Living Labs Atlantic – Final Report

BMP1: Use of fall seeded cover crop following primary tillage in the year before potatoes

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Project Rationale:

There has been considerable research conducted in recent years on the merits of fall cover crops in a variety of cropping systems. The use of fall cover crops are associated with a number of benefits, including reduced soil erosion, conservation of soil nutrients, improving soil organic carbon, improving soil health, and, in some cases, improving yields in subsequent crops. Research in potato cropping systems has been more limited. On-farm research in the United Kingdom (reference) showed a trend toward improved potato yields following a fall cover crop compared to a no cover control across multiple site-years of data. Plot-scale research in Southern Ontario (reference) in a field tomato crop rotation showed significant increases in both marketable yield as well as soil organic matter when cover crops were employed in six out of eight years in a four-year crop rotation.

At the same time, there has been interest in the Prince Edward Island potato industry to investigate both the agronomic and environmental benefits of utilizing more fall covers in the year before potato production. Historically, the majority of fields destined for potato production have been planted to forage crops in the year before potatoes, with fall tillage occurring late in the fall. For the most part, the timing of this tilling precludes the use of a cover crop. A number of progressive producers have instead moved termination of the forage up to the late summer or early fall, providing a much greater window for cover crop establishment. This has gone hand in hand with greater adoption of vertical tillage implements as opposed to traditional moldboard ploughing. Many of these vertical tillage implements can be fitted with a seeder box, allowing for cover crop establishment in one pass, which in turn decreases the cost and barriers to cover crop establishment. Given the receptivity of producers to this increased use of cover crops before potatoes, our research team was keen to investigate the effects of number of different cover crop species in on-farm trials to better understand the potential benefits, both agronomic and environmental, from this change in management practices.

Project Overview:

In 2019, the Prince Edward Island Potato Board was selected to lead a project under the Living Labs Atlantic initiative to investigate the use of fall planted cover crops following primary tillage in the year before potatoes. For three years (2019-2021), a number of field-scale trials were established on participating farms in the late summer or early fall where one or more fall cover crops were planted. Each field also had a control treatment where no cover crop was planted. These fields would then be followed into the next year (2022-2022) when potatoes were planted.

Table 1 describes the nature of data collection in these research fields.

Table 1: Description of data collected in BMP1 field trials over three-year period.

Tests Performed	Variables	Timing of Collection	Sampling Intensity
Soil Chemistry, analyzed at PEI Soil Lab	Organic Matter %, pH, individual nutrients	1. Before or immediately after cover crop establishment 2. Spring before potato planting	One composite sample per treatment. Exception: four samples per treatment in spring 2022.
Soil Health, analyzed at PEI Soil Health Lab	Active Carbon, Aggregate Stability, Soil Respiration, Biological Available Nitrogen	1. Before or immediately after cover crop establishment 2. Spring before potato planting	One composite sample per treatment
Root Lesion Nematodes, analyzed at Potato Quality Institute	Root Lesion Nematode counts	1. Before or immediately after cover crop establishment 2. Spring before potato planting	One composite sample per treatment
Verticillium, analyzed at Agricultural Certification Services	*Verticillium dahliae* counts	1. Before or immediately after cover crop establishment 2. Spring before potato planting	One composite sample per treatment
Soil Compaction	Soil Resistance (psi) measured by soil penetrometer	1. Spring before potato planting	Ten locations per treatment at multiple depths (6, 9, 12, 15 inches)
Soil Erosion, with soil weights analyzed at PEI Soil Lab	Accumulated soil (grams)	Multiple times over fall after cover crop planting	Subset of fields per year 2 or 3 splash pans installed per field
Soil Nitrates, analyzed by PEI Soil Lab	Soil Nitrate (ppm)	Following cover crop establishment	3 depths (0-6, 6-12, 12-18 inches), one composite sample per treatment Two or three sampling dates (early October to mid November)
Above Ground Biomass, analyzed using digital photos and Canopeo app	Percent Green Cover	Following cover crop establishment	Two or three sampling dates (early October to mid November)
Potato Yield and Quality, with grading at Cavendish Farms Central Grading	Total Yield, Marketable Yield, Percent Smalls, Percent > 10 oz, Percent Total Defects, Specific Gravity, Crop Value	Fall of second year, immediately before fields are to be harvested	Four 10-foot samples with an equal number of plants per sample per treatment.

