2015 Annual Progress Report
for the
Agriculture Demonstration of Practices and Technologies
(ADOPT) Program

Project Title: Incorporating tillage radish in annual crop production systems

Project Number: 20130440

Producer Group Sponsoring the Project: Western Applied Research Corporation (WARC)

Project Location(s): The project is conducted at the AAFC Scott Research Farm. Legal land description: NE 17 39 20 W3

Project start and end dates (month & year): May 2014 to December 2015

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Objectives and Rationale

Project objectives

The objectives of this experiment would be to determine **1)** when tillage radish should be seeded to maximize cover crop establishment and biomass accumulation **2)** what effects tillage radish have on its companion cash crop and N nutrient dynamics and **3)** if incorporating tillage radish in an annual cropping system will provide benefits in terms of improved seed yield and quality in the proceeding crop.

Project Rationale

Introducing a cover crop in an annual crop production system can increase diversity in the crop rotation. In addition to providing soil coverage, competing with winter annual weeds in fall and increasing biodiversity, cover crops have other benefits which can provide immediate benefits to the proceeding cash crops (Baerg, 2013). For example, tillage radish, which has a large, long taproot, can improve soil structure and water infiltration by breaking up hardpan. This leaves wide channels when it decomposes allowing water to quickly infiltrate. It can also act as a catch crop, utilizing excess N, reducing N losses due to leaching. The radish will decomposes quickly to release N for the succeeding crop. The use of tillage radish as a cover crop is limited mostly to the United States in corn, cotton and soybean crops, with little adoption in northern climates or in conventional annual cropping systems. This demonstration will allow farmers to evaluate if tillage radish provides benefits in terms of improvement in soil structure, N availability and proceeding crop yield and quality in northwestern Saskatchewan. It will also demonstrate the production practices to maximize productivity of cover crops for those farmers unfamiliar with growing cover crops.

Methodology and Results

In the 2014 growing season, pre-plant glyphosate (0.75 L/ac) was applied followed by glyphosate (1 L/ac) + Bromoxynil (0.4 L/ac) as pre-emergence weed control. Frontline XL (0.5 L/ac) + Axial (0.24 L/ac) were applied as in-crop herbicide. In the 2015 growing season, however, glyphosate (1 L/ac) +

Bromoxynil (0.4 L/ac) were applied as pre-plant with Axial (0.24 L/ac) + Buctril M (0.4 L/ac) as in-crop weed control. The cash crop gown in 2014 and 2015 growing seasons were spring wheat: Vesper and Shaw, respectively, at a rate of 300 seeds per m^2. Two rates of nitrogen (N) were applied (100 % and 150 % of soil test recommended rate) in the mid-row band. All other nutrients were applied in the seed-row according to soil test recommendations. Tillage radish was broadcast at four timings to coincide with other field operations (i.e. herbicide timing, fungicide timing, pre-harvest desiccation and post-harvest burndown). The experiment was set up as a randomized complete block design with four replicates and 10 treatments. Due to the unsuccessful tillage radish establishment in 2014, some modifications were made to the radish broadcast timing in the 2015 growing season as below (Table 1).

Tillage radish emergence counts were taken in 0.25 m^2 quadrats at two locations within a plot, two weeks after radish broadcast. Following the first fall killing frost, five radish plants were pulled from each plot, except the post-harvest treatments due to the fact that the plants were just emerging when the frost hit. Root lengths of the pulled plants were measured and the plants returned into the soil where possible. No desiccant was applied to quickened wheat dry down and control weeds due the radish plants. Whole plots were harvested with a plot combine and samples cleaned to determine wheat yield.

However, due to the lack of establishment of the radish in 2014 (possibly caused by the residual properties of Frontline XL), radish emergence counts and root lengths were not measured, only grain yield was measured after harvest. In 2015, radish emergence counts, radish root length and wheat grain yield were all determined.

Statistical Analysis

An analysis of variance (ANOVA) was conducted on all variables using the PROC MIXED in SAS 9.3. Nitrogen rate and tillage radish broadcast timing were considered as fixed effect and replication was considered a random effect factor. The assumptions of ANOVA (random, equal variance and normally distributed) were tested using PROC UNIVARIATE, Levine's test, and Shapiro-Wilks. The data fitted to the ANOVA assumptions and so there was no need for data transformation. Treatment means were separated using Fisher's Protected LSD test and considered significant at $P < 0.05$. Weather data was estimated from the nearest Environment Canada weather station (Table 3).

