2020 Impact of Cover Crops on No-Till Spring Grain Production

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Soil health is fundamentally important to crop productivity. Cover cropping is one method of improving soil health, by preventing soil erosion and nutrient runoff, improving soil aggregation and nutrients, as well as providing other benefits to soils and crop productivity. Cover crops have also been noted for their ability to suppress weeds. Some cover crops have been noted for their allelopathic characteristics, which can decrease the germination of weeds. No-till and reduced tillage practices can also increase water infiltration and reduce soil degradation while keeping carbon in the soil. Different types of cover crops, such as grasses, legumes, and brassicas, have different benefits for soil health and nutrient retention. Cover crops are even being utilized as a forage on dairy farms. There is a need for more research on cover crops to define the best species, varieties, and mixes for a Northeastern climate and for achieving higher cash crop yields. To examine the impact of winter terminated cover crops on yields of no-till spring wheat, the University of Vermont Extension’s Northwest Crop and Soils (NWCS) Team conducted a field trial with cover crops planted fall 2019 and spring wheat grown in the 2020 field season. The suitability of the cover crops as forages were also examined.

MATERIALS AND METHODS

Winter terminated cover crops were planted on 15-Aug 2019 at Borderview Research Farm in Alburgh, VT with a cone seeder (Table 1). The experimental design was a randomized complete block with four replicates and 5’ buffers. The previous crop was spring barley and the soil type was Benson rocky silt loam with 8-15% slopes.

Table 1. No-till spring grain cover cropping trial specifics for Alburgh, VT, 2019-2020.

	Borderview Research Farm Alburgh, VT
Soil type	Benson rocky silt loam 8-15% slopes
Previous crop	Spring barley
Cover crop planting date	15-Aug 2019
Plot size (feet)	5 x 20
Replicates	4
Spring wheat planting date	8-Apr 2020
Spring wheat seeding rate (lbs ac^{-1})	150
Harvest date	29-Jul 2020

The treatments included five cover crop treatments and a non-cover cropped control. Cover crop treatments consisted of ‘Piper’ Sudangrass at 50 lbs ac^{-1}, ‘Everleaf’ oats at 125 lbs ac^{-1}, ‘Wonderleaf’ millet at 30 lbs ac^{-1}, ‘Quest’ barley at 125 lbs ac^{-1}, and a cover crop mix planted at 75 lbs ac^{-1} (Table 2). The mix consisted of ‘Everleaf’ oats, ‘Dixie’ crimson clover, ‘Daikon’ tillage radish, ‘Everleaf’ oats, and ‘Aruica’ peas (at 60, 40, 4, 75, 50 lbs ac^{-1}, respectively).

Table 2. Cover crop treatments, 2019-2020.

Cover crop	Seeding rate lbs ac^{-1}
Piper sudangrass	50
Wonderleaf millet	30
Everleaf oats	125
Quest barley	125
Mix	75
Everleaf oats	*60 lbs*
Crimson clover	*40 lbs*
Daikon radish	*4 lbs*
Everleaf oats 2	*75 lbs*
Aruica peas	*50 lbs*

Fall biomass was harvested from two 0.25 m^2 quadrats in each plot on 9-Oct 2019, then weighed and dried in order to calculate dry matter content and yield. The biomass samples were ground in a Wiley mill, then ground again in an UDY Corporation cyclone laboratory mill (1mm screen) for forage quality analysis. Ground samples were analyzed for dry matter, crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF), and 48-hour digestible NDF (NDFD), and lignin using a FOSS NIRS (near infrared reflectance spectroscopy) DS2500 Feed and Forage analyzer at the University of Vermont's Cereal Grain Testing Laboratory, in Burlington, VT. The CP content of forages are mixtures of true proteins; amino acids and non-protein nitrogen and is determined by multiplying the amount of nitrogen by 6.25. The more fiber a forage contains, the greater the feeding value, since the fiber components of the plant are the less digestible fraction. Neutral detergent fiber (NDF) measures the total fiber content, which includes cellulose, hemicellulose, and lignin. NDFD is based on the in vitro digestibility calculation over a specified period of time. In this report, NDFD is based on 48-hour in vitro testing. Total digestible nutrients (TDN) and Net energy of lactation (NEL) were calculated from forage analysis data. Samples were analyzed for carbon and nitrogen at the University of Vermont's Agricultural and Environmental Testing Laboratory on a CN Elemental Analyzer. Percent spring residue cover of the cover crops was measured with the beaded string line-transect method (Sloneker and Moldenhauer, 1977) on 8-Apr 2020.

