Impact of High Glucosinolate Mustard Soil Amendments on Black Bean Yield 2014

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Brassicaceae crops (mustard family) contain chemicals called glucosinolates. These compounds are present in the leaves, stem, 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. The primary compound is isothiocyanate which can be biocidal to germinating seeds, insects, nematodes, and other microbes (fungi, bacteria, etc.). In recent years, plant breeders have worked to develop varieties of mustards with high glucosinolate contents to be used as biofumigants in crop production. These high glucosinolate mustards (HGM) are being used as cover crops and the entire plant biomass 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 and diseases.

Little research has been done in the Northeast to quantify the effects of HGM in reducing weed pressure and increasing yields in crops. Black beans (*Phaseolus vulgaris*), a specialty crop, are in high demand in the Northeast, with markets and cooperatives continuously encouraging growers to increase the regional supply. Black beans may be a more viable crop for Vermont growers if weed and disease pressure can be mitigated and yields improved. High glucosinolate mustard could be integrated into a crop rotation to address these management issues and enhance soil health. In 2013-2014, UVM Extension's Northwest Crops & Soils Program, in collaboration with the University of Maine Extension, set out to determine whether HGM cover crops could be used to decrease weed and disease populations while increasing yields in crop production.

MATERIALS AND METHODS

In 2013-2014, a research trial was conducted at Borderview Research Farm in Alburgh, VT (Table 1). The plot design was a randomized complete block, with HGM amendments as treatments, and three replications. The HGM treatments included whole plant cover crops of three different varieties, a fall-applied HGM meal, a spring-applied HGM meal, and a control (no HGM amendment). The soil type at the site was a Covington silt clay loam and the previous crop was oilseed sunflower. Plots were 10' x 20'.

Figure 1. HGM seed is pressed for oil extraction, and resulting meal used as a soil amendment.

Fall populations, plant vigor, and heights were measured for the HGM plots on 1-Oct 2013. The HGM Caliente varieties '199', '119', and '61' were planted on 19-Aug 2013 with a 10' wide Sunflower grain drill at 25, 25, and

16.7 lbs. of viable seed per acre respectively. The HGM Caliente varieties '119' and '199', blended 50/50 were, cold-pressed with a KK40 oilseed press on 29-Oct 2013 (Figure 1). The meal was hammer-milled immediately after extrusion to achieve a fine texture. Meal was applied in the 'fall-applied meal' treatment on 5-Nov 2013 at a rate of 2.4 lbs. per plot, or 522 lbs. per acre. On 5-Nov 2013, biomass samples of the HGM cover crop plots were taken by harvesting all plants in a known area. Subsamples were dried and collected, then shipped to Cumberland Valley Analytics in Hagerstown, MD for determination of nitrogen concentrations in the in HGM. The HGM whole plant plots were chopped with a rear-mounted brush hog on 5-Nov 2013 and all plots were disc harrowed to incorporate and prepare the seedbed. Soil samples were taken by treatment just prior to HGM incorporation and were processed by UVM's Agricultural and Environmental Testing Laboratory.

Table 1. Agronomic management of HGM and black bean trial, 2013-2014, Alburgh, VT.

Location	**Borderview Research Farm – Alburgh, VT**
Soil type	Covington silt clay loam
Previous crop	Sunflower
HGM treatments	Whole plant, fall-applied meal, spring-applied meal, control
Replications	3
Plot size (ft)	10 x 20
HGM planting date	19-Aug 2013
HGM seeding rate (lbs ac^{-1})	25 (119 & 199), 16.7 (61)
HGM termination	5-Nov 2013
Fall HGM meal application date	5-Nov 2013
Fall HGM meal rate (lbs ac^{-1})	522
Spring HGM meal application date	12-May 2014
Spring HGM meal rate (lbs ac^{-1})	522
Black bean variety	Midnight black turtle
Black bean planting date	2-Jun 2014
Black bean planting rate (seeds ft^{-1})	8-10
Weed control	Cultivated 23-Jun, 3-Jul; hand weeded 16-Jun
Harvest date	20-Oct 2014

In the spring of 2014, all plots were soil sampled to a depth of 12 inches. On 2-May 2014, HGM Caliente varieties '119' and '199' blended 50/50 were cold-pressed with a KK40 oilseed press, and the meal was hammer-milled. Meal was applied to the 'spring-applied meal' treatment on 12-May 2014 at a rate of 2.4 lbs. per plot, or 522 lbs. per acre. Plots were disked to incorporate meal on 19-May and the soil prepped for planting again on 29-May.

