NORTHWEST CROPS & SOILS PROGRAM

Maximizing Forage Yields in Corn Silage Systems with Winter Grains

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MAXIMIZING FORAGE YIELDS IN CORN SILAGE SYSTEMS WITH WINTER GRAINS

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Producing sufficient high quality forage on farms is becoming difficult given current economic and environmental pressures. Farmers are looking for strategies to improve yield and quality of their own forage to reduce the financial burden of purchasing feed off-farm. One strategy for accomplishing this is utilizing winter grains, such as rye, wheat and triticale, as forage crops. These crops could be grazed or harvested in the fall to extend the grazing season, and in the spring could provide early forage prior to planting corn silage. In the fall of 2015 the University of Vermont Northwest Crops and Soils Program initiated a trial investigating the integration of winter grains for forage into corn silage cropping systems.

MATERIALS AND METHODS

The soil type at the Alburgh location was a Benson rocky silt loam (Table 1). The seedbed was chisel plowed, disked, and finished with a spike tooth harrow. The previous crop was oats and spring wheat. Plots were 10’ x 20’and replicated 4 times. The winter grain portion of the trial was planted with a cone seeder on 31-Aug. At planting soil was sampled for nitrate nitrogen (N) and available phosphorus (P) content at the University of Vermont Agricultural and Environmental Testing Laboratory in Burlington, VT. Forage was harvested in the fall once temperatures had remained below 40°F for an extended period of time. On 28-Oct 2015 plots were harvested by hand by cutting forage in two 1 meter length sections to a height of three inches simulating grazing.

Table 1. Winter Grain Forage Trial Management, Alburgh, VT, 2015-2016.

Location	Borderview Research Farm – Alburgh, VT
Soil type	Benson rocky silt loam
Previous crop	Oats and Spring Wheat
Tillage operations	Chisel plow, disk and spike tooth harrow
Planting equipment	Cone Seeder (winter grains) No-till corn planter (corn)
Treatments (main plot)	Winter Rye (VNS) Winter Wheat (SW50) Winter Triticale (Trical 815)
Treatments (subplot)	0 lbs N 25 lbs N 50 lbs N
Corn variety	Dyna-Gro D26VP56RIB, 86 RM
Replications	4
Plot size (ft)	10 x 20
Planting dates (forage/corn)	31-Aug / 1-Jun
Harvest dates (forage/corn)	28-Oct 2015, 12-May and 31-May 2016 / 5-Oct 2016

An approximate 1 lb subsample was collected, dried, ground, and then analyzed for forage quality, nitrogen and phosphorus content. Dry matter yields were calculated. After harvest the entire trial area was mowed to a height of three inches and soil was sampled and again analyzed for nitrate-N and available P.

In early spring 2016 as soon as fields were accessible, soils were sampled again for nitrate-N and available P prior to imposing nitrogen treatments. Nitrogen treatments of 0, 25, and 50 lbs ac^{-1} were hand applied to individual plots using calcium ammonium nitrate on 18-Apr 2016. Forage was harvested when the boot stage was reached. Rye plots were harvested on 12-May and wheat and triticale plots on 31-May 2016 as they matured later than the rye. Plots were harvested using a Carter forage harvester in a 3' x 20' area. An approximate 1 lb subsample of the harvested material was collected, dried, ground, and then analyzed for forage quality. Dry matter yields were calculated. After harvest, the remainder of the plots were mowed to three inches and soil was sampled for nitrate nitrogen and available phosphorus. Winter grain stubble was terminated with RoundUp® on 31-May at a rate of 1 quart ac^{-1}. Short season corn was planted into the plots using a John Deere 1750 no-till corn planter at a rate of 34,000 live seeds ac^{-1} on 1-Jun. Plots were fertilized with 46-0-0 at a rate of 300 lbs ac^{-1} on 24-Jun. Prior to corn harvest, plant populations and number of ears were counted. Corn stalk nitrate samples were also collected by removing an eight inch section of corn stalk six inches above the ground for five random plants in each plot. These samples were dried, ground, and sent to the University of Massachusetts, Amherst for nitrate analysis. Corn was harvested on 5-Oct 2016. An approximate 1 lb subsample was collected, dried, ground, and then analyzed for quality.

