Integrating Technologies to Enhance the Simplicity of Strip Tillage Systems

Purpose:

The majority of Ontario corn is produced using conventional tillage which results in unprotected soil surfaces which are highly vulnerable to erosion. While the call for a shift towards reduced-tillage corn production has been made for decades, adoption has been limited due to productivity and logistical issues. Predictions for an increase in the intensity and duration of rainfall events in the future due to climate change are expected to exacerbate soil erosion losses from conventional tillage systems, and reinforce the requirement to develop simple and effective methods of reduced-tillage systems for corn. Strip tillage is one reduced tillage system which has demonstrated a capability to achieve corn yields similar to conventional tillage while providing meaningful protection against soil erosion. Unfortunately, the economic and environmental incentives of strip tillage have not been enough to convince corn producers to overcome the logistical hurdles associated with the conversion from a conventional-till system. This research project is aiming to develop a simple one-pass spring strip-tillage system which integrates various technologies to help simplify the transition from conventional-till systems, and promote its adoption to produce a more environmentally resilient corn production model.

Methods:

Strip tillage was conducted with a 6-row Dawn Pluribus® Strip Tiller mounted by 3 point to hitch to a Yetter® caddy cart with a Gandy Orbit Air® dry fertilizer box (Figure 1). Fertilizer was mixed between the coulters in 2014, while in 2015 side band tubes were included which delivered 1/3 of the fertilizer in a band to the outside of the coulter. Fields were selected which would be more conducive to spring strip tillage (lighter soil texture and residue).

To evaluate the viability of a one-pass spring strip tillage system, four key questions were investigated:

i) What is the yield impact of moving all P and K applications to the strip-tiller, and off of the planter?
ii) What is the safety of urea as a nitrogen source?
iii) What is the safety of a urea/ESN blend as a nitrogen source relative to a safe placement such as side-dressing UAN (ESN is a polymer coated urea for slow release of nitrogen – slow release may also help improve crop safety when applying in strip)?
iv) What is the yield response of spring strip tillage relative to conventional or no-till?

Fertilizer blends were made to always deliver 30 lb/ac of P_2O_5 and K_2O, and depending on treatment, 135 lb-N/ac supplied as a side-dress application of UAN, or as a Urea or a 50%/50% blend of ESN and Urea blend through the strip tiller. To compare P and K placement, a 19-19-19 blend was applied at 160 lb/ac either mixed through the strip tiller or through a 2”x2” planter band onto strips that received no fertilizer. The balance of nitrogen was applied as a side-dress application of UAN. To compare nitrogen product safety, a 35-8-8 fertilizer blend consisting of urea was applied through the strip tiller at a rate of 397 lb/ac, or a 34-8-8 fertilizer blend consisting of a mixture of Urea/ESN was applied at a rate of 390 lb/ac. At some locations, treatments also included a rate of Urea or ESN blend fertilizers which delivered a rate of 160 lb-N/ac to assess for higher nitrogen situations. At some locations, planter placed fertilizer blends were also compared in no-till, or conventional till practices. Conventional till treatments were typically 2 passes of a field cultivator or disk-harrow prior to planting. All statistical comparisons were made within location only and at a 5% level of significance.

Figure 1. Dawn Pluribus® strip tiller and Gandy Orbit Air® dry fertilizer box used to conduct treatments.

Contour strip tillage locations were also included in 2014 and 2015. Research in the U.S. has demonstrated that contour cropping (planting in right angles to the direction of slope) has shown an increase in water infiltration and reduced erosion through the berm-like action of crop rows in areas with significant topography. The goal was to demonstrate proof of concept for a system for developing accurate topography contours, and follow contours with high pass-to-pass accuracy through RTK GPS and active implement guidance via ProTrakker® hitch.