Black turtle beans (the variety 'Midnight') were planted on 2-Jun 2014 with a John Deere MaxEmerge 1750 corn planter. Beans were seeded in 30" rows at a rate of 8-10 seeds per row foot, or approximately 130,000 seeds per acre. On 16-Jun 2014, bean plants had emerged, and plots were hand-weeded. Plots were cultivated on 23-Jun and 3-Jul. Bean plants were counted to calculate plant population on 16-Jun 2014. Bean plant roots were visually assessed for disease on 11-July 2014 by digging up 10 randomly selected plants in each plot. Disease severity was rated for each plant on a 0-10 scale (0 indicating 0-10% infection, 10 indicating 90-100% infection). Pictures were also taken in each plot to assess percent of cover due to the beans using a computer imaging program. On 20-Oct 2014, beans were carefully harvested with an Almaco small plot combine, set low to the ground and with a low cylinder speed setting (Figure 2).

Figure 2. Research farm operator Roger Rainville harvests black beans.

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 ($p<0.10$).

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 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 the example at right, 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

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

2.0. This means that these treatments did not differ in the evaluated variable. 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 values evaluated variable of these treatments were significantly different from one another. The asterisk indicates that treatment B was not significantly lower than the top performing treatment C, indicated in bold.

RESULTS

Weather data was 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 2013-2014 growing season (Table 2). Historical weather data are from 1981-2010 at cooperative observation stations in Burlington, VT, approximately 45 miles from Alburgh, VT. In general, the fall of 2013 was slightly drier and cooler than normal. Temperatures well below zero were experienced during December 2013 and January 2014. The summer of 2014 had about 3 inches precipitation more than normal while the fall had about 2 fewer inches of precipitation. A total of 2,713 GDDs were accumulated during the 2013 season for mustard. This is 29 more GDDs than the 30 year average but 76 fewer than last year. A total of 2844 GDDs were accumulated for black beans during the 2014 season. This is 99 more than the 30 year average.

Table 2. Consolidated weather data and GDDs for black beans, Burlington, VT, 2013-2014.

	2013				2014				
Alburgh, VT	August	September	October	November	June	July	August	September	October
Average temperature (°F)	67.7	59.3	51.1	35.1	66.9	69.7	67.6	60.6	51.9
Departure from normal	-1.1	-1.3	2.9	-3.1	1.1	-0.9	-1.2	0.0	3.7
Precipitation (inches)	2.41	2.20	1.87	3.16	6.09	5.15	3.98	1.33	4.27
Departure from normal	-1.50	-1.44	-1.73	0.04	2.40	1.00	0.07	-2.31	0.67
Growing Degree Days (base 32°F)	1112	825	600	176	-	-	-	-	-
Departure from normal	-27	-33	98	-9	-	-	-	-	-
Growing Degree Days (base 50°F)	-	-	-	-	681	799	736	501	127
Departure from normal	-	-	-	-	27	-27	-31	3	127

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.

On 5-Nov 2013, just prior to chopping and incorporation of the whole plant HGM plots, biomass accumulation and quality was measured (Table 3). At this time, the moisture of the HGM plants averaged 82.3%, and average dry matter yield was 1816 lbs. per acre. This yield is 529 lbs. per acre lower than last year's whole plant treatment. This reduction in biomass was likely a result of cooler temperatures and deficient soil moisture during the fall of 2013. Variety 119 yielded 715 and 1021 lbs. dry matter per acre more than varieties 61 and 199 respectively.

