AIM Research Trial Report: **Biofumigation to reduce Potato Early Dying (PED)**
Working Group: Soil Improvement
Crop Year: 2021
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 the spring of 2020, three farms were identified as being interested in this project by Genesis. At two of the farms, four crops were established in 2020: ryegrass (check), Caliente Rojo mustard/arugula blend, Centennial brown mustard, and sorghum sudangrass. On the other farm, sorghum sudangrass was excluded.

Ryegrass, Centennial brown mustard and sorghum sudangrass was procured locally from regular seed suppliers. Caliente Rojo mustard/arugula mix was obtained from High Performance Seeds of Washington State. This was an 80% mustard, 20% arugula (Nemat variety) mix. Arugula was included as a “bait crop” for root lesion nematodes, with the intention of keeping them in the root zone at the time of incorporation, maximizing their exposure to the biofumigant gas.

The fields in question were located in New Annan, Springfield West, and Alma, all in Prince County. 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 despite dry weather in most of Prince Edward Island in 2020. 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

Fig 1. Flail chopping and incorporating Caliente Rojo mustard in 2020.

at the time of incorporation; however, this was very difficult in 2020 due to excessively dry weather for most of the growing season. As a result, all three fields were incorporated in drier than recommended soil conditions. Following incorporation, sowing a cover crop was recommended to the participating farms for the mustard treatments. Sorghum sudangrass was used as the post-incorporation cover crop.

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 ryegrass and sudangrass treatments were mowed through the season until tilled in the fall in preparation for potatoes in the spring of 2021.

Immediately after seeding in the spring of 2020 and immediately before seeding in the spring of 2021, soil testing was conducted for soil chemical analysis, soil health analysis, *Verticillium dahliae*, and root lesion nematode counts. In the fall of 2021, four 10 foot strips with an equal number of potato plants were harvested in each treatment, with grading performed by Cavendish Farms Central Grading.

Potato varieties planted in 2021 were: Prospect (2020-A), Mountain Gem Russet (2020-B), and Russet Burbank (2020-C). Russet Burbank is known to be particularly susceptible to PED in Prince Edward Island, with the other two varieties showing a somewhat increased level of resistance; however, none of these three varieties are “Verticillium-resistant.” In addition, the Prospect variety is quite susceptible to common scab, which was also under investigation in this trial.

Results:

Soil Fertility Properties:

Table 1: Soil Fertility metrics for Field 2020-A:

	OM %		pH		P_2O_5 ppm		K_2O ppm	
	2020	2021	2020	2021	2020	2021	2020	2021
Ryegrass	1.8	1.3	6.5	6.3	502	538	108	56
Caliente Rojo Mustard	2.1	2.0	6.4	6.1	571	586	115	86
Centennial Mustard	2.0	2.0	6.6	6.3	474	585	109	70
Sorghum Sudangrass	2.1	1.4	6.5	6.3	525	528	97	75

Table 2: Soil Fertility metrics for Field 2020-B:

	OM %		pH		P_2O_5 ppm		K_2O ppm	
	2020	2021	2020	2021	2020	2021	2020	2021
Ryegrass	2.4	2.5	5.5	5.5	640	781	193	198
Caliente Rojo Mustard	2.5	2.2	5.5	5.6	552	634	195	169
Centennial Mustard	1.9	2.1	5.9	5.7	623	658	163	200
Sorghum Sudangrass	2.5	2.3	5.7	5.5	607	555	257	175

Table 3: Soil Fertility metrics for Field 2020-C:

	OM %		pH		P_2O_5 ppm		K_2O ppm	
	2020	2021	2020	2021	2020	2021	2020	2021
Ryegrass	2.3	2.2	5.7	5.8	763	647	270	163
Caliente Rojo Mustard	3.4	2.5	5.4	5.8	640	522	225	196
Centennial Mustard	2.7	2.1	5.5	6.0	672	620	257	189

Both Fields B and C 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.