Results:

Six trials were conducted in 2015 at Arthur, Belwood, Bornholm, Elora, Paris and Woodstock where various NPK fertilizer blend and placement strategies were employed. A 7th site explored the integration of contour steering and implement guidance with the strip tillage and fertilizer banding approach at Belwood. Field characteristics and yields for all treatments in 2015 are presented in the Appendix. Information from 2014 trials is available in the 2014 crop advances summary (http://bit.ly/1SheUz7).

On a site-by-site basis, no significant yield responses were observed at these locations for moving P and K fertilizer applications from a 2”x2” band on the planter to mixing in the strips during the spring strip-tillage operation (Table 1). These locations ranged from medium to low probability of response for P and K fertilizers (Appendix 1). It is unknown if this response also holds true on soils with high probabilities of response to P and K fertilizers.

Table 1. Yields and response to P and K fertilizer applied through strip-tiller or planter.

Year	Location	Planter	Strip Tiller	Response	
		------------ yield (bu/ac) ------------			
2014	Bornholm	158	149	-9	NS
2015	Bornholm	153	159	+6	NS
2015	Elora	178	180	+2	NS
2015	Belwood	174	173	-1	NS
2015	Woodstock	224	223	-1	NS
2015	Paris	123	113	-10	NS

In 2014, using urea as the sole nitrogen source for in-strip fertility resulted in reduced yields relative to the safer application strategy of side-dressing UAN (Table 2). While not significant on a site-by-site basis, responses were consistently and largely negative. During the growing season, the urea plots appeared slightly shorter and paler yellow in colour relative to the other treatments. For 2015 results, see "2015 Case Study" below.

Table 2. Yields and response to nitrogen fertilizer applied as urea in-strip relative to side-dress application of UAN.

Year	Location	N Rate	Sidedress	Urea	Response	
		lb-N/ac	------------ yield (bu/ac) ------------			
2014	Bornholm	135	149	140	-9	NS
2014	Paris	135	186	178	-8	NS
2014	Bornholm	160	154	133	-21	NS

In 2014, using an ESN/urea blend applied in-strip as the sole nitrogen source resulted in similar yields to the safer application strategy of side-dressing UAN (Table 3), suggesting that unlike the straight urea treatment, crop injury was not an issue with this strategy at these locations. For 2015 results, see "2015 Case Study" below.

Strip-till yields were compared to yields under no-till at 7 locations across 2014 and 2015 (Table 4, fertilizer applied through planter in both treatments). Under the field conditions selected for (Appendix 1: lighter soil texture, low crop residue), strip tillage yields did not differ from no-till.

Table 3. Yields and response to nitrogen fertilizer applied as ESN/Urea blend in-strip relative to side-dress application of UAN.

Year	Location	N Rate	Sidedress	ESN/Urea	Response	
		lb-N/ac	------------ yield (bu/ac) ------------			
2014	Bornholm	135	149	159	+10	NS
2014	Paris	135	186	183	-3	NS
2014	Bornholm	160	154	154	0	NS

Table 4. Yields and yield response of strip tillage relative to no-till.

Year	Location	No-Till	Strip-Till	Response	
		------------ yield (bu/ac) ------------			
2014	Bornholm	159	158	-1	NS
2014	Woodstock	192	192	0	NS
2014	Paris	182	186	+4	NS
2015	Elora	176	178	+2	NS
2015	Bornholm	158	153	-5	NS
2015	Woodstock	221	224	+3	NS
2015	Paris	110	123	+13	NS

Strip-till yields were compared to conventional tillage yields at 4 locations. No significant differences in yields were observed. A large negative yield response was observed for strip tillage at Arthur in 2015. This was likely attributable to difficulty in making good strips in the spring as a result of red clover that had been sprayed but not killed the previous fall. Remnant red clover plants appeared to keep soil shaded and moist while taproots with good integrity were difficult to work, maintaining intact root balls during the strip tillage process. These conditions made it difficult to create a suitably worked strip, creating issues with seed to soil contact etc. when attempting to plant.

Table 5. Yields and yield response of strip tillage relative to conventional tillage.