Forage quality was analyzed using the FOSS NIRS (near infrared reflectance spectroscopy) DS2500 Feed and Forage analyzer at the University of Vermont Cereal Grain Testing Lab. Dried and coarsely-ground plot samples were brought to the lab where they were reground using a cyclone sample mill (1mm screen) from the UDY Corporation. The samples were then analyzed using the FOSS NIRS DS2500 for crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF), 48-hour digestible NDF (NDFD), and total digestible nutrients (TDN).

Mixtures of true proteins, composed of amino acids, and non-protein nitrogen make up the CP content of forages. The CP content of forages is determined by measuring the amount of nitrogen and multiplying by 6.25. The bulky characteristics of forage come from fiber. Forage feeding values are negatively associated with fiber since the less digestible portions of plants are contained in the fiber fraction. The detergent fiber analysis system separates forages into two parts: cell contents, which include sugars, starches, proteins, non-protein nitrogen, fats and other highly digestible compounds; and the less digestible components found in the fiber fraction. The total fiber content of forage is contained in the neutral detergent fiber (NDF). Chemically, this fraction includes cellulose, hemicellulose, and lignin. Because of these chemical components and their association with the bulkiness of feeds, NDF is closely related to feed intake and rumen fill in cows.

Yield data and stand characteristics were analyzed using mixed model analysis using the mixed procedure of SAS (SAS Institute, 1999). Replications within trials were treated as random effects, and mixtures were treated as fixed. Treatment mean comparisons were made using the Least Significant Difference (LSD) procedure when the F-test was considered significant ($p<0.10$).

Variations in yield and quality can occur because of variations in genetics, soil, and other growing conditions. Statistical analysis makes it possible to determine whether a difference among hybrids is real or whether it might have occurred due to other variations in the field. At the bottom of each table a LSD value is presented for each variable (i.e. yield). Least Significant Differences (LSDs) at the 0.10 level of significance are shown. Where the difference between two hybrids within a column is equal to or greater than the LSD value at the bottom of the column, you can be sure that for 9 out of 10 times, there is a real difference between the two hybrids. Hybrids that were not significantly lower in performance than the highest hybrid in a particular column are indicated with an asterisk. In the example above, hybrid C is significantly different from hybrid A but not from hybrid B. The difference between C and B is equal to 1.5, which is less than the LSD value of 2.0. This means that these hybrids did not differ in yield. The difference between C and A is equal to 3.0, which is greater than the LSD value of 2.0. This means that the yields of these hybrids were significantly different from one another. The asterisk indicates that hybrid B was not significantly lower than the top yielding hybrid C, indicated in bold.

Hybrid	**Yield**
A	6.0
B	7.5*
C	**9.0***
LSD	2.0

RESULTS

Weather data was recorded with a Davis Instrument Vantage Pro2 weather station, equipped with a WeatherLink data logger at Borderview Research Farm in Alburgh, VT (Table 2).

Table 2. 2015-2016 weather data for Alburgh, VT.

	2015				2016									
	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Average temperature (°F)	65.2	46.5	42.2	37.6	22.7	23.2	33.9	39.8	58.1	65.8	70.7	71.6	63.4	50.0
Departure from normal	4.70	-1.60	4.00	11.7	4.00	1.60	2.90	-4.90	1.80	0.00	0.10	2.90	2.90	1.90
Precipitation (inches)	0.30	2.50	1.80	3.50	1.30	3.60	2.50	2.60	1.50	2.80	1.80	3.00	2.50	5.00
Departure from normal	-3.30	-1.09	-1.30	1.13	-0.74	1.81	0.29	-0.26	-1.92	-0.88	-2.37	-0.93	-1.17	1.39
Growing Degree Days (base 32°F)	1010	464	329	220	50	64	209	291	803					
Departure from normal	154	-37	117	189	50	60	85	-98	50					
Growing Degree Days (base 50°F)										481	640	663	438	146
Departure from normal										7	1	82	104	34

Based on weather data from a Davis Instruments Vantage Pro2 with WeatherLink data logger.
Historical averages are for 30 years of NOAA data (1981-2010) from Burlington, VT.