Table 1. Treatment Lists for the 2014 and 2015 growing seasons at Scott, SK.

Trt #	2014	2015
1	100% N, no tillage radish	100% N, no tillage radish
2	150% N, no tillage radish	150% N, no tillage radish
3	100% N, tillage radish broadcast at 4-5 leaf stage	100% N, tillage radish broadcast at 50% flowering
4	150% N, tillage radish broadcast at 4-5 leaf stage	150% N, tillage radish broadcast at 50% flowering
5	100% N, tillage radish broadcast at 50% flowering	100% N, tillage radish broadcast at hard dough stage
6	150% N, tillage radish broadcast at 50% flowering	150% N, tillage radish broadcast at hard dough stage
7	100% N, tillage radish broadcast at hard dough stage	100% N, tillage radish post-harvest, broadcast, harrow
8	150% N, tillage radish broadcast at hard dough stage	150% N, tillage radish post-harvest, broadcast, harrow
9	100% N, tillage radish broadcast immediately after harvest	100% N, tillage radish post-harvest, drilled-in
10	150% N, tillage radish broadcast immediately after harvest	150% N, tillage radish post-harvest, drilled-in

Table 2. Residual Soil Nutrients for the 2014 and 2015 growing seasons at Scott, SK.

Depth	***0-15 cm***	***15-30 cm***	***15-60 cm***	***Total***
	---------------------------------------*2014*-------------------------------			
NO3-N	5	2	6	**13**
PO4-P	32	-	-	**32**
K	528	-	-	**528**
SO4-S	8	4	13	**25**
	-------------------------------------*2015*---------------------------------			
NO3-N	21	9	6	**36**
PO4-P	42	-	-	**42**
K	508	-	-	**508**
SO4-S	16	9	26	**51**

Growing season weather conditions

In 2014, Scott saw slightly lower than average temperatures in May and June, but summer and fall were at or slightly above average temperatures. Scott received 123 % of normal precipitation, most of which fell in July. The first fall frost at Scott, SK occurred on September 12th.

In 2015, the early growing season was very dry with only 4.1 and 19.4 mm accumulated precipitation during the month of May and June, respectively. In contrast, August received approximately 39 % more moisture compared to the long-term average. The mean monthly temperatures were comparable to previous years; however, the lack of moisture in the early growing season resulted in a challenging growing season. Furthermore, there was an increase in precipitation during August (74 mm), an increase of 27 % compared to the long term average (Table 3).

Table 3. Mean monthly temperatures and precipitation amounts along with long-term (1981-2010) averages for the 2014 and 2015 growing season at Scott, SK.

Year	**May**	**June**	**July**	**August**	**Sept.**	**Average /Total**
			Temperature (°C)			
2014	9.3	13.9	17.4	16.8	11.2	13.7
2015	9.3	16.1	18.1	16.8	10.9	14.24
Long-term^{z}	10.8	15.3	17.1	16.5	10.4	14.0
			Precipitation (mm)			
2014	23.1	60.4	128.0	30.1	23.6	265.2
2015	4.1	19.4	46.4	74.5	49.6	194.0
Long-term^{z}	36.3	61.8	72.1	45.7	36.0	215.9
			Growing Degree Days			
2014	144.5	264.8	384.5	363.4	188.0	1345.2
2015	140.3	332	405.1	365.8	179.8	1423.0
Long-term^{z}	178.3	307.5	375.1	356.5	162.0	1379.4

Results

Results for the radish emergence and root length is from the 2015 growing season only; however, wheat yield is for both the 2014 and 2015 growing seasons (Table 4).

Table 4. Nitrogen rate and radish broadcast timing effect on wheat yield (2014 and 2015), tillage radish emergence and tillage radish root length (2015).

