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USING WINTER RYE AS FORAGE IN CORN SILAGE SYSTEMS

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Producing sufficient high quality forage throughout the year 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 winter rye, 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. To better understand how to successfully integrate winter rye forage into corn silage cropping systems, the University of Vermont Northwest Crops and Soils Program initiated a trial altering winter rye planting dates in combination with varying corn maturities.

MATERIALS AND METHODS

In the fall of 2015, winter rye was planted on three dates spanning the month of September (Table 1). Soil was sampled at each planting date and analyzed for nitrate nitrogen (N) and available phosphorus (P) content at the University of Vermont Agricultural and Environmental Testing Laboratory in Burlington, VT.

Table 1. Winter Rye and Corn Maturity Trial Management, Alburgh, VT 2015-2016.

Location	Borderview Research Farm – Alburgh, VT
Soil type	Benson rocky silt loam
Previous crop	Oats
Tillage operations	Chisel plow, disk and spike tooth harrow
Planting equipment (rye/corn)	Cone seeder / No-till corn planter (corn)
Seeding rates (rye/corn)	110 lbs ac^{-1} / 34,000 seeds ac^{-1}
Treatments (main plot)	Rye planting date: 31-Aug 2015 15-Sep 2015 25-Sep 2015 No cover crop
Treatments (subplot)	Corn maturity and variety: Short Season (Dyna-Gro D26VP56RIB; 86 RM) Mid-Season (Dyna-Gro D32RR56; 92 RM) Long Season (Dyna-Gro D47RR23; 107 RM)
Replications	4
Plot size (ft)	10 x 20
Corn planting date	23-May 2016
Harvest dates (rye/corn)	28-Oct 2015, 12-May and 19-May 2016 / 4-Oct 2016

Forage was harvested in the fall once temperatures had remained below 40°F for an extended period of time designating the end of the growing season for the rye. On 28-Oct 2015, plots were harvested by hand by cutting forage in two 1m sections to a height of three inches simulating grazing. The rye planted on the third planting date was not harvested because minimal growth had occurred by the time of harvest. An approximate 1 lb subsample was collected, dried, ground, and then analyzed for forage quality, nitrogen and phosphorus content. Dry matter content and yield 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. This data is still pending lab analysis and the report will be updated with this information in the future.

In the spring 2016, forage was harvested at the boot stage. Plots planted on the first planting date were harvested on 12-May and the second and third planting dates were harvested on 19-May 2016. 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 content and yield were calculated. After harvest, the remainder of the plots were mowed to three inches and soil was sampled for nitrate-N and available P. Winter grain stubble was terminated with RoundUp® on 20-May at a rate of 1 quart ac^{-1}. Three varieties of corn were planted into the grain plots using a John Deere 1750 no-till corn planter at a rate of 34,000 live seeds ac^{-1} on 23-May. Dyna-Gro variety D26VP56RIB was used as the short season corn variety with a relative maturity of 86 days. This variety is a Genuity® VT Triple Pro® RIB Complete® variety. Dyna-Gro variety D32RR56 was used as the mid-season corn variety with a relative maturity of 92 days. This variety is a Roundup Ready® variety. Dyna-Gro variety D47RR23 was used as the long season corn variety with a relative maturity of 107 days. This variety is also a Roundup Ready® variety. Corn was fertilized according to a pre-sidedress nitrate test on 24-Jun with 46-0-0 at a rate of 300 lbs ac^{-1}. Just prior to harvest, plant populations and number of ears were counted in each plot. Corn stalk nitrate samples were also collected from each plot at this time by cutting an eight inch segment of corn stalk at a height of six inches off the ground from five random plants in each plot. The samples were dried, ground, and sent to the University of Massachusetts, Amherst for analysis. Corn in all plots was harvested on 4-Oct. An approximate 1 lb subsample of harvested material was 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 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), 30-hour and 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 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). Because of these components and their association with the bulkiness of feeds, NDF is closely linked 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, meaning the hybrid yields were 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.