From September 2015 through May 2016 there were 3440 Growing Degree Days (GDDs) accumulated for the winter grains, 570 more than the 30-year normal. Precipitation during this time was below normal for all months except December, February, and March. For the corn there were 2368 GDDs accumulated from June through October, 228 more than normal. Precipitation during this time was below normal for all months except for October. Temperatures only deviated from the normal by a few degrees except in

September and December 2015 which were 11.7 and 4.7 degrees above normal respectively, and April 2016 which was 4.9 degrees below normal.

Impact of Winter Grain Species

Fall forage yields and protein differed significantly by winter grain species (Table 3). Rye produced the highest yield of 0.747 tons ac^{-1} which was statistically similar to triticale which produced 0.709 tons ac^{-1}. This was about 0.25 tons ac^{-1} greater than wheat. Protein was highest in triticale and wheat with 25.0% CP concentration. The winter grain species did not differ statistically in terms of DM, ADF, NDF, NDF digestibility, or RFV. Overall, the quality of the forage provided by all of the winter grain treatments in the fall was very high.

Table 3. Fall winter grain harvest yield and quality by species, 2015.

Species	Dry Matter (DM)	DM Yield	Crude Protein	ADF	NDF	NDFD 30 hr	RFV
	%	tons ac^{-1}	% of DM	% of DM	% of DM	% of NDF	
Rye	22.3	**0.747***	23.6	19.0	33.7	49.8	205
Triticale	21.2	0.505	**25.0***	**18.2**	**33.1**	48.3	**210**
Wheat	21.6	0.709*	25.0*	19.1	34.1	**51.8**	203
LSD (*p* = 0.10)	NS	0.237	1.31	NS	NS	NS	NS
Trial Mean	21.7	0.654	24.5	18.8	33.6	54.6	206

Treatments with an asterisk* performed statistically similarly to the top performer in **bold.**
NS-No significant difference.

Spring forage yield and quality differed across the three species (Table 4). The highest yielding species was triticale producing 2.66 tons ac^{-1} dry matter. Wheat produced the highest dry matter content of 25.8% while statistically similar to triticale. This was more than 5% higher than the rye dry matter. It is important to remember that the rye was harvested 19 days earlier than the wheat and triticale due to maturity timing and likely explains these observed differences.

Table 4. Spring winter grain harvest yield and quality by species, 2016.

Species	Dry Matter (DM)	DM Yield	Crude Protein	ADF	NDF	NDFD 30 hr	RFV
	%	tons ac^{-1}	% of DM	% of DM	% of DM	% of NDF	
Rye	20.0	1.64	**18.9***	**25.6***	**42.3***	**57.7***	**152***
Triticale	25.2*	**2.66***	12.4	31.3	51.5	54.2	116
Wheat	**25.8***	2.23	13.9	27.1	43.6	51.2	145
LSD (*p* = 0.10)	1.31	0.344	1.14	0.503	0.961	0.628	3.47
Trial Mean	23.7	2.01	15.0	28.0	45.8	54.6	138

Treatments with an asterisk* performed statistically similarly to the top performer in **bold.**
NS-No significant difference.

In terms of quality, the rye outperformed the triticale and wheat (Figure 1). Rye produced forage with the highest protein of 18.9%, 5% higher than the next best species wheat. Rye also produced the lowest ADF and NDF of 25.6 and 42.3% respectively. Triticale had the highest ADF and NDF and consequently the lowest RFV score of 116 compared to 152 for rye.