All three fields would generally be described as low for soil organic matter, with Field A being noticeably low (< 2.0%). However, soil OM following the two mustard treatments remained relatively constant, while soil OM appeared to decrease in the other two treatments. This may have been due to the fact that the ryegrass and sudangrass treatments were ploughed rather than vertical tilled in the fall of 2020.

There was not much difference in soil fertility within fields before or after the 2020 crop year. All three fields had very high levels of phosphorus. Field B and C had high levels of potassium, while Field A had only moderate K levels.

Soil Health Metrics:

Table 4: Soil Health metrics for Field 2020-A, 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	
	2020	2021	2020	2021	2020	2021	2020	2021
Ryegrass	9	12	1	1	37	2	8	4
Caliente Rojo	13	15	1	1	50	20	16	13
Centennial	11	15	1	1	41	0	12	11
Sudangrass	15	4	0	4	40	8	14	9

Table 5: Soil Health metrics for Field 2020-B, 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	
	2020	2021	2020	2021	2020	2021	2020	2021
Ryegrass	16	25	1	48	60	30	39	27
Caliente Rojo	19	12	31	37	37	18	46	25
Centennial	15	9	5	28	43	28	64	27
Sudangrass	16	15	58	37	28	9	19	15

Table 6: Soil Health metrics for Field 2020-C, 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	
	2020	2021	2020	2021	2020	2021	2020	2021
Ryegrass	18	16	8	46	51	6	44	48
Caliente Rojo	35	19	42	51	66	5	88	25
Centennial	19	21	8	31	29	2	48	33

For Active Carbon, all three fields were generally ranked low before and after the 2020 crop year. No clear trends are evident across fields or across treatments.

For Soil Respiration, there was no change from 2020 to 2021 for Field A. This may be due to the very low soil OM levels in this field. In Fields B and C, ratings for soil respiration were quite a bit higher in 2021 than in the spring of 2020. The Centennial mustard treatment had the lowest rating in both fields, while ryegrass had very similar rankings in both fields (46-48).

In all three fields, moderate rankings for aggregate stability in the spring of 2020 were downgraded to low in the spring of 2021. This is undoubtedly due to the tillage necessary ahead of potatoes in 2021. In Field A, aggregate stability appeared to be slightly better in the Caliente Rojo treatment than the other three. This was not observed in the other two fields.

For Biological Nitrogen Availaiblity, rankings remain low across the board for Field A; again, this is likely due to lower soil OM levels. In Fields B and C, biological N availability appeared to be reduced from 2020 to 2021 in most treatments

***Verticillium* populations:**

Table 7: *Verticillum dahliae* and root lesion nematode test results for Field 2020-A:

	V. dahliae (cells/g soil)		Root Lesion Nematodes/kg soil	
Treatment	**Spring 2020**	**Spring 2021**	**Spring 2020**	**Spring 2021**
Ryegrass	8500	1138	4877	3483
Caliente Rojo Mustard	12228	2561	3615	3476
Centennial Mustard	7230	4848	2302	3179
Sorghum Sudangrass	7695	3157	2039	2565

Table 8: *Verticillum dahliae* and root lesion nematode test results for Field 2020-B:

	V. dahliae (cells/g soil)		Root Lesion Nematodes/kg soil	
Treatment	**Spring 2020**	**Spring 2021**	**Spring 2020**	**Spring 2021**
Ryegrass	2005	0	565	1179
Caliente Rojo Mustard	5910	7252	0	1903
Centennial Mustard	6450	1039	286	1159
Sorghum Sudangrass	5391	2208	284	1100

Table 9: *Verticillum dahliae* and root lesion nematode test results for Field 2020-C:

	V. dahliae (cells/g soil)		Root Lesion Nematodes/kg soil	
Treatment	**Spring 2020**	**Spring 2021**	**Spring 2020**	**Spring 2021**
Ryegrass	13393	1908	3100	4761
Caliente Rojo Mustard	18331	1614	1719	0
Centennial Mustard	6217	2741	3293	2348