Growing Degree Days (GDDs) were calculated for the winter grains at a base temperature of 32°F and 50°F for the corn. The fall of 2015 was exceptionally dry and the winter very mild. From September 2015 through May 2016, there were 3440 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 Planting Date

Fall rye yield and quality varied significantly by planting date (Table 3). Most notable was the fact that rye planted at the end of September did not produce enough biomass to warrant harvest by the end of October 2015 (Image 1). The rye planted by the beginning of September yielded more than three times that of the rye planted two weeks later in mid-September. However in terms of quality, the mid-September planted rye was less mature by the time of harvest and was higher quality. This translated into protein levels 6% higher and ADF and NDF values 2% lower than the first planting date and a relative feed value (RFV) 22 points higher. Hence, in terms of having adequate biomass for grazing in the fall, the winter rye should be planted by early September.

Image 1. Rye at fall harvest in late October 2015. From left to right: planted 25-Sep, 15-Sep, and 31-Aug.

Table 3. Winter rye fall harvest yield and quality across three planting dates, 2015.

Planting Date	**Dry matter yield**	**Dry matter**	**Crude protein**	**ADF**	**NDF**	**NDFD 30 hr**	**RFV**
	tons ac^{-1}	%	% of DM	% of DM	% of DM	% of NDF	
31-Aug	**0.534**	22.1	27.1	16.8	33.7	51.8	211
15-Sep	0.166	23.6	**33.1**	**14.1**	**31.2**	51.6	**233**
25-Sep	-	-	-	-	-	-	-
LSD (p = 0.10)	0.141	NS	1.91	1.62	1.65	NS	13.4
Trial Mean	0.350	22.8	30.1	15.4	32.4	51.7	222

The treatment in **bold** is the top performer for that parameter.
NS-No significant difference.

In the spring 2016, yield and quality also varied statistically by planting date (Table 4). The highest yields were obtained in the second and third planting date treatments producing 2.33 and 1.78 tons ac^{-1} dry matter while the first planting date produced only 1 ton ac^{-1}. However, it is important to note that the first planting date treatment reached the boot stage and was harvested 7 days before the second and third planting date. This may account for some of the observed differences in planting date in terms of yield in the spring. The first planting date also produced the highest quality forage with about 4% higher protein, 3% lower ADF, 3-5% lower NDF, and 2% higher NDF digestibility. This translated into a RFV score 22 and 17 points higher than the second and third planting dates respectively.

Table 4. Winter rye spring harvest yield and quality across three planting dates, 2016.

Planting date	Dry matter yield	Dry matter	Crude protein	ADF	NDF	NDFD 30 hr	RFV
	tons ac^{-1}	%	% of DM	% of DM	% of DM	% of NDF	
31-Aug	0.999	19.3	**19.3**	**25.0**	**41.3**	57.2*	**156**
15-Sep	**2.33**	19.4	15.8	28.4	46.6	**57.3**	134
25-Sep	1.78*	**19.2**	15.4	28.3	44.8	55.9	139
LSD (p = 0.10)	0.590	NS	1.18	0.588	1.21	1.12	4.26
Trial Mean	1.70	19.3	16.8	27.2	44.2	56.8	143

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

When we compare planting dates in terms of combined spring and fall yields, the first planting date provided the most forage in the fall but only about 1 ton ac^{-1} additionally in the spring. Conversely, the second planting date produced about 1/3 the dry matter of the 1st planting date in the fall, but over 2 tons ac^{-1} in the spring (Figure 1). This corresponds to the second planting date producing about 1 ton ac^{-1} more dry matter overall compared to the first planting date. Interestingly, even the third planting date produced similar overall yields to the first planting date, however all this biomass was produced in the spring as opposed to having some forage available in the fall with the first planting date. Again, it is important to note that the first planting date reached the boot stage in the spring 7 days before the second and third planting dates, so although yields were lower, there was an additional benefit of harvest timing that could allow for more timely corn planting following winter grain forage harvest.