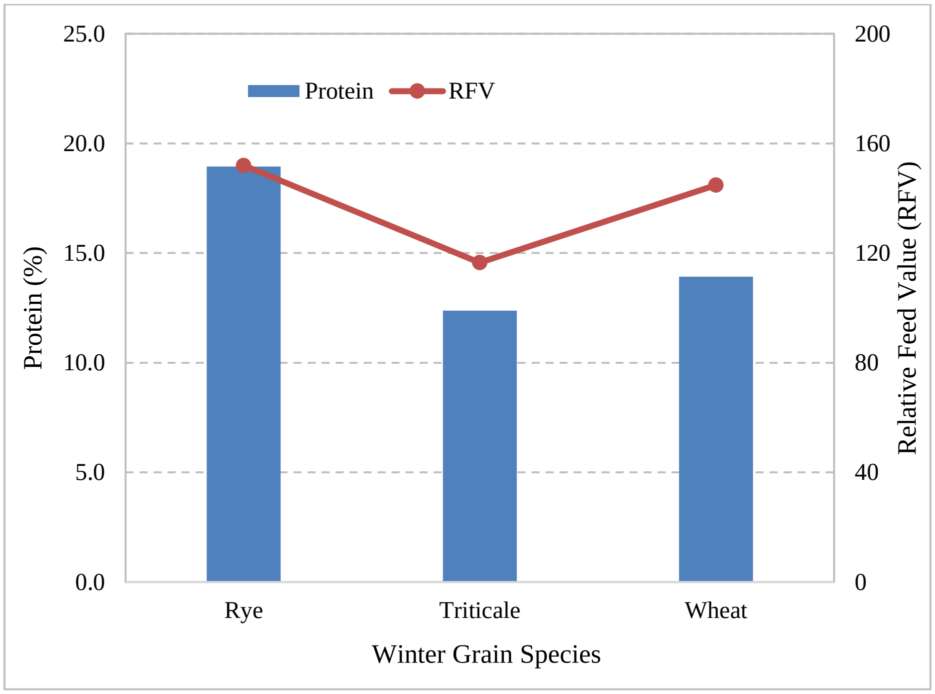

Figure 1. Protein and RFV of spring forage by winter grain species, 2016.

Winter grain species had minimal impact on corn silage stand characteristics and yield (Table 5). The only parameter that differed statistically was corn plant population with the control (no winter grain cover crop) producing the highest stand density of 33,142 plants ac^{-1}. The corn was planted no-till and the dense grain stubble and root system may have caused poor seed to soil contact. Closer attention should be paid to modify the planter for this type of situation.

Table 5. Corn stand characteristics by winter grain species, 2016.

Species	Yield at 35% DM	Population	Ears
	tons ac^{-1}	plants ac^{-1}	ears ac^{-1}
Control	21.2	**33142**	**31980**
Rye	21.5	23885	27987
Triticale	20.3	23994	27370
Wheat	**22.5**	27733	30819
LSD (*p* = 0.10)	NS	5009	NS
Trial Mean	21.4	27189	29539

Top performers appear in **bold.**
NS-No significant difference.

Interestingly, the decreased populations in the winter grain plots did not significantly affect silage yield. The corn variety used in the trial is categorized as a semi-flex ear type corn which compensate for low stand densities by producing larger ears, thus producing high yields despite low populations. This likely explains the observed discrepancy between populations and similar yields across treatments.

In terms of corn silage quality, winter grain species did not significantly impact corn quality (Table 6). Corn dry matter ranged from 42.2 to 44.3% but did not statistically differ across winter grain treatments. Protein ranged from 7.90 to 8.37% with a trial average of 8.07%. The ADF and NDF content also did not vary significantly by winter grain treatment. The ADF ranged from 19.6 to 20.5% and NDF ranged from 37.8 to 39.5%. The NDF digestibility (NDFD) did not differ across winter grain treatments ranging from 65.5 to 66.2%. The TDN, NE_L, and milk ton^{-1} were the highest in the rye treatment, however not statistically.

Table 6. Corn silage quality by winter grain species treatment, 2016.