Year	Location	Conventional	Strip-Till	Response	
		------------ yield (bu/ac) ------------			
2014	Arthur (plow)	141	144	+3	NS
2014	Arthur (disk ripper)	138	144	+6	NS
2015	Elora (cultivate)	170	178	+8	NS
2015	Bornholm (cultivate)	161	153	-8	NS
2015	Arthur (plow)	179	162	-17	NS

2015 Injury Case Study

In 2015, plots that received the urea or ESN/urea blend suffered significantly reduced plant stands on one half (3 rows) of each strip-tiller/planter pass (Figure 2). Investigating plants in the reduced population rows, root development was limited and demonstrated characteristic fertilizer burn symptoms. Plants that did emerge were slow and variable in leaf stage, while many appeared to stall and not emerge at all. Many seeds did not germinate.

Figure 2. Expected plant stand on left three rows and significantly reduced plant stand on right three rows of strip-tiller/planter pass with ESN/urea blend (135 lb-N, 30 lb-P_2O_5, 30 lb-K_2O) treatment at Paris in 2015.

Injury to this degree was not apparent in 2014. While drier conditions in 2015 may have exacerbated the potential for injury, some equipment modifications were also made between growing seasons. Side-band fertilizer tubes were added to help fasten one hose from the fertilizer air-box to each row unit, and delivered 1/3 of total fertilizer to each unit. These attachments placed fertilizer in a band to the outside bottom of the strip tillage coulter they were mounted to (Figure 3a). In this case, they were always mounted on the inside coulter relative to the middle of the strip tiller (Figure 3b). As assembled, it was found these fertilizer bands were placed at approximately the same depth as where seeds were being planted (Figure 3c). The pattern of mounting to the inside of each row unit likely attributed to injury on only one half of each pass (shifting planter pass off center of strip tiller would result in seed placement closer to fertilizer bands on one half of the pass and further away on the other half).

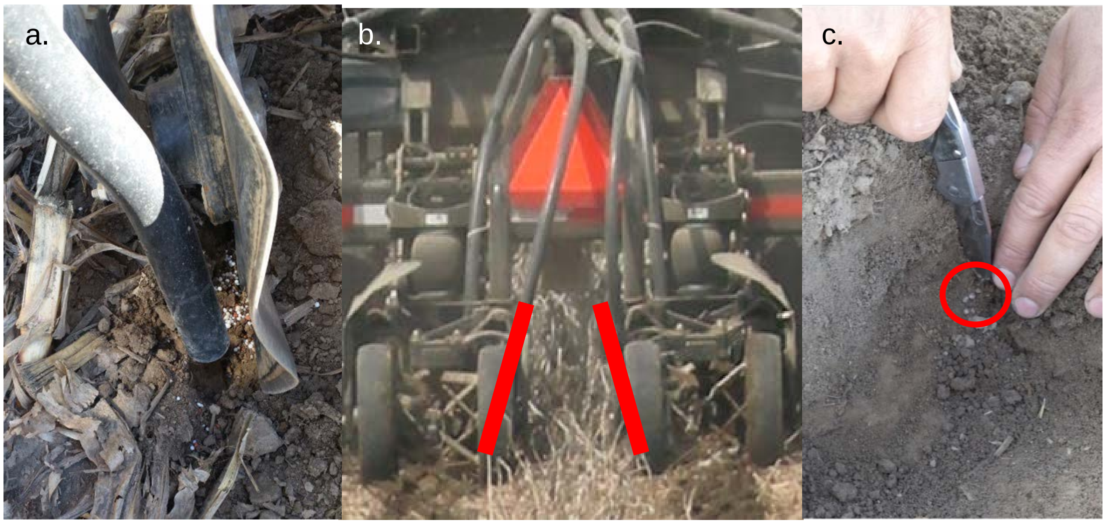

Figure 3. Side-band tube placement relative to strip tillage coulter (a), side-band tube attachment (red lines) relative to middle of strip-tiller (b) and position of fertilizer band from side-band tube in strip-tillage profile (c).