Organic ND Vitpro hard red spring wheat (Albert Lea Seed, Albert Lea, MN) was planted into no-till plots on 8-Apr 2020 with a Sunflower grain drill at a rate of 150 lbs ac^{-1}. Spring grains population data were collected on 13-May 2020 by counting the number of plants in three 1-foot sections along a planted row per plot. Grain was harvested on 29-Jul with an Almaco SPC50 plot combine and harvest areas were 5' x 20'. Prior to harvest, three heights per plot were measured with a meter stick, and lodging was assessed visually and recorded as a percentage of the plot. Also prior to harvest, two 0.25 m^2 quadrats of biomass from each plot was collected and sorted into wheat and weeds, and total weights of the wheat and weeds were measured in order to calculate weed density. Grain moisture, test weight, and yield were recorded at harvest. Moisture and test weight were measured with a DICKEY-John MINI GAC Plus meter.

Grain quality was determined at UVM Extension's Northwest Crop and Soils Quality Testing Laboratory (Burlington, Vermont). Samples were ground using the Perten LM3100 Laboratory Mill. Flour was analyzed for protein content using the Perten Inframatic 8600 Flour Analyzer. Most commercial mills target a protein content of 12-15%. Falling number was measured (AACC Method 56-81B, AACC Intl.,

2000) on the Perten FN 1500 Falling Number Machine. The falling number is related to the level of sprout damage in the grain. It is determined by the time it takes, in seconds, for a stirrer to fall through a slurry of flour and water to the bottom of a test-tube. Falling numbers greater than 350 indicate low enzymatic activity and sound quality wheat. A falling number lower than 200 indicates high enzymatic activity and poor-quality wheat. Deoxynivalenol (DON), a vomitoxin, was analyzed on one replicate using Veratox DON 5/5 Quantitative test from the NEOGEN Corp. This test has a detection range of 0.5 to 5 ppm. Samples with DON values greater than 1 ppm are considered unsuitable for human consumption.

Cover crop data were analyzed using a general linear model procedure of SAS (SAS Institute, 2008). Replications were treated as random effects, and treatments were treated as fixed. Mean comparisons were made using the Least Significant Difference (LSD) procedure where the F-test was considered significant, at $p<0.10$. Grain yield data were analyzed using a Mixed Model procedure of SAS. Mean comparisons were made using the Tukey-Kramer adjustment with a significance level of $p<0.10$.

Variations in genetics, soil, weather, and other growing conditions can result in variations in yield and quality. Statistical analysis makes it possible to determine whether a difference between treatments is significant or whether it is due to natural variations in the plant or 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. This means that when the difference between two treatments within a column is equal to or greater to the LSD value for the column, there is a real difference between the treatments 90% of the time. Treatments that were not significantly lower in performance than the highest value in a particular column are indicated with an asterisk. In the following example, treatment C was significantly different from treatment A, but not from treatment B. The difference between C and B is 1.5, which is less than the LSD value of 2.0 and so these treatments were not significantly different 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 treatments were significantly different from one another. Treatment B was not significantly lower than the top yielding treatment, indicated in bold. A lack of significant difference is indicated by shared letters.

Treatment	Yield
A	6.0^{b}
B	7.5^{ab}
C	**9.0^{a}**
LSD	2.0

RESULTS

Weather data were recorded with a Davis Instrument Vantage Pro2 weather station, equipped with a WeatherLink data logger at Borderview Research Farm in Alburgh, VT (Table 3). In the fall and winter of 2019, conditions were slightly cool except in October, while the spring 2020 growing season saw above average temperatures in June and July, which were 1.08° F and 4.17° F warmer than the 30-year norm. Precipitation was below average April-July 2020. While Growing Degree Days (GDDs) lagged behind in April and May, they increased in June and July. July 2020 saw 1326 GDDs, 132 above the average. Overall, precipitation from August 2019 to July 2020 was 2.38” below average, and 6442 GDDs were accumulated over the season, 45 less than the 30-year norm. From May to July 2020 alone, 3118 GDDs accumulated, 154 above the norm.

Table 3. Seasonal weather data collected in Alburgh, VT, 2019-2020.

