AIM Research Trial Report: **Biofumigation to reduce Potato Early Dying (PED)**
Working Group: Soil Improvement
Crop Year: 2022
Author: Ryan Barrett

Project Rationale:

For a number of years, there has been interest in evaluating the use of mustard for control of soil-borne pests and diseases, including potato early dying (PED), common scab, wireworm, etc. Research done by AAFC Charlottetown has repeatedly shown that use of mustard as a biofumigant crop, either double crop or single crop, has normally reduced wireworm damage in potatoes. What has been harder to establish is what affect mustard crops have on pathogens like Verticillium or on plant parasitic nematodes. As Prince Edward Island potato farmers do not have access to chemical soil fumigation, there is an interest in assessing whether biofumigation with mustard is an effective option.

There has been some work done on using both conventional brown mustard as well as specially bred high-glucosinolate varieties of mustard for biofumigation in PEI; however, these trials sometimes provided conflicting results and lacked replication. Therefore, there was an interest from the AIM Soil Working Group to set up a multi-year trial evaluating the use of a high-glucosinolate mustard variety compared with a standard crop and with a conventional brown mustard variety.

Project Overview:

We engaged the services of Genesis Crop Systems of Hampton, PEI to assist us with management of this trial. Starting in 2020, three farms had Caliente Rojo mustard/arugula mix planted in comparison with other crops, including a check crop that is normally seen to be neutral for Verticillium and nematodes (ie. barley, ryegrass). Those three fields were then planted to potatoes in 2021. Results from these three fields were reported on last year in full, but will be referenced at the end of this report in combination with 2022 results.

In 2021, three additional fields were established for this trial:

2021-D: Treatments: Caliente Rojo, brown mustard (cv. Centennial), barley (check). After all three treatments were incorporated, sorghum sudangrass was planted as a cover crop. 2022 potato variety: Prospect.

2021-E: Treatments: Caliente Rojo, brown mustard (cv. Centennial), buckwheat, sorghum sudangrass/forage pearl millet mix, timothy (check). No cover crop planted. 2022 potato variety: FL2155

2021-F: Treatments: Caliente Rojo, brown mustard (cv. Centennial), ryegrass. No cover crop planted. 2022 potato variety: potatoes not planted.

Caliente Rojo mustard/arugula mix was obtained from High Performance Seeds of Washington State. This was an 80% mustard, 20% arugula (Nemat variety) mix. Other seeds were obtained locally.

Planting dates varied somewhat between the three trial fields, but seeding was done in late May and early June 2020. Each grower was provided enough seed to plant approximately 10 acres of Caliente Rojo mix, in addition to the other crop treatments. At the recommendation of the seed supplier, the two mustard treatments also received between 100-125 lbs/acre of nitrogen and 20-25 lbs/acre of sulfur at planting.

For the two mustard treatments, growth and maturity was relatively rapid. Mowing and incorporation was done between 45 and 55 days after planting, based on weekly monitoring by Genesis with regard to biomass progression and seed pod development. It was suggested to time incorporation around rainfall events to maximize soil moisture at the time of incorporation.

A flail-mower was used at all three farms to sufficiently macerate the mustard biomass. The mower was then immediately followed in the field by a vertical tillage implement to incorporate the biomass as well as pack the soil surface. The other treatments were mowed through the season until tilled in the fall in preparation for potatoes in the spring of 2022.

Immediately after seeding in the spring of 2022 and immediately before seeding in the spring of 2022, soil testing was conducted for soil chemical analysis, soil health analysis, *Verticillium dahliae*, and root lesion nematode counts. In the fall of 2022, four 10 foot strips with an equal number of potato plants were harvested in each treatment, with grading performed by Genesis Crop Systems.

Potato varieties planted in 2022 were: Prospect (2021-D) and FL-2155 (2021-E). Field 2021-F ended up not being planted to potatoes due to lack of available seed in the spring of 2022, so no harvest results are available for this field. Prospect is known to be somewhat resistant to V. dahliae; however, it is susceptible to common scab, so mustard biofumigation is still very interesting in this case. FL-2155 is a late maturing chip variety with high tuber set, and resistance to V. dahliae is more unknown.

Results:

Soil Fertility Properties:

Table 1: Soil Fertility metrics for Field 2021-D:

	OM %		**pH**		**P_2O_5 ppm**		**K_2O ppm**	
	2020	2021	2020	2021	2020	2021	2020	2021
Barley	2.0	2.0	6.0	6.5	524	509	76	67
Centennial Mustard	1.9	2.0	5.6	6.2	551	538	59	80
Caliente Rojo Mustard	1.4	2.1	5.9	6.4	543	528	66	88

Table 2: Soil Fertility metrics for Field 2021-E:

