Title: Agronomic Value of Crop Rotations in NW Minnesota

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Abstract: Crop rotations potentially have many agronomic, economic and environmental benefits. Crop rotations may increase soil organic matter, improve soil structure, reduce soil degradation, and can result in greater long-term farm profitability. The cropping sequence (rotation) can reduce the influence of weeds, diseases, insects and other pest infestations resulting in significant reductions of commercial pesticides. Leguminous crops in the rotation fix atmospheric nitrogen increasing soil fertility and reducing synthetic nitrogen use. The objective of this research was to investigate the response of crops grown in northwestern Minnesota to various crop rotations to determine if specific cropping sequence (rotation) have the potential to increase crop productivity. The rotations included either wheat, soybean and canola or soybean, wheat, and perennial ryegrass. For the wheat, soybean, and canola rotations, the trials were conducted on-farm and included four rotations and demonstrated that soybean had a positive influence on canola yields when grown in a wheat-soybean-canola rotation versus a wheat-wheat-canola rotation. The wheat-canola-soybean rotation also produced significantly higher soybean yields versus the wheat-wheat-soybean rotation. For the turf seed, the study used small plot methodology and the crop sequence was soybean-wheat or fallow-perennial ryegrass and investigated the best management practices for perennial ryegrass establishment, seed yield and seed quality. Perennial ryegrass stand establishment and seed yield were positively influenced by the previous crop. The soybean-wheat-perennial ryegrass rotations with the perennial ryegrass either underseeded with the spring wheat or fall seeded into wheat stubble produced on average 40% higher seed yields the following year than planting into fallow ground. The presence of wheat had a positive effect on perennial ryegrass establishment, overwintering, and subsequent seed yields.

Introduction: Crop rotations have been shown to have many agronomic, economic and environmental benefits. Appropriate crop rotations increase soil organic matter, improve soil structure, reduce soil degradation, and can result in greater farm profitability in the long-term. Increased soil organic matter enhances water and nutrient retention; improves soil structure which in turn improves drainage, reduces risks of water-logging during floods, and boosts the supply of soil water during droughts. Crop rotations are used to control weeds and diseases, limit insect and other pest infestations and, as a result, can significantly reduce pesticide use. Leguminous crops in the rotation fix atmospheric nitrogen, increasing fertility and reducing the need for synthetic fertilizers. However, numerous trials have demonstrated that the sequence of crops and cropping practices can have a positive or negative impact on crop growth and development.

Canola grown in northwest Minnesota reached a peak of 200,000 acres in 1998. However, since that time, new advancements in soybean genetics have led to a proliferation of soybean acres in areas traditionally used for canola production. Limited research suggests that canola can play a vital role in this rotation as a yield enhancer for soybean production. Murdock and Herbeck (2014) compared double-crop soybean after canola to double-crop soybean after wheat ('89-'90 and '08-'09). They showed double-crop soybean yielded significantly higher when grown after canola 43 bu/A compared to 36 bu/A after wheat. In northwestern Minnesota, scientific comparisons of rotations are unavailable, but grower experience suggests that soybeans have yielded higher when grown following canola compared to following wheat.

In Minnesota, perennial ryegrass is the predominant turf seed crop being grown on over 30,000 acres primarily in Roseau, Lake of the Woods and Marshall Counties. The estimated dollar value to the local economy is over $8 million per year. Perennial ryegrass grown in northern MN acts as a biennial plant, as it is seeded in one calendar year and harvested in the following year. However, perennial ryegrass seed yields may be negatively impacted due to excessive plant growth and crop residue from the previous year's crop grown during the establishment year.

The objective of this project was to determine the effect of specific crop rotations that have shown potential to increase on-farm revenue due to one crop's positive influence on the following crop's yield. The canola rotation will include canola, soybean, and wheat. The turf seed rotation will include soybean, wheat and perennial ryegrass.

Materials and Methods: Canola and perennial ryegrass crop rotations will be investigated to determine the effects of cropping sequences on seed yield and quality of canola, soybean, and perennial ryegrass.