	Corn silage quality characteristics							Milk	
Species	Dry matter %	Crude protein % of DM	ADF % of DM	NDF % of DM	NDFD 48 hr % of NDF	TDN % of DM	NE_L Mcal lb^{-1}	ton^{-1} lbs	ac^{-1} lbs
Control	**44.3**	7.90	20.3	39.5	**66.2**	72.1	0.711	3361	56669
Rye	42.2	7.93	20.5	38.7	66.1	**72.6**	**0.719**	**3406**	60644
Triticale	43.3	8.09	20.1	38.4	65.6	72.0	0.712	3361	55114
Wheat	43.1	**8.37**	**19.6**	**37.8**	65.5	72.4	0.716	3390	**61898**
LSD (p = 0.10)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Trial Mean	43.2	8.07	20.1	38.6	65.8	72.3	0.715	3380	58581

Top performers appear in **bold.**
NS-No significant difference.

Impact of Spring Nitrogen Rate

Spring forage yield and quality also differed significantly by N treatment (Table 7). Yield ranged from 1.64 to 2.29 tons ac^{-1} with the highest yields observed in the 50 and 25 lb ac^{-1} treatments. Yields increased by about 0.50 tons ac^{-1} with the addition of 25 lbs ac^{-1} nitrogen.

Table 7. Spring winter grain harvest yield and quality by nitrogen treatment, 2016.

Nitrogen Rate lbs ac^{-1}	Dry matter %	DM yield tons ac^{-1}	Crude protein % of DM	ADF % of DM	NDF % of DM	NDFD 30 hr % of NDF	RFV
0	**24.7***	1.64	14.1	28.4	46.1	**54.7**	136
25	22.7	2.10*	**15.6***	**27.8***	45.9	54.7	137
50	23.6*	**2.29***	15.4*	27.9*	**45.4**	54.4	**140**
LSD (p = 0.10)	1.31	0.334	1.14	0.503	NS	NS	NS
Trial Mean	23.7	2.01	15.0	28.0	45.8	54.6	138

Treatments with an asterisk* performed statistically similarly to the top performer in **bold.**
NS-No significant difference.

However, yields were not significantly impacted by fertilizing with an additional 25 lbs ac^{-1} nitrogen (Figure 2). Forage quality also differed by N treatment. Protein levels increased by 1.5% from the addition of 25 lbs ac^{-1} nitrogen but did not increase further in the 50 lbs ac^{-1} treatment. The ADF concentrations decreased slightly with the addition of N while NDF did not differ across treatments. These minor differences in ADF and NDF consequently resulted in RFV scores that did not significantly vary by treatments. Spring forage overall was of high yield and quality.

