2017 High Glucosinolate Mustard as a Biofumigant Trial

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2017 HIGH GLUCOSINOLATE MUSTARD AS A BIOFUMIGANT TRIAL

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Brassicaceae plants (mustard family) contain chemicals called glucosinolates. These compounds are present in the leaves, stems, roots, and seeds of the plants. When the plant biomass is incorporated into the soil, these glucosinolates are broken down into a number of secondary compounds, including a compound called isothiocyanate. Isothiocyanate can be biocidal to seeds, insects, nematodes, and other microbes (fungi, bacteria, etc.). In recent years, plant breeders have worked to develop varieties of mustards with high glucosinolate content to be used as biofumigants in crop production. These high glucosinolate mustards (HGM) are being used as cover crops and the entire plant biomass is incorporated into the soil. Interestingly, mustards can also be used as oilseed crops with a potential use in biofuel production. Extraction of the oil from the seed produces a meal that is also high in glucosinolates as well as nitrogen. Hence, the meal used as a soil amendment could potentially provide nutrients and suppress weeds, pests, and diseases.

Little research has been done in the Northeast to quantify the effects of HGM as a cover crop and biofumigant. The commercial demand for potatoes *(Solanum tuberosum)* hinges on appearance. Consumers often refuse potatoes with skin defects such as common scab *(Streptomyces spp.)* or rhizoctonia and potatoes for seed are rejected if they have significant skin damage. *Rhizoctonia solani*, a soil fungus, is particularly common in cool, wet growing regions like the Northeast. In this trial, HGM was evaluated for its efficacy at reducing the incidence of soil borne diseases, minimizing weed pressure, and increasing yields for potatoes. The objectives of this study were to determine optimum HGM planting dates, seeding rates and best varieties for suppressing weeds and diseases in potatoes.

MATERIALS AND METHODS

Three research trials were conducted at Borderview Research Farm in Alburgh in 2016-2017. The trials included a HGM variety trial, HGM seeding rate study, and a HGM planting date trial. The experimental design for variety trial was a randomized complete block with 4 replicates. The treatments consisted of 5 HGM varieties (‘Caliente 199’, ‘Caliente 119’, ‘Kodiak’, ‘Trifecta’, ‘White gold’), and a control plot. The experimental design for the seed rate study was a randomized complete block design with 4 replicates. The variety ‘Caliente 199’ was grown at 5, 10, 15, 20, and 25 lbs ac^{-1} for the seeding rate trial. The variety and seeding rate trials were planted on 15-Aug 2016.

The varieties ‘Caliente 119’ and ‘Caliente 199’ were grown in the planting date trial and planted at three different times. For the planting date trial, the experimental design was a randomized split plot design with four replications. Main plot treatments consisted of the planting dates and split plot treatments consisted of the varieties. Plot size was 10’x20’. Planting dates for the planting date trial were 15-Aug, 23-Aug, and 29-Aug 2016. All experimental plots were seeded with a Great Plains plot drill. See Table 1 for trial details.

On 7-Sep, vigor was recorded for the variety and seeding rate trials by visually assessing each of the plots and rating them on a 1-5 scale (low to high vigor). Vigor was recorded for the planting date trial on 16-Sep. On 27-Sep, mustard plant height and white mold infection was recorded as present or absent

(0=absent and 1=present) for the variety and seeding rate trials; while this data was collected on 5-Oct for the planting date trial. On 22-Sep, populations were recorded for all three trials by counting the number of plants within a 1-foot row section, three times per plot. On 7-Oct, biomass yield was sampled for all trials by clipping the contents of two randomly placed 0.25 m^2 quadrats per plot. A subsample of mustard was dried at 105°F until it reached a stable temperature, in order to determine percent dry matter. Mustard samples from the variety trial then were analyzed to determine nutrient content. On 11-Oct, the mustard was terminated using a brush hog and incorporated immediately using disc harrows.