	2019					2020						
	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
Average temperature (°F)	68.3	60.0	50.4	31.2	26.0	23.5	21.8	35.0	41.6	56.1	66.9	74.8
Departure from normal	-0.51	-0.51	2.32	-6.76	0.46	4.62	0.41	3.94	-3.19	-0.44	1.08	4.17
Precipitation (inches)	3.50	3.87	6.32	2.38	1.29	2.63	1.19	2.79	2.09	2.35	1.86	3.94
Departure from normal	-0.41	0.21	2.76	-0.74	-1.06	0.63	-0.53	0.57	-0.72	-1.04	-1.77	-0.28
Growing Degree Days (base 32°F)	1125	840	571	128	67	37	48	193	315	746	1046	1326
Departure from normal	-15	-15	58	-122	-13	-12	-8	27	-99	-13	35	132

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.

Winter Terminated Cover Crop Quality

Fall 2019 cover crop quality results are displayed in Table 4. Cover crop yields and carbon and nitrogen concentrations were similar between treatments. The cover crop mix yielded the most biomass, 1778 lbs ac^{-1} dry matter, followed by the Everleaf oats at 1527 lbs ac^{-1}, then the Quest barley at 1468 lbs ac^{-1}. Dry matter content was significantly higher in the Piper sudangrass (14.6%), Wonderleaf millet (14.4%), Quest barley (13.3%), and the control (13.3%) than the Everleaf oats (10.6), and the mix (10.5%).

For forage quality, the mix was the top performer in several categories. The mix had a significantly lower NDF at 44.4% than the Piper sudangrass and Wonderleaf millet, and the mix also had a significantly higher TDN value (62.8) than Wonderleaf millet and Piper Sudangrass. Lignin was statistically lower in the Quest barley (5.23%) than the mix (7.42%), Everleaf oats (7.30%), and Piper sudangrass (6.98%). 48-hour NDF digestibility was greatest in the Everleaf oats at 91.3% NDF, which outperformed the Quest barley, Wonderleaf millet, and Piper sudangrass (82.0, 75.3, and 73.8% NDF respectively). While Everleaf oats was the top-performer, it was also similar to the control, at 86.9% NDF. Net energy of lactation was significantly greater in the mix, at 0.653 Mcal lb^{-1}, than the Wonderleaf millet and Piper sudangrass (0.531 and 0.553 Mcal lb^{-1}). Crude protein and ADF did not vary by cover crop treatment.

Table 4. Impact of treatment on cover crop yield and forage quality, Alburgh, VT, 2019-2020.

Treatment	DM yield	DM	Carbon	Nitrogen	CP	ADF	NDF	Lignin	TDN	48 hr-NDFD	NE_L
	lbs ac^{-1}	%	%	%	-------------------% DM------------------					% of NDF	Mcal lb^{-1}
Quest barley	1468	13.3^{a†}	40.7	3.22	25.5	31.2	49.9^{ab}	**5.23^{c}**	60.3^{ab}	82.0^{bc}	0.603^{ab}
Control	1011	13.3^{a}	**41.0**	**3.56**	**28.2**	**30.6**	45.8^{b}	5.80^{bc}	62.5^{a}	86.0^{ab}	0.639^{a}
Wonderleaf millet	1351	14.4^{a}	40.6	3.28	23.3	33.5	55.7^{a}	6.45^{abc}	55.3^{c}	75.3^{c}	0.531^{c}
Mix¥	**1778**	10.5^{b}	40.5	3.23	25.4	34.1	**44.4^{b}**	7.43^{a}	**62.8^{a}**	87.3^{ab}	**0.653^{a}**
Everleaf oats	1527	10.6^{b}	39.9	2.90	23.9	34.3	46.6^{b}	7.30^{a}	59.8^{ab}	**91.3^{a}**	0.621^{a}
Piper sudangrass	1028	**14.6^{a}**	40.7	3.39	25.0	35.0	54.8^{a}	6.98^{ab}	57.5^{bc}	73.8^{c}	0.553^{bc}
LSD (*p* = 0.10)‡	NS§	1.74	NS	NS	NS	NS	7.01	1.28	3.33	8.97	0.054
Trial Mean	1361	12.8	40.6	3.26	25.2	33.1	49.5	6.53	59.7	82.6	0.599

†Treatments within a column with the same letter are statistically similar. Top performers are in **bold**.

‡ LSD- Least significant difference at p=0.10. §NS- Not significant.

¥Mix; 'Everleaf' oats, crimson clover, 'Daikon' radish, 'Aruica' peas.

