**Green Manures and Seeding Rate in Malt Barley Production in the Northeast**

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## Introduction/ Rationale:

In malt barley production, nitrogen (N) applications must be managed to prevent excess protein levels in the grain. Legume cover crops/green manures may provide sufficient bioavailable (N) to barley while enhancing soil health. Crimson Clover (*Trifolium incarnatum*) and Sunn Hemp (*Crotalaria juncea*) are new legume cover crops to the New England region. We hypothesize that integrating these legume cover crops may partial meet the N requirements of malting barley, while the high lignin content of the Sunn Hemp will increase the soil organic carbon to contribute to overall soil health. In this trial, legumes were utilized as a green manure, planted in the late summer and then incorporated two weeks prior to planting winter barley. In this system, barley also serves a winter cover crop role, holding soil in place throughout the winter and early spring, decreasing the risk of run off and leaching during periods where spring barley would not yet have established root systems.

## Materials and Methods:

*Experimental Site:* This trial was conducted at the University of Massachusetts Agricultural Experiment Station Farm in South Deerfield, MA (42° N, 73° W). Soil at this site in the Connecticut River Valley is characterized as fine Hadley loam. In summer of 2015 the cover crops were planted into a block which had previously grown silage corn in the 2014 season, and which had been left fallow until this trial. The 2015-2016 winter was warmer than the norm for this location (Table 1). There was no significant winterkill in this trial.

*Experimental design:* Treatments consisted of four cover crop treatments, Sunn Hemp at 30 lbs/ac, (SH) Sunn Hemp at 15 lbs/ac in combination with Crimson Clover at 15 lbs/ac (SH+CC), Crimson Clover at 18 lbs/ac (CC) and no cover crop (None), two cultivars, Wintmalt (WM) and Charles (CH), and three barley seeding rates (300, 350 and 400 seeds per $m^2$ [WM: 118, 138, and 158 lbs/ac and CH: 107, 125, and 143 lbs/ac]). These were combined for a total of twenty-four treatments. All treatments were replicated 4 times in a randomized complete block design.

*Statistical Analysis:* Data were analyzed using PROC GLM in SAS version 9.4, and the significance of relationships between seeding rate and any of the measured indices was determined using ANOVA followed by orthogonal polynomial comparisons where significant. The significance of the impacts of cover crop treatment were determined through ANOVA followed by Tukey’s HSD where significant.

*Field Methods:* A pre-planting baseline soil sample of the top 6” of soil was collected by sampling a 5x4 grid of 20 samples across the block. The block was then amended (excluding N) appropriately as recommended by the UMass Extension soil analysis lab for barley production. Cover crop treatments were planted on July 25, 2015. All cover crops were flail mowed, chopped and rototilled into the soil on September 15, 2015. The winter barley cultivars were planted at ¾ inch depth using a cone drill planter on September 25, 2015. Spring N was applied at 25 lbs/ac on April 15, 2016, at approximately GS 30 following the collection of pre-fertilization soil samples.

*Field Measurements:* Cover crop biomass samples were collected as two 1-ft linear subsamples per plot on September 8, 2015 and dried at 150 °F in a forced air oven. Fall soil samples were collected immediately following the first hard frost on October 20, 2015. Winter survival was determined via visual assessment of the surviving area of the plot on April 11, 2016. Each plot was ranked from 0-10 to reflect the percentage of the plot surviving. A pre-fertilization soil sample was collected on April 14, 2015. Heading date, reported in Julian days, was declared when 50% of tillers had emerged heads. Height was measured to the top of the head in three subsamples per plot on June 24, 2016, and the means reported and analyzed in this report. Lodging/stem breakage was given a visual ranking on a 0-10 scale on July 12, 2016.

*Harvest:* Barley was harvested using a 1995 ALMACO SPC20 plot combine on July 19, 2016. All yields were standardized to 13.5% moisture. Grain was stored in a 100° F oven until processed to preserve kernel integrity. Sub samples from each plot were taken to determine test weight, thousand grain weight (TGW) and germination at 68-72 °F, using standard malt quality analysis procedures. Samples from the Wintmalt plots were sent to the University of Vermont's cereal grain testing lab for further malt quality analysis.