Care was taken at the Elora trial in 2015 to measure populations and yields separately for the normal and injured rows for the urea and ESN/urea blends. Plant populations in the normal rows of the urea and ESN/urea blend treatments were relatively similar to the 19-19-19 blends where no injury was apparent (Figure 4). For the ESN/urea blend, plant populations were only reduced when applied at the high rate (470 lb/ac of product), whereas plant populations were reduced by nearly 50% for both the normal and high application rates of the urea blend.

Similar to populations, yields in the normal rows of the urea and ESN/urea blend treatments were similar to the 19-19-19 blend where no injury was apparent (Figure 5). Yields were reduced in the injured rows across both rates for the urea and ESN/urea blends however, even for the normal rate ESN/urea treatment where populations were not reduced. These results demonstrate that in unaffected rows, these treatments could perform as well as the safer 19-19-19 treatment, but also demonstrate the significant risk of these treatments if not delivered in an appropriate manner.

Overall, farmers will be able to evaluate the potential field passes eliminated by this type of integrated strip tillage. For consideration one might argue that the elimination of other tillage practices is made possible ($35/acre); one broadcast application of fertilizer is eliminated ($12/acre), and a sidedress application of N may also be eliminated ($15/acre). In addition the planter does not require any special conservation tillage modifications and does not need to apply fertilizer this could represent a savings of $5/acre. The strip tillage operation if applying fertilizer can be estimated at $25/acre.

Potential cost reduction is estimated at 35+12+15+5-25 = $42 /acre. These values will be further examined over the remainder of the project.

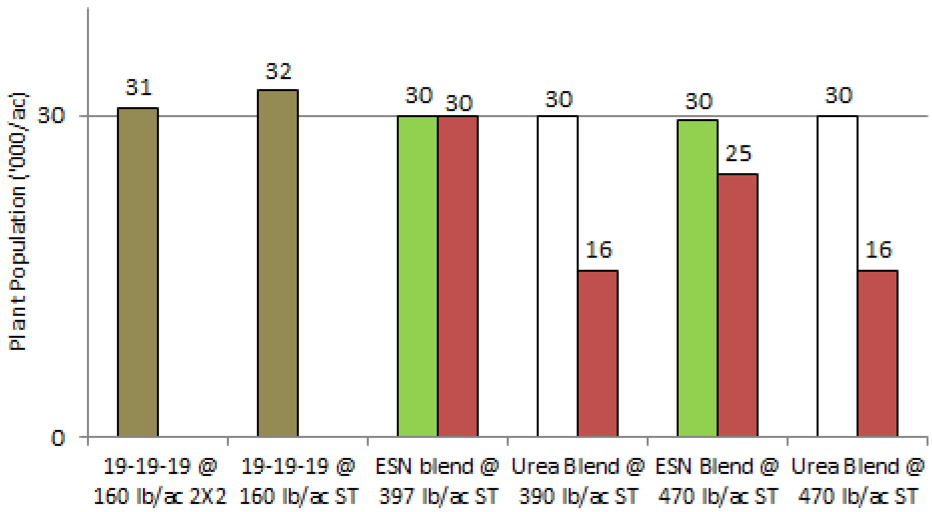

Figure 4. Plant populations for 19-19-19 blend treatments, as well as normal (left columns) and injured (right columns) rows of urea and ESN/urea blend treatments at Elora in 2015.