There were six fields established in 2019, eight established in 2020, and nine established in 2021 in this project. Fields were located in the three primary watershed areas participating in the Living Labs initiative: Kensington North, Dunk River, and Souris & area. Project staff worked collaboratively with the participating producers to select the cover crops to be evaluated, the timing and method of establishment, and the layout of the trial in the field.

In 2019, six fields were established with fall cover crops between August 28th and October 2nd. Four of the six fields were established after September 19th, which was later than planned for this project. This was largely due to weather conditions in the fall of 2019, which delayed tillage and cover crop planting.

In 2020, eight fields were established with fall cover crops between September 2nd and October 13th. Five of these fields were established between September 2nd and 11th, more in line with planned timelines for the project. Three of these fields had harvest data excluded from data analysis for the following reasons:

- One field had the primary trial area compromised by winter and spring traffic with heavy equipment.
- One field had unexpected levels of highly variable wireworm damage across multiple treatments
- One field was established very late with a very narrow control treatment. There was extreme variability in yield and quality results, including high levels of tuber rot prior to grading which compromised results.

In 2021, nine fields were established with fall cover crops between September 11th and 24th. Dry soil conditions delayed tillage in a number of fields, but establishment was still successful at all sites.

Cover crops planted across the twenty-three sites included:

- Barley (11 fields)
- Oats (5 fields)
- Spring Wheat (1 field)
- Brown Mustard (4 fields)
- Oilseed or Daikon Radish (8 fields)
- Radish/Mustard Mix (2 fields)
- Radish mixed with Oats or Wheat (3 fields)

Above Ground Biomass:

Unsurprisingly, the average percentage of green cover for the cover crop treatments (29.7%, averaged across all dates) was significantly higher ($p < 0.001$) than for the no cover crop treatments (3.3%). When broken down by cover crop, results are as follows:

Table 2: Percent green cover across all observation dates by cover crop species from 2019 to 2021.

Treatment	# of observations	Percentage Green Cover
Barley	27	28.2
Check	57	3.3
Mustard/Radish	3	57.0
Mustard	11	32.0
Oats	19	22.6
Radish-Wheat	3	50.1
Radish	16	29.0
Wheat	3	35.6
p value		< 0.001

Cover crop treatments with a brassica species (radish or mustard) averaged 34.4% green cover across all dates, compared to 26.5% green cover for all spring cereals (barley, oats, and wheat). However, it may not be fair to directly compare these two groups of observations, as planting dates were not consistent across both groups. Planting dates were generally earlier for the brassica crops, due to the recommended agronomic advice to establish these crops in the early fall.

When breaking down percent green cover by days after planting (DAP), the picture becomes a bit more clear.

Table 3: Percent green cover across all observation dates for brassica and cereal species sorted by days after planting (DAP) from 2019 to 2021.

Treatment	DAP	# of samples	% Green Cover
Brassica	1-30	3	6.7
	31-50	14	36.8
	51+	16	37.6
Cereals	1-30	9	14.1
	31-50	19	27.8
	51+	21	30.6
No Cover	1-30	9	1.0
	31-50	25	2.8
	51+	23	4.8

The difference in percent green cover between brassicas and cereals is less when adjusting for days after planting; nonetheless, those covers planted in late August or early September will still have an advantage over those planted in mid to late September.

Soil Erosion:

Due to limitations in the number of splash pans available, only a subset of fields across the three years of study had splash pans installed to measure the potential for soil erosion caused by dislodging of soil by rainfall or wind from the soil surface. In eight treatments where there was a cover crop present, average accumulated soil in the splash pans was 91 g, compared with 141.8 g for the six check treatments. This was a non-significant difference, as variability was high and number of observations was low. Efforts to use erosion pins to observe differences in soil erosion were fraught with multiple issues, including installation error and frost heaving.

Soil Nitrates:

Soil nitrates were measured at three depths (0-6 inches, 6-12 inches, 12-18 inches) using a dutch auger at multiple dates each fall after cover crop establishment. Where results were labeled "<5.00 ppm" by the PEI Analytical Lab, these were recorded as 0 ppm. Fields where most or all of the results were <5.00 ppm were excluded from analysis.

Table 4: Comparison of soil nitrates (ppm) at three depths in cover crop treatments compared with no cover crop treatments from 2019 to 2021.