On 9-May 2017, each plot from the HGM variety trial was soil sampled for nitrates. On 19-May 'Yukon Gold' potatoes were planted in the middle 3'x10' area of each plot of the HGM variety trial. On 26-Jun, populations of potatoes per plot was recorded. On 19-Jun, the number of broadleaf and grass weeds in one 0.25 m^2 quadrat per plot was recorded to determine weed populations; weed cover was determined as a percent of total plant cover using the web based IMAGING crop response analyzer. Digital images were taken with a compact digital camera, Canon PowerShot G12 (Melville, NY) (10.4 Megapixels). Digital images were analyzed with the automated imaging software, which was programmed in MATLAB (MathWorks, Inc., Natick, MA) and later converted into a free web-based software (www.imaging-crop.dk). On 23-Aug, potatoes were harvested by hand and yield was recorded. A subsample of 10 potatoes was evaluated visually for scab and rhizoctonia infection (Image 1) and severity was recorded using a 1-4 scale (1=trace/no disease and 4= high infection).

Image 1. Potato scab, *Streptomyces spp.*, and *Rhizoctonia solani*, left to right, Alburgh, VT, 2017.

Table 1. Agronomic information for high glucosinolate mustard (HGM) as a biofumigant trial 2016-17, Alburgh, VT.

Location	**Borderview Research Farm, Alburgh, VT**
Soil type	Benson rocky silt loam, 8-15% slope
Previous crop	Spring barley
Replications	4
Plot size (ft)	10x20
Soil amendments	18-May 2017, 0.75 tons ac^{-1} of Pro-Gro (5-4-3) and 1 ton ac^{-1} of Pro-Boost (10-0-0) (North Country Organics, Bradford, VT)
Variety trial Varieties Planting date Seeding rate	Caliente 199, Caliente 119, Kodiak, Trifecta, White gold 15-Aug 2016 25 lbs ac^{-1}

Seeding rate trial Variety Planting date Seeding rate	Caliente 199 15-Aug 2016 5, 10, 15, 20, 25 lbs ac^{-1}
Planting date trial Varieties Planting date Seeding rate	Caliente 199, Caliente 119 15-Aug, 23-Aug, 29-Aug 2016 25 lbs ac^{-1}
HGM row spacing	7.5”
Planting equipment	Great Plains NT60 Cone Seeder
HGM termination date	11-Oct 2016
Potato variety	‘Yukon gold’ potato
Potato planting date	19-May 2017
Row spacing (inches)	30
Potato plot size (ft)	3x10
Potato harvest date	23-Aug 2017

Data were analyzed using mixed model analysis using the mixed procedure of SAS (SAS Institute, 1999). Replications within trials were treated as random effects, and soil amendment treatments were treated as fixed. Mean comparisons were made using the Least Significant Difference (LSD) procedure when the F-test was considered significant ($p<0.10$).

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

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 treatments 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, except where analyzed by pairwise comparison (t-test). 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 treatments. Treatments that were not significantly lower in performance than the top-performing treatment in a particular column are indicated with an asterisk. In this example, 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.

RESULTS

Seasonal precipitation and temperature were recorded with a Davis Instrument Vantage Pro2 weather station, equipped with a WeatherLink data logger at Borderview Research Farm in Alburgh, VT. The

2016 season was warmer and dryer than usual, with August and September being 2.9°F warmer than usual per month (Table 2). The 2017 season was cooler and wetter than usual and received 108 fewer growing degree days than usual.

Table 2. Seasonal weather data[1] collected in Alburgh, VT, 2016-2017.