Effects	**Yield (Kg/ha)** ***Wheat (Vesper)***	**Yield (Kg/ha)** ***Wheat (Shaw)***	**Plants Emergence (#/ .5m^{-2})** **(*Tillage radish*)**	**Root length (cm)** **(*Tillage radish*)**
	2014	***2015***	***2015***	***2015***
	p- value			
Nitrogen Rate (NR)	0.4734	***0.0400***	0.2231	0.2231
Radish Timing (RT)	0.4512	0.9576	***<.0001***	***<.0001***
NR x RT	0.2472	0.6870	0.2755	0.2755

Tillage Radish emergence

There was a significant effect of radish broadcast timing on plant population (*P <.0001*) in the 2015 growing season (Table 4). Both in-crop broadcasts are not significantly different compared to each other, but were significantly different from the postharvest broadcast (Figure 1).

As the radish was seeded in the drilled-in method, it facilitated seed to soil contact, resulting in a higher emergence compared to the other broadcast methods. The harrowed-in method recorded lower plant population, due to the fact that the harrow dragged most of the broadcasted seed out of the plots, resulting in a lower plant density in the plots.

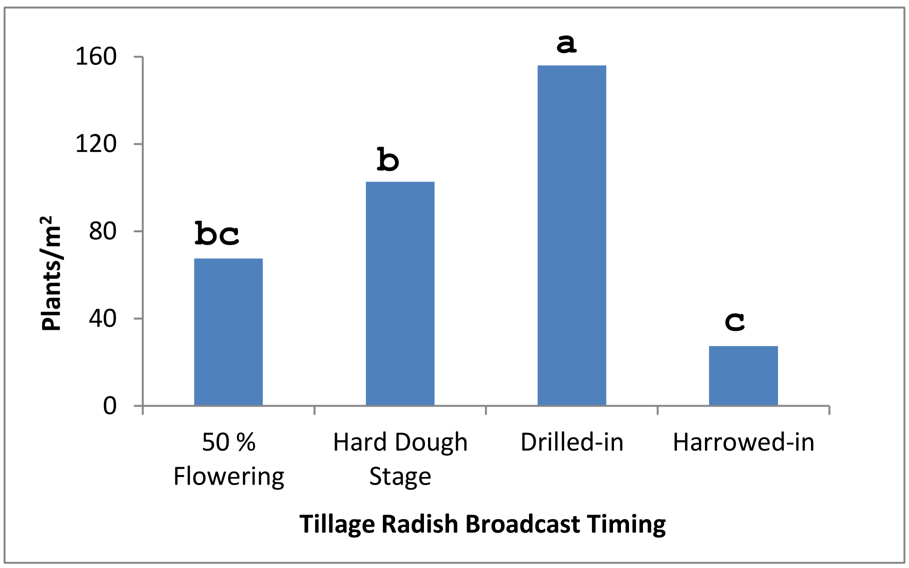

Figure 1: Effects of tillage radish broadcast timing on radish emergence for 2015 growing season at Scott; SK. Vertical bars followed by the same letters are not significantly different according to Tukey's Honestly Significant Difference (HSD) (P > 0.05).

Tillage Radish Root Length

There was a significant effect of radish broadcast timing on root length (*P <.0001*) in the 2015 growing season (Table 4). Both the postharvest timings did not reach the stages for root length measurements. To ensure proper establishment to smother weeds, radish should be planted at least three weeks before killing frost (Weil et al., 2009). In this study, root length was to be measured after the first fall killing frost. However, in the postharvest timings, the frost came before the recommended three weeks, leading to delayed growth and emergence. Thus, measurements were not collected for the postharvest treatments (Figure 2). The 50 % flowering timing had significantly longer (15%) and larger root mass compared to the hard dough stage. The relatively shorter root length in this study suggests that the radish did not achieve their full root length, and therefore it is less likely that it will modify the soil structure. Previous studies have shown tillage radish root length of up to 3 feet including root hairs (WCFA, 2011).

The lack of data for the postharvest timings may due to their slower growth when seeded late as a study found late seeded radish plants proven to be slow to establish due to lack of moisture in late summer (WCFA, 2011).

