Northern NY Agricultural Development Program
2016-2017: Final Project Report

Double Cropping with Cereal Rye and Corn Silage: Impacts on Nutrient Efficiency and Forage Production

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Cooperating Producer:

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Background:

Corn silage is an economically important annual forage grown by Northern New York dairy producers. Maximizing yield, quality, and nutrient efficiency in corn silage systems increases farm profitability while reducing nutrient losses. Research has demonstrated that cereal rye (*Secale cereale* L. *ssp. cereal*) planted after corn can reduce soil erosion and nitrate-N leaching potential compared to corn left fallow. Additional benefits of planting rye after corn silage include greater total forage production if rye is harvested as a hay crop forage.

The potential yield and quality impacts of growing cereal rye before corn compared to the standard practice of corn silage left fallow are not well known in Northern New York. Studies in other regions show that timing of termination (or harvest), length of time between harvest and corn planting, and tillage can all impact corn yield following rye. The objective of our project was to determine the impact of a winter cereal rye forage crop on corn silage yield and nutrient losses in surface runoff and tile drainage.

Methods:

Four replicate edge-of-field plots were designed to monitor surface and subsurface tile drain runoff.

After corn silage harvest on 9/19/16, composted dairy manure was applied at a rate of approximately 10 tons/acre to all plots and incorporated with a disk harrow. Cereal rye was planted with a grain drill at 100 lb/ac on 10/11/16 in two of the four drainage plots.

Cereal rye was sampled weekly during spring 2017 for biomass and nutrient contents.

On 6/7/17, rye was cut using a Pottinger Nova Cat 356F mower and chopped for hay crop silage on 6/8/17 followed by one-pass tillage using a disk harrow.

On 6/15/17, corn silage was planted with a six-row, JD 1750 Max Emerge planter at 34,000 seeds/ac with 100 lb/ac of 23-12-18 dry fertilizer was band applied through the planter.

Corn silage was harvested on 10/11/17. Corn yields were determined by chopping six subplots within each main plot using a JD 3975 harvester and taking the average.

Runoff events were monitored during fall 2016 through 2017. Surface and tile drainage flows were continuously measured during runoff events. Total Phosphorus (TP), soluble reactive Phosphorus (SRP), nitrate-N, and total Nitrogen (TN) were measured in runoff samples. Autosamplers were used to sample runoff and were combined with flows to estimate nutrient loading.

Instrumentation for measuring runoff has been previously described in Northern New York Agricultural Development Program reports for this work. Runoff flows were estimated by established relationships between water height in v-notch buckets and measured water flow rates. Equations used to predict runoff flows from each plot are available upon request.

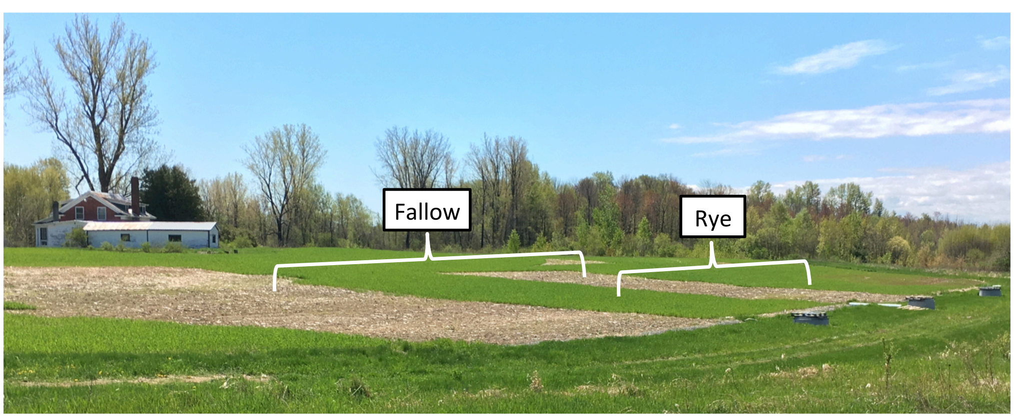

Figure 1. Rye and fallow plots at the Lake Alice Wildlife Management Area, NNYADP double cropping project, 2017.