Treatment	# of samples	NO_3 ppm 0-6 inches	NO_3 ppm 6-12 inches	NO_3 ppm 12-18 inches
Cover Crops	45	6.2	6.1	3.2
No Cover Crop	30	10.2	9.9	5.4
Difference		-4.0	-3.8	-2.2
p value		0.018	0.007	0.054

Across these three years, we observed a 38-41% decrease in soil nitrates in the presence of a cover crop compared with no cover crop. This indicates that an actively growing cover crop will uptake soil nitrate, preventing it from being leached later in the fall during the wet conditions normal for Prince Edward Island.

If we look only at observations after October 25th, after the cover crop has had the opportunity to fully establish:

Table 5: Comparison of soil nitrates (ppm) at three depths recorded on or after October 25th in cover crop treatments compared with no cover crop treatments from 2019 to 2021.

Treatment	# of samples	NO_3 ppm 0-6 inches	NO_3 ppm 6-12 inches	NO_3 ppm 12-18 inches
Cover Crops	30	5.2	6.2	3.2
No Cover Crop	17	10.4	11.2	7.5
Difference		-5.2	-5.0	-4.3
p value		0.008	0.010	0.002

At these later observation dates, the average reduction in soil nitrate is even greater, ranging from 45-57% lower in the cover crop treatments.

No statistical difference was observed when comparing brassica and cereal cover crops for their ability to decrease soil nitrate levels. Both groupings had significantly lower soil nitrate levels than the no cover crop treatments at $p = 0.10$.

Soil Nutrients and Soil Health:

Across all three years of the study, there were no observed difference in soil nutrient levels following a cover crop compared with a no cover crop check. It does not appear that the presence of a cover crop changed soil nutrient concentrations or pH values.

In the first two years of the study, soil organic matter was assessed by one composite sample from each treatment area, sampled before or at cover crop established in the fall and again the following spring prior to potato planting. Over these two years, no significant differences or trends were identified in soil organic matter percentage following cover crop establishment. In the spring of 2022, sampling intensity was increased to four samples per treatment, taken at representative locations within the field. The following results were obtained:

Table 6: Comparing soil organic matter percentage and pH in cover crop and no cover crop treatments from eight fields in spring 2022.

	# of samples	**soil organic matter %**	**pH**
Cover Crop	44	2.302	5.95
No Cover Crop	32	2.172	5.91
Difference		0.13	0.04
p value		0.057	0.500

There was a statistically significant difference in soil organic matter observed in favour of the cover crop treatments. However, it should be noted that measuring differences in soil organic matter over short time frames can be difficult. It may be that there was undecomposed plant material present in the cover crop treatment soil samples that would elevate organic matter levels in the short term but would not represent true additions to the stable fraction of soil organic matter. Nonetheless, it does indicate that there is additional carbon being returned to the soil. Future studies could look at the long-term improvement in soil organic matter over multiple years of cover cropping.

Table 7: Comparing soil health metrics for cover crop treatments compared with no cover crop treatments from spring sampling from 2020 to 2022.

	# samples	Soil OM %	Active C µg/g	Soil Respiration mg/g	Aggregate Stability %	Bio. N Availability mg/kg
Cover Crop	32	2.32	407.7	0.459	23.93	21.04
No Cover	23	2.32	382.1	0.437	23.62	19.55
Difference		0.00	25.6	0.022	0.31	1.49
p value		0.984	0.244	0.471	0.860	0.298

No significant differences were observed for the soil health metrics listed in Table 7. There were some positive trends observed for Active Carbon and Biological N Availability that were not statistically significant but would bear watching in future studies or with higher sampling frequency. Increases in these two metrics would make logical sense, as the presence of a cover crop in the fall would increase carbon cycling and conserve nitrogen compared with bare soil.

Table 8: Comparing soil pathogen populations and soil compaction readings for cover crop treatments compared with no cover crop treatments from spring sampling from 2020 to 2022.

	# samples	RL Nematodes #/kg	V. dahliae cells/g	Compaction at 6 in psi	Compaction at 9 in psi	Compaction at 12 in psi
Cover Crop	32	6838	3510	76	160	257
No Cover	23	8668	3396	70	155	276
Difference		-1830	114	6	5	-19
p value		0.228	0.888	0.730	0.822	0.352

No significant differences were observed for either root lesion nematode or Verticillium dahliae counts between cover crop treatments and no cover crops. This appears to indicate that the presence of fall cover crops does not appear to impact these soil-borne pathogens in any substantial manner.