	2016			2017			
Alburgh, VT	**August**	**September**	**October**	**May**	**June**	**July**	**August**
Average temperature (°F)	71.6	63.4	50.0	55.7	65.4	68.7	67.7
Departure from normal	2.90	2.90	1.90	-0.75	-0.39	-1.90	-1.07
Precipitation (inches)	3.00	2.50	5.00	4.1	5.6	4.9	5.5
Departure from normal	-0.93	-1.17	1.39	0.68	1.95	0.73	1.63
Growing degree days (base 44°F)	849	595	254	384	637	766	736
Departure from normal	82	98	49	0	-17	-60	-31

[1]Based on weather data from a Davis Instruments Vantage Pro2 with WeatherLink data logger. Alburgh precipitation data from August-October was provided by the NOAA data for Highgate, VT. Historical averages are for 30 years of NOAA data (1981-2010) from Burlington, VT.

Impact of variety HGM on growth, yield, and quality

The HGM varieties did not differ significantly in yield with the average biomass produced being 3570 lbs per acre (Table 3). White gold, Trifecta, and Caliente 119 produced the tallest plants and Kodiak had the greatest population. White gold was the only variety without white mold. Varieties did not differ in nitrogen content and as a result had similar impacts on soil nitrate levels.

Table 3. HGM variety growth characteristics, yield and quality, Alburgh, VT, 2016.

Variety	Soil NO_3	Early vigor†	Height	Population	Dry matter yield	Carbon	Nitrogen	White mold‡
	mg kg^{-1}	1 to 5 rating	inches	plants ac^{-1}	lbs ac^{-1}	%	%	0 or 1 rating
Caliente 119	4.18	2.00	89.4*	1,684,320	3188	39.2	2.39	0.75
Caliente 199	5.12	1.75	79.3	1,597,200	3615	38.5	2.34	0.75
Kodiak	5.35	1.50	82.4	**2,398,704***	3354	38.9	2.64	1.00
Trifecta	5.40	2.00	97.1*	1,748,208	3791	39.5	2.66	1.00
White gold	4.71	2.25	**98.0***	1,086,096	3900	39.7	2.47	**0.00***
LSD (0.10)	NS	NS	9.71	416,862	NS	NS	NS	0.39
Trial mean	4.95	1.90	89.3	1,702,906	3570	39.2	2.56	0.70

*Treatments marked with an asterisk did not perform statistically different than the top performing treatment (p=0.10) shown in **bold.**
NS – There was no statistical difference between treatments in a particular column (p=0.10).
†Early season vigor was rated on a 1 to 5 scale with 1 = high vigor and 5 = low vigor.
‡White mold was rated as 0=absent or 1=presence.

Impact of HGM variety on potato yield, disease, and weed populations

Potato yield and disease were not impacted significantly by any of the HGM varieties compared to the control (Table 4). HGM varieties did not reduce weeds compared to the control. Grass weed population was the lowest in plots where Kodiak was grown, which was statistically similar to the Caliente 119, Trifecta, and control plots.

Table 4. The impact of high glucosinolate mustard variety on potatoes yield, quality, and weeds, Alburgh, VT, 2017.

Variety	Potato yield	Potato population	Rhizoctonia‡	Scab‡	Broadleaf weeds	Grass weeds	Weed cover
	tons ac^{-1}	plants ac^{-1}	1 to 4 rating	1 to 4 rating	plants 0.25m^{-2}	plants 0.25m^{-2}	%
Caliente 119	16.1	55,176	1.25	2.00	57.3	60.5*	41.1
Caliente 199	16.8	53,361	1.05	2.15	52.3	76.5	46.6
Kodiak	15.8	49,731	1.05	2.15	56.8	**41.5***	34.9
Trifecta	18.7	47,553	1.05	2.18	86.5	67.0*	52.9
White gold	17.2	52,635	1.10	1.70	89.5	82.3	59.4
Control	18.3	52,635	1.00	2.00	139	42.3*	51.4
LSD (0.10)	NS	NS	NS	NS	NS	30.4	NS
Trial mean	17.2	51,849	1.08	2.03	80.2	61.7	47.7

‡Rhizoctonia and scab were rated on a 1 to 4 scale with 1(trace) = 0-1% of skin infected, 2 (light) = >1-5% of skin infected, 3 (moderate) = >5-10% of skin infected, 4 (heavy) = >10% of skin infected.
*Treatments marked with an asterisk did not perform statistically worse than the top performing treatment (p=0.10) shown in **bold.**
NS – There was no statistical difference between treatments in a particular column (p=0.10).

