Trials Overview: BMP3- Full Season Soil Building Crops in Rotation

Trials Overview:

In BMP3, we examined different full-season soil building crops planted in the spring of 2020, the year before planting potatoes in 2021. In each field, we compared two soil building crops or mixtures against a check strip crop (either ryegrass or red clover hay mix) growing side by side in a commercial field. The purpose of these trials is to look at the biological, physical and chemical components of soil and assess the short-term impact of these crops on the resulting potato yield and quality in the following year. There were 7 trials set-up in the spring of 2020 for BMP3, including 2 in East Prince, 2 in the Souris and Area Watershed and 3 in Kensington North Watershed.

They are outlined below, listed from earliest to latest planting date:

Trial #1: Ryegrass Check (20 lb/ac) and Multi-Species Mix (MSM) (45 lb/ac) (Planted June 6 and June 20, 2020 Respectively)

Trial #2: Ikarus Radish vs Caliente Mustard/Arugula (75:25 ratio), vs Ryegrass Check (Planted June 11, 12 and July 8, 2020 Respectively)

Trial #3: Ryegrass Check (18lb/ac) vs Sorghum Sudangrass (30 lb/ac) (Planted June 17, 2020)

Trail #4: Sorghum Sudangrass (30 lb/ac) (Planted June 22, 2020) vs Ikarus Radish (22lb/ac) and Ryegrass-Forage Mix Check (18 lb/ac) (Planted July 7, 2020)

Trail #5: Sorghum Sudangrass-Pearl Millet/Oilseed Radish (SSPMOR) (25 lb/ac) in (2:1) ratio, vs Ryegrass Check (15 lb/ac) (Planted June 29 and July 10, 2020 Respectively)

Trail #6: Ryegrass Check vs Sorghum Sudangrass vs Oilseed Radish (Planted June 30, 2020)

Trial #7: Red Clover-Timothy Mix (70:30 ratio) vs Buckwheat (30 lb/ac) (Planted July 3, 2020)

Note: We initially had 2 other trials set-up (1 in East Prince and 1 in Souris) but due to changes in their crop rotation sequence, the final data collection in each was postponed, so those trials will be reported on in a different report at a later date.

Methods:

Soil sampling was done in the spring of 2020 to collect baseline composite samples for soil nutrient analysis, the soil health package, root lesion nematodes (RLN), and *Verticillium dahliae* (Vd). The soil chemistry and health samples were analyzed at the PEI Analytical Labs in Charlottetown. The RLN samples were analyzed at the Potato Quality Institute (PQI). The Vd samples were sent to Fredericton, NB to the Agricultural Certification Services (ACS) lab for analysis. Spring surface and subsurface compaction were also measured with a needle-type field penetrometer, as close to 2-3 days after heavy rainfall events as possible. There were 10 compaction readings taken per treatment in each trial at depths of 6”, 9” and 12”, as marked by the 3-inch intervals on the pole. Fall 2020 soil sampling was completed for soil chemistry to assess the nutrient levels, relative to the spring time. Soil samples and penetrometer readings were taken again in the spring of 2021 for all the same components to compare values to 2020 results, before the treatment crops were planted.

In the fall of 2021, four (4) potato yield strip samples (each 10 ft long) were collected per treatment area to compare total yields (cwt/ac), percent defects, percent smalls, percent of potatoes over 10-ounce size, specific gravity, marketable yields (cwt/ac), and crop value in $/acre. These potato samples were temporarily stored either at Agriculture and Agri-Food Canada cold storage facilities in Charlottetown, or at grower warehouses until being collected and graded at Cavendish Farms in New Annan, PEI. Statistical analysis was done with ANOVAs using a confidence interval of 95% (α=0.05) and the appropriate Multiple Means comparison if applicable. If significance was borderline, α=0.1 was also tested, just to be aware if differences were present at a lower confidence interval due to high field and within-field variability. Some further analysis was also done across trials that had the same treatment and check crops for comparison.