Canola Rotation Trials: Four different crop rotations were investigated in on-farm trials over four years. The rotations are: 1) wheat-wheat-soybean; 2) wheat-canola-soybean; 3) wheat-wheat-canola; and 4) wheat-soybean-canola. The experiment was conducted as a randomized complete block design with four replications. Individual research plots were 30 by 120 feet. The four crop rotations were established 2013-2015 and repeated in 2014-2016. Soil samples were taken and analyzed for N-P-K-S and plots were fertilized for optimum crop growth based on best management practices. Tillage system and production practices followed local grower practices to achieve optimal yields. Liberty Link canola was used to more easily control volunteer soybeans following Roundup Ready soybeans. Short residual herbicides were applied to the wheat crop to avoid carryover concerns to following crops. Fungicides were applied to reduce disease in each crop, in particular sclerotinia in canola and soybean. Data collected included: yield, oil, protein, stand count, crop height, shattering, and disease evaluations for sclerotinia. Data will be evaluated using proper statistical procedures with SAS software.

Perennial Ryegrass Rotation Trials: This rotation experiment was conducted using small plot methodology and equipment. The experiment was conducted as a randomized complete block design with four replications. Individual plot size was 20 by 20 feet with a 25 foot border between replications. The three year rotation treatments were as follows: 1) soybean-spring wheat with underseeded perennial ryegrass-perennial ryegrass for seed; 2) soybean-fallow with perennial ryegrass seeded in late August-perennial ryegrass for seed; and 3) soybean-spring wheat with perennial ryegrass seeded into wheat stubble in September-perennial ryegrass for seed. The three crop rotations were established in 2013-2015 and repeated in 2014-2016 on the University of Minnesota Magnusson Research Farm. Background soil samples were taken and fertilizer was applied for a 40 bu/A soybean crops, a 60 bu/A wheat crop, and a 1,500 lb/A ryegrass seed yield goal. Spring tillage was done twice with a field cultivator in the wheat seeded plots. Perennial ryegrass was established by three methods: 1) underseeded at 5 lbs/A with spring wheat in early June; 2) seeded at 5 lbs/A into fallow ground with 20 lbs spring wheat for winter cover in late August; and 5 lbs/A into wheat stubble with a no-till drill in early September. Individual perennial ryegrass plots were hand harvested for yield and seed quality assessments. Data collected included: background soil fertility for wheat planted in 2014 and 2015, perennial ryegrass plant emergence and vigor ratings, chlorophyll meter ratings, lodging, plant height, and perennial ryegrass seed yield in 2015 and 2016.

Results and Discussion: The canola rotation trials were conducted on-farm with field scale equipment. The canola and soybean yield data is presented in Tables 1a-d. For the wheat-wheat-canola versus the wheat-soybean-canola rotation, in both years there was a yield advantage to having canola follow soybean. Residual soil nitrogen levels were about twice as high in the wheat-soybean-canola rotation when compared to the wheat-wheat-canola rotation. Canola yields averaged 325 lbs/A higher in the wheat-soybean-canola rotation, an increase in yield of 16%. Very few other differences were observed for traits in the third year of the rotation trial including no differences in stand counts, plant height, or shattering. For the wheat-wheat-soybean versus the wheat-canola-soybean rotation, there again was a yield advantage to the more diverse crop rotation. In the third year, the wheat-canola-soybean rotation yielded 55.4 bu/A soybean versus 50.6 bu/A soybean for the wheat-wheat-soybean rotation. No other differences were detected in stand counts or plant height. Based on these results, it appears there is a yield advantage to using crop rotations that have canola following soybean and vice versa. There appears to be a synergism to having these crops in rotation with spring wheat. However, with both soybean and canola being moderately susceptible to sclerotinia stem rot, variety selection and enhanced management for sclerotinia must be implemented when deciding to grow these two crops back to back.