Results and Discussion:

Winter rye growth increased linearly by an average of 3-fold from 5/18/17 to 6/7/17 (Figure 2) at an average rate of 0.15 tons of dry matter/day.

On 5/21/17, 70 lb N/ac (as urea ammonium nitrate) was applied and likely contributed to the rapid biomass growth. Ketterings et al. (2015) concluded that 2 tons of dry matter/acre was the break-even yield for winter forage assuming 75 lb N/ac was applied and a corn silage yield penalty of 1 ton/dry matter acre for the subsequent corn crop.

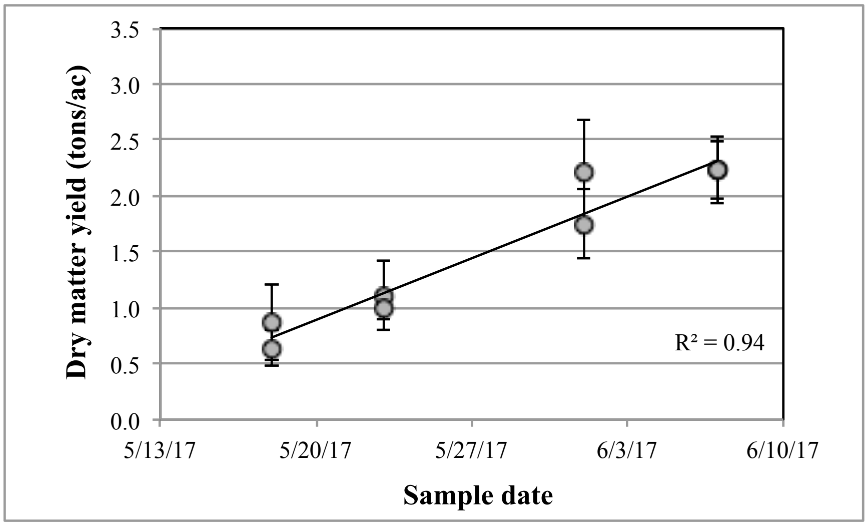

Figure 2. Rye biomass growth for replicate plots during spring 2017, NNYADP double cropping project, 2017.

Winter rye forage was harvested on 6/7/18 as hay crop silage. Forage quality was good quality with a mean crude protein content (CP) of 18.3% and 30-hr NDF digestibility (NDFD30) of 64% (Table 1). Fiber digestibility in this range is comparable to brown midrib corn silage or grass hay harvested at peak digestibility, suggesting that winter rye offers good potential as a high quality dairy forage. Based on a CP of 18.3% and a mean P content of 0.39%, approximately 129 lb N/acre and 17 lb P/ac was removed by the rye crop after harvest.

Table 1. Mean forage quality measures for winter rye forage harvested on 6/7/17, NNYADP double cropping project, 2017. Standard error of the mean is below in parentheses.

Crude Protein (%DM)	**ADF** (%DM)	**aNDF** (%DM)	**NDFD30** (% of NDF)
18.3	37.7	62.3	64.0
(0.1)	(0.3)	(1.2)	(0)

There was no significant difference in corn silage yield between corn grown after rye and corn plots left fallow (Table 2). In contrast, 2016 results showed a significant yield penalty for corn silage grown after rye that was in part due to no-till planting into the standing rye. The combination of a dense rye crop and the lack of down force on the planter created difficulty in getting seed to the proper depth consistently. This resulted in seed left on the soil surface and ultimately a lower stand population and silage yield. Damage from geese in one of the rye plots also negatively impacted the corn crop.

