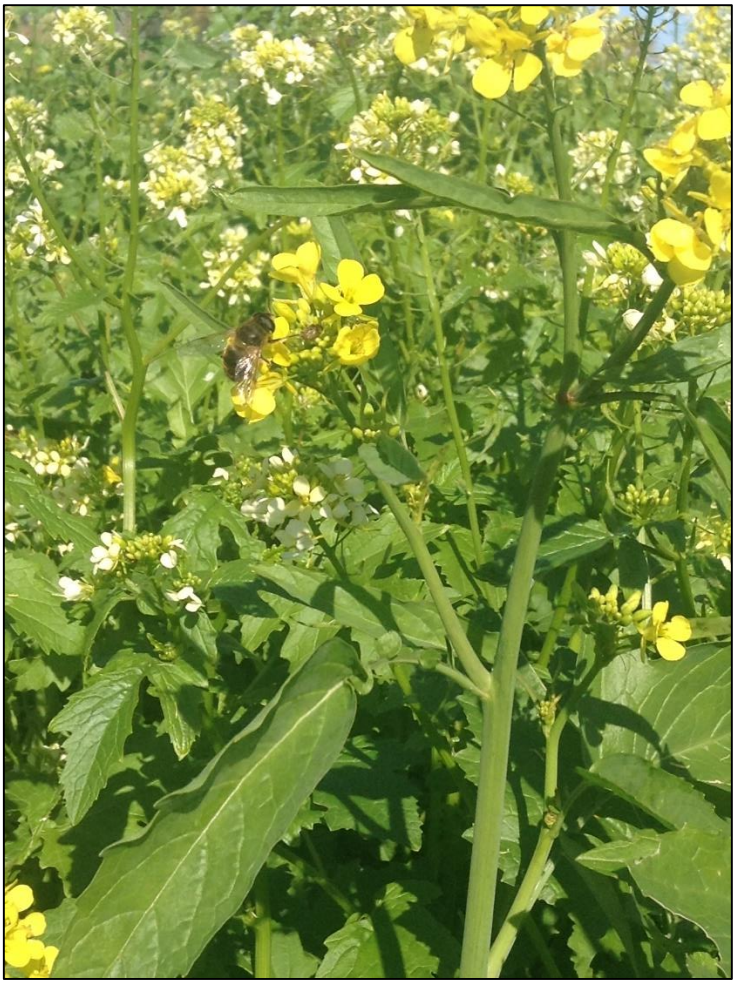
NORTHWEST CROPS & SOILS PROGRAM

2019-2021 Brassica Cover Crops in Vegetable Rotations Trial



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THE UNIVERSITY OF VERMONT EXTENSION

2019-2021 BRASSICA COVER CROPS IN VEGETABLE ROTATIONS TRIAL

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Brassica crops are an important crop on diversified vegetable farms in Vermont and the Northeast. Brassicas are becoming more popular as a cover crop due to their unique benefits to soil health. They provide ground cover and cover crop biomass rapidly in the fall, and brassicas with long taproots further break up soil compaction. Brassicas grown on vegetable farms include rutabaga, cabbage, cauliflower, kale, broccoli, Brussels sprouts, collards, and mustard greens. Despite the benefits, not all vegetable producers are quick to add brassica cover crops to their brassica cash crop rotations due to concern that pests and disease are likely to transfer from one brassica crop to another. An increased use of high tunnels has also created a "green bridge" for disease and pests in the winter months. To assess the risk of pest and disease carryover between brassica crops, the University of Vermont Extension Northwest Crop and Soils (NWCS) Team conducted a field trial at two locations over two full field seasons with fall-planted brassica cover crops, followed by a broccoli cash crop.

