NORTHWEST CROPS & SOILS PROGRAM

Impact of Cover Crop Termination Timing on Grain Corn Productivity

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IMPACT OF COVER CROP TERMINATION TIMING ON GRAIN CORN PRODUCTIVITY

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In 2020, UVM Extension's Northwest Crops & Soils Program initiated a three-year trial at Borderview Research Farm in Alburgh, VT to assess the impact of cover crop termination timing on weed biomass, corn seedling populations, vigor, pest damage, and grain corn yield. Cover crops can offer a wide range of benefits including improved soil health, weed suppression, and erosion control. These benefits can contribute to higher crop yield and better crop quality. However, the impact a cover crop has on these benefits can be impacted by amount of plant material (biomass), which can increase with later termination timing. This project evaluated early season corn grain plant stands, weed biomass, and yields of four cover crop management practices: no cover crop, planting brown (cover crop terminated 3-4 weeks before corn planting), planting green/brown (cover crop terminated 2-8 days before corn planting), and planting green (cover crop terminated 3-5 days after corn planting).

MATERIALS AND METHODS

The corn cropping system trial was established at Borderview Research Farm in Alburgh, VT in 2020. The experimental design was a randomized complete block with five replicated treatments of corn grown under various cover crop management practices (Table 1). The trial location moved to a different field each year of the study.

Table 1. Cover crop termination practices and descriptions.

Management Practice	Description
No cover crop	Bare
Terminated 3-4 weeks before planting	Brown
Terminated 2-8 days before planting	Green/Brown
Terminated 3-5 days after planting	Green

The soil type at the research site was a Covington silty clay loam 0-3% slope (Table 2). Each cover crop management practice was replicated 5 times in 40' x 50' plots. Cover crops were planted to winter rye (var. AC Hazlet) at 70 lbs ac^{-1}, at the end of September or early October each year. Cover crop biomass was measured just prior to termination with a glyphosate herbicide. Cover crop dry matter yields were calculated by collecting material from quadrats in each plot. Brown cover crop treatments were terminated at the end of April, Green/Brown cover crop treatments in mid-May, and Green cover crop treatments at the end of May. Bare plots were also sprayed to remove any weedy biomass in each plot. Weed biomass was assessed in each plot when corn was in the 5th leaf stage (V5). Weed biomass was collected in quadrats and dry yields were calculated from each plot.

Corn was seeded in 30" rows with a John Deere 1750 corn planter. The corn variety was Seedway 3854RR (RM 95) in year one and Syngenta NK9535-3220 (RM 95) in subsequent years. Across years, seeding rate varied between 30,000 and 31,800 seeds ac^{-1}. At planting, starter fertilizer was applied to all corn plots.

Soil samples were collected for presidedress nitrate tests (PSNTs). The PSNT soil samples were collected with a 1-inch diameter Oakfield core to 12 inches in depth at seven locations per plot. The samples were combined by plot and analyzed by UVM's Agricultural and Environmental Testing Lab using KCl extract and ion chromatograph. Sidedress nitrogen was applied according to PSNT test results.

Corn seedling vigor was evaluated when corn plants in the plots reached the 3rd leaf stage (V3). Vigor was assessed by counting corn seedling populations in two rows each 1/1,000 of an acre and determining the majority growth stage. Corn seedling pest damage was evaluated when corn plants in the plots reached the 5th leaf stage (V5). Damage was assessed by counting corn seedling populations and the number damaged in 9.84''sections in three rows. Corn was harvested in four rows 17'5" long the first year and with a combine harvester the length of the plot in subsequent years. Yield was calculated at harvest with scales. Grain moisture and test weight were determined at harvest (DICKEY-john Mini GAC moisture and test weight meter, Auburn, IL). Yields were calculated and adjusted to 13% moisture.

Table 2. Agronomic information for cover crop practice management, Alburgh, VT, 2020-2023.