Starting levels of *V. dahliae* were generally considered high in all three fields in the spring of 2020. In all three fields, levels of *V. dahliae* (in cells per gram of soil) were largely lower across all treatments. Reduction was greatest in Field C, evident across all treatments. In Field A, Verticillium levels were also largely reduced but not by the same degree as Field C. Due to the margin of error in these tests, it is difficult to determine whether there is much difference in inoculum between the different treatments prior to potato planting in 2021. In Field B, *V. dahliae* levels were noticeably lower in 3 of the 4 treatments in 2021, with the levels observed in the Caliente Rojo strip being comparable to the starting level in 2020.

For root lesion nematodes, Field B did not have a large starting level of nematodes in 2020, and these levels remained low in 2021. In Field A, root lesion nematode levels appeared to be mostly unchanged from 2020 to 2021. In Field C, root lesion nematode numbers were zero following the Caliente Rojo mustard; however, this part of the field also had the lowest starting population. Nematodes number were moderate in the other two treatment areas, though twice as high in the ryegrass area than the Centennial mustard area.

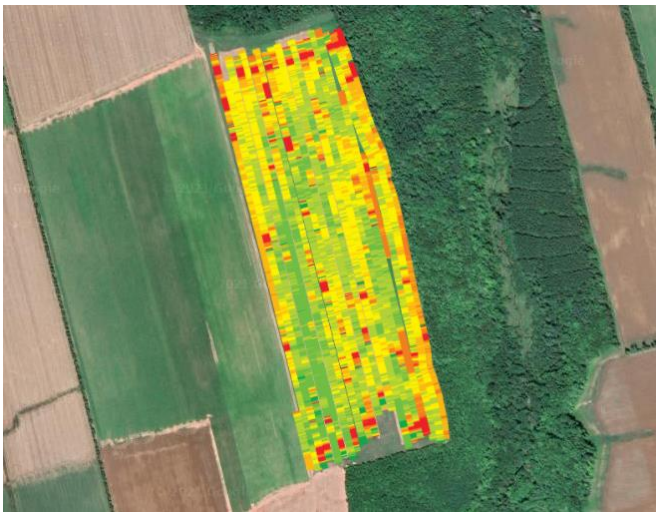
From these results, it appears that all three fields saw a decrease in Verticillium levels from 2020 to 2021, regardless of crop planted. There did not appear to be a noticeable advantage to the treatment crop (both mustard varieties and sorghum sudangrass) with relation to lowering Verticillium levels. For root lesion nematodes, none of the three fields started with excessive levels of nematodes, in relation to past work done on root lesion nematodes in PEI. Once again, there does not appear to be a visible trend relating to nematode levels following the different treatment crops compared with ryegrass, which has been observed to be a preferred host for root lesion nematodes in PEI.

Yield Data:

Table 10: Yield and quality for Prospect variety in Field 2020-A

Treatment	Total Yield cwt/ac	Smalls %	> 10 oz %	Total Defects %	Specific Gravity	M. Yield cwt/ac	Payout $/acre
Ryegrass	264.2	6.6 b	6.6	3.6 a	1.081	237.9	2855
Caliente Rojo Mustard	289.1	4.1 a	9.4	11.1 b	1.080	250.9	2997
Centennial Mustard	265.4	2.8 a	10.5	1.1 a	1.081	256.1	3087
Sorghum Sudangrass	306.2	2.4 a	21.0	3.2 a	1.077	289.1	3422

In Field A, there does not appear to be much difference in gravity across the treatments. The percentage of 10 oz tubers appears to be larger in the sudangrass treatment; however, it should be noted that the sudangrass treatment was closest to a wooded hedgerow, and may have had more shade and slightly better moisture levels than the other three, more exposed treatments. The only variables which showed statistical significance ($p < 0.10$) was % smalls (where ryegrass was higher) and % total defects (where the Caliente Rojo mustard was higher).



