Trial Report – BMP3: Full-Season Soil-Building Crops

Trials Overview:

In BMP3, we examined different full-season soil building crops the year before planting potatoes. In each field, we compared one or two soil building crops or mixtures against a check strip growing side by side in a commercial field. The purpose of these trials is to assess soil health from biological, physical and chemical standpoints, as well as the effect of these crops on marketable yield of potatoes the following year. There were eight trials established in the spring of 2019, and planted to potatoes in 2020.

Of those six trials, there were three established in the Kensington North region; two in the East Prince region and two in the Souris area. Based on planting date (from earliest to latest), the trial crops are outlined as follows:

Trial #1- Hemp vs Buckwheat vs Timothy/Clover Check Strip <u>(Planted June 15, 2019)</u>

Trial #2- Multi-Species Mix (8 Species) vs Sorghum Sudangrass vs Oats Check Strip <u>(Planted June 26, 2019)</u>

Trial #3- Sudangrass vs Red Clover Check Strip <u>(Planted July 6, 2019)</u>

Trial #4- Oilseed Radish vs Brown Mustard vs Timothy/Clover Check Strip <u>(Planted July 8, 2019)</u>

Trial #5- Mustard/Radish vs Mustard/Sorghum vs Multi-Species Mix (8 Species) vs Mustard Check Strip <u>(Planted July 10, 2019)</u>

Trial #6- Multi-Species Mix (10 Species) vs Ryegrass Check Strip <u>(Planted July 10, 2019)</u>

Trial #7- Sorghum Sudangrass vs Italian Ryegrass Check Strip <u>(Planted July 24, 2019)</u>

Trial #8- Sorghum Sudangrass/Pearl Millet/Peas vs Ryegrass with Compost, vs Ryegrass without Compost <u>(Planted July 24, 2019)</u>

Methods:

Soil sampling was done in the spring of 2019 to collect composite samples for the chemical nutrient analysis, the soil health package, root lesion nematodes (RLN) and *Verticillium dahliae* (Vd). Soil collected for chemical and health analysis were analyzed at the PEI Analytical Labs. Soil nematodes were analyzed at the Potato Quality Institute, also in PEI. The *Verticillium dahliae* samples were sent to Agricultural Certification Services (ACS) in Fredericton, NB.

In the fall of 2020, four or five 10-foot harvest samples/treatment were collected to compare total yields, percent defects, percent smalls, percent of potatoes over 10-ounce size, specific gravity, marketable yields and crop value in $/acre. Statistical analysis was done for the potato yield attributes to a confidence interval of 90% (α=0.1). Variance was tested to confirm if each dataset was equally or unequally varied. Then the appropriate t-test was conducted. These samples were stored until grading in early November at Cavendish Farms Central Grading.

Results- Soil Health:

Within each trial, the soil chemical and health metrics were similar between the two spring seasons, but collecting this data was valuable to assess the impact of the treatment crops a year later in rotation. The average textural analysis showed a sandy loam class with roughly 60% sand, 30% silt and 10% clay across all trial fields. Working to build organic matter levels is important so that sandy soils can hold onto water and nutrients better. The organic matter levels varied by trial, with one field being at 2.0%, three of them with organic matter in the 2.0-2.5% range, and the remaining four with levels in the 2.5-3.0% range. We did not observe any trends with regard to soil nutrient levels between treatments. Most differences between the treatments were very small within the margin of error or non-existent.

With the exception of one trial, the remaining seven had aggregate stability scores close to, but below 50% during measurements in the first spring of 2019. In the second spring of 2020, the scores ranged from 15-40%, and showed a decrease from the first spring to the second. It is anticipated that a history of heavy tillage/soil disturbance compacting the soil structure paired with high sand-content contributed to these low scores in all the trials. There was no observable trend of soil improvement in aggregate stability following cover crops in these fields.

There were more noticeable differences in the biological N-fixation (BNF) between the spring composite of 2019 and the results by treatment in 2020, with 6 of the 8 trials showing substantially less following rotation crops in the spring of 2020 **(Table 1).** This could in part, be related to the types of crops in rotation, their density, if underseeded with another crop, and the length of time since they have been grown in the trials. BNF could also be affected by the timing of tillage. The differences between treatments in 2020 was was smaller, and depended on the crop of interest as compared to the check crop. The average difference between treatments across 14 comparisons was not much different from zero.