The perennial ryegrass rotation/date of seeding trials were conducted as small plot research trials. The perennial ryegrass seed yield data from 2015 and 2016 is presented in Table 2. In both 2015 and 2016, the seed yields of perennial ryegrass were highest in the treatments that were either underseeded with wheat in early June or no-till seeded it into wheat stubble in early September. Yields averaged 1143 lbs/A versus 678 lbs/A for perennial ryegrass seeded into fallow ground with 20 lbs/A spring wheat to provide cover in late August (a prevent plant scenario). Being able to establish perennial ryegrass either by underseeding it with spring wheat or planting into wheat stubble produced, on average, 40% more perennial ryegrass seed the following year. While newer varieties of perennial ryegrass are substantially more winter hardy, there are still winters that cause injury to the crop. Wheat stubble generally provides additional snow cover which tends to reduce the potential for winter injury in both the treatments where the perennial ryegrass was underseeded with spring wheat or no-till planting into wheat stubble. In the “prevent plant” scenario where the perennial ryegrass is seeded in mid to late

August into fallow ground with a low seeding rate of spring wheat, the crop has the potential to suffer significant injury resulting in reduced seed yields the following production year. Depending on the growing conditions during the fall of the establishment year, the spring wheat can produce sufficient growth to smother the perennial ryegrass seedling resulting in poorer stands and less vigorous plants. In addition, the wheat seeded in August does not produce as uniform a cover in the field as a fields seeded in the spring to wheat. This can result in more winter injury due to non-uniform snow catch and a lack of stubble in the field to moderate the microclimate.

In summary, it appears a positive synergy exists between canola and soybean when included in a rotation with spring wheat in northwestern Minnesota. Yield of the oilseed crops was significantly higher for both canola and soybean in the third year of the rotation when compared to yields following spring wheat planted in two sequential years. For perennial ryegrass grown for seed, the recommended practices of underseeding with spring wheat or seeding into wheat stubble produced significantly higher seed yields the following year compared to seeding into fallow ground.

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Keywords: canola, soybean, spring wheat, perennial ryegrass, rotations

Table 1a – d. Canola and soybean rotation data collected in 2015 and 2016 at the completion of the three year rotation treatments.

Table 1a. Canola stand counts, spring residual nitrogen, plant height, shattering, oil percentage, and yield in 2015 after a three year rotation of either wheat-wheat-canola or wheat-soybean-canola.

	Stand[1]	Soil Residual N (NO_3-N)[2]	Height (in.)		Shattering (lbs/A)		Oil[5]	2015 Canola Yield[5]
2013-2015 Rotation	6/24/15	4/26/15	6/24/15	Harvest	Counts[3]	Visual[4]	%	lbs/A
Wheat-Wheat-Canola	407,000	25	19	41	257	649	52	1430
Wheat-Soybean-Canola	367,000	57	21	41	282	548	49	1817
LSD (0.05)	NS	---	NS	NS	NS	NS	2	108

Table 1b. Canola stand counts, spring residual nitrogen, plant height, Sclerotinia ratings, oil percentage, and yield in 2016 after a three year rotation of either wheat-wheat-canola or wheat-soybean-canola.

	Stand[1]	Soil Residual N (NO_3-N)[2]	Height (in.)	Sclerotinia		Oil[5]	Canola Yield (lbs/A)[5]	
2014-2016 Rotation	6/14/16	5/5/16	Harvest	Incidence	Severity	%	2016	2015-16 Mean
Wheat-Wheat-Canola	500,000	23	43	1.0	1.7	48.1	2309	1998
Wheat-Soybean-Canola	516,000	41	46	1.7	3.0	48.2	2546	2323
LSD (0.05)	NS	---	NS	NS	0.8	NS	NS	280

Table 1c. Soybean stand counts and plant heights in 2015 after a three year rotation of either wheat-wheat-soybean or wheat-canola-soybean. Yield data was not taken by the farmer cooperator by mistake in 2015.