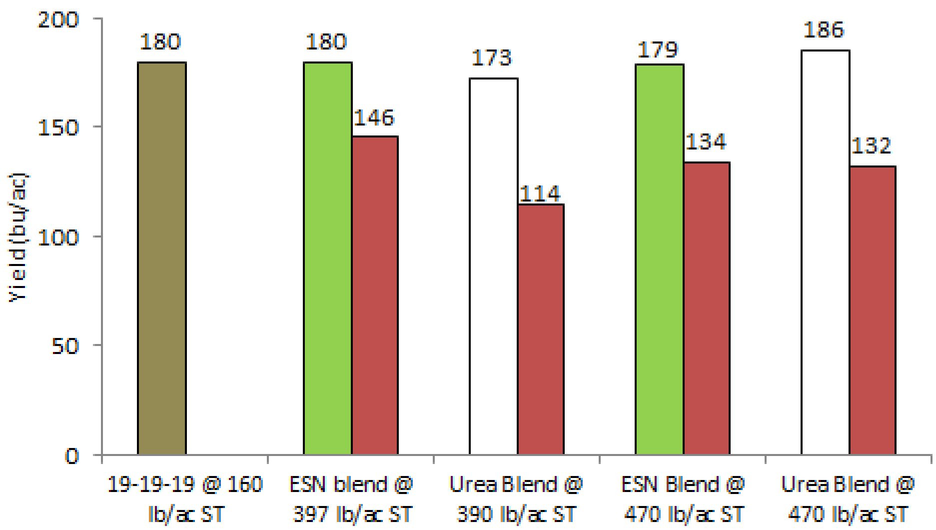

Figure 5. Grain yields for 19-19-19 blend treatment, as well as normal (left columns) and injured (right columns) rows of urea and ESN/urea blend treatments at Elora in 2015.

Contour Strip Tillage

Contour strip-tillage was completed at a field near Belwood in 2015. While no fertilizer treatments or erosion measurements were implemented, this portion of the project did successfully demonstrate proof of concept.

The key challenge of implementing this system was to develop guidance lines that would accurately follow the contour of the land (Figure 6). In this case, contours were developed from an RTK elevation survey completed prior to strip tillage operation. Growers may already have this data available from field operations. The elevation survey was brought into spatial management software (many software options are available in the precision ag market place) and transformed into a contour elevation map. This contour elevation map was used as the basis for creating a prescription map which could be loaded and visualized into the strip tillage tractor monitor, which allowed for the manual driving of a “Curve AB” guidance line in the field.

a) elevation map	b) elevation contour map	c) elevation “prescription” map	d) AB curve contour guidance line

Figure 6. Steps used to create a curve AB contour guidance line from elevation map.

The active hitch performed well, maintaining pass-to-pass accuracy for the strip tiller and planter despite the impact of contour driving and operating on a side-hill. The 15’ strip-till and planter passes were harvested without any issues with a 20’ corn head. Over the two years of attempting contour strip tillage, there were a couple of challenges:

i) Repeatability of curve guidance lines – In a portable RTK base station system, we were unable to exactly match passes if the base station was taken down between operations requiring the same guidance lines (ie. strip-tilling and planting), even after flagging and measuring the beacon position. A fixed beacon position would make this more reliable. We were also unable to re-establish exact replications of the original curve AB guidance lines as small errors in doing so would multiply with passes out from the original “0” pass.
ii) Tight turns – Contour lines may be tighter than equipment can reasonably handle (see smoothing in guidance line between Figure 6c and 6d), which can create active hitch issues as well as complications with subsequent equipment passes, harvesting etc. Some monitors will warn if tight turns exist when creating or following guidance lines.

iii) Soil conditions on knolls – In selecting for fields with topography, often there is selection for eroded knolls where soil conditions can be more difficult to perform suitable spring strip tillage.
iv) Limitations with field topography – Not all fields will have contours conducive to operating – may be too complex or in direction not desirable for field operations

Summary:

