

Measuring the Effects of Residue Tillage Equipment in Prince Edward Island: A review of recent field-scale research

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Abstract: Three different studies comparing primary residue tillage (PRT) with moldboard ploughing were conducted between 2010 and 2017. Experimental design was not identical across all three studies, but many of the reported variables were similar. Data analysis was conducted in early 2018 across years and fields within each study, and then the results of the three studies were compared. Results from this data analysis indicate that:

1. PRT is associated with higher marketable yields. Two studies showed a 30 cwt/ac or higher advantage to PRT.
2. There may be a slight negative impact on specific gravity, though this was only statistically significant in one study.
3. Impact of PRT on common scab is still inconclusive. Two studies saw a reduction in scab, the other saw an increase.
4. PRT is associated with higher concentrations of potassium (K) and magnesium (Mg).
5. Some numerical evidence that PRT is associated with higher soil pH than moldboard ploughing, though not statistically significant in these studies.



Lemken primary residue tillage (PRT) implement in use in Prince Edward Island. Photo: Mary Kay Sonier.

For many years, one of the essential tools in potato production in Prince Edward Island and elsewhere has been the traditional moldboard plough. Potatoes are a row crop requiring significant amount of loose soil in order to make a raised hill, so the soil must be prepared accordingly. Generally, Island potato growers have favoured the use of a moldboard plough in the fall, in order to satisfactorily handle multi-year sod from forages grown in rotation and ensure that this sod is adequately broken down and the soil is sufficiently dry before potatoes are planted in the spring.

While traditional methods of land preparation have

done an excellent job of preparing a seed bed for potato planting and has produced many favourable crops over the years, they present some challenges, both agronomically and environmentally. Studies by researchers at AAFC in Charlottetown have found that ploughing early in the fall without use of cover crops is associated with increased leaching of soil nitrate, presenting both an environmental concern as well as a loss of nitrogen that could be used for the following year crop. Opting to delay ploughing until air and soil temperatures have decreased (late fall) reduces the risk of nitrate loss, but also ensures a bare soil exposed to the elements through the winter and spring.

This exposed soil is then at significant risk of soil erosion from both water and wind. This is becoming even more of a concern in recent years, as warmer winter temperatures and more frequent freeze and thaw cycles increases the risk of soil erosion.

Additionally, use of a moldboard plough for tillage has been identified as a major factor in the decline of soil organic matter by studies around the world. While it has been a very effective tool for land preparation, it is important to investigate other tillage options that may prove to be more beneficial to short term marketable yields as well as to soil health over the medium and long term.

In recent years, many potato growers in Prince Edward Island have invested in primary residue tillage (PRT) equipment. These implements are sold in multiple forms and brand names, but generally perform similar tillage operations. Instead of inverting the soil profile (ie. flipping sod) like a moldboard plough, they incorporate above ground residue into the soil profile, usually at a shallower total depth than the plough. Normally, this type of tillage equipment will require a tractor with more horsepower to be effectively operated, but residue tillage equipment can work more acres per hour than a moldboard plough.

In a 2013 study by Tyler Wright with the PEI Department of Agriculture and Fisheries comparing operation of a moldboard plow (7 bottom) with a 13 foot wide Synkro 4003 implement, there was significant differences in tillage cost between the two implements. After factoring in the cost of purchase cost, fuel, depreciation, maintenance, insurance, and tractor costs, there was a \$10.55 advantage in tillage costs per acre in favour of the Synkro over the plough (\$22.25/acre for Synkro, \$32.80/acre for plough).

One of the key selling points for these types of implements is that they leave more crop residue on the top of the soil (generally between 20% to 25% in PEIDAF studies) than the plough. This residue is more likely to help prevent soil erosion from wind and water during the winter and spring, as the fields with higher percentages of crop residue have been shown to catch more snow during the winter and be less susceptible to producing the “red snow” that has been evident in many PEI winters. Additionally, if one chooses to plant a cover crop following use of PRT, there is the opportunity to reduce the potential for nitrate leaching and other over-winter nutrient losses.