Table 1. Weather Data during cover crops and barley growing period at the Agricultural Research Farm, South Deerfield, MA, 2015-2016*

| Year | Month | Avg Temp (F) | Departure from avg. | Max Temp (F) | Departure from avg. | Min Temp (F) | Departure from avg. | Total Rain (in)** | Departure from avg. | GDD 32*** | Departure from avg. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2015 | July | 69.9 | -0.6 | 90.8 | -0.6 | 52.3 | 4.0 | 3.3 | -0.3 | 1217.3 | -10.6 |
| | August | 70.0 | 1.2 | 90.5 | 0.6 | 52.3 | 6.8 | 2.5 | -1.1 | 1222.9 | 39.1 |
| | September | 65.0 | 3.7 | 91.4 | 5.6 | 40.8 | 6.4 | 6.4 | 2.2 | 1044.9 | 126.5 |
| | October | 48.6 | -0.1 | 73.9 | -2.5 | 18.7 | -5.2 | 2.2 | -2.0 | 520.3 | -20.6 |
| | November | 43.1 | 4.1 | 73.6 | 7.9 | 15.9 | 2.1 | 2.0 | -1.1 | 348.7 | 99.5 |
| | December | 39.2 | 9.8 | 61.6 | 3.3 | 22.1 | 20.5 | 4.7 | 1.4 | 250.3 | 164.4 |
| 2016 | January | 27.1 | 4.4 | 51.8 | 0.3 | 4.1 | 13.9 | 1.5 | -1.2 | 34.4 | -5.7 |
| | February | 28.6 | 3.2 | 58.9 | 7.3 | -15.0 | -11.0 | 4.1 | 1.6 | 100.1 | 62.7 |
| | March | 40.5 | 6.8 | 77.9 | 13.5 | 17.6 | 14.3 | 3.3 | -0.2 | 310.7 | 146.4 |
| | April | 45.4 | -0.5 | 79.2 | -1.8 | 12.2 | -9.1 | 2.1 | -1.0 | 414.0 | -37.6 |
| | May | 57.5 | 0.5 | 90.6 | 3.4 | 29.0 | -0.7 | 2.6 | -0.8 | 807.5 | -1.5 |
| | June | 66.3 | 0.8 | 87.7 | -2.5 | 41.6 | 0.7 | 1.4 | -3.2 | 1039.1 | -0.3 |
| | July | 72.2 | 1.7 | 93.9 | 2.5 | 49.9 | 1.6 | 1.7 | -2.0 | 1263.9 | 36.0 |

*Averages of weather data were obtained from the airport weather station in Orange, MA 23 mi from the South Deerfield location due to increased number of years available

**Rain data were obtained from the airport weather station in Orange, MA.

***GDD: Growing degree days are calculated using the following formula: GDD$\left(\Sigma \frac{(T_{max}+T_{min}}{2}\right) - T_b$, where $T_{max}\ and\ T_{min}$= maximum and minimum daily temperatures and $T_b$=$T_{base}$ (32°F)

**Results:**

SH and SH+CC produced significantly higher biomass than CC alone, and contributed significantly higher amounts of all measured nutrients than CC alone. SH alone contributed 77 lbs N/ac, followed by SH+CC (53lbs/ac), while CC contributed only 13lbs N/ac. (Table 2).

Table 2. Cover crops aerial biomass and their potential nutrients reovery[1]. University of Massachusetts, Agricultural Research Farm, South Deerfield, MA, 2015

| Cover Crop | Biomass (lbs/ac) | | N (lbs/ac) | | P (lbs/ac) | | K (lbs/ac) | | Ca (lbs/ac) | | Mg (lbs/ac) | | Lignin (lbs/ac) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SH+CC | 2274 | a | 52.9 | a | 4.3 | a | 58.2 | a | 24.8 | a | 7.2 | a | 215.4 | a |
| CC | 497 | b | 12.9 | b | 0.9 | b | 13.5 | b | 8.7 | b | 2.1 | b | 36.2 | b |
| SH | 2962 | a | 77.3 | a | 6.0 | a | 73.5 | a | 31.6 | a | 8.3 | a | 290.4 | a |
| None | … | | … | | … | | … | | … | | … | | … | |
| *Treatment effects[2]* | | | | | | | | | | | | | | |
| Cover crop | ** | | ** | | ** | | ** | | ** | | ** | | ** | |

[1]Means with the same letter in each column are not significantly different from one another (Tukey's HSD ranking p≤0.05)
[2] t indicates P≤0.1, *indicates a significant relationship or difference (P≤0.05), **indicates a highly significant relationship or difference (P≤0.01), ***(P≤0.001) indicates a very highly significant relationship or difference

Plots planted with SH alone had significantly higher soil nitrate at frost than plots planted with CC alone, or no cover crop. Plots planted with SH+CC did not have significantly different soil nitrate than any other treatments (Figure 1). Cultivar type and seeding rate had no significant impact on soil nitrate at frost. None of the main treatments or their interactions had any significant impact on soil nitrate at the spring, pre-fertilization sample date (Table 3).