Table 1: Biological N-fixation (mg/kg) across trials over 2019-2020

	Biological N- Fixation (mg/kg)			
Trial: Treatment	**Spring 2019 (Composite)**	**Spring 2020 (Treatment)**	**Spring 2020 (Control)**	**Spring 2020 (Difference)**
Field 1: Buckwheat	94	32	39	-7
Field 1: Hemp	94	27	39	-12
Field 2: Multi-Species	100	62	55	+7
Field 2: Sorghum Sudangrass	100	45	55	-10
Field 3: Sudangrass	99	44	12	+32
Field 4: Oilseed Radish	66	35	45	-10
Field 4: Brown Mustard	66	61	45	+16
Field 5: Mustard/Radish	100	33	53	-20
Field 5: Mustard/Sorghum	100	32	53	-21
Field 5: Multi-Species	100	29	53	-24
Field 6: Multi-Species	66	40	25	+15
Field 7: Sorghum Sudangrass	100	24	58	-34
Field 8: SS/PM*/Peas with Compost	46	58	11	+47
Field 8: Ryegrass with Compost	46	79	11	+68
Average	**84**	**43**	**40**	**3**

Note: SS/PM= Sorghum Sudangrass/Pearl Millet

There were a number of Multi-Species Mixes in this set of BMP3 trials, including some legume crops that fix nitrogen among other plants. However, given the diversity of different species, it can be challenging to assess their impact on soil health and crop yields. Some of the species may help address one soil constraint, but contribute to another. For example, if a mix has both mustard and red clover in it, the mustard may help suppress root lesion nematodes, but then the red clover may multiply them again. Therefore, mixes with fewer species (up to 3) may be more beneficial to evaluate their role in the soil.

There were some noticeable differences in the RLN and Vd levels between each treatment crop and check crop. The comparisons are shown below, with significant values bolded at α=0.1 **(Table 2).**

Table 2: Difference in root lesion nematodes (RLN) and *Verticillium dahliae* (Vd) before and after planting different crops or mixtures

Field/ Treatment	RLN (#/kg soil)	Vd (cells/g soil)
1.Timothy/Clover (Check)	**+11,057**	-87
1.Buckwheat	+653	**+7,439**
1.Hemp	**+12,843**	**-2,084**
2. Oats (Check)	+1,162	**+4,058**
2. Multi-Species Mix	-810	+1,993
2. Sorghum Sudangrass	**-2937**	+250*
3. Red Clover (Check)	**+8,509**	+1,576
3. Sorghum Sudangrass	+93	**+5,792**
4. Timothy/Clover (Check)	+1,689	**+5,145**
4. Oilseed Radish	**+2,349**	-932
4. Brown Mustard	**+4,674**	-1,614
5. Brown Mustard (Check)	**-3,228**	-224
5. Mustard/Radish	+1,995	-1,227
5. Mustard/ SS	**+2,095**	**+2,021**
5. Multi-Species Mix	-677	+1,933
6. Ryegrass (Check)	**+15,833***	**-5,533**
6. Multi-Species Mix	**+4,410**	+571
7. Ryegrass (Check)	-2,046	**-9,552**
7. Sorghum Sudangrass	**+10,101**	**-7,592**
8. Ryegrass (Check)	**+3,565***	-1,871
8. Ryegrass with Compost	**+6,370***	-1,145
8. SS/PM/Peas with Compost	**+4,874**	**-3,374**

*Signifies that the spring 2019 test result was not recorded, so the average of the other samples from the same field were used for comparison.

Out of a total of 22 treatments across eight fields, 18 treatments experienced an increase in root lesion nematodes between the spring of 2019 and the spring of 2020. Twelve of these crops increased RLN counts by more than 2000 per kg of soil. Only two treatments (brown mustard and sudangrass) resulted in a substantial decrease in RLN year-over-year. This is not entirely surprising, as most crop species can host RLN. In three out of four treatments where ryegrass was present, the increase in RLN was considerable. The RLN also multiplied significantly in two of the three fields where red clover was present.