MATERIALS AND METHODS

The trial was conducted at two sites: Borderview Research Farm, in Alburgh, VT, and the University of Vermont's Horticulture Research Farm in South Burlington, VT, from fall 2019 through the 2021 summer season. Brassica cover crop treatments were planted each fall in the same plots and were followed by broccoli in the summer. The Horticulture Research Farm site had a history of vegetable production, resulting in an increased risk of pathogens present in the soil, while the Alburgh site had not previously been used for vegetable production, but for small grains, corn, milkweed, and hemp. The experimental design was a complete randomized block design with four replications and an untreated control (Table 1). The brassica cover crop treatments were high glucosinolate mustard (HGM) (*var: Trifecta*), tillage radish (*var: Eco-till*), an oats and peas mix (*vars: Everleaf, Arvica*), an oats, peas, and radish mix, and an oats, peas, and HGM mix. Seeding rates are displayed in Table 2. Cover crops were planted into 10 x 20-foot plots. Brassica cover crops were scouted for pests and disease biweekly in September and October by walking in a M-shaped route through the plot, stopping at 5 random plants. Roots were inspected if the plant appeared yellow or stunted, and the percent total disease damage of three leaves was recorded, in the middle canopy of the plant, for the five plants.

Table 1. Trial agronomic information, 2019-2021.

Location	Borderview Research Farm-Alburgh, VT	Horticulture Research Farm-South Burlington, VT
Soil type	Benson rocky silt loam 8-15% slope	Duane & Deerfield soils, 5-12 % slope
Previous crop	Spring wheat	Grass hay
Plot size (feet)	10 x 20	10 x 20
Replicates	4	4
Cover crop planting dates	15-Aug 2019, 12-Aug 2020	25-Aug 2019, 2-Sep 2020
HGM incorporation dates	29-Oct 2019, 28-Oct 2020	N/A, early Sept 2020
Broccoli planting dates	20-May 2020, 26-May 2021	2-Jun 2020, 4-Jun 2021
2019 Cover crop scouting period	13-Sep to 28-Oct	13-Sep to 25-Oct

2020 Broccoli scouting period	12-Jun to 24-Jul	10-Jun to 25-Jul
2020 Cover crop scouting period	9-Sep to 7-Oct	3-Sep
2021 Broccoli scouting period	8-Jun to 19-Jul	17-Jun to 18-Jul

Table 2. Brassica cover crop treatments, Alburgh & South Burlington VT, 2019-2021.

Treatment	Variety	Seeding rate lbs ac^{-1}
High glucosinolate mustard (HGM)	*Trifecta*	12
Tillage Radish	*Eco-till*	6
Oats	*Everleaf*	75
Peas	*Arivca*	50
Oats	*Everleaf*	70
Peas	*Arivca*	48
Radish	*Eco-till*	3
Oats	*Everleaf*	70
Peas	*Arivca*	50
HGM	*Trifecta*	5

Common diseases scouted for included black rot, black leg, *Alternaria* leaf spot, downy mildew, club root, powdery mildew, and *Sclerotinia* white mold. Pests scouted for included cabbage root maggot, flea beetle counts and percent damage, swede midge, cabbage aphid, and caterpillar larvae; imported cabbageworm (ICW), cabbage looper (CL), and diamondback moth (DBM). In 2019, the HGM and HGM mixes were terminated at the Alburgh site on 29-Oct with a brush hog and incorporated with a disc harrow. One plot in the 4th replicate that was intended to be radish had both HGM and oats due to a seeding error, which was also mowed down. Broccoli starts were planted in Alburgh on 20-May in spring 2020 and on 26-May in spring 2021. Broccoli starts were planted at the Horticultural Research Farm South Burlington on 2-Jun in 2020 and on 4-Jun in 2021 on rows of plastic. There were only three replicates with a control at the horticulture farm in 2020. Broccoli was scouted for the same pests and diseases as the brassica cover crop, with the same methods described above, on a biweekly basis from June to the end of July when the broccoli crop was fully mature. In fall 2020, the cover crops were planted in the same plots at the same rates as the previous year and were scouted during September and October for the Alburgh site, and only on 3-Sep 2020 for the South Burlington site, due to early termination of the cover crops by a mower. Broccoli were planted in Alburgh on 26-May 2021 and in South Burlington on 4-Jun 2021. Broccoli was scouted again for pests and diseases, with the same methods as the previous year, on a biweekly basis from June to the end of July. The crop was harvested on 27-Jul 2021 and yields recorded. Broccoli heads were visually rated on a 1-5 scale to record marketability (Figure 1).