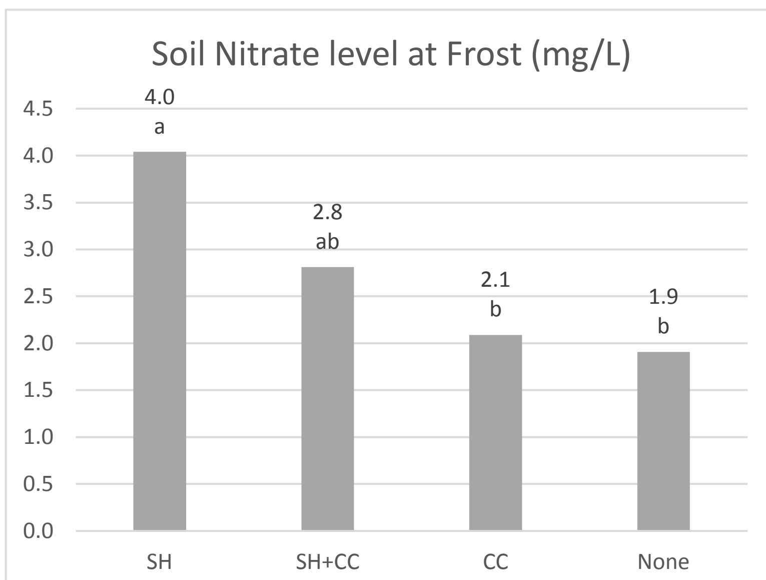


Figure 1. Soil Nitrate level at first frost, S. Deerfield, MA, 2015-2016

Charles headed out significantly earlier than Wintmalt. However, constrictions of harvesting equipment required simultaneous harvest. Charles therefore had a lower test weight, yield, and total germination due to delayed harvest, in addition to a higher rate of lodging/stem breakage than Wintmalt (Table 4). Charles would be expected to have lower lodging/stem breakage if grown and harvested in a single cultivar stand that permitted timely harvest. Malt quality analysis of protein, falling number, and DON levels were therefore only conducted for the Wintmalt plots.  There were no significant impacts of cover crop or seeding rate on the tested quality indices (Table 4).

Table 3. Influence of cover crop species, barley cultivar, and barley seeding rate on soil nitrate level at frost and pre-fertilization time at the Agricultural Research Farm, South Deerfield, MA, 2015-2016

| Cover Crop | Cultivar | Seeding rate (seeds/m^2) | Soil Nitrate at frost (mg/L) (Oct 20, 2015) | Soil nitrate Pre-fertilization (mg/L) (Apr 14, 2016) |
|---|---|---|---|---|
| SH+CC | WM | 300 | 2.2 | 8.5 |
| | | 350 | 4.4 | 5.3 |
| | | 400 | 2.4 | 4.2 |
| | CH | 300 | 2.9 | 4.3 |
| | | 350 | 1.9 | 2.3 |
| | | 400 | 3.0 | 4.0 |
| CC | WM | 300 | 2.9 | 6.5 |
| | | 350 | 2.0 | 4.6 |
| | | 400 | 1.6 | 2.1 |
| | CH | 300 | 2.2 | 4.2 |
| | | 350 | 2.1 | 0.0 |
| | | 400 | 1.8 | 2.6 |
| SH | WM | 300 | 4.3 | 3.8 |
| | | 350 | 6.4 | 2.3 |
| | | 400 | 3.3 | 3.9 |
| | CH | 300 | 2.9 | 3.3 |
| | | 350 | 3.2 | 3.9 |
| | | 400 | 4.1 | 4.4 |
| None | WM | 300 | 1.9 | 5.9 |
| | | 350 | 1.6 | 1.1 |
| | | 400 | 2.1 | 4.2 |
| | CH | 300 | 1.9 | 1.9 |
| | | 350 | 1.8 | 5.5 |
| | | 400 | 2.1 | 3.6 |
| **Cover Crop** | | | | |
| SH+CC | | | 2.8 | 4.8 |
| CC | | | 2.1 | 3.3 |
| SH | | | 4.0 | 3.6 |
| None | | | 1.9 | 3.7 |
| **Cultivar** | | | | |
| WM | | | 2.9 | 4.4 |
| CH | | | 2.5 | 3.3 |
| **Seeding Rate** | | | | |
| 300 | | | 2.7 | 4.8 |
| 350 | | | 2.9 | 3.1 |
| 400 | | | 2.6 | 3.6 |
| *Significance[1] by main factors* | | | | |
| Cover crop (CC) | | | * | ns |
| Cultivar (C) | | | ns | ns |
| Seeding rate (SR) | | | ns | ns |
| CCxC | | | ns | ns |
| CCxSR | | | ns | ns |
| CxSR | | | ns | ns |
| CxCCxSR | | | ns | ns |