Impact of planting date on HGM growth, yield, and quality

Planting date significantly impacted mustard yield and characteristics (Table 5). The 15-Aug planting date had the highest yield, population, height, and early season vigor. The 23-Aug planting date performed comparably for vigor and population. The 29-Aug planting date had the lowest white mold incidence.

Table 5. The impact of high glucosinolate mustard planting date on mustard yield and quality, across the varieties Caliente 119 and Caliente 199, Alburgh, VT, 2016.

Planting date	Early vigor†	Height	Population	Dry matter yield	White mold
	1 to 5 rating	inches	plants ac^{-1}	lbs ac^{-1}	0 or 1 rating‡
15-Aug	**2.63***	**101***	**1,649,472***	**2606***	1.00
23-Aug	2.88*	80.5	1,486,848*	2206	1.00
29-Aug	4.00	52.0	1,312,608	1589	**0.38***
LSD (0.10)	0.548	5.46	257,378	310	0.279
Trial mean	3.17	77.8	1,482,976	2133	0.792

*Treatments marked with an asterisk did not perform statistically different than the top performing treatment (p=0.10) shown in **bold.**
NS – There was no statistical difference between treatments in a particular column (p=0.10).
†Early season vigor was rated on a 1 to 5 scale with 1 = high vigor and 5 = low vigor.
‡White mold was rated as 0=absent or 1=presence.

Impact of seeding rate on HGM growth, yield, and quality

HGM seeding rate had a significant impact on early season vigor, with the 15 lbs ac^{-1} seeding rate being the best performer and the 20 and 25 lbs ac^{-1} seeding rates performing comparably (Table 6). The 20 and 25 lbs ac^{-1} seeding rates also had the highest populations.

Table 6. The impact of HGM seeding rate on mustard yield and quality, Alburgh, VT, 2016.

Seeding rate	Early vigor†	Height	Population	Dry matter yield	White mold
	1 to 5 rating	inches	plants ac^{-1}	lbs ac^{-1}	0 or 1 rating‡
5	3.50	103	662,112	2694	0.50
10	2.25	92.7	1,208,064	2689	1.00
15	**1.25***	102	1,661,088	3044	0.50
20	1.50*	95.3	1,806,288*	2625	0.50
25	1.75*	86.5	**2,207,040***	2840	0.50
LSD (0.10)	0.771	NS	417,344	NS	NS
Trial mean	2.05	95.8	1,508,918	2779	0.60

*Treatments marked with an asterisk did not perform statistically worse than the top performing treatment (p=0.10) shown in **bold.**
NS – There was no statistical difference between treatments in a particular column (p=0.10).
†Early season vigor was rated on a 1 to 5 scale with 1 = high vigor and 5 = low vigor.
‡White mold was rated as 0=absent or 1=presence.

DISCUSSION

The highest HGM yields were observed from mid-August planting dates and it was clear that increasing seeding rates above 5 lbs per acre did not necessarily boost yields. All of the HGM varieties performed similarly in terms of yield. The fall-planted mustard did not seem to effect potato yield, disease, or weed populations as there were no significant differences between mustard plots and the control.

The mustard grown in this trial did not produce as much biomass as commonly seen in the Pacific Northwest, where HGM has become a popular biofumigant. It is possible that more HGM biomass is needed to have a stronger impact on subsequent vegetable plantings. In addition, growers have experimented with rolling, packing, covering with a tarp, or irrigating freshly incorporated HGM to help create a seal over the soil surface and increase release of biofumigants in the soil. It is possible that other techniques may be more effective at using HGM as a biofumigant. Additional research is needed to continue developing best agronomic practices for this pest control measure. It is important to remember that these data represent only one year of research, and in only one location.

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