Location	Borderview Research Farm – Alburgh, VT
Soil type	Covington silty clay loam 0-3% slopes
Previous crop	2020: soybean 2021: corn grain 2022: corn silage
Cover crop variety and seeding rate	Hazelet winter rye at 70 lbs ac^{-1}
Cover crop planting date	5-Oct 2020 20-Sep 2021 4-Oct 2022
Plot size (ft)	40 x 50
Replications	5
Cover crop management treatments	No cover crop (Bare), terminated 3-4 weeks before planting (Brown), terminated 2-8 days before planting (Green/Brown), 3-5 days after planting (Green)
Bare termination date	21-May 2021 28-Apr 2022 27-Apr 2023
Brown termination	26-Apr 2021 28-Apr 2022 27-Apr 2023
Green/brown termination date	10-May 2021 11-May 2022 9-May 2023
Green	21-May 2021 18-May 2022 18-May 2023

Table 2. Agronomic information for cover crop practice management trial, Alburgh, VT, 2020-2023 (cont'd).

Location	Borderview Research Farm – Alburgh, VT
Bare herbicide and rate	2021: PowerMax® 1 qt ac^{-1} 2022: PowerMax® 1 qt ac^{-1} 2023: Glystar® plus 1 qt ac^{-1}
Brown herbicide and rate	2021: PowerMax® 1 qt ac^{-1} 2022: PowerMax® 1 qt ac^{-1} 2023: Glystar® plus 1 qt ac^{-1}
Green/brown herbicide and rate	2021: PowerMax 1 qt ac^{-1} 2022: Glyphosate 1 qt ac^{-1} 2023: Cornerstone® Plus 1 qt ac^{-1}
Green/ herbicide and rate	2021: PowerMax® 1 qt ac^{-1} 2022: PowerMax® 1 qt ac^{-1} 2023: Cornerstone® Plus 1 qt ac^{-1}
Seeding rates (seeds ac^{-1})	2021: 31,800 2022: 30,813 2023: 30,000
Planting equipment	John Deere 1750 corn planter
Planting date	18-May 2021 13-May 2022 15-May 2023
Row width (in.)	30
Corn starter fertilizer (at planting)	2021: urea (46-0-0) at 100 lbs ac^{-1} with ContainMax 2022: urea (46-0-0) at 120 lbs ac^{-1} with ContainMax 2023: 10-20-20 at 200 lbs ac^{-1}
Corn growth stage V3 date	9-Jun 2021 6-Jun 2022 9-Jun 2023
Corn growth stage V5 date	22-Jun 2021 22-Jun 2022 21-Jun 2023
Corn sidedress date, type, and rate	17-Jun 2021: 25-12-18 at 400 lbs ac^{-1} 21-Jun 2022: 46-0-0 at 350 lbs ac^{-1} 21-Jun 2023: 46-0-0 at 250 lbs with Contain Advantage ac^{-1}
Corn harvest dates	20-Oct 2021 25-Oct 2022 19-Oct 2023

Cover crop biomass and yield data and were analyzed using mixed model analysis in *R* (Rstudio, 2024) using the *dplyr* (Wickham, et al., 2023), *lmerTest* (Kuznetsova, et al., 2017), and *agricolae* (de Mendiburu, 2023) packages. Replications within trials were treated as random effects, and cover crop practice treatments were treated as fixed. Interaction terms between year and treatment were considered. 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, weather, 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 an 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 treatments 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. Treatments that did not perform significantly different from each other share the same letter. In this example, treatment C is significantly different from treatment A, but not from treatment 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 treatments 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 with these treatments were significantly different from one another. The shared letter indicates that treatment B was not significantly lower than the top yielding treatment C, indicated in bold.

Treatment	Yield
A	6.0[b]
B	7.5[a]
C	**9.0[a]**
LSD	**2.0**

RESULTS

Weather Data

Weather data were collected with an onsite Davis Instruments Vantage Pro2 weather station equipped with a WeatherLink data logger. Temperature, precipitation, and accumulation of Growing Degree Days (GDDs) are consolidated for the cover crop and grain corn 2020-2023 growing seasons (Tables 3 and 4). Historical weather data are from 1991-2020 at cooperative observation stations in Burlington, VT, approximately 45 miles from Alburgh, VT.

