Impact of High Glucosinolate Mustard Biomass and Meal on Black Bean Yield

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2013 HIGH GLUCOSINOLATE MUSTARD AND BLACK BEAN TRIAL

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Brassicae crops (mustard family) contain chemicals called glucosinolates. These compounds are present in the leaves, stem, roots, and seed 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 high glucosinolate varieties of mustard 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, the mustard is also an oilseed with a potential use in biofuel production. Extraction of the oil from the seed leaves 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 weed 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 2012-2013, 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 2012, a research trial was conducted at Borderview Research Farm in Alburgh, VT (Table 1). The plot design was a randomized complete block, with HGM treatments as the main plots, and three replications. The HGM treatments included a whole plant cover crop, 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 silty clay loam with 0-3% slope, and the previous crop was oilseed sunflower. Plots were 10' x 25.'

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

The HGM Caliente variety '199,' was planted on 23-Aug 2012 with a 10' wide Sunflower grain drill at 9 lbs per acre. The HGM variety 'Pacific Gold', was cold-pressed with a KK40 oilseed press on 11-Oct 2012 (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 2012 at a rate of 3 lbs per plot, or 523 lbs per acre. On 5-Nov 2012, 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 brushhog on 5-Nov 2012, and all plots were disc harrowed to incorporate and prepare the seedbed. Soil samples from the whole plant plots and control plots, collected 5-Nov 2012, were processed by UVM's Agricultural and Environmental Testing Laboratory.

Table 1. Agronomic management of HGM and black bean trial, 2012-2013, Alburgh, VT.

Location	**Borderview Research Farm – Alburgh, VT**
Soil type	Covington silty clay loam, 0-3% slope
Previous crop	Sunflower
HGM treatments	Whole plant, fall-applied meal, spring-applied meal, control
Replications	3
Plot size (ft)	10 x 25
HGM planting date	23-Aug 2012
HGM seeding rate (lbs ac^{-1})	9
HGM termination	5-Nov 2012
Fall HGM meal application date	5-Nov 2012
Fall HGM meal rate (lbs ac^{-1})	523
Spring HGM meal application date	4-Jun 2013
Spring HGM meal rate (lbs ac^{-1})	523
Black bean variety	Midnight black turtle
Black bean planting date	4-Jun 2013
Black bean planting rate (seeds ft^{-1})	8-10
Weed control	Tineweeded 20-Jun 2013, hand-weeded 24-Jul 2013
Harvest date	4-Oct 2013

On 29-Apr 2013, HGM seed ('Pacific Gold' variety) was cold-pressed with a KK40 oilseed press, and the meal was hammer-milled. Meal was applied to the 'spring-applied meal' treatment on 4-Jun 2013 at a rate of 3 lbs per plot, or 523 lbs per acre.

Black turtle beans (the variety 'Midnight') were planted on 4-Jun 2013 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 20-Jun 2013, bean plants had emerged, and plots were tineweeded. On 13-Jun 2013, plots were sampled for soil nitrate analysis, provided by UVM's Agricultural and Environmental Testing Laboratory. Bean plants were counted to calculate plant population on 27-Jun 2013. Bean and weed populations were assessed on 9-Jul 2013. Additional weed control was provided as hand-weeding on 24-Jul 2013. On 4-Oct 2013, 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, 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

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

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

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 2012-2013 growing season (Table 2). Historical weather data are from 1981-2010 at cooperative observation stations in Burlington, VT, approximately 45 miles from Alburgh, VT. For the most part, temperatures were above average in 2012 and through the winter, while it was colder and wetter than average in the spring of 2013, when black beans were planted. In June 2013, there were 5.54 more inches of precipitation than normal. The summer of 2013 was drier than normal, with an average of 5.20 inches fewer than normal in July, August, and September.

GDDs are calculated at a base temperature of 32°F for HGM and 50°F for black beans. The late fall of 2012 was warmer than average, with 2789 GDDs accumulated for mustard after planting and before it was plowed under in the beginning of November. Between planting and harvesting, there were an accumulated 1947 GDDs for black beans, 66 fewer than the 30-year average.

Table 2. Consolidated weather data and GDDs for black beans, Burlington, VT, 2012-2013.