Table 3. HGM cover crop biomass samples collected 5-Nov 2013, Alburgh, VT.

HGM Variety	Moisture	Dry matter yield
	%	lbs. ac^{-1}
199	83.4	1374
61	83.3	1680
119	82.8	2395
Mean	82.3	1816

Soil nutrient content was assessed in late fall 2013. Soil samples were bulked from all whole plant plots and compared to a bulked sample from all control plots (Tables 4 and 5). Statistical analysis was not performed as soil samples from plots were bulked by treatment. Whole plant plots were higher in all measured soil characteristics (Tables 4 and 5). Soil pH, available phosphorous (P), aluminum (Al), magnesium (Mg), and zinc (Zn) were fairly consistent between whole plant and control plots. Potassium (K) and calcium (Ca) were both higher in the whole plant plots by 16.7 and 1137 ppm respectively. The cation exchange capacity (CEC) was also 5.8 meq. per 100 g greater in whole plant plots. Organic matter was slightly higher (0.4 %) in the whole plant plots as well.

Table 4. Soil nutrient analysis of HGM whole plant and control plots, 5-Nov 2013, Alburgh, VT.

HGM treatment	Soil pH	Available P	K	Mg	Al	Ca	Zn	CEC	Organic matter
		ppm	ppm	ppm	ppm	ppm	ppm	meq 100 g^{-1}	%
Whole plant	**7.5**	**8.2**	**72.7**	**70.7**	**10.3**	**3701**	**0.7**	**19.3**	**4.4**
Control	7.2	8.0	56.0	67.0	10.0	2565	0.5	13.5	4.0
Trial mean	7.3	8.1	64.3	68.8	10.2	3133	0.6	16.4	4.2

Statistical analysis was not conducted; treatments shown in **bold** are top-performing in a particular column.

Whole plant plots were higher in all micronutrients (Table 5). The greatest difference was observed in manganese (Mn) which was 1.6 ppm or 64% higher in whole plant plots. Boron (B) also differed more between treatments as it was 0.17 ppm or was also 34% higher in whole plant plots.

Table 5. Soil micronutrients of HGM whole plant and control plots, 5-Nov 2013, Alburgh, VT.

HGM treatment	S	Mn	B	Cu	Fe	Na
	ppm	ppm	ppm	ppm	ppm	ppm
Whole plant	**6.00**	**4.10**	**0.67**	**0.13**	**1.50**	**21.0**
Control	5.00	2.50	0.50	0.10	1.40	20.0
Trial mean	5.50	3.30	0.58	0.12	1.45	20.5

Statistical analysis was not conducted; treatments shown in **bold** are top-performing in a particular column.

Soil nutrient content was again assessed, this time for all plots, in the spring 2014. This was done prior to the spring meal applications so at this point in time the spring meal and control treatments have experienced the same conditions. Soil pH, Mg, Ca, and CEC varied statistically across HGM treatments (Table 6). Magnesium was highest in the whole plant variety 61 treatment at 99 ppm. This differed statistically from the fall and spring meals as well as whole plant variety 119. Calcium was also the highest in the whole plant varieties 61 and 199. The CEC was also the highest in the 61 and 199 varieties at 39.2 and 29.3 meq $100g^{-1}$ respectively. Organic matter, zinc, potassium, and phosphorous did not differ across treatments. Interestingly, the varieties that produced greater changes in soil nutrients and quality, varieties 61 and 199, were not as high yielding as variety 119 which had consistently lower soil nutrients.

Table 6. Soil nutrient analysis for HGM treatments, 25-Apr 2014, Alburgh, VT.