[1] t indicates P≤0.1, *indicates a significant relationship or difference (P≤0.05), **indicates a highly significant relationship or difference (P≤0.01), ***(P≤0.001) indicates a very highly significant relationship or difference

Table 4 Influence of cover crop species, barley cultivar, and barley seeding rate on barley grain yield and its growth metrics at the Agricultural Research Farm, South Deerfield, MA. 2015-2016

| Cover crop | Cult. | Seeding rate (seeds/m^2) | 50% heading date | Mean height (in) | Lodging/ stem breakage | Yield (bu/ac) | Test weight (kg/hL) | TGW (g) | Total germ | Percent protein (12%M) | Falling number | DON (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SH+CC | WM | 300 | 141.0 | 19.8 | 0.3 | 70.4 | 60.4 | 49.4 | 95.8 | 8.3 | 187.5 | 0.2 |
| | | 350 | 140.5 | 21.4 | 0.5 | 86.2 | 59.9 | 49.6 | 98.3 | 8.3 | 194.8 | 0.2 |
| | | 400 | 140.8 | 19.8 | 0.3 | 65.1 | 58.6 | 49.5 | 87.0 | 8.4 | 189.8 | 0.2 |
| | Char. | 300 | 134.8 | 19.1 | 2.5 | 46.2 | 57.9 | 42.1 | 68.3 | … | … | … |
| | | 350 | 136.3 | 15.1 | 2.3 | 39.7 | 56.7 | 44.7 | 60.5 | … | … | … |
| | | 400 | 134.8 | 17.4 | 3.3 | 45.3 | 58.6 | 42.0 | 67.0 | … | … | … |
| CC | WM | 300 | 143.0 | 20.1 | 0.4 | 63.1 | 60.8 | 50.7 | 97.8 | 8.5 | 199.0 | 0.2 |
| | | 350 | 141.5 | 18.8 | 0.3 | 67.7 | 59.3 | 49.5 | 98.0 | 8.2 | 193.8 | 0.1 |
| | | 400 | 142.5 | 19.5 | 0.4 | 76.1 | 57.9 | 50.3 | 97.0 | 8.7 | 192.3 | 0.2 |
| | Char. | 300 | 134.0 | 15.2 | 3.0 | 32.3 | 56.5 | 43.3 | 72.3 | … | … | … |
| | | 350 | 132.3 | 15.4 | 2.0 | 45.1 | 57.9 | 42.8 | 70.0 | … | … | … |
| | | 400 | 134.0 | 16.6 | 1.8 | 48.3 | 57.9 | 43.1 | 63.0 | … | … | … |
| SH | WM | 300 | 140.0 | 22.1 | 0.4 | 86.3 | 60.8 | 50.2 | 97.8 | 9.0 | 195.3 | 0.2 |
| | | 350 | 141.0 | 21.8 | 0.1 | 72.4 | 59.7 | 49.7 | 99.3 | 8.0 | 203.5 | 0.2 |
| | | 400 | 140.5 | 20.2 | 0.4 | 77.7 | 59.2 | 49.2 | 97.8 | 8.4 | 193.0 | 0.1 |
| | Char. | 300 | 135.5 | 17.0 | 2.5 | 40.4 | 56.6 | 42.6 | 65.5 | … | … | … |
| | | 350 | 133.0 | 20.4 | 3.9 | 59.2 | 56.6 | 42.1 | 79.0 | … | … | … |
| | | 400 | 134.8 | 18.8 | 3.3 | 43.8 | 56.9 | 42.0 | 65.0 | … | … | … |
| None | WM | 300 | 142.5 | 18.5 | 0.6 | 61.3 | 59.1 | 49.8 | 97.5 | 8.5 | 198.3 | 0.1 |
| | | 350 | 139.0 | 21.0 | 0.4 | 58.1 | 61.1 | 48.7 | 98.0 | 8.6 | 194.5 | 0.2 |
| | | 400 | 142.0 | 19.4 | 0.1 | 63.1 | 59.4 | 49.0 | 98.3 | 8.1 | 197.8 | 0.3 |
| | Char. | 300 | 136.5 | 15.0 | 2.8 | 37.2 | 54.0 | 43.3 | 63.3 | … | … | … |
| | | 350 | 134.0 | 19.5 | 3.1 | 37.7 | 56.6 | 44.1 | 70.8 | … | … | … |
| | | 400 | 137.5 | 15.2 | 2.8 | 37.9 | 55.6 | 41.8 | 61.3 | … | … | … |
| **Cover Crop** | | | | | | | | | | | | |
| SH+CC | | | 138.1 | 18.8 | 1.5 | 58.8 | 58.7 | 46.2 | 79.5 | 8.4 | 190.7 | 0.2 |
| CC | | | 137.9 | 17.6 | 1.3 | 55.4 | 58.4 | 46.6 | 83.0 | 8.5 | 194.6 | 0.2 |
| SH | | | 137.3 | 20.1 | 1.8 | 63.3 | 58.3 | 45.9 | 84.0 | 8.5 | 197.3 | 0.2 |
| None | | | 138.6 | 18.1 | 1.6 | 49.2 | 57.6 | 46.1 | 81.5 | 8.4 | 196.8 | 0.2 |
| **Cultivar** | | | | | | | | | | | | |
| WM | | | 141.2 | 20.2 | 0.3 | 70.6 | 59.7 | 49.6 | 96.9 | … | … | … |
| CH | | | 134.8 | 17.1 | 2.8 | 42.8 | 56.8 | 42.8 | 67.1 | … | … | … |
| **Seeding Rate** | | | | | | | | | | | | |
| 300 | | | 138.4 | 18.4 | 1.5 | 54.7 | 58.3 | 46.4 | 82.3 | 8.6 | 194.7 | 0.1 |
| 350 | | | 137.2 | 19.2 | 1.6 | 58.3 | 58.5 | 46.4 | 84.2 | 8.3 | 196.6 | 0.1 |
| 400 | | | 138.3 | 18.3 | 1.5 | 57.2 | 58.0 | 45.8 | 79.5 | 8.4 | 193.2 | 0.2 |