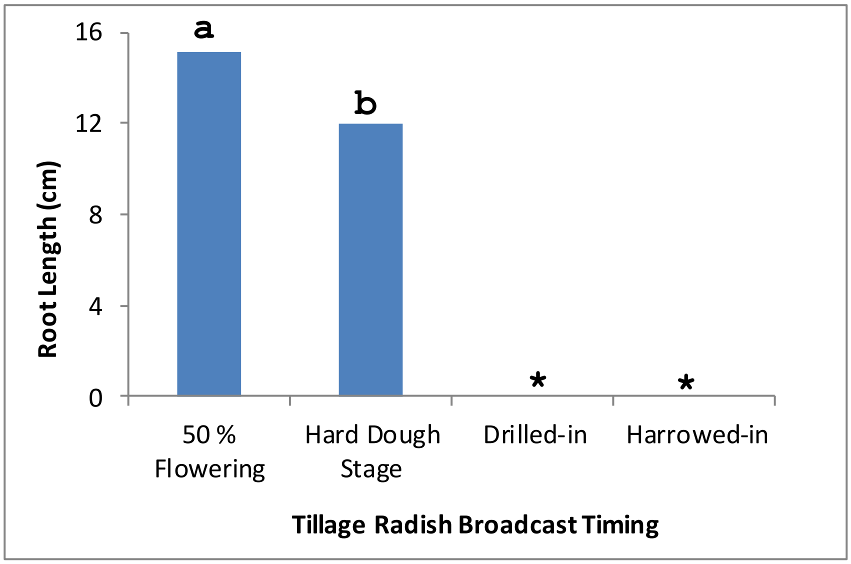

Figure 2: Effects of tillage radish broadcast timing on radish root length for 2015 growing season at Scott, SK (* represents unavailable data). Vertical bars followed by the same letters are not significantly different according to Tukey's Honestly Significant Difference (HSD) ($P > 0.05$).

The lack of significance of N rate to both tillage radish emergence and root length (Table 4) may be because of being excellent scavengers of residual N following (Dean and Weil, 2009). Due to their deep root system, rapid root extension, and heavy N feeding, radishes take up N from both the topsoil and from deeper soil layers, storing the N in their shoot and root biomass. With favorable fall growing conditions, radishes typically take up more than 100 lb/ac of N. Much higher amounts of N may be acquired when N is abundant—for example, when a drought-stricken summer crop has failed to utilize much of the available N (Dean and Weil, 2009).

Grain yield

There was a significant effect of N rate on wheat yield ($P = 0.0400$) in the 2015 growing season but not in the 2014 growing season (Table 4). The difference in yield might be varietal, as two different varieties were seeded in both years. The Vesper variety resulted in a 19% and 15% yield increase compared to CDC Shaw at the 100 and 150 % NR, respectively (Figure 3).There was lack of significant effects of tillage radish timing on wheat yield in both 2014 and 2015 growing seasons (Table 4).

In order for the tillage radish to positively influence the cash crop yield, it requires proper establishment and an extensive rooting system to influence nutrient cycling and thus affecting the cash crop yield. This situation occurs mostly in the second season of establishment as opposed to the year of establishment. Because unlike cereal rye and other cereal cover crops whose residues decompose slowly and immobilize N in the spring, tillage radish residue decomposes rapidly and releases its N early (Weil et al., 2009). Studies from the University of Maryland confirmed that corn yields increased by 10 % (12 bu/acre advantage) and soybean yields increased by 11% (8 bu/acre) in heavily compacted soil using tillage radish relative to no cover crop as the prior year crop (Weil et al., 2009). Additional research shows that mixing 2 lbs of Tillage radish seed with winter wheat seeding can result in a 5-12 bu/acre yield increase (Weil et al., 2009).