Likewise, there was no significant difference in soil compaction observed either. On average, the level of compaction at 12 inches would be described as substantial and having the potential to limit yields.

Potato Yield and Quality:

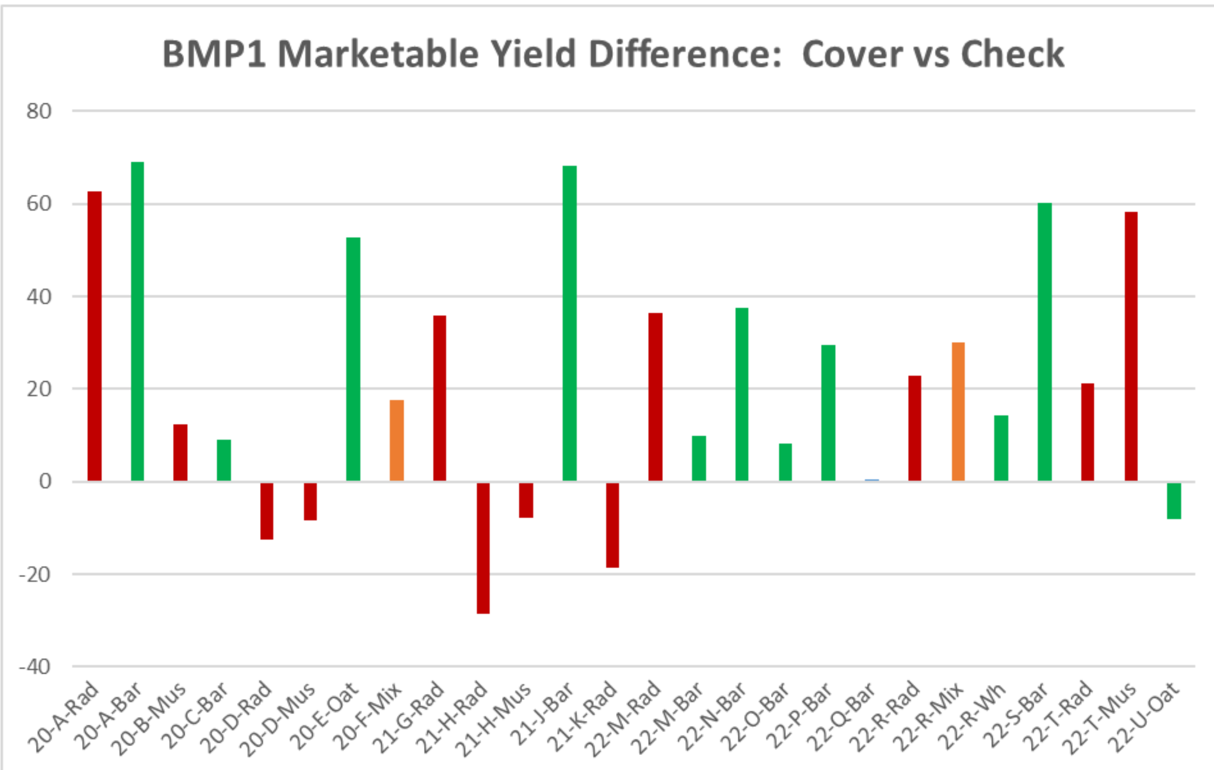
Table 9: Comparing potato yield and quality variables following cover crop establishment compared with no cover crop for fields from 2020 through 2022.

	# Samples	**Total Yield cwt/ac**	**% Defects**	**% Smalls**	**% > 10 oz**	**Spec. Gravity**	**Market. Yield cwt/ac**	**Crop Value $/acre**
Cover	108	352.7	4.8	6.9	16.9	1.088	316.6	4601
No Cover	76	318.5	4.1	8.5	15.9	1.086	284.7	4065
Difference		**34.2**	0.7	**-1.6**	1.0	0.002	**31.9**	**536**
p value		**0.002**	0.490	**0.049**	0.651	0.268	**0.006**	**0.005**

Across 19 fields analyzed for potato yield and quality, there were statistically significant differences observed for total yield, percent smalls, marketable yield and crop value in favour of cover crops. Interestingly, the degree of difference in yield was quite similar in each of the three years of the study. With the exception of a slight decrease in the percentage of small tubers, the majority of improvement was due to an increase in overall tuber production and not substantial differences in tuber quality.