Results-Soil Health:

Table 1: Soil active carbon (µg/g) across trials from 2020 and 2021 spring soil sampling

	Soil Active Carbon (µg/g)			
Trial: Treatment	Spring 2020 (Composite)	Spring 2021 (Treatment)	Spring 2021 (Control)	Spring 2021 (Difference)
Field 1: Multi-Species Mix	208	218	226	-8
Field 2: Ikarus Radish	407	338	348	-10
Field 2: Caliente Mustard/Arugula	467	333	348	-15
Field 3: Sorghum Sudangrass	376	432	391	+41
Field 4: Ikarus Radish	296	273	299	-26
Field 4: Sorghum Sudangrass	296	323	299	+24
Field 5: SS/PM/OR*	363	463	463	0
Field 6: Sorghum Sudangrass	405	440	473	-33
Field 6: Oilseed Radish	405	527	473	+54
Field 7: Buckwheat	300	376	393	-17
Average	352	372	371	+1

Note: SS/PM/OR*=Sorghum Sudangrass/Pearl Millet/Oilseed Radish. Red values were rated as being among the lowest 25% of samples tested in the PEI database. Orange ratings are still considered low, but not the lowest. Yellow ratings are medium. Green ratings are high (not observed above).

Soil Health Observations:

In the spring of 2021, there were 3 fields with soil organic matter (SOM) levels less than 2.0%, another 3 fields with SOM between 2.0-2.5%, and the remaining field above 2.5%. The average SOM across all trials was 2.0%. There was no trend observed between years or treatments for this indicator. Although given the short period of soil sampling, it could be a limitation to see differences. Continuing to build SOM is critical for the health and sustainability of regenerative agricultural practices to support crop production practices.

The soil active carbon values were generally low across all samples tested throughout both years of data collection, before and after the treatment crops grew there. The average soil active carbon was 352 µg/g in the fall of 2020, with averages of 371 and 372 µg/g in the control and treatment areas respectively in the spring of 2021 (Table 1). This indicates to us that the effect of a cover crop did not appear to have much of a short-term impact on the active carbon fraction of soil carbon in this study.

Soil aggregate stability and soil respiration scores were also generally low across all trials in both. Overall basis, there did not appear to be much change in these parameters between the two years, with any slight differences likely within the margin of error.

Results- Soil Compaction:

Table 2: Average compaction values across trials by check crop measured at 3 depths in spring 2021

		Depth in Soil Profile (Inches)		
Treatment	**# Treatments**	**6"**	**9"**	**12"**
Ryegrass	6	46	147	310
Timothy/Clover	1	31	171	303
Averages		**81**	**150**	**309**

Table 3: Average compaction values across trials for soil-building crops across trials measured at 3 depths in spring 2021

		Depth in Soil Profile (Inches)		
Treatment	**# Treatments**	**6"**	**9"**	**12"**
Radish	3	83	158	281
Sorghum Sudangrass	3	84	219	332
Mustard	1	22	33	247
Buckwheat	1	43	177	351
Multi-Species Mix	1	92	243	337
SSPMOR*	1	46	213	276
Averages		**70**	**180**	**305**

Note: SSPMOR= Sorghum Sudangrass/Pearl Millet/Oilseed Radish Mix

Soil Compaction Observations:

These compaction results from spring 2021 will be compared to the previous spring 2020 results in individual reports by trial rather than trying to generalize across them over both years in this report due to variability in baseline amounts for comparison, and the complexity of the tables to see clear trends. Although it will be noted here that the compaction values were consistently higher at all depths measured in the spring of 2020 compared to observations from 2021.

From Tables 2 and 3, there is not much difference in soil compaction (as measured with a needle penetrometer) between our soil-building treatments and our check crops. It is hard to compare the different treatment crops against each other given the structure of this trial, and also given that some of these crops are more deeply rooted than others. More will be assessed on a trial-by-trial basis.

Results- Soil Pathogens:

Table 4: Soil root lesion nematode (RLN) and *Verticillium dahliae* (Vd) populations from spring of 2020 and 2021 and differences between years of sampling