Overall, the 2020-2021 cover crop and corn growing seasons were dryer and warmer than the historical average during respective critical growing periods of both cover crop and grain corn. The 2021-2022 cover crop growing season had lower than average temperatures, but was on average 3.2°F warmer than usual during the critical growing periods, October and May. The 2022 corn growing season average temperature and precipitation was typical, but notably cooler and wetter during the critical growth period of June. The 2022-2023 cover crop growing season was on average warmer and wetter. However, it received more than three inches less rain than typical during the critical growing months of October and May. The 2023 corn grain growing season was much wetter than usual. Although average temperatures were higher during the 2023 corn grain growing season, they were on average 1.75°F lower during critical growing months, May-August.

Table 3. Consolidated weather data and GDDs for cover crop growing period (Oct-May), Alburgh, VT, 2020-2023.

Alburgh, VT	2020-2021	2021-2022	2022-2023
Average temperature (°F)	37.6	36.1	38.9
Departure from normal	0.634	-1.11	1.71
Precipitation (inches)	12.4	22.8	20.3
Departure from normal	-9.35	0.780	1.68
Corn GDDs (base 41°F)	1,451	1,455	1,425
Departure from normal	301	293	263

Based on weather data from a Davis Instruments Vantage Pro2 with WeatherLink data logger. Historical averages are for 30 years of NOAA data (1991-2020) from Burlington, VT.

Table 4. Consolidated weather data and GDDs for grain corn, Alburgh, VT, 2021-2023.

Alburgh, VT	2021	2022	2023
Average temperature (°F)	64.7	63.4	63.4
Departure from normal	0.990	-0.264	-0.311
Precipitation (inches)	19.3	26.4	31.2
Departure from normal	-3.87	3.33	8.06
Perennial forage GDDs (base 50°F)	2,830	2,284	2,711
Departure from normal	144	-1.75	25.0

Based on weather data from a Davis Instruments Vantage Pro2 with WeatherLink data logger.
Historical averages are for 30 years of NOAA data (1991-2020) from Burlington, VT.

Cover Crop Biomass at Termination Results

Cover crop biomass was collected from all plots just prior to termination (Table 5). A significant difference was observed in cover crop biomass at termination among years and there was year by treatment interaction. This indicates that the conditions of each year (e.g. weather) influenced the amount of cover crop biomass. However, to understand general cover crop biomass performance, cover crop biomass was also averaged across years. The last terminated cover crop treatment, Green, produced an average 1,931 lbs ac^{-1} more biomass than the Green/Brown treatment and averaged 3,336 lbs ac^{-1} more than the earliest terminated treatment, Brown. On average, the Brown treatment produced 1,405 lbs ac^{-1} less than the Green/Brown treatment.

Table 5. Cover crop biomass by termination timing across years, Alburgh, VT, 2021-2023.

Management practice	2021	2022	2023	Trial mean
	lbs ac^{-1}			
Brown	765^{c}†	1,346^{c}	1,577^{c}	1,229^{c}
Green/Brown	1,670^{a}	2,565^{b}	3,666^{b}	2,634^{b}
Green	4,335^{a}	3,404^{a}	5,955^{a}	4,565^{a}
LSD (0.10)‡	427	480	558	289
Trial Mean	2,257	2,438	3,732	2,809

† Within a column, treatments with the same letter did not perform significantly different from each other.
‡ LSD – Least Significant Difference at p=0.10.

Weed Biomass at V5 Results

Weed biomass was collected from all plots just prior to cover crop termination (Table 6). A significant difference was observed in weed biomass at V5 among years and there was year by treatment interaction. This indicates that the conditions of each year (e.g. weather) influenced the amount of weed biomass. In 2021, weed biomass was relatively low and there was not a difference among cover crop treatments. However, there were significant differences in 2022, 2023, and the overall trial mean. Weed biomass was significantly lower by more than 60 lbs ac^{-1} in the Green/Brown and Green treatments than the Bare and Brown treatments. The increased cover crop biomass of later terminated cover crops likely shaded the soil, decreasing weed germination and growth.

Table 6. Weed biomass by termination timing across years, Alburgh, VT, 2021-2023.

Management practice	2021	2022	2023	Trial mean
		lbs ac^{-1}		
Bare	3.21	506[b]†	359[b]	289[b]
Brown	0.713	453[b]	283[b]	245[b]
Green/Brown	6.96	73.8[a]	12.5[a]	31.1[a]
Green	3.39	71.8[a]	8.45[a]	27.9[a]
LSD (0.10)‡	NS§	171	86.5	64.2
Trial mean	3.57	276	166	148

† Within a column, treatments with the same letter did not perform significantly different from each other.
‡ LSD – Least Significant Difference at p=0.10.
§ NS – No significant difference was determined among the treatments.