In Figure 1, the difference in marketable yield between the cover crop treatment and the no cover crop control treatment are graphically represented. Bars in green represent spring cereal cover crops. Bars in red represent brassica cover crops (radish, mustard), while bars in orange represent mixtures of cereals and brassicas. The majority of individual treatment comparisons are positive, particularly for cereal crops. Most of the negative comparisons are brassica treatments, with some of these cover crops planted outside of the ideal planting window for radish or mustard, resulting in lower levels of accumulated biomass.

Figure 1: Distribution of marketable yield differences between cover crop treatment and no cover control treatments for fields assessed from 2020 to 2022.



While the project team expected to see an increase in yield following cover crops, the level of increase and the general consistency of response was encouraging. In terms of explaining why the presence of a cover crop the fall before potatoes can result in these yield improvements, it is likely that there are several factors at play. The reductions in soil nitrate levels that we observed indicate that the cover crops uptake nitrate that would normally be leached from the soil in the fall. If this nitrogen is carried over to the following growing season, it may provide additional nitrogen to the crop. However, since nitrogen is rarely a limiting factor for potato production in PEI, this would require further study to determine how much impact this nitrogen carryover may have. Other factors which may contribute to improved yields following a cover crop that weren't sufficiently captured in this study could include increased activity of the soil microbiome, improvement in soil structure and water holding capacity, increases in soil organic matter, and reductions in soil-borne pests and diseases.

Discussion and Next Steps:

In this project, our team wanted to answer a couple of basic questions. Firstly, what impact do fall-seeded cover crops have on soil health in the fall ahead of potatoes? While it is very difficult to assess improvements to soil health and soil organic matter in a short term project such as this one, there are indications that early-established fall cover crops may have some short term positive impacts on soil health metrics such as Active Carbon and Biological Nitrogen Availability. This could be further explored in future projects by increasing the sampling density as well as assessing soil health over a longer period of time. This has been proposed to be analyzed as part of future Living Labs research. There also appears to be no negative impact of these cover crops on soil-borne pests or pathogens such as root lesion nematodes or *Verticillium dahliae*, which are key factors in potato early dying complex.

Our second question was assessing what impact do fall-seeded cover crops have on potato yield and quality the following year. From this study, it appears that fall-seeded cover crops that self-terminate over the winter are associated with increased marketable yields of potatoes. While we can not yet explain which factors are contributing most to this yield increase, the level of increase is enough to drive increased adoption of cover crops on PEI potato farms. Since the beginning of the Living Labs Atlantic project, we have seen a 25% increase in fall cover crop adoption in the year before potatoes. We feel that this is due in large part to the results from this research.

The number one reason to adopt cover crops on any farm is to reduce the risk of soil erosion. Keeping soil in the field is fundamental to the long term success of any farm, and the impact can often not be measured in the short term. Likewise, improvements in soil organic matter and soil health take many years to properly assess. Therefore, being able to show short-term improvements in marketable yield makes it easier to entice producers to adopt cover cropping, as the return on investment is considerable. Assuming a cost to establish a fall cover crop at $50 per acre, the yield improvements uncovered in this study represent a 10 to 1 return on investment. If producers were even able to achieve half of the yield improvement seen in this study, a 5 to 1 return on investment would be seen as worthwhile. This is in addition to the long-term benefits to both the producer and the environment from increased cover crop adoption.

Results from this project should provide incentive to an increasingly number of potato producers in PEI to move up primary tillage to late summer or early fall combined with planting of a cover crop, compared with the traditional practice of late fall ploughing with no cover crop. For those that have legume crops in rotation in the year before potatoes (such as red clover or alfalfa), this earlier termination should also result in a larger proportion of nitrogen mineralization from those legumes to occur earlier in the growing season. This should also allow producers to reduce applied nitrogen rates if organic nitrogen mineralization is more reliable and at a more advantageous time.

In looking at next steps for cover crop research, it would be valuable to assess the longer term impact of cover crops on soil organic matter and soil health with more years of cover cropping. In addition, there is interest in assessing how cover crops that survive the winter (ie. cereal rye) and that need to be terminated ahead of potato planting impact both soil health and potato yields. While these crops stay green and actively growing for a longer period of time, they do require additional management and could tie up nitrogen ahead of potato planting. More research is required to explore these impacts.

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