	OM %		**pH**		**P_2O_5 ppm**		**K_2O ppm**	
	2020	2021	2020	2021	2020	2021	2020	2021
Buckwheat	2.5	2.6	5.7	6.0	457	435	95	136
Centennial Mustard	2.7	2.7	5.2	5.9	545	467	160	155
Caliente Rojo Mustard	2.9	3.0	5.3	5.8	491	471	119	146
Sudangrass/Pearl Millet	2.8	2.8	5.6	6.1	552	521	101	182
Timothy/Clover	3.0	3.0	5.6	5.9	501	496	87	135

Table 3: Soil Fertility metrics for Field 2021-F:

	OM %		pH		P_2O_5 ppm		K_2O ppm	
	2020	2021	2020	2021	2020	2021	2020	2021
Centennial Mustard	2.3	2.4	5.2	6.1	617	626	75	150
Ryegrass	2.1	2.1	5.1	6.1	620	569	81	110
Caliente Rojo Mustard	2.2	2.5	5.2	5.9	640	631	79	171

Both Fields E and F had starting pH levels that were lower than recommended by the Caliente Rojo seed supplier, as at low pH levels, the glucosinolates can breakdown into nitriles rather than isocyothanate gases. pH variability within field was low to moderate. For all fields, pH was much higher prior

Fields D and F would be considered low for soil OM, while field E would be considered average for soil OM. There was very little difference in soil OM from year to year.

There was not much difference in soil fertility within fields before or after the 2021 crop year. All three fields had very high levels of phosphorus. Fields E and F would have high levels of K for the potato crop in 2021, while Field D would be considered more moderate for K.

Soil Health Metrics:

Table 4: Soil Health metrics for Field 2021-D, scored on a 0-100 scale by the PEI Analytical Lab based on comparison against other PEI fields in potato rotation:

	Active Carbon		Soil Respiration		Aggregate Stability		Bio. N Availability	
	2021	2022	2021	2022	2021	2022	2021	2022
Barley	18	21	5	4	75	47	22	21
Cen. Mustard	16	21	5	28	74	61	58	46
Caliente Rojo	15	26	2	1	78	47	23	19

Table 5: Soil Health metrics for Field 2021-E, scored on a 0-100 scale by the PEI Analytical Lab based on comparison against other PEI fields in potato rotation:

	Active Carbon		Soil Respiration		Aggregate Stability		Bio. N Availability	
	2021	2022	2021	2022	2021	2022	2021	2022
Buckwheat	35	35	25	8	36	27	90	33
Cen. Mustard	61	43	0	3	45	14	75	14
Caliente Rojo	56	37	1	7	35	22	71	18
SSPM	39	43	7	78	10	7	67	55
Timothy/Clover	41	39	8	37	44	30	61	56

Table 6: Soil Health metrics for Field 2021-F, scored on a 0-100 scale by the PEI Analytical Lab based on comparison against other PEI fields in potato rotation:

	Active Carbon		**Soil Respiration**		**Aggregate Stability**		**Bio. N Availability**	
	2021	2022	2021	2022	2021	2022	2021	2022
Cen. Mustard	15	20	31	46	59	37	33	38
Ryegrass	13	21	1	51	57	41	14	34
Caliente Rojo	17	21	5	10	65	34	26	32

For Active Carbon, so trend (positive or negative) was detected across all three fields. For Soil Respiration, sizeable increases were detected for some of the forage species in fields E and F. Starting levels were quite low in all three fields at the start of sampling in 2021.

Aggregate Stability generally declined in 2022 compared to 2021. This isn't surprising, as multiple tillage events happened during these 12 months. The ranges of decline was generally similar across all treatments.

Biological N availability varied slightly by field. In Fields D and F, there was relatively similar rankings from 2021 to 2022, and the overall numbers are on the low end. For Field E, there was a large decline in BNA from 2021 to 2022 for the three "biofumigant" crops (buckwheat, Centennial Mustard, and Caliente Rojo mustard). This indicates that there is less nitrogen to be available to the potato crop in 2022 in these treatments. Starting levels were quite high to start with in this field, compared to the other two.

***Verticillium* populations:**

Table 7: *Verticillum dahliae* and root lesion nematode test results for Field 2021-D:

	V. dahliae (cells/g soil)		**Root Lesion Nematodes/kg soil**	
Treatment	**Spring 2021**	**Spring 2022**	**Spring 2021**	**Spring 2022**
Barley	2655	4026	3608	3376
Cen. Mustard	4600	4128	6639	2573
Caliente Rojo	2479	3724	6516	19297

Table 8: *Verticillum dahliae* and root lesion nematode test results for Field 2021-E:

	V. dahliae (cells/g soil)		**Root Lesion Nematodes/kg soil**	
Treatment	**Spring 2021**	**Spring 2022**	**Spring 2021**	**Spring 2022**
Buckwheat	618	3008	5411	2704
Cen. Mustard	2740	4456	3214	592
Caliente Rojo	1800	3864	1188	1487
SSPM	2258	3622	7316	10345
Timothy/Clover	1313	3872	7191	8543

Table 9: *Verticillum dahliae* and root lesion nematode test results for Field 2021-F:

	V. dahliae (cells/g soil)		Root Lesion Nematodes/kg soil	
Treatment	**Spring 2021**	**Spring 2022**	**Spring 2021**	**Spring 2022**
Cen. Mustard	1209	0	2296	7002
Ryegrass	474	1011	2567	5098
Caliente Rojo	0	0	1145	3752

Field D would be considered high for populations of both V. dahliae and root lesion nematodes in spring 2021. V. dahliae counts were relatively consistent across the field in 2021 and did not appreciable change in 2022. Root lesion nematode counts appeared to decrease slightly in the Centennial mustard treatment but increased substantially following Caliente Rojo. As we did not see this large increase in any of the other fields in this trial, we would suspect that this was a non-representative sample.