Conversely, only nine treatment crops experienced an increase in *Verticillium dahliae* levels with only four of these treatments increasing Vd by more than 2000 cells/g. Six treatments decreased Vd levels by more than 2000 cells/g. Vd levels decreased in all of the ryegrass treatments, which is consistent with ryegrass not being a host for this pathogen. Other crops and mixtures provided inconsistent results. The largest increase in Vd was seen following buckwheat in Field #1.

Results - Potato Grades/Yields:

A few trials had significant differences for a handful of potato crop quality attributes. The differences between the check and each treatment crop(s) are shown below individually by trial **(Table 3).**

Table 3: Potato yield and quality measurement differences between treatment and control from 2020 harvest samples

Trial / Treatment	Total Yield (cwt/ac)	% Smalls	% Over 10 oz	Specific Gravity	Marketable Yields (cwt/ac)	Crop Value ($/Acre)
Field 1: Buckwheat	-0.4	-1.7	**+2.2**	NA	+7.0	+121
Field 1: Hemp	+25.3	-4.8	+1.2	NA	**+35.5**	**+614**
Field 2: Multi-Species Mix	-9.2	+4.5	+2.4	-0.002	-23.5	-302
Field 2: Sorghum Sudangrass	-1.1	**+6.1**	**-2.4**	0	-17.6	-225
Field 3: Sudangrass	+15.8	0	+6.5	0	+6.0	+111
Field 4: Oilseed Radish	+10.3	+2.2	**-7.1**	**+0.003**	+3.0	+68
Field 4: Brown Mustard	**+36.2**	-0.3	-0.5	+0.001	**+31.9**	**+394**
Field 5: Mustard/Radish	**+40.3**	-0.5	+5.9	+0.002	**+33.2**	**+459**
Field 5: Mustard/Sorghum	+16.4	**-2.0**	+9.5	+0.003	+16.7	+282
Field 5: Multi-Species Mix	-6.9	+1.0	+2.5	+0.001	-13.4	-127
Field 6: Multi-Species Mix	**+49.2**	-2.2	-5.3	-0.003	**+47.7**	+436
Field 7: Sorghum Sudangrass	+2.0	+4.0	-2.0	+0.002	-2.0	+13
Average	**14.8**	**0.5**	**1.1**	**0.001**	**10.4**	**154**

Note: NA= Not Available. SS/PM= Sorghum Sudangrass/Pearl Millet. Statistically significant differences between treatments at α=0.1 are bolded.

It is difficult to identify trends across fields in this trial, as the check crop was not the same across all eight fields, and the treatment crops/mixtures were also different. Across all seven fields where there was a comparison of a treatment crop with a check crop, there was an average increase in marketable yield of 10.4cwt/ac and an increased crop value of $154/acre. In looking at some more specific comparisons for two treatments that were planted in more than one field, see the table below **(Table 4).**

Table 4: Aggregate difference from control for potato yield and quality following Multi-Species mixtures and sorghum sudangrass treatments each across three fields

Trial / Treatment	Total Yield (cwt/ac)	% Smalls	% Over 10 oz	Specific Gravity	Marketable Yields (cwt/ac)	Crop Value ($/Acre)
Multi-Species Mixes (3 Fields)	+11.0	+1.1	-0.1	-0.001	+3.6	+2.0
Sorghum Sudangrass (3 Fields)	+5.6	+3.4	+0.7	+0.001	-4.5	-34

From this data, the average effect of these crops on potato yields and quality in 2020 appears not to be different than zero. This should be taken with a great deal of caution, as noted that the number of fields in this comparison is small, and the control crop was not the same in each comparison. Nonetheless, it does not appear that these crops provided a big improvement in potato yield and quality in 2020.

In Field 8, the research team lost part of the check at the time of potato planting in 2020 therefore we can only compare the effect of the addition of compost in this field **(Table 5).** In this case, both crops performed equally well with the addition of compost compared to no compost added to the ryegrass. These differences were statistically significant, and are of a degree that would warrant further evaluation of the impact of adding compost or manure.