A one-pass, full NPK fertility spring strip-till system was evaluated for its viability relative to more conventional practices at ten locations in 2014 and 2015. Applying all N, P and K via strip tiller was shown to be possible with proper equipment and fertility management. If urea was the sole source of nitrogen applied in the strip tillage zone then fertilizer burn was evident and reduced stands and yields were observed at most locations. Using 50% ESN in the zone eliminated this problem in 2014, but not in 2015 where reduced plant stands and yields also occurred with the ESN treatment. This may have been associated with equipment modifications in 2015 where 1/3 of the fertilizer was applied as a band instead of mixed in the row. Further research may be required to investigate this. At most locations, there was not a large difference in yield between where P and K was applied on the strip tiller instead of the planter. A few locations had larger, but non-significant reductions in yield which could not be explained by soil test values. Strip tillage yields did not appear to significantly improve corn yields compared to no-till at most locations, while yield response relative to conventional tillage was variable. Using the contour path option on the tractors GPS guidance system combined with implement GPS steering allowed for the successful implementation of strip tillage on the contour. In regards to other management considerations, good red clover kill appears to be important if it is grown the year previous to a spring strip tillage operation.

Next Steps:

2015 was the final year of this two year project. This project is now complete.

Acknowledgements:

Funding for this project was provided by Ontario Farm Innovation Program (OFIP), Grain Farmers of Ontario (GFO) and Innovative Farmers Associations of Ontario. The Strip-tiller was provided courtesy of Delta Power Equipment and DAWN Equipment. Appreciation is expressed to the farm co-operators, as well as the technical assistance provided by C. Lemon.

Project Contact:

Ben Rosser, OMAFRA, ben.rosser@ontario.ca

Appendix:

Appendix 1. Soil Texture and Phosphorous (P) and Potassium (K) Soil Test Values at 2015 Trial Locations.

Location	Texture	Previous Crop	Soil P (ppm)		Soil K (ppm)	
Arthur	Silt Loam	Wheat	11	MR	84	MR
Belwood	Silt Loam	Wheat	13	MR	95	MR
Woodstock	Silt Loam	Soybeans	13	MR	65	MR
Paris	Sandy Loam	Soybeans	30	LR	104	MR
Elora	Silt Loam	Fall Rye Cover	21	LR	69	MR
Bornholm	Silt Loam	Soybeans	26	LR	91	MR

Appendix 2. Yield response to various fertilizer placement methods at Arthur*, ON in 2015.

Tillage	Fertilizer Blend	Placement	--- Nitrogen (lb-N/ac) ---			Yield (bu/ac)	
			Strip	Planter	Side Dress		
Strip-Till	18-18-18 @ 137lb/ac	Planter	0	26	84	162	A
Strip-Till	34-8-8 (ESN) @ 324 lb/ac	Strip-Tiller	110	0	0	172	A
Conventional	18-18-18 @ 137 lb/ac	Planter	0	26	84	179	A
Conventional	18-18-18 @ 137lb/ac	Strip-Tiller	26	0	84	184	A

* Struggled to make good spring strips at Arthur due to red clover from previous wheat crop which had been sprayed, but not killed
"ESN" implies that 50% of the N supplied was from ESN and 50% form urea.

Appendix 3. Yield response to various fertilizer placement methods at Belwood, ON in 2015.

Tillage	Fertilizer Blend	Placement	-- Nitrogen (lb-N/ac)*--			Yield (bu/ac)	
			Strip	Planter	Side Dress		
No-Till	12-20-20 @ 125lb/ac	Planter	0	15	0	180	A
Strip-Till	12-20-20 @ 125lb/ac	Planter	0	15	0	174	A
Strip-Till	12-20-20 @ 125lb/ac	Strip-Tiller	15	0	0	173	A

* Balance of nitrogen was applied as surface applied UAN after planting

Appendix 4. Yield response to various fertilizer placement methods at Bornholm, ON in 2015.