Notwithstanding some of these potential advantages, it is important for potato growers to know how the use of these implements will impact marketable yields of



Pottinger Synkro 4003 tilling land in PEI. Photo: Tyler Wright.

potatoes in comparison with moldboard ploughing. As a result, there have been a number of different field-scale studies performed with Island growers over the past few years to compare these two types of tillage. In this analysis, we were able to assess the results of three separate studies that were independently designed and conducted but that had similar trial design and data collection. It was felt that it is important to analyze all of this available data to better understand what trends are being demonstrated over multiple farms and multiple years. The three studies with data analyzed were performed by:

- Prince Edward Island Department of Agriculture and Fisheries and PEI Soil & Crop Improvement Association, led by Tyler Wright, Soil & Water Engineer.
- Kensington North Watershed Association, led by Barry Murray (Watershed Coordinator) and Matt Ramsay (potato producer from Hamilton, PEI).
- East Prince Agri-Environmental Association and Agriculture & Agri-Food Canada, led by Bonnie Robertson (Soil Engineer), Scott Anderson, Rick Peters, and John Phillips (EPAA)

We will discuss the design and results of each of these trials individually, before examining commonalities or differences observed between the three studies.

PEIDAF/PEISCIA Trials (2010-2016):

In these trials, moldboard plowing in the fall was compared with primary residue tillage (PRT) in the fall at two different farms in central Prince Edward Island. The same field was used for each farm across years. At

one farm (Farm A), a Pottinger Synkro 4003 implement was compared against fall ploughing in 2013 and 2016. At the other farm (Farm B), a Jobber Rotobeach was compared against fall ploughing in 2010 and 2013 (with levelling roller in 2013) while a Pottinger Synkro 4003 was compared against fall ploughing in 2016.

At Farm A, plots between 0.4 and 1.2 acres in size were established in the fall before potato planting. Four plots were established for each treatment (Synkro vs plough). Plots to be worked with the Synkro implement were sprayed with glyphosate prior to tillage. Russet Burbank was the variety used in both 2013 and 2016, and two yield samples were taken from each plot, giving a total of eight yield samples for each treatment. Samples consisted of tubers from ten consecutive plants in rows with 16.5 inch plant spacing and 34 inch row width. Soil samples were collected after harvest each year.

At Farm B, plots of approximately 0.2 acres in size were established in the fall before potato planting. Four plots were established for each treatment (Synkro vs plough). The entire field was treated with glyphosate before tillage. Russet Burbank was the variety used in 2010 (at 15 inch in-row spacing), while Prospect was planted in 2013 (10 inch spacing) and Ranger Russets were used in 2016 (12 inch spacing). Samples consisted of tubers from ten consecutive plants in rows with 36 inch row width. Soil samples were collected after harvest each year.

Because of differences in varieties, equipment and pre-tillage chemical treatment, the only variable considered in this analysis is the comparison of PRT with moldboard ploughing. From analysis of the data across farms and across years, there were some significant differences evident at a 95 percent confidence level.

In this study, PRT practices significantly increased both the total and marketable yields (Canada #1 grade standard) when compared with moldboard ploughing. The increase in marketable yield favouring residue tillage was 8 percent, or approximately 30 cwt/acre. No statistically significant difference in cullage rates was observed. In 2016, additional grading was performed according to Cavendish Farms grade standards for processing potatoes. Once again, PRT was associated with an increase in total yield (approx. 35 cwt/acre improvement).

However, PRT in this study was associated with an increase in scab severity and percent scab on the surface of potatoes. PRT increased percent scab to 8.5%, up from 4.0% for moldboard ploughing. The numerical increase

in scab severity (assessing the depth /pitted nature of scab) was not as great, but was still deemed significantly higher for PRT samples. No significant differences were observed for other diseases, including Rhizoctonia, silver scurf, and Fusarium. In the 2016 Cavendish grades, total defects (including scab) were also significantly higher for the residue tillage samples, with Farm B experiencing high levels of scab in both treatments. Despite these higher levels of defects (24.9% for residue tillage versus 11.3% for plough), the total payout per acre calculated from the Cavendish Farms contract still favoured PRT (\$3684/acre) when compared with moldboard plough (\$3330).

In examining differences in soil test results, PRT was associated with significantly higher soil levels of potassium (K), magnesium (Mg), and manganese (Mn) than moldboard ploughing. In addition, both soil organic matter and soil pH were observed to be numerically higher for PRT plots, but this difference was not shown to be statistically significantly different. For both of these variables, it may require more years to show a significant upward trend.