Field Season and Harvest Results

The Everleaf oats, followed by the barley then cover crop mix, had the greatest spring ground cover (Image 1). Everleaf oats resulted in 92% ground cover (Table 5). While there were no statistical differences this year, these top-performers also had the highest percent ground cover in 2019, and were statistically different than other treatments in that year. In 2020, wheat populations, heights, lodging, and weed density at grain harvest also did not differ statistically. The mix resulted in the highest wheat population at 321 plants m^{-2}, the millet resulted in the highest average wheat height at 66.8 cm, and all treatments had an average of 1 for lodging on a 0-9 scale, where 0 is no wheat lodging and 9 is a completely lodged plot. Weed density at grain harvest was the lowest in the cover crop mix treatment plots, at 10.5%, followed by Quest barley at 13.6%. While not significant, these treatments had much lower rates of weeds than the other plots, which ranged from 21.1% to 37.8%. Weed density increased in comparison to last year; the trial average was 9.54% in 2019. This may be due to poor wheat establishment in spring 2020.

Table 5. Field season measurements in no-till spring wheat by cover crop treatment, Alburgh, VT, 2020.

Treatment	Spring cover crop ground cover %	Population m^2	Average height cm	Lodging 0-9†	Weed density % of biomass
Quest barley	88.5	269	64.9	1.00	13.6
Control	80.0	256	63.0	1.00	33.5
Wonderleaf millet	79.0	215	**66.8**	1.00	21.1
Mix‡	85.5	**321**	62.6	1.00	**10.5**
Everleaf oats	**92.0**	291	59.6	1.00	30.1
Piper sudangrass	73.5	194	56.0	1.00	37.8
LSD (*p* = 0.10)§	NS¥	NS	NS	NS	NS
Trial Mean	83.1	273	62.6	1.00	22.1

†‡Lodging is on a 0-9 scale where 0 is none and 9 is completely lodged. ‡Mix; 'Everleaf' oats, crimson clover, 'Daikon' radish, 'Aruica' peas. §LSD; Least significant difference at p=0.10. ¥NS; Not significant.

Image 1. Spring cover in plots with Everleaf oats, cover crop mix, Sudangrass, and a non-cover cropped control (left to right). Alburgh, VT, 2020.

Grain yields in the cover crop treatments were similar, and out-yielded the control (Table 6, Figure 1). The only statistically significant metric was harvest moisture, where the barley had a significantly lower moisture (17.3%) than the sudangrass (21.4%). The mix had the highest wheat yield at 13% moisture, yielding 963 lbs ac^{-1}. All treatments were below the USDA standard test weight of 58 lbs bu^{-1}. Quest barley had the highest test weight at 54.3 lbs bu^{-1}, and the Piper sudangrass treatment had the lowest at 50.7 lbs bu^{-1}. The Piper sudangrass treatment had wheat with the highest flour crude protein, 17.0% at 12% moisture, and the control had the highest falling number, 401 seconds. No detectible levels of DON were found.

Table 6. Spring wheat heights and yields by treatment, Alburgh, VT, 2020.

Treatment	Grain yield at 13% mst lbs ac^{-1}	Harvest moisture %	Test weight lbs bu^{-1}	Crude protein @ 12% moisture %	Falling number seconds
Quest barley	877	**17.3**^{a†}	**54.3**	16.3	391
Control	535	19.9^{ab}	52.0	16.9	**401**
Wonderleaf millet	639	19.4^{ab}	52.8	16.9	356
Mix‡	**963**	18.4^{ab}	52.6	16.6	391
Everleaf oats	788	19.6^{ab}	51.9	16.6	387
Piper sudangrass	753	21.4^{b}	50.7	**17.0**	361
P-value (p<0.10)	NS¥	0.078	NS	NS	NS
Trial mean	786	19.0	52.7	16.6	386

†Treatments within a column with the same letter are statistically similar.
‡Mix; 'Everleaf' oats, crimson clover, 'Daikon' radish, 'Aruica' peas.
¥NS; Not significant.