Corn Populations and Vigor Results at V3

Corn populations were assessed in all plots when the majority of corn seedlings reached the third leaf stage (V3), typically in early June (Table 7). There was not a significant difference among years observed in corn populations, but there was a significant year by treatment interaction. This indicates that the conditions of each year (e.g. weather) influenced corn populations. However, to understand general corn population performance, populations were also averaged across years. In 2021, there was no difference in corn populations among treatments. In 2022, Bare, Brown, and Green/Brown treatments all had significantly higher populations compared to the Green treatment. In 2023, Bare and Brown treatments had significantly higher average populations than Green/Brown and Green treatments by more than 7,500 seedlings ac^{-1}. This was similar for the trial mean where Bare and Brown treatments had significantly higher average populations than Green/Brown and Green treatments by more than 4,000 seedlings ac^{-1}.

Table 7. Corn populations at V3 across years, Alburgh, VT, 2021-2023.

Management practice	2021	2022	2023	Trial mean
		plants ac^{-1}		
Bare	24,810	29,012[a]†	30,713[a]	28,179[a]
Brown	27,312	29,612[a]	27,912[a]	28,279[a]
Green/Brown	26,211	27,911[a]	20,008[b]	22,556[b]
Green	24,110	22,109[b]	20,408[b]	24,144[b]
LSD (0.10)‡	NS§	4,491	6,922	2,844
Trial mean	25,611	23,161	24,760	25,844

† Within a column, treatments with the same letter did not perform significantly different from each other.
‡ LSD – Least Significant Difference at p=0.10.
§ NS – No significant difference was determined among the treatments.

At the same time plant populations were counted, corn stage was assessed by determining majority vegetative stage (number of leaves with collars) (Table 8). There was a significant difference among years observed in corn populations and a significant year by treatment interaction. In 2021, there were no significant difference in growth stage among treatments. In 2022, the corn in the Bare and Brown treatments were significantly more developed than the Green/Brown and Green treatments. In 2023, growth stages were significantly different among all treatments with greater growth in no cover or earlier cover crop termination date treatments (i.e., Bare>Brown>Green/Brown>Green). Considering all years at once, seedling vegetative stage was significantly more developed in the Bare treatment than any other treatment. The Brown treatment had a more advanced growth stage compared to Green/Brown or Green treatments.

The Green/Brown and Green treatments had statistically similar growth stages. This indicates that no or low cover crop biomass does not inhibit corn seedling germination or growth.

Table 8. Corn vigor at V3 across years, Alburgh, VT, 2021-2023.

Management practice	2021	2022	2023	Trial Mean
	Corn stage			
Bare	2.60	3.0[a]†	3.0[a]	2.87[a]
Brown	2.20	2.9[a]	2.5[b]	2.53[b]
Green/Brown	2.30	2.0[b]	1.8[c]	2.03[c]
Green	2.40	2.0[b]	1.2[d]	1.87[c]
LSD (0.10)‡	NS§	0.119	0.333	0.200
Trial Mean	2.39	2.48	2.13	2.33

† Within a column, treatments with the same letter did not perform significantly different from each other.
‡ LSD – Least Significant Difference at p=0.10.
§ NS – No significant difference was determined among the treatments.

Corn Pest Damage Assessment Results at V5

Corn pest damage was assessed when corn reached growth stage V5, typically in mid-June (Table 9). There was a significant difference among years observed in the percentage of corn population impacted by pests and a significant year by treatment interaction. This indicates that the conditions of each year (e.g. weather) influenced pest populations and subsequent crop damage. Percent pest damage varied by year. In 2021, Bare and Brown treatments had significantly less pest damage than Green/Brown and Green treatments by more than 13%. However, in 2022 the results were opposite; Green/Brown and Green treatments had significantly less pest damage than Bare and Brown treatments by more than 12%. In 2023, Bare, Brown, and Green/Brown treatments had significantly less damage than the Green treatment by more than 8%. When data is combined across years, there was no significant difference in pest damage among the treatments. This indicates that weather may influence impact of cover crop biomass on extent of corn pest damage.