Kensington North Watershed Trials (2015-2017):

In partnership with local potato growers, the agronomy team with the Kensington North Watershed Association conducted trials on seven farms across three years (2015, 2016, 2017), with no individual field evaluated more than once. Each field involved in the study was split between the use of a PRT implement (Synkro or Lemken) and moldboard plough. Between three and five yield samples were taken from each side of the field and were submitted for grading to Cavendish Farms Central Grading, including a calculation of total payout per acre for each treatment according to Cavendish Farms processing contract specifications for that variety. In addition, tests for soil nitrate levels were completed at four different depths (6, 12, 18 and 24 inches) and at different dates during the growing season, to assess the mobility of nitrates in the soil profile.

Data analysis from this study showed that PRT significantly increased total yield per acre (+26 cwt/acre) and marketable yield per acre (+39 cwt/acre) when compared to moldboard ploughing. PRT was also associated with a decrease in total defects (including scab), with 1.9% defects for PRT as compared to 4.5% for ploughing. When using the calculated payout per acre provided by Cavendish Farms, PRT also showed a significantly higher payout (\$411/acre) than ploughing. Pitted scab incidence was generally low for both PRT and ploughing in this study, but levels were found to be significantly lower in

the PRT treatments.

Analysis of soil nitrate data did not show significant differences on most dates when comparing PRT versus fall moldboard ploughing. Across six sampling dates in 2016, only one date (September 6th) showed significant difference in soil nitrate levels (higher in residue tillage samples). When comparing the interaction between tillage type and sampling depth, significant differences were observed early in the growing season, with PRT samples having lower soil nitrate levels at the lower sample depths (18 and 24 inches) when compared to the ploughed samples. This could be due to residual soil nitrogen being less susceptible to leaching under PRT than ploughing, or it may be the case that areas under PRT management retain applied nitrogen fertilizers in the upper levels of the soil profile better than areas where ploughing was performed. This interaction was not observed later in the season, when much of the available nitrogen would be utilized by the growing potato crop.

AAFC/EPAA Trials (2016-2017):

In partnership with Agriculture and Agri-Food Canada through a project supported in part by the Prince Edward Island Potato Board, the East Prince Agri-Environment Association undertook a three year study to investigate the use of PRT equipment (Lemken) in the fall in comparison with moldboard ploughing in the fall and PRT in the spring. Three fields were assessed in each of three years. Tillage was performed in the year before potatoes were planted. Soil and tuber samples were then taken the following fall, with tuber grades performed by AAFC. All three fields were in a three year rotation of potatoes, followed by a grain crop and then a forage crop. These fields were all located in eastern Prince County.

Additionally, there was research performed to compare percent ground cover and water infiltration rates among treatments, but that data was unavailable for this analysis and is not presented here.

Across individual fields and years in this study, there was no significant difference in marketable yield observed between PRT and ploughing in the fall, with a numerical difference of 10 cwt per acre favouring PRT. There was a significant difference between ploughing in the fall and the use of the Lemken implement in the spring, with the spring tillage resulting in a depressed yield (291.6 cwt versus 328.1 cwt). There was a significant difference in this study between both PRT treatments (fall and spring) and fall ploughing for specific gravity, with both residue



Lemken Karat 9 tillage implement. Photo: Mary Kay Sonier.

tillage treatments averaging 1.086 for specific gravity, compared to 1.089 for fall ploughing.

When looking at disease ratings, there was no significant differences observed between fall ploughing and fall residue tillage for Rhizoctonia, common scab, or silver scurf (both severity rating and percentage of skin coverage). On the other hand, there were significant differences observed between the spring PRT treatment and the fall ploughed control for all four diseases, with the PRT treatment having the higher incidence of disease for each of Rhizoctonia, common scab, silver scurf, and Fusarium.

In looking at the soil test data, there were significantly higher soil test readings for potassium and magnesium, and significantly higher base saturation percentages for potassium, magnesium and calcium for the fall PRT treatments compared with the fall ploughing control. Conversely, concentrations of copper, zinc, and sodium were significantly lower under PRT management. In comparing spring residue tillage compared with fall ploughing, the only soil nutrient to be significantly higher in the under PRT was phosphorus. Soil organic matter percentages were not significantly different, although there was not a comparison of soil organic matter before and after tillage, so within-field variation in soil organic matter percentage was not a factor in this study. Soil pH was also not determined to be significant different between treatments, although soil pH was numerically higher by approximately 0.1 in the fall PRT treatment compared to the other two tillage methods.