Table 4. continued

| *Significance[1] by main factors* | 50% heading date | Mean height (in) | Lodging/ stem breakage | Yield (bu/ac) | Test weight (kg/hL) | TGW (g) | Total germ | Percent protein (12%M) | Falling number | DON (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|
| Cover crop (CC) | ns | ns | ns | ns | ns | ns | ns | ns | ns | ns |
| Cultivar (C) | ** | t | *** | * | * | ns | * | … | … | … |
| Seeding rate (SR) | * | ns | ns | ns | ns | t | ns | ns | ns | ns |
| CCxC | ns | ns | ns | ns | ns | ns | ns | … | … | … |
| CCxSR | ns | ns | ns | ns | ns | ns | ns | ns | ns | ns |
| CxSR | ns | ns | ns | ns | * | ** | ns | … | … | … |
| CxCCxSR | ns | ns | ns | ns | ns | ns | ns | … | … | … |

[1] t indicates P≤0.1, *indicates a significant relationship or difference (P≤0.05), **indicates a highly significant relationship or difference (P≤0.01), ***(P≤0.001) indicates a very highly significant relationship or difference

**Conclusion:**

Fall soil nitrate varied significantly by cover crop treatment, but this variation did not carry through to pre-fertilization soil nitrate levels, nor did it have a significant impact on any of the barley metrics. While cover crop treatments did not have a significant impact on growth parameters or yield in the first year of this trial, a second year of the trial is currently ongoing, in addition to replication at the University of Vermont. Additional data from these trials may lead to more concrete conclusions regarding the potential role of these cover crops as green manures and seeding rates in malt barley production in the Northeastern United States.

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