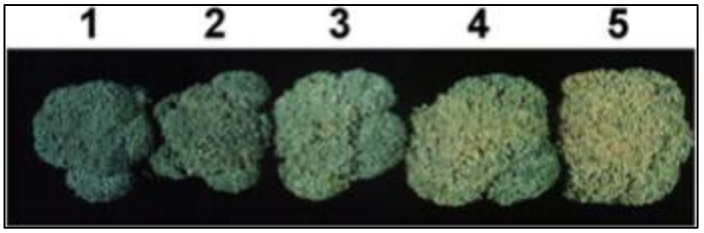

Figure 1. Broccoli head marketability scale.

Data were analyzed using a mixed linear model with repeated measures procedure of SAS (SAS 9.4, SAS Institute, Cary NC). The experimental design was a randomized complete block design with replication, where replications were random effects, and treatment and date were fixed effects, and their interaction was included in the model. Date was a repeated factor with rep*treatment as the subject. A significant

main effect was followed by pairwise comparisons and a significant interact was followed by examination of simple effects. Mean comparisons were done with Tukey's method, where $p < 0.05$. Before analysis, the disease data was converted to a proportion to be arcsine square root transformed, and all data was averaged by plot. All data was analyzed by plot, as opposed to by plant.

Variations in genetics, soil, weather, and other growing conditions can result in variations in yield and quality. Statistical analysis makes it possible to determine whether a difference between treatments is significant or whether it is due to natural variations in the plant or field. For this data analysis, tables show the p-values, and there is a significant difference when $p<0.05$. When there is a difference in the treatments, a "connecting letters" table is displayed with the means from the Tukey's method. The letters show which treatments are similar to each other, and which are statistically different. For example, if one treatment has "AB" and the other has "C", then there is a real difference between the treatments (cover crop types) 95% of the time. This is based on the 0.05 p-value. A lack of significant difference is indicated by shared letters. The treatment with the highest pest and disease means are indicated in bold.

RESULTS

Weather data was recorded with a Davis Instrument Vantage Pro2 weather station, equipped with a WeatherLink data logger at Borderview Research Farm in Alburgh, VT (Tables 4-7). October 2019 was unusually warm, 2.32°F higher than normal, and saw 2.76 more inches of precipitation. These are prime conditions for soil-borne pathogens. The 2019-2020 trial period saw 5317 Growing Degree Days (GDDs), 30 below the 30-year normal. In spring 2020, conditions were drier than average, which continued through July to the end of broccoli scouting. There were 3.18 fewer inches of precipitation than average from April to July. In the broccoli's growing season, temperatures were hot, especially in July, which was 4.17°F above average, and had 1326 Growing Degree Days, 132 above the 30-year norm. These warm and dry conditions are less favorable to pathogens. Fall 2020 was drier than average for September through December; it saw 3.58 inches less of precipitation than average in that period. Temperatures were below normal in September by 3.53°F and were above normal in November by 2.69°F. May 2021 was drier than the 30-year norm, follow by a slightly dry and warmer June, with an average temperature of 70.3°F, followed by a cool and dry July, with and average temperature of 68.1°F. The 2019-2020 trial period saw 5653 GDDs, 182 above the 30-year normal. The 2021 broccoli growing season, from May to July, saw 3086 GDDs, 49 below the norm.

Table 4. Weather data for Alburgh, VT, Fall 2019.

Alburgh, VT	September	October	November	December
Average temperature (°F)	60.0	50.4	31.2	26.0
Departure from normal	-0.51	2.32	-6.76	0.46
Precipitation (inches)	3.87	6.32	2.38	1.29
Departure from normal	0.21	2.76	-0.74	-1.06
Growing Degree Days (base 32°F)	840	571	128	67
Departure from normal	-15	58	-122	-13

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.

Table 5. Weather data for Alburgh, VT, 2020.