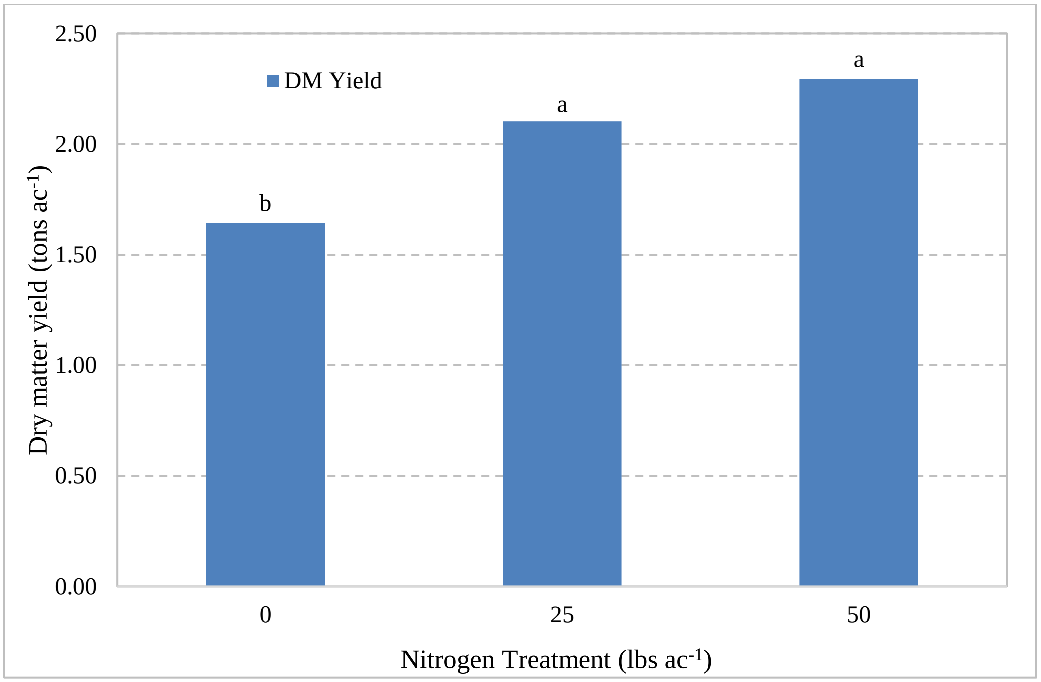

Figure 2. Spring forage yield by nitrogen treatment, 2016.
Treatments that share a letter performed statistically similarly.

Corn silage stand characteristics were not significantly impacted by cover crop N treatment (Table 8). Yields ranged from 20.0 to 22.2 tons ac^{-1}. Plant populations ranged from 26,245 to 27,770 plant ac^{-1} and corn ears ranged from 27,933 to 30,846 ears ac^{-1}. These data suggest that N applications of 0-50 lbs ac^{-1} to winter grain cover crops do not impact subsequent corn silage stand characteristics or yields. It is important to note that PSNT soil samples were taken to determine N needs of the corn crop. Hence, the corn was fertilized to the rate recommended in the soil test. So it is not expected that the N rate applied to the winter forage would impact the subsequent corn silage yields.

Table 8. Corn stand characteristics by cover crop nitrogen treatment, 2016.

Species	Yield at 35% DM	Population	Ears
	tons ac^{-1}	plants ac^{-1}	ears ac^{-1}
0	21.9	26245	27933
25	**22.2**	**27770**	**30846**
50	20.0	27552	29839
LSD (*p* = 0.10)	NS	NS	NS
Trial Mean	21.4	27189	29539

Top performers appear in **bold.**
NS-No significant difference.

Corn silage quality was also not significantly impacted by cover crop nitrogen treatments (Table 9). Dry matter ranged from 43.0 to 43.6% indicating even maturity at harvest. Protein decreased slightly, but not statistically significantly, with the addition of nitrogen. Similarly, ADF and NDF content increased slightly with the addition of nitrogen, but these increases were also not statistically significant. TDN and NE_L averaged 72.3% and 0.715 Mcal lb^{-1} respectively and did not differ by nitrogen treatment.

Table 9. Corn silage quality by cover crop nitrogen treatment, 2016.

	Corn silage quality characteristics							Milk	
Species	Dry Matter (DM)	Crude Protein	ADF	NDF	NDFD 48 hr	TDN	NE_L	ton^{-1}	ac^{-1}
	%	% of DM	% of DM	% of DM	% of NDF	% of DM	Mcal lb^{-1}	lbs	lbs
0	**43.6**	**8.20**	**19.7**	**37.9**	**65.9**	**72.4**	**0.716**	**3388**	59726
25	43.0	8.01	20.3	38.8	65.9	72.4	0.716	3387	**61402**
50	43.0	8.01	20.4	39.2	65.8	72.1	0.712	3364	54615
LSD (p = 0.10)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Trial Mean	43.2	8.07	20.1	38.6	65.8	72.3	0.715	3380	58581

Top performers appear in **bold.**
NS-No significant difference.

Interactions between winter grain species and spring nitrogen treatment

Significant interactions between winter grain species and spring N treatments were found for spring forage protein, ADF, and RFV values (Figure 3). These interactions indicate that the winter grain species responded differently to the N treatments in terms of these parameters. For example, protein levels increased with increasing N rates in rye treatments but seemed to have little impact on triticale and wheat protein concentrations. This difference may be related to the overall yield of the forages. Since the winter rye had the lowest spring yields, it is expected the protein content may be higher.