In 2017, the decision to use one-pass tillage after rye harvest reduced the yield penalty associated with growing a rye forage crop. It should be noted that damage from geese also occurred in one of the rye plots in 2017, which may have contributed to the numerically lower corn silage yield. Notwithstanding, total forage yield for rye plots (corn silage + rye forage) was greater than corn left fallow.

Table 2. Silage corn yield in 2016 and 2017 after rye or corn after corn, NNYADP double cropping project, 2017.

Treatment	Yield at 35% DM (tons/ac)	Yield at 35% DM (tons/ac)
	2016	2017
Rye	16.1a §	15.8a
Control	20.7b	16.6a

§ Means with different letters differ at $P \leq 0.05$.

Quality measures for rye and fallow plots were similar, with no statistically significant differences (Table 3). This suggests that with proper field preparation, sacrifices in yield and quality of corn silage are not inevitable with double cropping with rye.

In addition to some level of tillage for some soils, adding manure or additional N fertilizer for corn following rye is another way to further reduce the risk of a yield penalty for corn. Further research is needed to determine how best to avoid possible yield depression when double cropping with rye forage and corn silage.

Table 3. Quality measures for corn silage grown following a winter rye forage crop or corn following corn in 2017, NNYADP double cropping project, 2017.

Treatment	Starch	NDF	CP	Lignin	ADF
	--------------------% Dry matter----------				
Rye	26.6a§	45.5a	7.6a	3.1a	26.6a
Control	28.9a	44.5a	8.0a	3.0a	25.8a

§ Means with different letters differ at $P \leq 0.05$.

Nutrient Losses in Runoff

Nitrogen (N) and phosphorus (P) losses in runoff were monitored over 2016-2017. In general, N and P losses in surface runoff were consistently lower for rye plots (Appendix Tables 6-9) with the exception of a few events. Losses in tile drainage were more variable between plots for both N and P losses.

Rye appeared particularly effective at reducing TP and SRP losses for two snow melt events in 2017 (Figures 3 and 4). While these events occurred when rye was at a small growth stage, it was well established the previous fall and the soil surface was covered with biomass for these events. We hypothesize that rye biomass, even at this growth stage, was still effective in reducing runoff water velocity and retaining P.

Total N and nitrate losses were also significantly lower for rye plots for these two snowmelt events (Appendix).

Snowmelt events can be important contributors to nutrient losses and account for a large fraction of annual losses in northern climates.

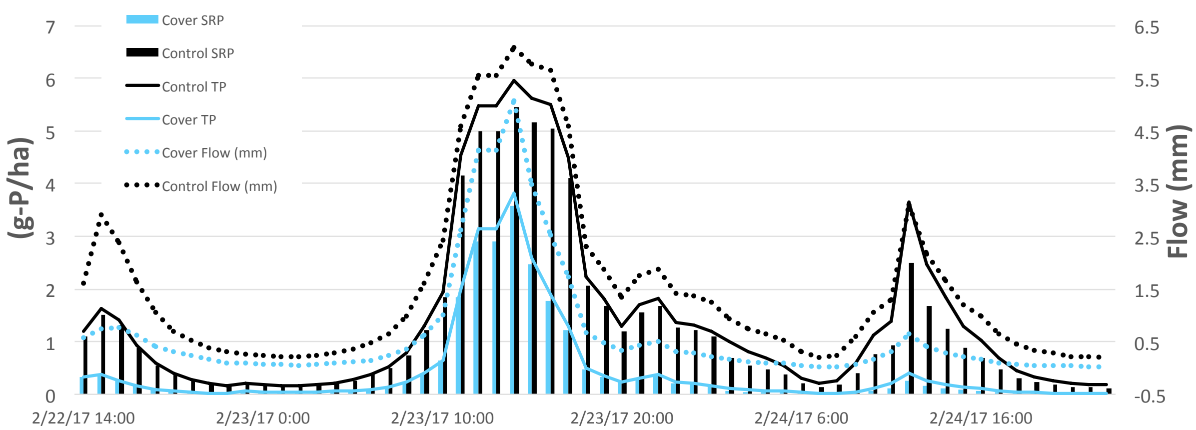

Figure 3. Total P, SRP, and water export in surface runoff for a 2017 snowmelt event, NNYADP double cropping project, 2017.