Alburgh, VT	January	February	March	April	May	June	July
Average temperature (°F)	23.5	21.8	35.0	41.6	56.1	66.9	74.8
Departure from normal	4.62	0.41	3.94	-3.19	-0.44	1.08	4.17
Precipitation (inches)	2.63	1.19	2.79	2.09	2.35	1.86	3.94
Departure from normal	0.63	-0.53	0.57	-0.72	-1.04	-1.77	-0.28
Growing Degree Days (base 32°F)	37	48	193	315	746	1046	1326
Departure from normal	-12	-8	27	-99	-13	35	132

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.

Table 6. Weather data for Alburgh, VT, Fall 2020.

Alburgh, VT	September	October	November	December
Average temperature (°F)	59.2	48.3	42.0	29.4
Departure from normal	-3.53	-2.01	2.69	1.20
Precipitation (inches)	2.75	3.56	1.41	1.40
Departure from normal	-0.92	-0.27	-1.29	-1.10
Growing Degree Days (base 32°F)	816	521	352	100
Departure from normal	-107	-48	117	52

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.

Table 7. Weather data for Alburgh, VT, 2021.

Alburgh, VT	January	February	March	April	May	June	July
Average temperature (°F)	21.5	19.8	33.2	48.1	58.4	70.3	68.1
Departure from normal	0.64	-3.07	0.93	2.52	-0.03	2.81	-4.31
Precipitation (inches)	0.39	0.47	0.97	3.52	0.66	3.06	2.92
Departure from normal	-1.74	-1.30	-1.27	0.45	-3.10	-1.20	-1.14
Growing Degree Days (base 32°F)	8	32	241	497	818	1149	1119
Departure from normal	8	21	103	85	-1	86	-134

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.

2019-2020 Field Season

Pest and disease results are displayed in the tables below. The p-value is highlighted in bold in Table 8 when it is significant, and significant results by treatment are shown in Table 9. “None” means that there were no observations. Fall season results are for the cover crops, and summer season results are for the broccoli cash crop following each of the cover crop treatments. Table 8 shows the results for the South Burlington site for the 2019-2020 season. In fall 2019 at the Horticulture Research Farm, there were only statistically significant treatments for Alternaria leaf spot and downy mildew. Alternaria leaf spot was

significantly higher in the HGM brassica plots than the oats/peas treatment and the control, and downy mildew was higher in the oats/peas/HGM brassica plots than the oats/peas and the control (Table 9). No powdery mildew or imported cabbage worms were observed, and the arthropods scouted did not vary by brassica cover crop treatment in fall 2019 (Table 8). In the following summer, no diseases were observed on the broccoli cash crop, and arthropods did not differ by cover crop treatment except for the diamondback moth (p= 0.0068, Table 8). The presence of the diamondback moth was statistically greater in the oats/peas/HGM plots than in the oats/peas/radish and HGM cover crop treatments (Table 9).

Table 8. 2019-2020 Horticulture Research Farm Treatment Results, South Burlington, VT.

Hort Farm	Alternaria Leaf Spot	Downy Mildew	Powdery Mildew	Flea Beetles	FB Damage	ICW	Cabbage looper	DBM	Midge	Aphid
Fall 2019	**0.0183**	**0.0054**	None	0.4457	None	None	0.1249	0.4457	0.0652	0.0187
Summer 2020	None	None	None	0.2140	0.5126	0.1059	0.1834	**0.0068**	None	0.5199

FB= flea beetle, ICW= imported cabbage worm, DBM= diamondback moth. Statistical significance is based on p<0.05.