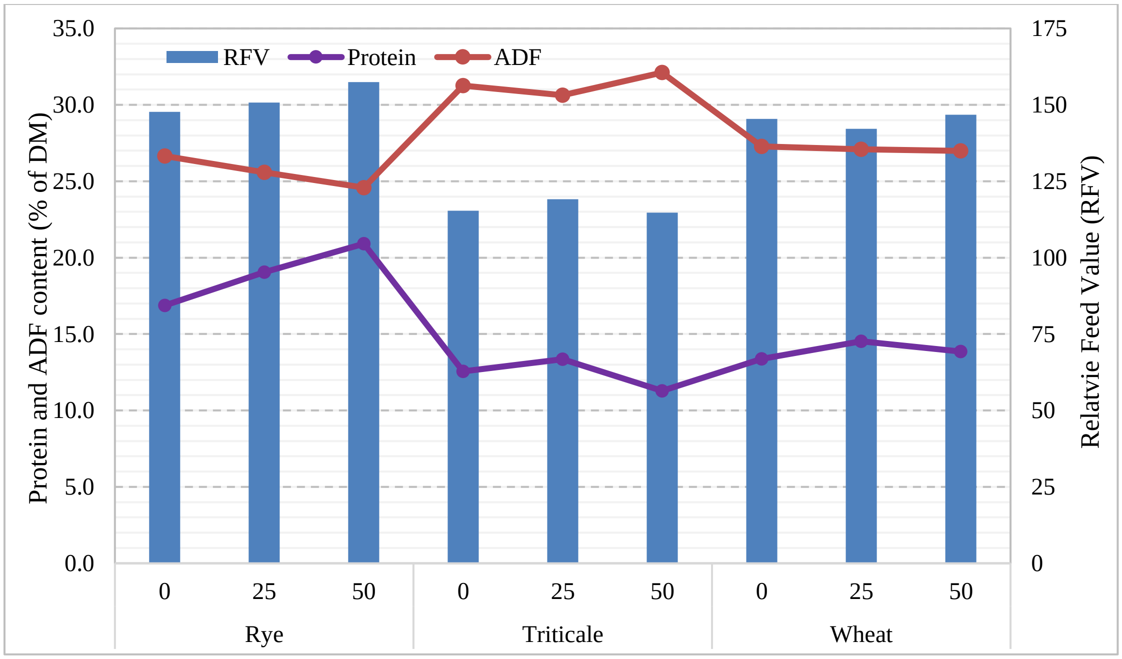

Figure 3. Interactions between winter grain species and nitrogen treatment in winter grain protein, ADF, and RFV, 2016.

DISCUSSION

This project demonstrates that winter grains, such as rye, wheat, and triticale, have the potential to add significant amounts of high quality forage to a corn silage system in the northeast. Overall, total dry matter produced from both winter grains and corn averaged about 10.1 tons ac^{-1} compared to control plots that produced about 7.5 tons ac^{-1} dry matter of just corn silage. In general, higher spring N applications translated into higher spring forage yields. However in terms of quality for rye, additional N increased protein consequently lowering ADF and increasing RFV. Triticale and wheat did not have as strong or clear of an N response as protein, and other quality parameters remained more consistent regardless of N treatment. These differential responses are important for producers to understand how management decisions for quality may differ based on the species of winter grain chosen. In addition, a critical point to remember is the difference in maturation timing of the winter grains in the spring. Ideally, we aim to harvest forage around the boot stage to take advantage of the highest yield and quality potential of the plant. However, this timing differed drastically for the winter grains as rye reached a harvestable maturity 19 days before triticale or wheat. Delaying cover crop termination and corn planting by 19 days may compromise corn yield and quality if a short maturity corn variety is not chosen. Alternatively the triticale and wheat could be harvested as early as the rye was, however decreased yield and quality may be observed in that situation. Understanding the differences in these winter grains, and how they may impact the suitability in your own operation is critical for successful integration of this practice. These data, however, only represent one year and should not be used alone to make management decisions.

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