		RLN (#/kg dry soil)			Vd (cells/g soil)		
Treatment	**# Treatments**	**Spring 2020**	**Spring 2021**	**Difference**	**Spring 2020**	**Spring 2021**	**Difference**
Ryegrass (Check)	6	3171	2599	**-572**	3654	810	**-2844**
Timothy/Clover (Check)	1	21,791	28,001	**+6210**	4482	1732	**-2750**
Sorghum Sudangrass	3	3971	8673	**+4702**	4019	363	**-3656**
Radish	3	2123	3738	**+1615**	3994	1466	**-2528**
Multi-Species Mixes	1	5581	0	**-5581**	3255	1120	**-2135**
Caliente Mustard /Arugula Mix	1	311	1191	**+880**	1807	0	**-1807**
SSPMOR*	1	2099	1233	**-866**	8039	1536	**-6503**
Buckwheat	1	6341	10,707	**+4366**	6552	1005	**-5547**
Median		3571	3169	1248	4007	1063	**-2797**
Mean		5674	7018	1344	4475	1004	**-3471**

Note: SSPMOR*= Sorghum Sudangrass-Pearl Millet-Oilseed Radish. Positive values in the table indicate that the pathogen levels were higher in spring of 2021 compared to the spring of 2020. Negative values indicate that the pathogen levels were higher in first spring than the second spring.

Root Lesion Nematode Observations:

Baseline root lesion nematodes (RLN) in the spring of 2020 ranged anywhere from 300-21,000/kg dry soil, with median and mean values of 3571 and 5674/kg dry soil respectively. Noteworthy is the timothy/clover mix, which had already been growing for a year prior to trial set-up, going into its second year when the rest of the trials were initiated. Therefore, the highest RLN populations from this area make sense, since red clover is known to be a preferred host crop for this pathogen. The levels for the other treatments in the spring of 2020 are more reflective of previous land management and crop rotation history.

During the spring of 2021, the RLN counts ranged from zero in the Multi-Species mix (MSM) with 13 Species to 28,000/kg dry soil again in the timothy/clover mix. It is not clear why the MSM came back as having no RLN, whether it is due to an effect of the crop mixture or an error in sampling/testing. The RLN populations increased in the red clover/timothy mix by over 6000/kg dry soil between the first and second year of having red clover/timothy mix in rotation. In this second spring, the median across treatments was lower than the first year, but the mean was higher relative to the first year of sampling due to two particular trials with very high counts. Overall, RLN counts appeared to be slightly higher in 2021 than 2020 across both treatment and control crops. More will be discussed in individual site results.

Soil *Verticillium dahliae* (Vd) Observations:

The baseline *Verticillium dahliae* (Vd) counts in the spring of 2020 ranged from roughly 1800-8000 cells/g soil during baseline sampling the first spring, with median and mean values of 4007 and 4475 cells/g soil respectively. The range of these observations was smaller relative to that of the baseline RLN. During the spring of 2021, the data ranged from 0-1700 cells/g soil, which showed a marked decline from the previous spring in every treatment. Both the median and mean values dropped considerably in the second sampling year. The median and mean differences between treatments were close to 2800 and 3500 cells/g soil respectively. These results are common with trends seen in previous potato crop rotation research trials, in that *Verticillium* counts generally decrease as the time from the last potato crop increases. This appears to have more impact on Vd counts than the choice of crops in our trials, as few (if any) of these crops would be considered preferred hosts to multiple *Verticillium*. It can take a number of years to see long-term improvements in soil health including pest suppression.

Results- Potato Yields and Quality:

Table 5: Potato yield and quality data by trial and treatment from fall 2021 grading samples