	2012					2013								
Alburgh, VT	Aug	Sep	Oct	Nov*	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Average temperature (°F)	71.1	60.8	52.4	36.7	28.7	20.6	21.9	32.1	43.6	59.1	64.0	71.7	67.7	59.3
Departure from normal	2.3	0.2	4.2	-1.5	2.8	1.8	0.4	1.0	-1.2	2.7	-1.8	1.1	-1.1	-1.3
Precipitation (inches)	2.92	5.36	4.13	0.68	3.49	0.60	1.08	1.04	2.12	4.79	9.23 ł	1.89	2.41	2.20
Departure from normal	-0.99	1.72	0.53	-2.44	1.12	-1.45	-0.68	-1.17	-0.70	1.34	5.54	-2.26	-1.50	-1.44
Growing Degree Days (base 32°F)	1241	896	652	144	535	47	21	89	348	848	967	1235	1112	825
Departure from normal	102	38	150	-40	535	47	21	89	-36	91	-47	37	-27	-33
Growing Degree Days (base 50°F)	674	392	193	0	29	0	0	0	39	312	427	677	554	289
Departure from normal	93	74	81	0	-303	0	0	0	39	113	-47	37	-27	-29

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.
* Nov 2012 data are based on National Weather Service data from cooperative observation stations in South Hero, VT.
ł June 2013 precipitation data based on National Weather Service data from cooperative stations in South Hero, VT.

On 5-Nov 2012, 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 89.0%, and dry matter yield was 2345 lbs per acre. The average nitrogen content of the HGM was 4.24%.

Table 3. HGM cover crop biomass samples collected 5-Nov 2012, Alburgh, VT.

HGM treatment	Moisture	Dry matter yield	Nitrogen
	%	lbs ac^{-1}	% of DM
Whole plant	89.0	2345	4.24

Soil nutrient content was assessed in late fall 2012. 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. The pH was lowered in the whole plant plots, and there was more available phosphorous (P) than in the control plots. Potassium (K), magnesium (Mg), aluminum (Al), and calcium (Ca) were all lower in plots with HGM plants. Zinc levels were greater in whole plant plots than in the control treatment. The cation exchange capacity (CEC) was greater in control plots (33.3 meq per 100 g) than in HGM whole plant plots (16.4 meq per 100 g). Organic matter was greater in whole plant treatment than in the control, and averaged 3.70% overall.

Table 4. Soil nutrient analysis of HGM whole plant and control plots, 5-Nov 2012, 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	7.30	**3.30**	63.0	80	14.0	3122	**0.40**	16.4	**3.80**
Control	**7.70**	2.30	**68.0**	**101**	**15.0**	**6450**	0.30	**33.3**	3.60
Trial mean	7.50	2.80	65.5	91	14.5	4786	0.35	24.9	3.70

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

Micronutrients varied less between whole plant plots and the control treatment. Sulfur (S) was equal in the whole plant and control treatments, as was boron (B) and copper (Cu). Manganese (Mn), iron (Fe), and Sodium (Na) levels were higher in the control than in the whole plant treatment.

Table 5. Soil micronutrients of HGM whole plant and control plots, 5-Nov 2012, Alburgh, VT.

HGM treatment	S	Mn	B	Cu	Fe	Na
	ppm	ppm	Ppm	ppm	ppm	ppm
Whole plant	**7.00**	6.5	**0.50**	**0.15**	1.80	17.0
Control	**7.00**	**10.7**	**0.50**	**0.15**	**2.30**	**25.0**
Trial mean	7.00	8.6	0.50	0.15	2.05	21.0

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

On 13-Jun 2013, soil nitrate levels did not differ significantly by HGM treatment (Table 6). There was no statistical difference in bean populations, assessed in late June, by HGM treatment. Likewise, bean populations were not statistically different in July, but averaged 45.0 plants per square meter.

Table 6. Nitrate levels, population, and harvest data for black beans, 2013, Alburgh, VT.

HGM treatment	June		July			Harvest		
	Nitrates	Bean population	Beans	Grasses	Broadleaves	Moisture	Test weight	Yield
	mg kg^{-1}	plants m^{-2}	plants m^{-2}	plants m^{-2}	plants m^{-2}	%	lbs bu^{-1}	lbs ac^{-1}
Whole plant	3.56	24.5	36.3	**22.7**	24.2	13.8	61.7	**1594**
Fall-applied meal	**4.18**	23.0	**53.0**	53.0	**21.2**	13.6	60.7	1379
Spring-applied meal	3.24	**26.4**	43.9	95.3	48.4	**13.9**	61.3	1064
Control	2.73	24.9	46.9	46.9	49.9	13.6	**61.8**	1323
LSD (0.10)	NS	NS	NS	NS	NS	NS	NS	NS
Trial mean	3.43	24.7	45.0	54.5	35.9	13.7	61.4	1340

NS – Treatments were not significantly different from one another (p=0.10).
Treatments shown in **bold** are top-performing in a particular column.

Weed populations did not differ significantly by HGM treatment; grass species averaged 54.5 plants per square meter, while there was an average of 35.9 broadleaf weeds per square meter (Figure 3).

