Cover Crop; **5-Yr Avg; 5** Year Average

[2] Corn silage grain content 2011-2015: 15.0, 55.3, 88.0, 45.0, 78.6, (Average 56.4 bu/ac)

[3] Average total 5-year net return for HRSW-C and rotation crops (HRSW- ROT, WT-HV&CC, Corn Silage, Pea Barley, and Sunflower)

[a] 2011 Cover Crop did not germinate - no crop

[b] 2015 Winter Kill - no crop

Figure 2. Nitrate-N application to spring wheat and rotation crops 2011-2015

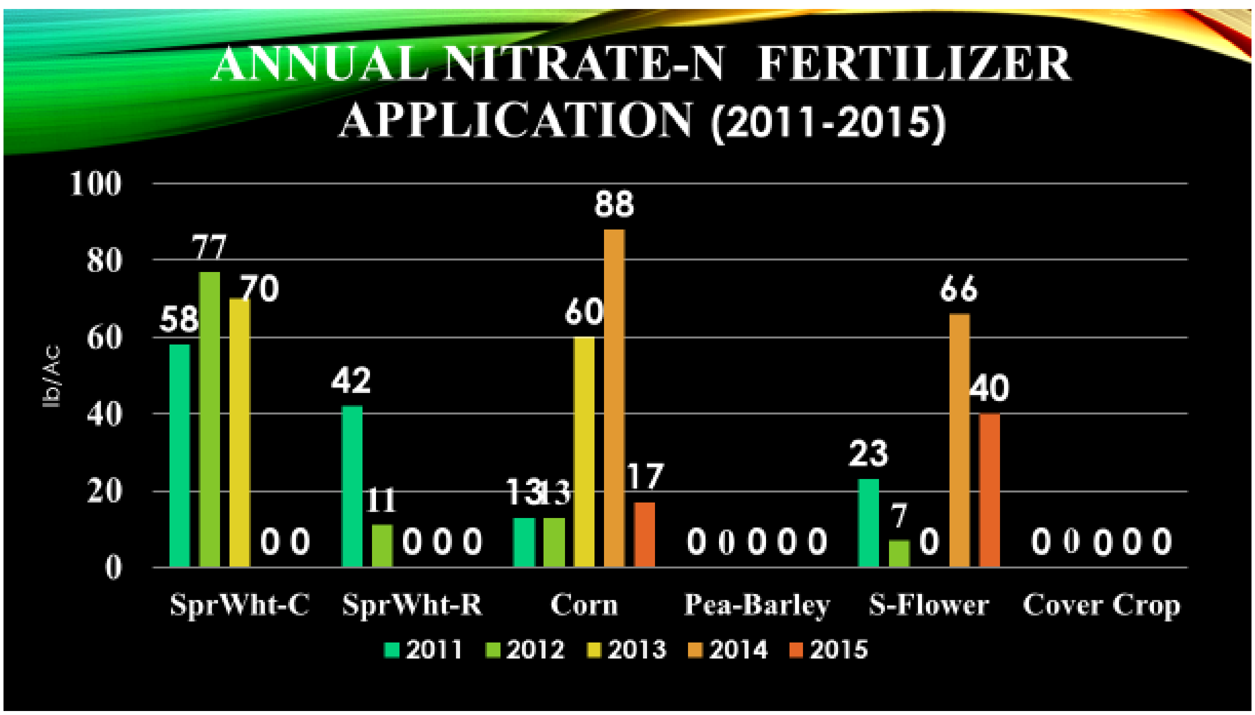

Figure 3. Regression analysis contrasting soil mineral nitrogen content versus soil organic matter (2014 and 2015)