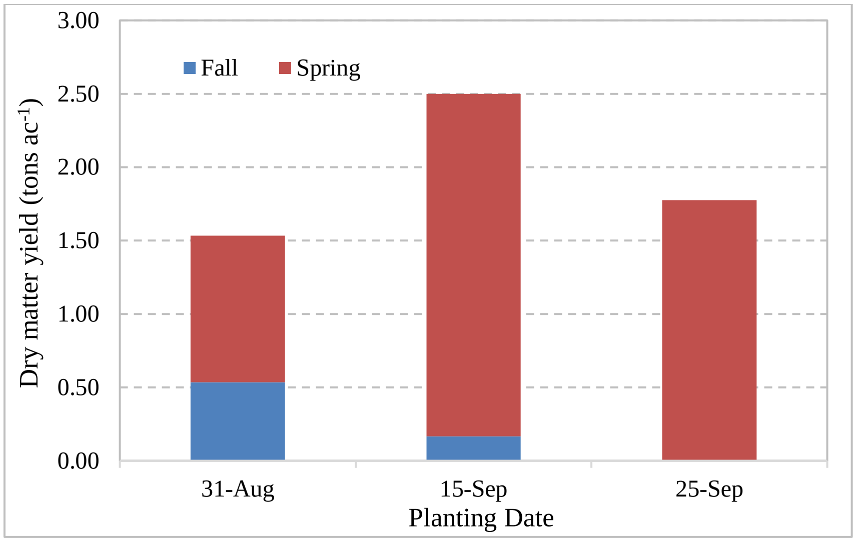

Figure 1. Combined fall and spring dry matter yield by planting date, 2016.

Corn silage yield did not differ significantly by cover crop planting date (Table 5). Yields ranged from 22.1 to 24.5 tons ac^{-1} with an average of 23.4 tons ac^{-1}. These data indicate that no yield penalty was experienced as a result of having a winter grain cover crop prior to a corn silage crop. In this system, where cover crop biomass is largely removed through harvesting or grazing, there is less concern of tying up nitrogen during cover crop decomposition compared to traditional cover cropping systems. Corn populations and number of ears also did not differ significantly by planting date. Populations were low compared to seeding rates but were consistently low across planting date treatments including the control. This was due to excessively dry conditions at the time of planting. It is important to note that harvesting a small grain forage crop prior to growing a corn crop will require more fertility to be added to this field.

Table 5. Corn silage yield and stand characteristics, 2016.

Planting Date	Yield at 35% DM	Population	Ears
	tons ac^{-1}	plants ac^{-1}	ears ac^{-1}
Control	22.1	24866	25289
31-Aug	23.6	**27842**	**27479**
15-Sep	**24.5**	24575	25483
25-Sep	23.3	24829	25337
LSD (p = 0.10)	NS	NS	NS
Trial Mean	23.4	25578	25882

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

Corn silage quality did significantly vary by cover crop planting date for some parameters (Table 6). Plots where no cover crop was planted produced corn with the highest TDN, NE_L, and milk ton^{-1}, as well as the lowest ADF and NDF. However for each of these parameters, the control performed statistically similarly to rye planted on 31-Aug or 25-Sep.

Table 6. Corn silage quality across four cover crop planting date treatments, 2016.

Planting Date	Corn silage quality characteristics							Milk	
	Dry matter	**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
Control	42.0	**8.09**	21.3*	**39.6**	68.0	**72.7***	**0.720***	**3414***	26422
31-Aug	**41.0**	7.96	**21.3**	39.8*	**68.1**	72.5*	0.717*	3394*	28058
15-Sep	41.5	7.78	22.5	42.2	67.8	71.3	0.702	3297	**28332**
25-Sep	42.4	7.62	21.9*	40.7*	68.3	72.3*	0.714*	3377*	27594
LSD (p = 0.10)	NS	NS	0.953	1.70	NS	0.759	0.009	60.6	NS
Trial Mean	41.7	7.86	21.8	40.6	68.1	72.2	0.713	3370	27601

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

Impact of Corn Relative Maturity

Corn silage yields varied significantly by relative maturity (Table 7). The highest yields were observed in the mid-season corn with a maturity of 92 days which produced 25.7 tons ac^{-1}. This was statistically similar to the long-season corn with a maturity of 107 days which produced 23.3 tons ac^{-1}. The short-season corn only yielded 21.2 tons ac^{-1}, about 2 tons less than the trial average. Populations and number of ears did not vary significantly across the corn maturities.