This yield map from Field 2020-A shows higher average yields (in green) on the left hand side (west side) of the field. This is the side of the field that had the Caliente Rojo treatment in 2020. However, our sampling points were largely toward the north end of the field for all four treatments. This may have resulted in us not capturing all of the variability in yield due to the 2020 crop treatments.

Table 11: Yield and quality for Mountain Gem Russets in Field 2020-B:

Treatment	Total Yield cwt/ac	Smalls %	> 10 oz %	Total Defects %	Specific Gravity	M. Yield cwt/ac	Payout $/acre
Ryegrass	386.6	4.9	42.1	9.5	1.075 a	343.0	4216
Caliente Rojo Mustard	374.7	6.3	43.1	7.9	1.078 ab	329.5	4123
Centennial Mustard	385.6	6.6	34.4	8.3	1.081 b	339.7	4330
Sorghum Sudangrass	408.7	4.8	50.0	15.2	1.077 ab	339.2	4221

In Field B, there appears to be very little difference in total yield, % smalls, % 10 oz, marketable yield, and crop value across the four treatments. This may be due to the fact that Mountain Gem are more resistant to PED. As well, this field has comparatively lower levels of *V. dahliae* and root lesion nematodes than the other two fields. There was statistical significance for specific gravity ($p < 0.10$) where Centennial mustard had higher specific gravity than ryegrass.

Table 12: Yield and quality for Russet Burbanks in Field 2020-C:

Treatment	Total Yield cwt/ac	Smalls %	> 10 oz %	Total Defects %	Specific Gravity	M. Yield cwt/ac	Payout $/acre
Ryegrass	328.7	11.9	17.1	1.4	1.076 a	289.4	3463
Caliente Rojo Mustard	378.5	10.6	21.2	3.7	1.083 b	327.1	4119
Centennial Mustard	383.6	10.6	25.3	1.3	1.079 ab	338.3	4195

In Field C, both of the mustard treatments appeared to have higher total yield, marketable yield, and crop value per acre than the ryegrass control. The ryegrass treatment also looked to produce the smallest percentage of tubers under 10 oz. as well as the lowest specific gravity. However, none of these differences were statistically significant at $p < 0.10$. The only variable which was statistically significant ($p < 0.05$) was specific gravity, where the Caliente Rojo mustard treatment had higher average gravity than the ryegrass treatment.

Summary:

Some key observations from this trial:

- All three fields struggled with low soil organic matter and relatively low indices for soil health. Two of the fields had relatively low soil pH levels, which may have affected the efficacy of biofumigation.
- There was no obvious trend in soil chemical or soil health readings between treatments.
- *Verticillium dahliae* counts were largely reduced in 2021 from 2020, regardless of treatment crop. There was not a clear difference in *V. dahliae* reduction between the treatment crops across all three fields.
- Root lesion nematode counts were relatively unchanged from year to year in all three fields. None of the three fields had nematode counts in the spring of 2021 that would be considered high compared to past research in Prince Edward Island.

- None of the three fields demonstrated a significant difference in yield or crop value between treatments. There were some significant differences detected for quality measurements in all three fields.
- In Field 2020-C, there appeared to be a numerical trend toward both mustard treatments having improved total and marketable yields compared to the ryegrass treatment; however, this was not statistically significant.
- It is possible that the dry soil conditions at the time of incorporation in 2020 limited the effectiveness of biofumigation. In addition, Fields A and B were planted with varieties that are somewhat more resistant to potato early dying than Russet Burbank.

Next Steps:

Under this project, three more fields were set up with Genesis Crop Systems in 2021, with two being in East Prince and the other in West Prince. These fields will be planted to potatoes in 2022. Weather conditions were more favourable in 2022, so mustard growth was rapid and there was more soil moisture present at incorporation than in 2021. In addition, two fields were planted with Caliente Rojo mustard as part of the Living Labs Atlantic BMP3 project. At the end of 2022, data from both projects will be pooled and a full economic analysis will also be performed.

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