Trial: Treatment	Total Yields (cwt/ac)	%Total Defects	%Smalls	Specific Gravity	%> 10 oz	Marketable Yields (cwt/ac)	Payout ($)
1: Ryegrass	297.4 a	**0.3 b***	**17.3 a***	1.080 a	**8.7 b****	246.1 a	2980 a
1: MSM	261.4 a	**2.9 a***	**8.4 b***	1.081 a	**17.1 a****	236.7 a	2882 a
2: Ryegrass	443.7 a	**0.8 b****	5.0 a	1.085 a	19.1 a	420.9 a	5327 a
2: IkRad	407.0 a	**1.4 b****	6.5 a	1.085 a	34.0 a	379.2 a	4927 a
2: CalMus-Arg	452.5 a	**6.8 a****	6.9 a	1.085 a	30.4 a	401.9 a	5245 a
3: Ryegrass	**284.1 a***	1.3 a	7.8 a	1.075 a	29.0 a	259.8 a	**3199 a****
3: SS	**253.6 b***	1.9 a	8.1 a	1.075 a	19.6 a	230.6 a	**2784 b****
4: Ryegrass	299.2 a	3.5 a	7.4 a	**1.080 b****	17.1 a	268.8 a	3335 a
4: SS	318.0 a	3.0 a	6.3 a	**1.085 a****	19.2 a	293.1 a	3758 a
4: IkRad	348.5 a	1.1 a	7.0 a	**1.085 a****	18.1 a	322.3 a	4005 a
5.Ryegrass	**265.7 b***	0 a	13.2 a	1.092 a	19.1 a	**230.4 b***	**3096 b***
5: SSPMOR	**322.3 a***	1.1 a	11.2 a	1.094 a	17.0 a	**283.2 a***	**3782 a***
6: Ryegrass	334.9 a	2.9 a	5.3 a	1.080 a	29.5 a	310.6 a	3822 a
6:SS	348.7 a	5.7 a	5 a	1.085 a	23.5 a	321.9 a	4148 a
6: OR	345.5 a	6.2 a	4.4 a	1.085 a	32.3 a	319.3 a	4219 a
7: Timothy/ Clover	299.7 a	10.0 a	3.5 a	1.074 a	37.8 a	268.0 a	3248 a
7: BW	288.1 a	18.6 a	2.7 a	1.073 a	40.3 a	231.9 a	2800 a

Note: Treatments with significant differences are bolded. Those including one * asterisk are statistically significant at α=0.1, and those with two ** asterisks are statistically significant at α=0.05.

Potato Yield and Quality Observations:

Trial #1 showed a significantly lower percentage of smalls and greater percentage of tubers over 10 ounce size with a Multi-Species mix (MSM), but also a significantly greater percentage of total defects compared to ryegrass. The higher defects with the MSM could perhaps be related to the types of crops in the mix, as some might be more beneficial to the potato rotation than others.

Trial #2 resulted in a significantly higher percentage of total defects in mustard compared to the other treatments, but this could in part be attributed to the soil compaction levels the year prior, being higher in the mustard at 9" compared to the radish part of the field.

In Trial #3, the ryegrass treatment showed significantly higher total yields and payout compared to the sorghum sudangrass treatment. It is speculated that the higher soil compaction in the sorghum treatment measured in both spring seasons may help to explain this result.

In Trial #4, both of the soil-building crops (sorghum sudangrass or radish) showed significantly higher specific gravity relative to the ryegrass check. This is a good finding to support production of high quality processing potatoes.

In Trial #5, the SSPMOR mix showed significantly higher total, marketable yields and payout compared to a ryegrass check. This 3-species mix is a powerful soil builder, not only helping to break up pathogen cycles, but also helping to reduce soil compaction as supported by the spring 2021 results for this trial.

In Trial #6, there were no significant differences detected between treatments, but the sorghum sudangrass and ikarus radish both resulted in better yield and quality data overall compared to ryegrass. The field was incredibly stressed during the summer of 2020, barley receiving a drop of rainfall all season and faced high weed pressure, particularly from lamb's quarters, which perhaps contributed to lessening the effects of the treatments on the yield results.

In Trial #7 there were also no significant differences detected. Although the timothy/clover resulted in higher total, marketable yields and payout than buckwheat, it was observed that the soil compaction averages measured at each depth in the spring of 2021 were higher in the buckwheat relative to the check. We have only done a few trials with buckwheat to date through this project, and therefore we are still assessing its impact on soil RLN and Vd.

Results-Overall Differences in Potato Yield and Quality:

Table 6: Differences in potato yield and quality data between each treatment crop and check by trial in fall 2021

Trial: Treatment	Total Yields (cwt/ac)	%Total Defects	%Smalls	Specific Gravity	%> 10 oz	Marketable Yields (cwt/ac)	Payout ($)
1: MSM	-36.0	**+2.6***	**-8.9***	+0.001	**+8.4****	-9.4	-98
2: IkRad	-36.7	+0.6	+1.5	-0.001	+14.9	-41.7	400
2: CalMus-Arg	+8.8	**+6.1****	+1.9	+0.001	+11.3	-19.1	-83
3: SS	**-30.5***	+0.6	+0.3	-0.001	-9.4	-29.2	**-415****
4: SS	+13.7	+2.8	-0.3	**+0.004****	-6.0	+11.3	+326
4: IkRad	+10.5	+3.4	-0.9	**+0.005****	+2.8	+8.7	+396
5: SSPMOR	**+56.6***	+1.1	-2.0	+0.002	-2.1	**+52.8****	**+686***
6:SS	+18.8	-0.50	-1.1	+0.004	+2.1	+24.3	+423
6: OR	+49.3	-2.5	-0.4	+0.001	+1.0	+53.5	+670
7: BW	-11.6	+8.6	-0.78	-0.001	+2.5	-36.1	-448
Averages:	+4.3	+2.3	-1.1	+0.002	+2.6	+1.5	+186