Table 7. Corn silage yield and stand characteristics, 2016.

Relative Maturity	Yield at 35% DM	Population	Ears
	tons ac^{-1}	plants ac^{-1}	ears ac^{-1}
Short (86 Days)	21.2	25156	26354
Mid (92 Days)	**25.7***	**26272**	**27198**
Long (107 Days)	23.3*	25156	24094
LSD (p = 0.10)	2.93	NS	NS
Trial Mean	23.4	25578	25882

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

Corn quality also varied significantly across corn maturity treatments (Table 8). Dry matter ranged from 38.7 to 43.6%. As expected dry matter decreased with increasing maturity, however the short and mid-season corn treatments had statistically similar dry matter levels. This indicates that, at the time of harvest, the short and mid-season corn treatments had dried down to similar levels while the long season corn had dried significantly less. All corn maturities reached adequate dry matter levels for proper ensiling. Corresponding to yield performance, the mid- and long season corn treatments produced corn with the highest projected milk yield in terms of lbs milk ac^{-1} which were 30,352 and 27,584 lbs ac^{1} respectively. Corn maturities performed consistently in terms of NDF, TDN, NE_L, and milk ton^{-1}. Protein was highest in the long season corn treatment with 8.20% which was statistically similar to the short season corn. ADF was the lowest in the mid-season corn with 20.7%, 2% lower than the short and long season treatments. NDF digestibility was highest in the mid-season treatment of 68.5%, similar to the long season treatment.

Table 8. Corn silage quality across three corn maturity treatments, 2016.

Relative Maturity	Corn silage quality characteristics							Milk	
	Dry matter	**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
Short (86 Days)	**43.6***	7.78*	22.3	40.6	67.3	71.8	0.710	3347	24868
Mid (92 Days)	42.8*	7.60	**20.7***	**39.9**	**68.5***	72.3	0.713	3376	**30352**
Long (107 Days)	38.7	**8.20***	22.3	41.2	68.4*	**72.4**	**0.716**	**3389**	27584*
LSD (p = 0.10)	1.32	0.491	0.826	NS	0.685	NS	NS	NS	3529
Trial Mean	41.7	7.86	21.7	40.6	68.1	72.2	0.713	3370	27601