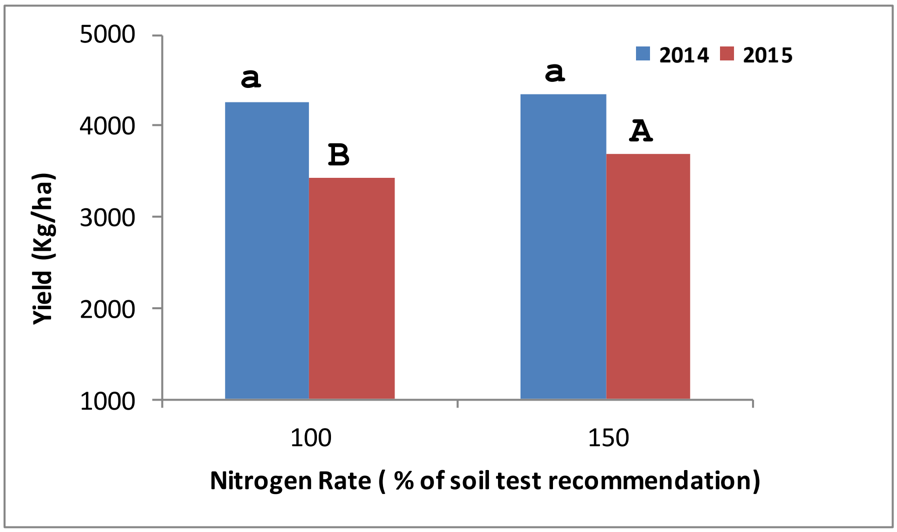

Figure 3: Effects of N rate on wheat yield for 2014 and 2015 growing season at Scott, SK. Vertical bars followed by the same letters are not significantly different according to Tukey's Honestly Significant Difference (HSD) ($P > 0.05$).

Conclusions and Recommendations

From the study it can be concluded that radish timing does not interfere with the cash crop yield at least in the year of seeding, but variable N rates can effectively alter crop yields. However, the broadcast timing influences radish establishment and root biomass, and thus affecting its function of soil structure improvement. Based on the results and from other studies, farmers can incorporate radish at seeding time (by drilling) up to the hard dough stage (by broadcasting) in cereals. This would ensure proper establishment. Studies have shown that good stands of radishes can be established by drilling 6–10 lb/ac or broadcasting at 8-12 lb/ac. Finally, herbicides with long term residual effects should be avoided prior to broadcast. Farmers should seed into the tillage radish in the following year, because most of the yield advantages are seen on the crop following several years of establishment.

Supporting Information

Acknowledgements

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growing season. This report will be distributed through WARC's website and included in WARC's and Agri-Arm annual reports.

Abstract

Abstract/Summary

Introducing a cover crop in an annual crop production system can increase diversity in the crop rotation. In addition to providing soil coverage, competing with winter annual weeds in fall and increasing biodiversity, cover crops can provide immediate benefits to the proceeding cash crops. For example, tillage radish, which has a large, long taproot, can improve soil structure and water infiltration by breaking up the hardpan. This leaves wide channels when it decomposes allowing water to quickly infiltrate. It can also act as a catch crop, utilizing excess N, reducing N losses due to leaching. The radish will decomposes quickly to release N for following crop. This study was set up at Scott, SK in the 2014 and 2015 growing seasons to determine the ideal time for incorporation of tillage radish into an existing cash crop. The other objective was to determine the effects of tillage radish on yield of its companion cash crop and N nutrient dynamics. A very high percentage of tillage radish seeds in the treatment list did not germinate during the 2014 growing season due to possibly residual effects of Frontline XL used as an in-crop herbicide. Nitrogen rate had a significant effect on wheat grain yield in the 2015 growing season ($P = 0.0440$) but not in 2014 ($P = 0.4734$). Both tillage radish emergence and root length were significantly affected by tillage radish broadcast timing ($P<.0001$). In summary, tillage radish can be used to modify soil structure, improve water infiltration and aeration, and nutrient cycling. The optimum time for incorporation should be at 50 % flowering stage or at the latest, the hard dough stage. Further investigation is required to determine the long term effects of tillage radish and other cover crops in terms of soil health and nutrient cycling.

References

Baerg M. 2013. Tillage Radishes – A New Option for Improved Soil Health. In: Top Crop Manager West - December 2013. Online at: http://www.mydigitalpublication.com/article/Tillage+Radishes+%E2%80%93+A+New+Option+For+Improved+Soil+Health+/1563296/0/article.html [6 Dec 2013].

Dean, J. E., and R. R. Weil. 2009. Brassica cover crops for nitrogen retention in the Mid-Atlantic coastal plain. *J. Environ. Qual.* 38: 520–528.

Weil, R., C. White, and Y. Lawley. 2009. Forage radish: A new multi-purpose cover crop for the Mid-Atlantic. Fact Sheet 824. Univ. of Maryland Coop. Ext., College Park.

Western Central Forage Association. 2015. Tillage Radish. Available at: http://www.westcentralforage.com/projects/tillage-radish%C2%AE.aspx (date accessed November 26, 2015).