Tillage	Fertilizer Blend	Placement	-- Nitrogen (lb-N/ac)*--			Yield (bu/ac)	
			Strip	Planter	Side Dress		
No-Till	19-19-19 @ 160 lb/ac	Planter	0	30	105	158	A
Strip-Till	19-19-19 @ 160 lb/ac	Planter	0	30	105	153	A
Strip-Till	19-19-19 @ 160 lb/ac	Strip-Tiller	30	0	105	159	A
Strip-Till	34-8-8 (ESN) @ 397 lb/ac	Strip-Tiller	135	0	0	148	AB
Strip-Till	35-8-8 (Urea) @ 390 lb/ac	Strip-Tiller	135	0	0	128	B
Strip-Till	34-8-8 (ESN) @ 470 lb/ac	Strip-Tiller	160	0	0	150	AB
Strip-Till	35-8-8 (Urea) @ 470 lb/ac	Strip-Tiller	160	0	0	155	A
Cultivate	19-19-19 @ 160 lb/ac	Planter	0	30	105	161	A

"ESN" implies that 50% of the N supplied was from ESN and 50% form urea.
"Urea" implies that 100% of the N supplied was form urea.

Appendix 5. Yield response to various fertilizer placement methods at Elora, ON in 2015.

Tillage	Fertilizer Blend	Placement	-- Nitrogen (lb-N/ac)*--			Yield (bu/ac)	
			Strip	Planter	Side Dress		
No-Till	19-19-19 @ 160 lb/ac	Planter	0	30	105	176	A
Strip-Till	19-19-19 @ 160 lb/ac	Planter	0	30	105	178	A
Strip-Till	19-19-19 @ 160 lb/ac	Strip-Tiller	30	0	105	180	A
Strip-Till	34-8-8 (ESN) @ 397 lb/ac	Strip-Tiller	135	0	0	180	A
Strip-Till	35-8-8 (Urea) @ 390 lb/ac	Strip-Tiller	135	0	0	173	A
Strip-Till	34-8-8 (ESN) @ 397 lb/ac	Strip-Tiller	160	0	0	179	A
Strip-Till	35-8-8 (Urea) @ 390 lb/ac	Strip-Tiller	160	0	0	186	A
Fall Strip-Till	19-19-19 @ 160lb/ac	Planter	0	30	105	175	A
Cultivate	19-19-19 @ 160 lb/ac	Planter	0	30	105	170	A

"ESN" implies that 50% of the N supplied was from ESN and 50% form urea.
"Urea" implies that 100% of the N supplied was form urea.

Appendix 6a. Yield response to various fertilizer placement methods for combine harvest at Paris, ON in 2015.

Tillage	Fertilizer Blend	Placement	-- Nitrogen (lb-N/ac)*--			Yield (bu/ac)	
			Strip	Planter	Side Dress		
No-Till	19-19-19 @ 160 lb/ac	Planter	0	30	105	110	A
Strip-till	19-19-19 @ 160 lb/ac	Planter	0	30	105	123	A
Strip-till	19-19-19 @ 160 lb/ac	Strip-Tiller	30	0	105	113	A

Appendix 6b. Yield response to various fertilizer placement methods for hand harvest[1] at Paris, ON in 2015.

			-- Nitrogen (lb-N/ac)*--			
Tillage	Fertilizer Blend	Placement	Strip	Planter	Side Dress	Yield (bu/ac)
Strip-till	19-19-19 @ 160 lb/ac	Strip-Tiller	30	0	105	83 A
Strip-till	34-8-8 (ESN) @ 397 lb/ac	Strip-Tiller	135	0	0	99 A

"ESN" implies that 50% of the N supplied was from ESN and 50% form urea.
1 Stand loss from injury with ESN/urea blend treatment prevented machine harvesting in a reliable manner.

Appendix 7. Yield response to various fertilizer placement methods at Woodstock, ON in 2015.

			--- Nitrogen (lb-N/ac) ---			
Tillage	Fertilizer Blend	Placement	Strip	Planter	Side Dress	Yield (bu/ac)
No-Till	Farmer N & Starter Blend	Planter	0	160	0	221 A
Strip-till	Farmer N & Starter Blend	Planter	0	160	0	224 A
Strip-till	Farmer N & Starter Blend	Strip-Tiller	160	0	0	223 A
Strip-till	34-8-8 (ESN) @ 467 lb/ac	Strip-Tiller	160	0	0	198 B

"ESN" implies that 50% of the N supplied was from ESN and 50% form urea.