Table 9. 2019-2020 Horticulture Research Farm Significant Results by Treatment

Treatment	Fall 2019 Alternaria Means	Fall 2019 Downy Mildew Means	Summer 2020 DBM Means
HGM	**0.0033^{a}**	0.0043^{ab}	0.0024^{b}
radish	0.0023^{ab}	0.0005^{ab}	0.0071^{ab}
oats/peas/radish	0.0004^{ab}	0.0007^{ab}	0.0048^{b}
oats/peas/HGM	0.00^{ab}	**0.0062^{a}**	**0.0262^{a}**
control	0.00^{b}	0.00^{b}	0.0063^{ab}
oats/peas	0.00^{b}	0.00^{b}	0.0190^{ab}

*Highest incidence is highlighted in **bold**. Treatments that share letters are statistically similar at p <0.05.*

Some dates had significantly higher amounts of disease or arthropods scouted in comparison to other dates; this is expected, as ideal conditions for disease and arthropods increase in the fall after they move onto the crop, then decrease as the winter approaches and the species go dormant for the winter. In the summer, conditions for pathogens are ideal when the weather is cool and damp, and so as time goes on and the weather becomes drier and hotter, the risk of pathogens generally decreases. Arthropods will vary by date in the summer due to their weekly life cycle changes. For example, during the summer of 2020, all the arthropods scouted except midges varied statistically by date, which is due to the emergence of the species from eggs and brief times spent on the plants until the next life cycle.

At the Alburgh site, results were similar. On the fall 2019 brassica cover crops, only downy mildew (p=0.0008) and midges (p=0.0002) varied statistically by treatment (Table 10). The oat/peas/HGM brassica cover crop treatment had significantly more downy mildew than the radish, oats/peas, and control plots, and the radish cover crop had significantly more midges than all other cover crops and the control (Table 11). In the subsequent broccoli crop, there were no diseases observed in the summer. No midges were seen during scouting. Only the cabbage looper varied statistically by treatment, where there were more cabbage loopers in the control than the oat/pea/HGM and radish cover crop treatments. The control was statistically

similar to the other treatments (Table 11). Overall, treatment effects did not transfer between the fall brassica cover crop and the following summer brassica crop at both of the locations.

Table 10. 2019-2020 Borderview Research Farm Treatment Results, Alburgh, VT.

Alburgh, VT	Alternaria Leaf Spot	Downy Mildew	Powdery Mildew	Flea Beetles	FB Damage	ICW	Cabbage looper	DBM	Midge	Aphid
Fall 2019	None	**0.0008**	None	0.4563	0.2895	0.4824	0.0860	None	**0.0002**	0.4054
Summer 2020	None	None	None	0.2404	0.4627	0.6188	**0.0149**	0.7110	None	0.4824

FB= flea beetle, ICW= imported cabbage worm, DBM= diamondback moth. Statistical significance is based on p<0.05.

Table 11. 2019-2020 Borderview Research Farm Significant Results by Treatment, Alburgh, VT.

Treatment	Fall 2019 Downy Mildew Means	Fall 2019 Midge Means	Summer 2020 Cabbage Looper Means
oat/pea/HGM	**0.0052^{a}**	0.0167^{c}	0.0024^{b}
HGM	0.0038^{ab}	0.00^{c}	0.0143^{ab}
oat/pea/radish	0.0027^{abc}	0.0667^{b}	0.0048^{ab}
radish	0.0006^{bc}	**0.0389^{a}**	0.00^{b}
control	0.00^{c}	0.00^{c}	**0.0214^{a}**
oats/peas	0.00^{c}	0.00^{c}	0.0095^{ab}

*Highest incidence is highlighted in **bold**. Treatments that share letters are statistically similar at p <0.05.*

2020-2021 Field Season

Brassica cover crops at the Alburgh, VT site.

2020-2021 pest and disease results are displayed below in Tables 12-14. In fall 2020 at the Horticultural Research Farm in South Burlington, VT, plots were terminated early due to a mowing error, resulting in only one scouting date; September 3rd. On this date, there were no significant effects between the cover crop treatments (Table 12). While this resulted in a loss of fall cover crop scouting data, the cover crop treatment was still applied to the plots and the biomass was incorporated for a second year. The subsequent broccoli crop in summer 2020 had no disease, and no significant differences in arthropods by cover crop treatment. Some arthropods varied by scouting date, as was expected due to their spring and summer life cycles. At Borderview Research Farm in Alburgh VT, the fall 2020 cover crops had some disease present: Alternaria leaf spot and downy mildew, but no powdery mildew (Table 13). Downy mildew was significantly greater in the HGM cover cropped plots (p=0.0026) in comparison to the oat/peas/HGM, oat/peas, radish, and control (Table 14). Flea beetles were significantly greater in the HGM treatment (p=0.0017) than the oat/pea/radish, oat/peas, and control (Table 14). No other arthropods were scouted in the fall, and no arthropods were significantly different between brassica treatments in the following summer 2021 broccoli crop. No disease was observed in summer 2021.