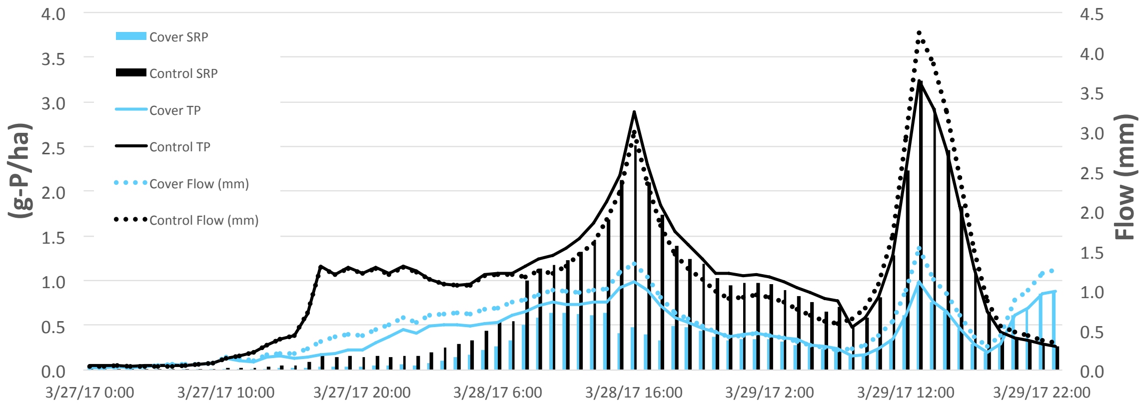

Figure 4. **Total P, SRP, and water export in surface runoff for a 2017 snowmelt event, NNYADP double cropping project, 2017.**

Cumulative nitrate, SRP, TN, and TP losses over 2016-2017 were significantly lower for rye plots (Table 4). Cumulative surface runoff from rye plots was nearly half of control plots, though not significant. Results suggest that rye reduced runoff and associated nutrient losses from corn plots relative to corn left fallow. Our results are supported by other studies that have shown cover crops after corn have the potential to reduce erosion and nutrient losses in surface runoff (Sharpley and Smith, 1991).

Table 4. Cumulative export of water and nutrients in surface runoff.

Treatment	Nitrate	SRP	TN	TP	Flow
	---------------------------lb/ac------------				(in)
Cover	0.3	0.9	5.1	1.0	4.43
Control	0.5	1.8	9.3	2.1	8.18
P-value	0.01	0.03	0.01	0.01	0.27

Surface and tile nutrient loads were combined to provide an estimate of total nutrient loss (Table 5). There were no significant differences between rye and control plots for nitrate or TN when surface runoff and tile drainage runoff were combined (Table 5).

It is important to note that the vast majority (>95%) of mean nitrate loss was from tile drainage flow, whereas nearly all TP (85% for rye and 100% for control) and SRP loss (>99.5%) was due to surface runoff (Tables 4 and 5). This highlights the importance of:

(a) surface water runoff as the main pathway for P loss, and tile drainage as the main pathway for nitrate loss, and

(b) the importance of using a cover crop to reduce P loss in surface runoff.

Studies in the Midwest have shown that rye can also be effective at reducing nitrate leaching to tile drains following corn grain, however, we did not observe this in our study. The fact that nitrate or TN loads from tiles were not lower in rye plots could be due to spatial variability in subsurface flows and/or to the more dynamic nature of the N cycle and associated differences in N mineralization/nitrification of organic N.

Table 5. Cumulative export of water and nutrients in surface runoff + tile drainage flow, NNYADP double cropping project, 2017.