In Field E, starting values for V. dahliae were a bit lower in 2021 but increased across all treatments in 2022. As most of the crops used are not thought to be hosts for V. dahliae, this is surprising. Nematode counts did not appear to change much year over year, but there were much higher counts in the sudangrass/pearl millet treatment area, both before and after planting of the cover crop. Number also remained high following the timothy/clover treatment (check).

In Field F, starting values for V. dahliae were comparatively lower and remained low following 2022 spring sampling. In fact, V. dahliae was undetected in two samples. Given that this field has been in three year potato rotation for a number of years, it is very unlikely that Verticillium counts are zero, but they obviously are on the lower end of the spectrum. Starting nematode counts were also low, but increased in all treatment areas by spring 2022; however, the growth in population was lowest in the Caliente Rojo treatment.

Overall, there are no obvious trends with regard to the effect of either mustard crop on suppression of either V. dahliae or root lesion nematodes.

Yield Data:

Table 10: Yield and quality for Prospect variety in Field 2021-D

Treatment	**Total Yield cwt/ac**	**Smalls %**	**> 10 oz %**	**Specific Gravity**	**M. Yield cwt/ac**	**Tubers/ Plot**
Barley	262.6	5.0	9.9	1.078	249.6	64
Centennial Mustard	300.3	13.4	8.7	1.070	260.0	69
Caliente Rojo	245.7	4.8	15.9	1.077	234.0	62

While there was a slightly higher total yield following Centennial mustard, a higher percentage of small tubers for that treatment resulted in there being no appreciable difference in marketable yield across the treatments. These potatoes were planted quite late (June) and were not able to reach full yield potential, despite a favourable growing season. There was no observed difference in common scab

coverage between treatments in this field.

Table 11: Yield and quality for Mountain Gem Russets in Field 2021-E:

Treatment	Total Yield cwt/ac	Smalls %	> 10 oz %	Specific Gravity	M. Yield cwt/ac	Tubers/ Plot
Buckwheat	275.6	14.2	0	1.108	236.6	111
Centennial Mustard	263.9	21.7	0	1.099	206.7	112
Caliente Rojo Mustard	280.8	13.9	0	1.105	241.8	115
Sudangrass/Pearl Millet	269.1	15.9	0	1.108	226.2	110
Timothy/Clover	276.9	11.3	0	1.106	245.7	107

In Field E, there is no statistical difference in yield or quality among the treatments. While there is a lot of variability in specific gravity, only one composite sample was analyzed per treatment. Specific gravity readings are extremely high, but understandable for a chip variety. All of the total yield means are within 17 cwt/acre, indicating that there is no appreciable difference between the treatments in yield.

Summary:

Some key observations from this trial:

- There were no readily detectable trends in the effect on soil fertility or soil health metrics following the mustard treatments in comparison to the other crops used. Aggregate stability scores were generally lower in 2022 than in 2021, but this is expected due to the additional tillage performed. Two of the fields (E and F) had low starting pH readings.
- There was no obvious trends in V. dahliae or root lesion nematode counts following mustard crops.
- There was no statistical differences in yield or quality for potato yield between the cover crop treatments in 2022.

While conditions were more favourable for biofumigation in 2021 compared with 2020, there are still questions on whether we have sufficient soil moisture in the summer months to get effective levels of isothiocyanate gas produced through incorporation of mustard. We generally are not seeing a difference in pathogen levels in the spring following biofumigation.

Looking at the five fields that were part of this study from 2020 to 2022, only field (2020-C) showed a statistically significant increase in marketable yield following mustard biofumigation. This was the field with the highest starting population of V. dahliae, a pH close to 6.0, and a Verticillium-susceptible variety (Russet Burbank). The other fields in the study seem to indicate that when inoculum is not very high, or pH is low, or when a somewhat resistant variety is grown, there may not be a significant impact of using mustard as a biofumigant crop in PEI.

Acknowledgements:

The research team would like to thank:

- Our participating growers in 2021/2022: MacLennan Properties, Monaghan Farms, and MacSull Farms
- Steve Watts of Genesis Crop Systems
- High Performance Seeds for providing Caliente Rojo mustard seed at a reduced price for this research.
- Dr. Judith Nyiraneza and Morgan McNeil for their assistance with data and statistical analysis