Table 12. 2020-2021 Horticulture Research Farm Treatment Results, South Burlington, VT.

Hort Farm	Alternaria Leaf Spot	Downy Mildew	Powdery Mildew	Flea Beetles	FB Damage	ICW	Cabbage looper	DBM	Midge	Aphid
Fall 2020	None	None	0.4457	0.4457	None	None	None	None	None	None
Summer 2021	None	None	None	0.4879	0.3140	0.6949	0.6223	0.8413	None	None

FB= flea beetle, ICW= imported cabbage worm, DBM= diamondback moth. Statistical significance is based on p<0.05.

Table 13. 2020-2021 Borderview Research Farm Treatment Results, Alburgh, VT.

Alburgh, VT	Alternaria Leaf Spot	Downy Mildew	Powdery Mildew	Flea Beetles	FB Damage	ICW	Cabbage Looper	DBM	Midge	Aphid
Fall 2020	0.5111	**0.0026**	None	**0.0017**	0.4457	None	0.4457	0.4457	0.5640	0.0540
Summer 2021	None	None	None	0.4391	None	0.6469	0.4457	None	0.4457	0.2469

FB= flea beetle, ICW= imported cabbage worm, DBM= diamondback moth. Statistical significance is based on p<0.05

Table 14. 2020-2021 Borderview Research Farm Significant Results by Treatment, Alburgh, VT.

Treatment	Fall 2020 Downy Mildew Means	Fall 2020 Flea Beetle Means
HGM	**0.0073^{a}**	**0.0333^{a}**
oat/pea/radish	0.0021^{ab}	0.00^{b}
oat/peas/HGM	0.0014^{b}	0.0222^{ab}
radish	0.0006^{b}	0.0278^{ab}
oat/peas	0.0001^{b}	0.00^{b}
control	0.00^{b}	0.00^{b}

*Highest incidence is highlighted in **bold**. Treatments that share letters are statistically similar at p <0.05.*

2021 Broccoli Harvest

The 2021 broccoli yield at the South Burlington site averaged 82.7 lbs ac^{-1}, with an average marketability rating of 2.6 on a 1-5 scale, where 1 was the most marketable. At the Alburgh site, the average yield was 248 lbs ac^{-1}, and the average marketability rating was 2.24. Flea beetles infested all of the plots on both years, especially when they were hatching, which reduced quality and yield.

DISCUSSION

Over two growing seasons from 2019-2021, at two sites in Vermont, this trial showed no carryover of pests and disease from the brassica cover crop treatments to the subsequent broccoli crops. The South Burlington site had a higher risk of pathogens and pests due to previous vegetable cultivation. While there was no apparent carryover between the fall cover crops and cash crop, in the fall the HGM had significantly more disease present (Alternaria leaf spot, downy mildew) than other brassica cover crops. This may indicate that HGM or mixes with HGM are more susceptible to disease than other brassica cover crops. While the concerns that vegetable growers have about pest and disease carryover were not observed in two years of this trial, it is important to note that disease carryover risk can be reduced in hot, dry conditions, and summer

weather was warm and dry in both years of the study. Additionally, the fall cover crops in 2020 at the South Burlington site were only scouted on one date. This trial adds to the little research available on brassica disease carryover in the Northeast, and further research is needed.

For more information on pathogens, pests, and Integrated Pest Management, see the New England Vegetable Management Guide, available at: https://nevegetable.org/

References

New England Vegetable Management Guide, 2022, University of Massachusetts Amherst. https://nevegetable.org/

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