Table 5: Comparison of potato yield and quality attributes between SS/PM/Peas and Ryegrass with compost treatments

Trial / Treatment	Total Yield (cwt/ac)	% Smalls	% Over 10 oz	Specific Gravity	Marketable Yields (cwt/ac)	Crop Value ($/Acre)
Field 8: SS/PM*/Peas with Compost	**+54.8**	+0.2	**-3.3**	**-0.005**	**+50.5**	**+566**
Field 8: Ryegrass with Compost	**+48.4**	+0.7	**-3.3**	**-0.004**	**+43.8**	**+559**

Note: SS/PM= Sorghum Sudangrass/Pearl Millet

Summary:

Based on the eight trials discussed above, the differences in organic matter and most soil health package attributes measured between years and treatment crops were minimal, with some exceptions, but these fields would likely have to be followed further to assess for longer-term trends. The biological N-fixation was most variable by year of sampling, while the root lesion nematode and *Verticillium dahliae* levels were variable by year and treatment crop. In general, root lesion nematode levels increased regardless of crop (18 out of 22 treatments) while *Verticillium dahliae* levels generally decreased or stayed the same across the eight fields, with a few exceptions.

Given the diversity of Multi-Species Mixes, the types and amounts of species they are composed of, it was more challenging to determine the impact they have on soil health, pathogens, potato yield and quality compared to treatments with just one or two species. A closer look at the particular species in the mixes would be useful to assess if they are compatible for potato rotations.

It was hot and dry during the 2019 growing season, with moisture limitations in most fields that contributed to smaller differences between control treatments and soil-building treatment crops. The 2020 growing season was even hotter and drier, with some fields getting anywhere from less than half to almost no rainfall all summer. Many of the ryegrass crops did not establish well because they were bone-dry. This trend of changing weather patterns is quite concerning, and has encouraged growers to look at more drought-resistant crops and crop varieties and building organic matter where possible to help hold onto moisture that is available. Adding manure, compost or other organic fertility sources would be beneficial to build soil organic matter levels.

It can also be challenging collecting soil samples from all the trials before the primary spring tillage takes place, because of tight timelines getting to all the sites in a timely fashion, and communication with growers or their staff working around their schedules. Soil compaction testing was conducted to three depths (6, 9 and 12”) in 2019, but due to time constraints to sample double the number of trials in 2020 (including follow-up sampling from trials established in 2019), there was not enough time to collect follow-up compaction data in the second year of these trials. Also making sure all the staff collect data to the same depths in both years is important to be able to make comparisons throughout different stages of the crop rotation. Collecting more penetrometer data is an area that will receive more addition in future years of trials in this BMP project to get two years of data back to back to compare; by either ensuring more staff are available to help collect the data on the field days, or adding additional field days to the schedule to specifically collect that data.

One of the suggestions during co-development in the winter of 2020 was to attempt to reduce the number of “check crops” in order to facilitate more across field comparisons. This diversity of check crops is reflected in this report. However, the uptake of fewer check strip options was more successful when the 2020 trials were established, with just two options: either red clover grass or ryegrass used.

As mentioned in other reports, despite being in the middle of a global CO-VID pandemic, it has not affected the data collection aspect of the work plans through the Potato Board to the same extent as some other collaborative Living Labs research partners. The main set-back to-date was a delay submitting soil samples to some laboratories in the spring of 2020 during the Public Health directive to restrict business services for a period of roughly 8 weeks. The research team experienced some delays receiving results from some of the laboratories, which in turn, delayed providing results to participating growers. In future years, the research team will endeavour to provide interim results to growers as soon as it is reasonable to do so. Some of the delays were related to CO-VID-19, which will hopefully not be an issue in future years. Once it was safe for the labs to re-open sample, submissions resumed smoothly. Additionally, one adaptation was made moving most meetings online (with a much smaller in-person component) to share results with larger audiences. However, it can be less interactive communicating over these technologies compared to in-person meetings.

Also as mentioned previously, when the soil sampling for the health package began in 2019, it was originally collected using the shovel method described in the Cornell Soil Health Manual (CSHA). However, after discussing it with a local nutrient management specialist, since an auger reaches a similar depth of 6 inches (15cm) and taking into account the additional time that would be required to collect many samples with a shovel, a decision was made to switch to an auger for the 2020 year. Soil sampling for chemical analysis in 2019 was originally done using a soil probe to reach a 30cm depth, but based on efficiency with other soil sampling protocols, it was justified to switch to using an auger for the 2020 sampling to the same depth.

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