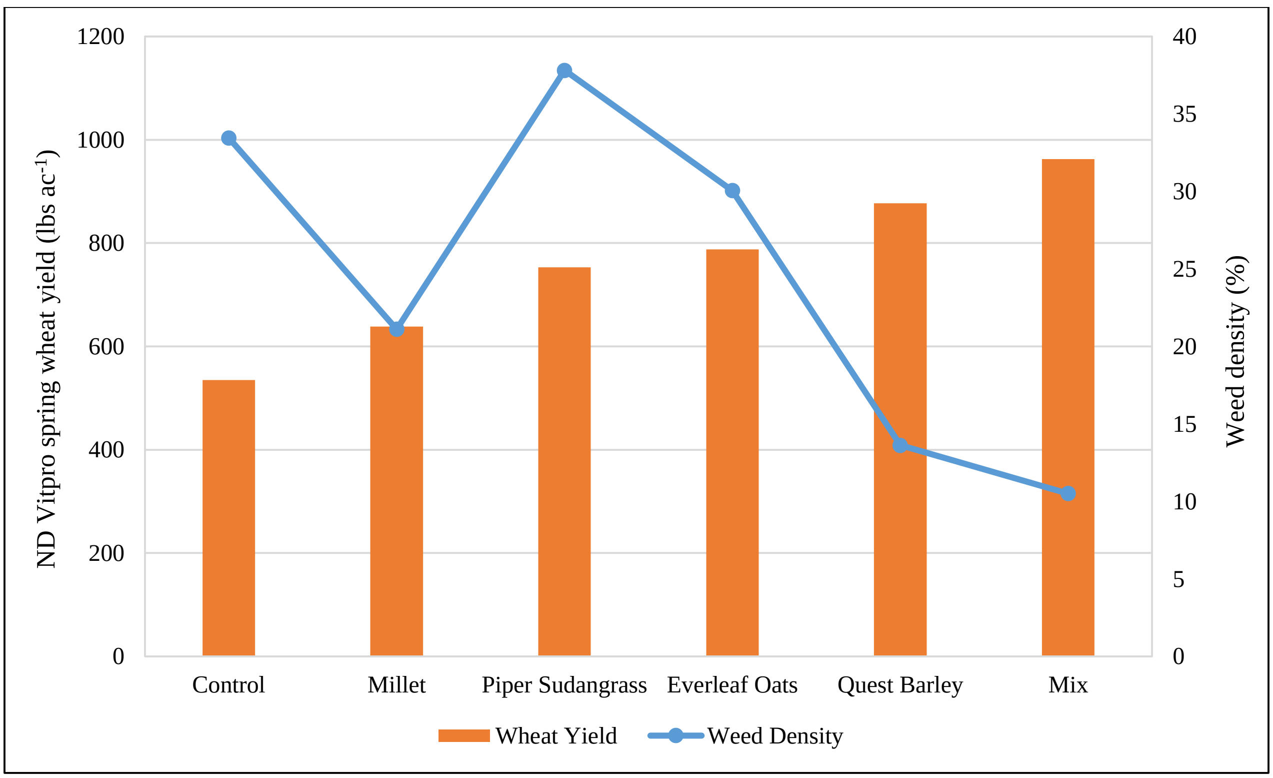

Figure 1. Weed density and spring wheat yields by cover crop species, Alburgh, VT, 2020.

DISCUSSION

The cover crop mix, Everleaf oats, and barley provided the best cover crop forage yields, spring ground cover, and wheat yields in comparison to the other treatments, though there were no statistical differences. The cover crop mix, followed by the barley, had the lowest weed densities at harvest. These results are similar to previous years, when Everleaf oats, barley, and a mixture containing Everleaf oats were also the top performers. Oats have been documented to produce root exudates that can suppress seed germination. Further research must be conducted to evaluate if oats can provide adequate weed suppression. One reason these top-performers may not be statistically different this year, unlike in 2018 and 2019, may be due to loss of data. Harvest data for several plots was not collected due to plots being mowed out unintentionally. The cover crops exhibited value as a forage for livestock operations.

It is important to remember this trial only represents one season of data. Further study is needed to evaluate the efficacy of oats and barley as cover crops. If the results of this trial are reproducible in future years, oats may be a cover crop that farmers could implement to suppress weeds, and barley, along with oats, may be used to increase cover crop yields while improving soil health and water quality.

REFERENCES

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ACKNOWLEDGEMENTS

The UVM Extension Northwest Crops and Soils Program would like to thank Roger Rainville and the staff at Borderview Research Farm for their generous help and hosting this trial as well as Henry Blair, John Bruce, Catherine Davidson, Hillary Emick, Lindsey Ruhl, and Sara Ziegler for their assistance with data collection and entry. Any reference to commercial products, trade names, or brand names is for information only, and no endorsement or approval is intended.

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