Treatment	Nitrate	SRP	TN	TP	Flow
	-------------------------lb/ac-----------				(in)
Cover	13.9	0.9	16.7	1.2	7.71
Control	13.1	1.8	18.7	2.1	10.78
P-value	0.68	0.0001	0.45	0.01	0.04

Conclusions/Outcomes/Impacts:

Our results showed that winter rye can be successfully established after corn silage and produce a high quality dairy forage the following spring. We recommend adding additional N to rye for fields with a limited manure history to increase dry matter yield and crude protein content.

There was a minimal yield penalty for corn grown after rye harvest that was not statistically significant. In addition, there were no apparent differences in corn forage quality grown after rye compared to corn planted after corn.

Results showed that a rye cover crop substantially reduced both N and P losses in surface runoff, however, there was no apparent effect on nutrient losses in tile drainage. Nearly all P was lost in the form of surface runoff, whereas most of the N was lost in tile drainage flow. Future work evaluating the impacts of double cropping on corn silage and nutrient losses may benefit from using a paired watershed approach conducted over multiple years to better account for variability in soils, weather, and runoff patterns.

Outreach:

Results from this project were presented at the 2017 American Society of Agronomy/Crop Science Society/Soil Science Society of America annual meeting in October 2017, and at the Lake Champlain Basin Conference, January 2018.

Acknowledgments:

We thank the Miner Institute Dairy Farm for help and cooperation with this project.

Reports and/or articles in which results of project have been published.

None as yet.

For More Information:

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References:

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Sharpley, A.N. and S.J. Smith. 1991. Effects of cover crops on surface water quality. pp. 41-49. In: Cover crops for clean water. W.L. Hargrove (ed.) Soil and Water Conservation Society, Ankeny, Iowa.

Appendix: Double Cropping with Cereal Rye and Corn Silage: Impacts on Nutrient Efficiency and Forage Production

Table 6. Mean nitrogen losses from surface runoff by event, NNYADP double cropping project, 2017.

Event Date	Treatment	Nitrate g-N/ha	SD	TN g-N/ha	SD
4.7.16	Cover	11	9	11	9
	Control	39	42	33	33
6.5.16	Cover	1	2	2	2
	Control	26	37	27	38
6.28.16	Cover	9	7	15	10
	Control	6	9	10	14
7.9.16	Cover	5	1	5	1
	Control	4	5	8	12
7.18.16	Cover	1	0	2	0
	Control	1	2	2	3
8.28.16	Cover	0	0	0	0
	Control	0	0	0	0
10.20.16	Cover	7	0	39	43
	Control	82	93	495	666
2.20-2.24	Cover	**28**	17	**1310**	285
	Control	**90**	28	**3922**	217
2.25.17	Cover	66	34	143	100
	Control	11	16	280	283
3.27-3.29	Cover	**97**	48	**324**	143
	Control	**221**	55	**636**	235
4.2.17	Cover	101	55	232	151
	Control	249	149	554	340
4.6.17	Cover	120	12	158	39
	Control	56	77	74	104
6.29.17	Cover	15	18	17	17
	Control	18	26	28	40

Means between rye and control plots in red differ at $P \leq 0.05$

Table 7. Mean nitrogen losses from tile drainage by event, NNYADP double cropping project, 2017.