HGM treatment	Soil pH	Available P	K	Mg	Al	Ca	Zn	CEC	Organic matter
		ppm	ppm	ppm	ppm	ppm	ppm	meq 100 g^{-1}	%
Whole plant-61	7.5*	6.4	81.3	**99.0***	11.7	**7628***	**0.7**	**39.2***	3.8
Whole plant-119	7.2*	6.1	77.0	79.0	13.0	3906	0.6	20.4	3.8
Whole plant-199	**7.5***	6.1	72.7	83.3*	8.7	5682*	0.6	29.3*	**4.0**
Control	7.3*	**7.4**	74.7	84.3*	9.7	4198	0.6	21.9	3.8
Spring Meal	7.1	7.0	73.0	74.0	**13.0**	3594	0.5	18.8	3.7
Fall Meal	7.3*	7.1	**84.7**	78.3	11.0	4103	0.6	21.4	3.6
LSD (0.10)	0.3	NS	NS	18.2	NS	2652	NS	13.4	NS
Trial mean	7.3	6.7	77.2	83.0	11.2	4852	0.6	25.1	3.8

NS- No significant difference.
Values in **bold** indicate top performers.
*Values with an asterisk next to them do not differ statistically from the top performer.

Soil micronutrients also varied slightly by HGM treatment (Table 7). Sulfur was highest in the whole plant varieties 119 and 199 at 9.0 and 8.0 ppm respectively. Manganese was highest level in the whole plant variety 61which was significantly greater than all other treatments. The lowest was in the spring meal treatment at 10.1 ppm. Boron was highest in the whole plant 199 variety at 0.77 ppm, higher than all other treatments. The lowest also being observed in the spring meal treatment. Copper, iron and sodium did not differ statistically across treatments.

Table 7. Soil micronutrients for HGM treatments, 25-Apr 2014, Alburgh, VT.

HGM treatment	S	Mn	B	Cu	Fe	Na
	ppm	ppm	ppm	ppm	ppm	ppm
Whole plant-61	7.33	**19.0***	0.65	0.13	2.60	16.00
Whole plant-119	**9.00***	11.6	0.62	0.15	2.50	17.33
Whole plant-199	8.00*	13.1	**0.77***	0.15	2.07	18.00
Control	7.67	11.0	0.58	0.15	2.33	**19.33**
Spring Meal	7.67	10.1	0.53	0.15	2.43	16.00
Fall Meal	7.67	11.3	0.58	**0.17**	**2.63**	16.00
LSD (0.10)	1.07	5.5	0.11	NS	NS	NS
Trial mean	7.89	12.7	0.62	0.15	2.43	17.1

NS- No significant difference.
Values in **bold** indicate top performers.
*Values with an asterisk next to them do not differ statistically from the top performer.

Table 8. Black bean pre-harvest characteristics and yield, 2014.

HGM Treatment	Population plants m^2	Ground Cover %	Disease 0-10	Yield lbs. ac^{-1}
Whole Plant-61	51*	85.2	**0.0**	**3203***
Whole Plant-119	**54***	**86.7**	0.8	2859*
Whole Plant-199	49*	77.2	0.0	3012*
Fall Meal	41	82.8	0.0	2972*
Spring Meal	51*	79.9	0.0	2921*
Control	45*	86.5	0.0	2762
LSD (.10)	11.4	NS	NS	374
Trial Mean	49.0	83.1	0.1	2955

NS- No significant difference.
*Values in **bold** indicate top performers and values with an asterisk next to them do not differ statistically from the top performer.

Prior to harvesting black bean populations, disease incidence and ground cover from bean plants were assessed (Table 8). Plant populations of black beans prior to harvest varied by HGM treatment (Figure 3). The highest population of 54 plants per square meter was observed in the variety 119 treatment although this only differed statistically from the fall applied meal treatment. Ground cover provided by black bean plants ranged from 77.2% to 86.7% although all treatments were statistically similar. Disease incidence was low in all treatments and did not vary statistically.

Figure 3. Black bean plant populations by HGM treatment, 2014.
Treatments that share a letter do not differ statistically.

Black beans were harvested in late October at moisture levels that were above the calibration of our moisture meter (>28%). Yields ranged from 2762 to 3203 lbs. per acre, with the greatest yield in the treatment with whole plant HGM variety 61 (Figure 4) however this only differed statistically from the control. Yields were double last year's yields over all treatments.