	Stand[1]	Height (in.)	
2014-2016 Rotation	6/24/15	6/24/15	Harvest
Wheat-Wheat-Soybean	192,000	6	29
Wheat-Canola-Soybean	192,000	6	28
LSD (0.05)	NS	NS	NS

Table 1d. Soybean stand counts, plant height, and soybean yield in 2016 after a three year rotation of either wheat-wheat-soybean or wheat-canola-soybean.

	Height (in.)	Stand[1]		Soybean Yield (bu/A)[5]
2014-2016 Rotation	Harvest	6/14/16	Harvest	2016
Wheat-Wheat-Soybean	43	183,300	178,250	50.6
Wheat-Canola-Soybean	46	150,800	153,625	55.4
LSD (0.05)	NS	NS	NS	1.4

[1]Stand: counted plant per acre based on multiple quadrant plant counts per treatment.
[2]Soil residual N measured on two soil cores (0-24 inch depth) composited per treatment.
[3]Shattering counts: shattered seed counted in two 0.25 m^2 quadrant per plot.
[4]Shattering visual: estimate visually assessed of seed shattering and bird predation of crop.
[5]Oil percentage and yields adjusted to 8.5% dry matter basis.

Plot Design and Management: The experiments were conducted as a randomized complete block design with 4 replicates. Best management practices were utilized. Fertilizer applications were made with a 12 foot Gandy drop spreader on 4/16/2015 and 5/5/2016. Application rates per acre were as follows: 18-40-40-10S for soybeans and 140-40-40-20S for wheat and canola. Plots were seeded by the farmer cooperator using field scale equipment on a farm located 4 miles east of Roseau, MN on 4/14/2015 and 5/5/2016. Herbicide applications per acre were as follows: 22 oz. Liberty + 1 gal AMS applied 6/12/2015 to canola and soybean and 6/9/2016 to canola and 16 oz. Roundup PowerMax + 1 pt. AMS applied 6/9/2016 to soybean. Fungicide applications per acre were as follows: 6.5 oz. Prosaro + 1.28 oz. Grizzly + 4 oz. Trophy Gold Advance applied 7/2/2015 to canola and 5.7 oz. Proline + 4 oz. NIS applied on 7/8/2016 to canola.

Table 2. Perennial ryegrass seed yield data collected in 2015 and 2016 at the completion of the three year rotation and date of seeding trials.

	Planting date		Seed Yield (lbs/A)			RCI[4]	Lodging[5]		Harvest Height (in.)	
Treatment	2014	2015	2015	2016	Mean	2016	2015	2016	2015	2016
Wheat + Perennial Ryegrass[1]	6/04	6/01	954	1317	1136	203	6.3	7.1	26	24
Fallow[2]	8/29	8/19	469	887	678	223	4.0	6.9	22	25
Wheat Stubble[3]	9/08	9/03	776	1524	1150	226	5.5	7.5	26	25
LSD (0.05)			240	227	212	NS	NS	NS	4	NS

[1]Treatment 1: Spring wheat was seeded at 100 lbs/A and underseeded with 5 lbs/A perennial ryegrass in early June, 2014 and 2015.

[2]Treatment 2: Perennial ryegrass is seeded into fallow ground in late August at 5 lbs/A with 20 lbs/A spring wheat to provide cover.

[3]Treatment 3: Perennial ryegrass was no-till drilled at 5 lbs/A into spring wheat stubble in early October.

[4]RCI: Relative Chlorophyll Index is a visual estimate or quantification of the amount of chlorophyll present.

[5]Lodging: Lodging is scored at harvest on a scale of 1 to 9 where 1 = upright to 9 = completely laying flat.

Plot Design and Management: The experiments were conducted as a randomized complete block design with 4 replicates. Plot size was 20 ft. by 20 ft. Best management practices were utilized and plots were soil sampled and fertilized according to yield goals of 40 bu/A soybean yield, 60 bu/A spring wheat yield, and 1500 lbs/A perennial ryegrass seed. Growth regulators and fungicides were applied to the perennial ryegrass seed yield plots according standard best management practices. Arctic Green was the perennial ryegrass variety used in all treatments.