Note Abbreviations: MSM=Multi-Species Mix, CalMus=Caliente Mustard, Arg=Arugula, SS=Sorghum Sudangrass, IkRad= Ikarus Radish, PM=Pearl Millet, OR=Oilseed Radish, BrMus= Brown Mustard, BW= Buckwheat. The bolded differences represent treatments where significant differences were detected at α=0.1 if including an * or at α=0.05 with two asterisks **.

Overall Potato Yield and Quality Difference Observations:

There were a few significant differences for a handful of grade attributes between treatments across the 7 trials discussed in this report. However, there were no clear trends across this set of trials that the same grade attributes were significant as they varied by site. Furthermore, there were no positive trends that any of the soil building crops resulted in higher or better quality yields than a check, with the exception of Trial #5 comparing SSPMOR mix to ryegrass. In 4 of the 6 trials, although non-significant, the check crops resulted in better overall grades while the remaining 2 trials showed the opposite result.

Overall, there is essential no statistical difference between the check crops (as a group) when compared with the treatment crops across seven fields with yield data. The range in crops as well as the range in field variability may make it difficult to treat all treatment crops as a group. We will continue to investigate the effect of these soil-building crops on an individual basis, in an effort to identify which crops may prove to be more associated with improved potato yield and quality than others. It should also be noted that the 2021 growing season was particularly good across all of PEI; as a result, disease pressure and the effects of insufficient soil moisture were reduced in 2021, which may reduce the sensitivity to observe differences between check crops and treatment crops.

Summary:

Some key observations from this year's sites:

- There were no obvious trends evident for soil nutrient levels, soil organic matter or pH between treatment crops and check crops. Many other indicators of soil health were low across the duration of the trial including active carbon, soil respiration and aggregate stability.
- Average soil compaction values were quite similar between treatments in the spring of 2021, Compaction data from the spring of 2020 showed much higher values compared to 2021.
- There was a large range in counts for RLN across treatments. During the spring of 2021, the majority of the soil building crop treatments had slightly higher RLN counts than the spring 2020 results. The mustard/arugula and SSPMPOR treatments showed some of the lowest amounts, which is a reasonable finding since mustard is known to suppress RLN populations, and pearl millet (one of the crops in the SSPMOR mix) is not a host for this pathogen. The red clover/timothy mix showed the highest levels, which is also reasonable given that fact that red clover is a preferred host crop for them.
- There was a smaller range in the *Verticillium dahliae* counts across treatments in both years, but definite reductions in all of the treatments during spring sampling in 2021 compared to 2020. The buckwheat and SSPMOR treatments showed some of the highest soil Vd levels in the second spring.
- Rainfall events were abundant during the 2021 growing season, which resulted in a great crop. July was particularly wet, followed by an especially wet end of August and early September with Hurricane Ida. Luckily, October was clear and dry, making for excellent harvest conditions.
- Looking at the potato yield and quality data, statistically significant differences were detected for a few indicators in the majority of the trials, but only a few of them showed significantly different yield results.
- Despite some significant differences observed in individual trials, the average difference between treatments and check crops across all fields did not show much of a trend, either positive or negative. It may be that there is too much difference between some of our treatment crops to compare them all together. Following the completion of this project later in 2022, we will hopefully have enough site-years for some of these soil-building crops to get a truer picture as to their effects on soil health, soil-borne pathogens, and marketable yield.

Despite still being in the midst of a global pandemic, we have been able to continue with all the Living Labs research work with some adaptations. The pandemic has reduced our ability to visit with growers more frequently in person or hold meetings in person to discuss trial details and results on a more on-going basis, but we feel more of those opportunities will open up again soon. Online meetings are still possible, but we prefer to do them in person where possible because they tend to be more interactive.

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