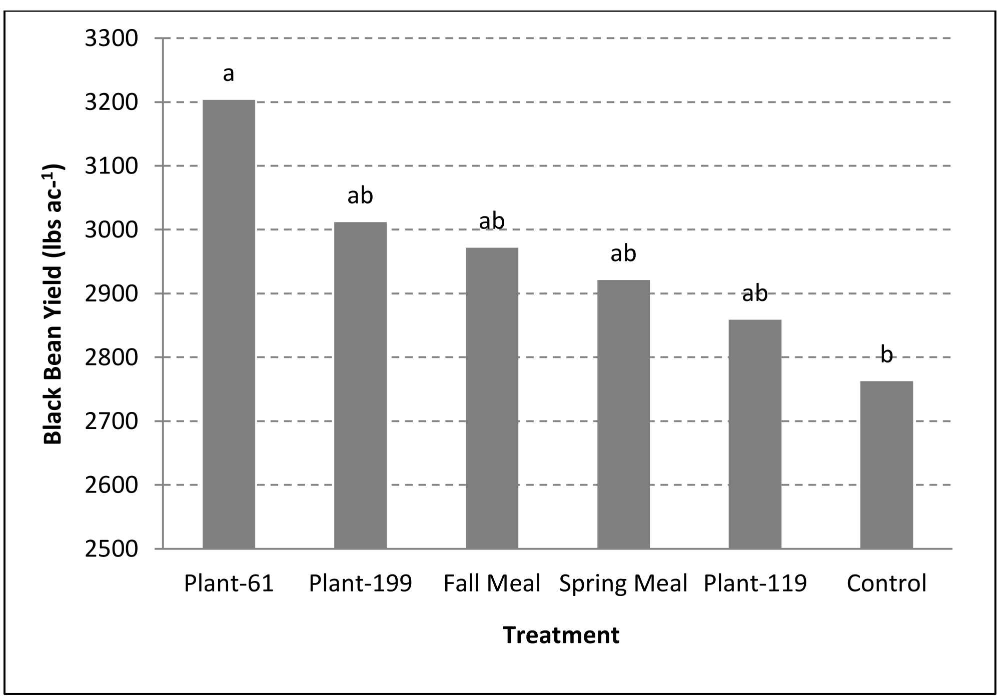

Figure 4. Yields by HGM treatment, 2014.
Treatments that share a letter do not differ statistically.

DISCUSSION

Although little to no disease was observed in any of the treatments and weeds were controlled the same throughout the trial, HGM, both applied as seed meals and planted as a cover crop, produced higher black bean yields than the control. The highest yield was produced by the variety 61; over 400 lbs. per acre more than the control. Although the variety 119 produced more biomass on a dry matter basis, it yielded only 97 lbs. per acre more for black beans than the control. The CEC in the 119 treatment was much lower than the 61 and 199 treatment. Overall, soil nutrients were enhanced in the HGM variety treatments 199 and 61. This indicates that the HGM cover crops could greatly influence physical, biological, and chemical properties of the soil. It does appear that production of the cover crop has more benefits than just incorporating the HGM meal as a soil amendment. In addition, since disease was not an issue this season, perhaps greater differences would be seen in a wetter, cooler season or if the trial was located on more marginal soils. The HGM biomass yields observed in this trial are still much lower than others in the Pacific Northwest, suggesting that perhaps these yields need to be increased to fully realize the benefits of this system for this region. Therefore, varietal differences in performance of HGM cover crops should be evaluated for the Northeast.

ACKNOWLEDGEMENTS

This project is funded by a USDA NESARE Research and Education grant, Project # LNE 12-317. UVM Extension would like to thank Roger Rainville at Borderview Research Farm for his generous help implementing and maintaining this research trial. We would like to acknowledge Katie Blair, Connor Burke, Lily Calderwood, Julija Cubins, Hannah Harwood, Ben Leduc, Laura Madden, and Dana Vesty of the UVM Extension Northwest Crops & Soils Program for their assistance with data collection and entry.