Event Date	Treatment	Nitrate g-N/ha	SD	TN g-N/ha	SD
3.28.16	Cover	752	464	792	408
	Control	937	367	1137	497
4.7.16	Cover	925	455	1032	301
	Control	1436	691	1590	981
4.11.16	Cover	1190	551	1657	775
	Control	1012	585	1431	882
6.5.16	Cover	**409**	102	496	74
	Control	**710**	182	928	417
8.14.16	Cover	62	88	0	0
	Control	42	19	0	0
8.28.16	Cover	0	0	0	0
	Control	0	0	0	0
10.20.16	Cover	2596	1695	2857	2034
	Control	671	514	950	632
2.25.17	Cover	783	140	783	140
	Control	786	278	786	278
3.27-3.29	Cover	200	232	306	219
	Control	589	694	589	739
4.6.17	Cover	5149	654	5494	166
	Control	4840	16	4939	155
6.29.17	Cover	3187	340	3207	332
	Control	3056	31	3079	63

Means between rye and control plots in red differ at $P \leq 0.05$

Table 8. Mean phosphorus losses in surface runoff from tile drainage by event, NNYADP double cropping project, 2017.

Event Date	Treatment	SRP g-P/ha	SD	TP g-P/ha	SD
4.7.16	Cover	0.2	0.3	0.7	0.6
	Control	0.9	1.0	0.8	2.1
6.5.16	Cover	0.0	0.1	0.1	0.0
	Control	1.6	2.2	2.5	0.3
6.28.16	Cover	**0.9**	0.9	**0.9**	0.2
	Control	**0.6**	0.8	**0.6**	0.2
7.9.16	Cover	0.2	0.1	0.2	0.0
	Control	0.3	0.5	0.3	0.0
7.18.16	Cover	0.1	0.1	0.1	0.0
	Control	0.1	0.2	0.1	0.0
8.28.16	Cover	**1.0**	0.8	1.2	0.0
	Control	**0.8**	0.8	1.0	0.0
10.20.16	Cover	2.4	2.8	4.8	0.2
	Control	20.2	27.5	48.9	8.2
2.20-2.24	Cover	**232.5**	45.5	**252.9**	0.5
	Control	**706.3**	34.7	**816.9**	4.1
2.25.17	Cover	**3.6**	2.6	10.7	0.3
	Control	**11.3**	3.4	35.5	7.7
3.27-3.29	Cover	**53.3**	46.8	**57.7**	0.1
	Control	**133.1**	85.3	**140.7**	0.1
4.2.17	Cover	19.7	13.8	27.2	0.5
	Control	66.1	36.6	76.8	3.0
4.6.17	Cover	2.0	1.4	6.6	1.1
	Control	1.4	1.9	2.4	0.3
6.29.17	Cover	0.3	0.0	0.5	26.5
	Control	1.0	1.3	1.2	13.7

Means between rye and control plots in red differ at $P \leq 0.05$

Table 9. Mean phosphorus losses from tile drainage by event, NNYADP double cropping project, 2017.

Event Date	Treatment	SRP g-P/ha	SD	TP g-P/ha	SD
3.28.16	Cover	0.6	0.5	4.4	5.5
	Control	0.4	0.0	0.8	0.4
4.7.16	Cover	2.0	1.7	9.4	3.2
	Control	1.1	1.3	3.7	4.8
4.11.16	Cover	0.2	0.2	0.6	0.6
	Control	0.1	0.0	0.1	0.1
6.5.16	Cover	0.4	0.5	0.8	1.0
	Control	0.1	0.1	0.1	0.1
8.14.16	Cover	0.0	0.0	0.0	0.0
	Control	0.0	0.0	0.0	0.0
8.28.16	Cover	0.0	0.1	0.0	0.1
	Control	0.8	1.1	1.3	1.7
10.20.16	Cover	21.1	28.5	107.3	146.4
	Control	14.3	19.3	45.3	60.5
2.25.17	Cover	1.9	2.5	13.9	13.8
	Control	0.4	0.4	4.5	5.5
3.27-3.29	Cover	7.6	2.8	8.1	2.1
	Control	1.2	0.9	2.6	0.9
4.6.17	Cover	3.6	4.2	25.3	26.9
	Control	1.2	1.2	9.2	10.5
6.29.17	Cover	0.5	0.4	4.0	5.0
	Control	0.7	0.0	1.9	0.2

Means between rye and control plots in red differ at $P \leq 0.05$