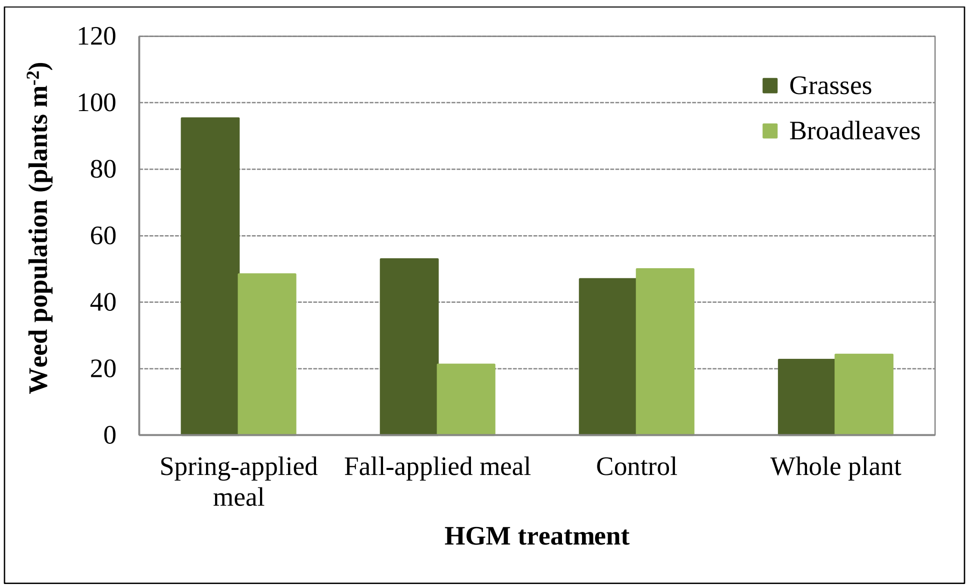

Figure 3. Weed population by HGM treatment. There were no statistical differences in grass or broadleaf weed pressure by treatment (p=0.10).

Black beans were harvested in early October at an average moisture level of 13.7%. Test weights and yields did not differ significantly by HGM treatment. The greatest test weight was in the control treatment (61.8 lbs per bushel), though this was not statistically significant. Yields ranged from 1064 to 1594 lbs per acre, with the greatest yield in the treatment with whole plant HGM (Figure 4).

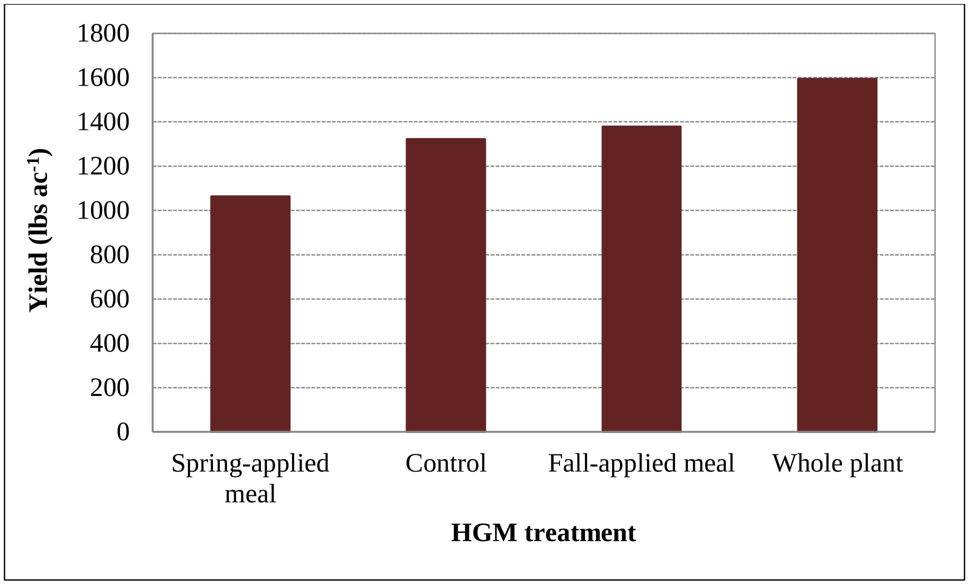

Figure 4. Yields by HGM treatment. There were no significant differences by treatment (p=0.10).

DISCUSSION

In this 2012-2013 trial, soil amended HGM cover crops or meal did not significantly impact soil characteristics, weed populations, plant populations, or yield and quality of black beans. In whole plant plots, HGM was plowed under and incorporated with an average biomass accumulation of 2345 lbs per acre. These yields are lower than those reported in research trials conducted in the Pacific Northwest. Yields of HGM in these trials ranged from 3 to 5 tons of dry matter per acre. Yields of HGM will likely need to be increased in order to have enough biomass to impact disease and weed pressure in the soil ecosystem. Higher seeding rates and earlier planting dates may help to achieve yield increases. Meal amendments may also need to be increased to impact pest populations. It is possible that higher rates of meal may increase available nitrogen in the soil and potentially cause increased annual weed populations. Additional research needs to be conducted to better understand how HGM crops could be incorporated into the Northeastern cropping system.

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