Table 9. Corn pest damage at V5 across years, Alburgh, VT, 2021-2023.

Management practice	2021	2022	2023	Trial Mean
	Percent of corn population			
Bare	19.0[a]	57.1[b]	8.21[a]	28.1
Brown	21.1[a]	58.1[b]	10.9[a]	30.0
Green/Brown	40.0[b]	37.7[a]	14.1[a]	30.5
Green	48.1[b]	35.6[a]	27.0[b]	36.9
LSD (0.10)‡	12.1	11.4	7.19	NS§
Trial Mean	30.4	39.4	15.0	31.4

† Within a column, treatments with the same letter did not perform significantly different from each other.
‡ LSD – Least Significant Difference at p=0.10.
§ NS – No significant difference was determined among the treatments.

Grain Corn Yield Results

Corn yield was collected from all plots after corn reached physiological maturity (Table 10). A significant difference was observed in grain corn yield among years, but there was not a year by treatment interaction. In 2021 and 2022, there were no significant differences among yield. In 2022, The Brown and Bare treatments had similar yields as did the Green/Brown and Green treatments. The Brown treatment had significantly higher yields than the Green/Brown and Green treatments. When yields across years are considered, there was a significant difference in trial average grain yields among treatments. Grain corn yield was significantly higher in the Brown treatment than the Green/Brown and Green treatments by 17-25 bu ac^{-1}, respectively, but Brown had similar grain corn yields to Bare. This indicates that cover crop termination timing and cover crop biomass can impact corn grain yields. The trial average Bare and Green treatment yields were similar to the Green/Brown treatment yields. However, trial average Bare treatment had 22 bu ac^{-1} higher yield than the Green treatment.

Table 10. Corn grain yields by termination timing across years, Alburgh, VT, 2021-2023.

Management practice	2021	2022	2023	Trial Mean
		bu ac^{-1}		
Bare	143	212[ab†]	222	192[ab]
Brown	149	224[a]	212	195[a]
Green/Brown	142	189[c]	203	178[bc]
Green	126	193[bc]	193	170[c]
LSD (0.10)‡	NS§	21.7	NS	16.4
Trial Mean	140	205	208	184

† Within a column, treatments with the same letter did not perform significantly different from each other.
‡ LSD – Least Significant Difference at p=0.10.
§ NS – No significant difference was determined among the treatments.

DISCUSSION

The goal of this project was to evaluate impact of cover crop termination timing on weed biomass, corn grain populations, vigor, pest damage, and yield. Based on the analysis of the data, some conclusions can be made about the results of this three-year trial. Cover crops gain significant biomass in the spring, with biomass differences observed when termination timing differed by as little as seven days (e.g. the number of days between 2022 Green/Brown and Green termination timing). It is difficult to parse out the extent to which cover crops biomass directly impacts corn grain yield. Weather conditions may also impact corn grain yield, as cover crop biomass was statistically different in all years and corn grain yields were not. Although weather varied by year, both 2022 and 2023 were considerably cooler and wetter during critical corn growing periods. When cover crop biomass was lowest in 2021 and highest in 2023, there was no difference in corn yields. This suggests that cover crop biomass may not directly impact corn grain yields. However overall, corn populations and vigor were significantly higher in Bare and Brown treatments than Green/Brown and Green treatments. This may have contributed to some yield differences observed at the end of the season as it is possible that cover crop biomass decreased population and delayed growth early in the season by blocking sunlight and reducing photosynthetic capabilities. Impacts of pest damage by cover crop treatment varied across years with no statistical impact when data was averaged across years. There are some tradeoffs with having higher cover crop biomass as weed biomass was significantly lower in later terminated cover crop, which may decrease the need for additional early season herbicide applications or tillage passes.

The findings in this three-year trial indicate that there are multiple ways cover crops and weather can impact corn grain yields through increased competition for sunlight (weed biomass), reduced weed pressure (weed biomass), growth suppression (populations and vigor), and increased pest incident (percent damage). Long term studies would elucidate the concomitant influence of weather and what impacts cover crop termination date consistently has on grain yield. In addition. This study was conducted on grain corn and different outcomes may be produced with corn silage as the whole plant is harvested.

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