Comparing Results Across Studies:

Table 1: Difference between PRT (treatment) and moldboard ploughing (control) for select variables across three different studies.

	PEIDAF	KNWA	AAFC
Market. Yield (cwt/ac)	+29.7*	+39.4	+10.1
Total Yield (cwt/ac)	+30.1*	+26.4	+0.5
Specific Gravity	-0.002	-0.001	-0.003
Common Scab %	+4.5	-1.1	-0.4
Potash (ppm)	+31.1	--	+30.5
Magnesium (ppm)	+11.3	--	+11.9

** For the PEIDAF trial, marketable yield and total yield were not significantly different when expressed in cwt/acre, but were significantly different when comparing sample weights based on 10 plants. This discrepancy may be due in part to differences in row widths between the two farms in this study.*

In Table 1, we compare the results from each of the three studies for common variables. For each variable, the difference between fall primary residue tillage (PRT) (treatment) and fall moldboard ploughing (control) is shown. If that difference is significantly different at a confidence level of 90%, that is indicated in bold. Positive numbers indicate a numerical advantage to PRT, while negative numbers show a numerical advantage to moldboard ploughing:

From this data analysis, it appears that we can make some summary statements comparing fall PRT versus fall moldboard ploughing:

1. PRT is associated with marketable yields that are as good as or better than yields associated with fall moldboard ploughing. In two out of the three studies, there was between a 30 and 39 cwt advantage in marketable yield associated with fall PRT.
2. There is a slight negative impact on specific gravity associated with the use of fall PRT, although this was only deemed significant in one study.
3. The impact of fall PRT on common scab is still somewhat inconclusive, and may be confounded with other variables such as change in soil pH and potato variety. Two of the studies showed a slight reduction of common scab incidence (one significantly) under fall PRT, while the other had a significantly higher common scab incidence level under fall PRT.
4. In the two studies where soil tests were performed,

concentrations of potassium and magnesium were significantly higher under fall PRT, with very similar differences observed between the two studies.

5. There is some numerical evidence from two studies that PRT is associated with an increase in soil pH; however, this increase was not shown to be statistically different. Perhaps with more sites and more years of study, it would be possible to explore this further.

Summary and Conclusions:

The primary goal of this investigation and data analysis was to assess the agronomic merit of using fall residue tillage (PRT) equipment for primary tillage ahead of potatoes instead of the conventionally-used moldboard plough in the fall. From the data analyzed in these three studies, the general trend appears to be that PRT is associated with improved yields and improved availability of some soil nutrients, which may in fact have a strong linkage. If K and Mg are more available in the root zone following PRT than moldboard ploughing, it may have an association with the beneficial effect on yield. It may also necessitate a need to re-examine fertility rates for these nutrients under residue tillage.

Results related to common scab are less clear. In two studies, there was negligible difference and low overall incidence levels of scab. In the other, there was a significantly higher incidence of scab associated with PRT; however, this large difference was largely seen at only one farm and was particularly worse under Ranger Russet (a scab susceptible variety) than in other varieties. What is unclear is the effect of PRT on soil that may have led to higher scab incidence in this study. Perhaps a higher average soil pH (5.85 for PRT vs 5.7 for ploughed) is responsible for this increase in scab incidence. This may necessitate a change in lime application for fields where PRT is used, as well as paying close attention as to where scab susceptible varieties are planted.

What was not addressed in these studies is the long-term agronomic and environmental benefit associated with reduced soil erosion. Any change in practices that limits the amount of topsoil lost from fields will have significant long-term benefit for any farm.

Further study may be warranted to determine whether PRT is conclusively associated with increased soil organic matter. No statistically significant difference was seen in the two studies that conducted soil tests in this analysis;

however, neither study conducted “before and after” soil tests to assess change in soil organic matter percentage. In addition, it may not be able to see a perceptible improvement in only one year; instead, multiple years of rotation may be required to show differences. The one study that conducted trials in the same field over multiple rotations indicated a trend for PRT to be associated with an increase in soil organic matter, but it may require more sites and more years of study to verify this trend.

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Lemken implement in action. Photo: Tyler Wright.