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

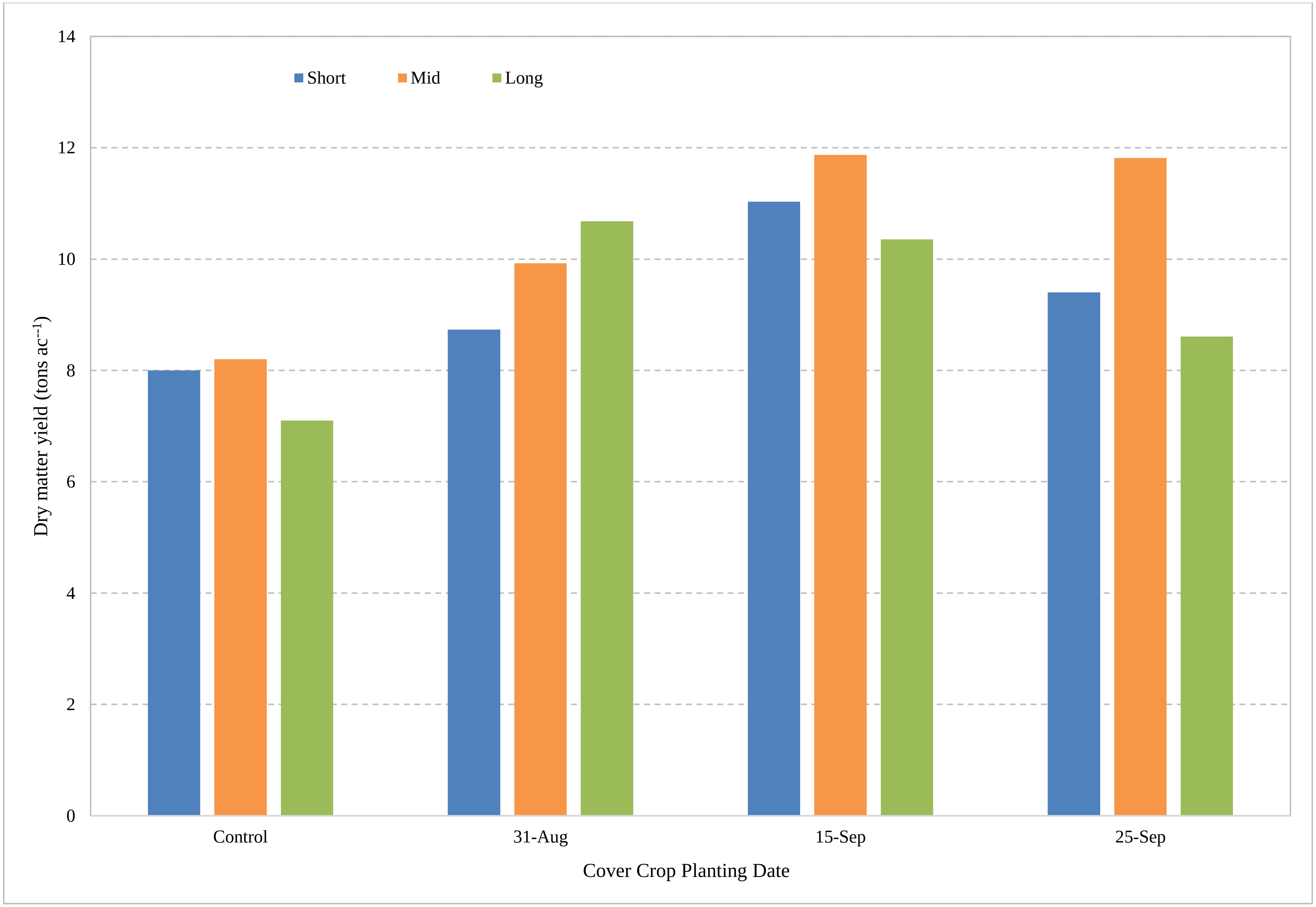

Figure 2. Combined dry matter yield of rye cover crop and corn silage over three planting dates and three corn maturities

DISCUSSION

This project demonstrates that winter rye can be utilized to increase forage yields in corn silage systems in the northeast. If planted by early September, winter rye provided about 0.50 tons ac^{-1} of high quality forage for harvest or grazing into late October. If planted by mid-September, lower fall yields were observed, however substantial yields over 2 tons ac^{-1} were be obtained in the following spring. If planted by late September, winter rye did not have adequate time to grow to a harvestable size to provide any forage in the fall. However, the following spring yields over 1.5 tons ac^{-1} were obtained. Furthermore, rye planted in mid- and late September matured later in the spring than rye planted in early September, delaying harvest and subsequently corn planting. Delaying corn planting may not be of concern if using a corn variety with a short relative maturity. However, delaying planting when using a long season corn variety can pose complications with the crop having ample time to fully mature and dry down in the fall, depending on weather conditions. This year weather conditions were very dry for the majority of the summer and into the fall reducing this risk; all corn maturity groups reached adequate dry matter for proper ensiling. Despite corn yields of mid- and late maturity corn treatments being a few tons ac^{-1} higher than short season treatments this year, this relationship will likely be different in a year with less favorable weather conditions. It is important to understand how both rye planting date and corn maturity can impact yield and quality of forage provided throughout the season. Combined dry matter yields of corn silage and rye forage averaged 9.64 tons ac^{-1} in this trial, demonstrating the potential for winter rye to add substantial forage of high quality to corn silage cropping systems in this region (Figure 2). It is important to note that these data only represent one year, and therefore should not be used alone to make management decisions.

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