Cover crops versus good rotation
vs no-till

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“Trifecta of soil health”: Crop rotation, cover crops, no-till

**trí·fect·a**

/trɪˈfɛktə/

*noun*  
NORTH AMERICAN  AUSTRALIAN/NZ

a bet in which the person betting forecasts the first three finishers in a race in the correct order.

- a run of three wins or grand events.

"today is a trifecta of birthdays"
“I may not be able to define exactly what soil health should be, but I can tell you what it is not. It is not found on farms, that for the last 25 years have had a history of 50% or more soybeans grown in the rotation. But these farms have been profitable for the owners. Who am I to say this is wrong? But when I walk on these fields in the spring I get an uneasy feeling. They are hard and crunchy compared to farms with a more diversified rotation, which are softer and mellower. We can make a seedbed in these parts out of hard and crunchy. It takes brute force and steel to do it and it is done. At the end of the day, the steel and brute force is the part that bothers me. Soils are chock full of living beings. Is it right to use brute force to mold them into a definition that is based on economics alone. Some would argue yes. I can respect that opinion. I just don’t agree with it. “ Russ Barker (St Mary’s area CCA and Dupont Pioneer Seed Dealer).
Harvested areas (hectares) of major field crops shown as % of total harvested area from 1970 to 2014 for Ontario. (Source: Statistics Canada, 2016.) (Reproduced from Deen et al., 2016)
% total harvested areas USDA-NASS, 2014
Elora Research Station: 1625 acres, silt loam soil, 900mm annual rainfall, 2700-2800 CHU

- Initiated in 1980
- Rotations – CCCC, AAAAA, CCAA, CCSS, CCSW, CCSW(rc), CCOB, CCO(rc)B(rc)
- Conventional tillage and no-till
LONG TERM ROTATION x TILLAGE x N TRIAL

Initiated in 1995 (21-year)
Ridgetown Research Station

Crop diversity gradient (± wheat)
2009 ± RC split, 4 N (12 starter, 0-180 kgN/ha)
1 crop = Continuous Corn / Continuous Soy
2 crops = Corn-Soy / Soy-wheat
2 crops + 1 cover crop = Soy-Wheat\textsubscript{(RC)}
3 crops = Corn-Soy-Wheat
3 crops + 1 cover crop = Corn-Soy-Wheat\textsubscript{(RC)}

Tillage gradient
Heavy tillage (Moldboard plow)
No till / Strip till (corn)
Corn/soybean rotation is associated with:

- Reduced yield and greater yield instability
- Lowest soil organic matter/poorest soil structure
- Increased nitrogen requirement
- Reduced input use efficiency
- Increased GHG emission
- Reduced success of no-till/reduced till
- Reduced opportunity to incorporate cover crops
- Reduced opportunity for sustainable biomass removal

Cropping sequence diversification provides a systems approach to reduce yield variations and improve resilience to multiple environmental stresses. Yield advantages of more diverse crop rotations and their synergistic effects with reduced tillage are well documented, but few studies have quantified the impact of these management practices on yields and their stability when soil moisture is limiting or in excess. Using yield and weather data obtained from a 31-year long term rotation and tillage trial in Ontario, we tested whether crop rotation diversity is associated with greater yield stability when abnormal weather conditions occur. We used parametric and non-parametric approaches to quantify the impact of rotation diversity (monocrop, 2-crops, 3-crops without or with one or two legume cover crops) and tillage (conventional or reduced till-age) on yield probabilities and the benefits of crop diversity under different soil moisture and temperature scenarios. Although the magnitude of rotation benefits varied with crops, weather patterns and tillage, yield stability significantly increased when corn and soybean were integrated into more diverse rotations. Introducing small grains into short corn-soybean rotation was enough to provide substantial benefits on long-term soybean yields and their stability while the effects on corn were mostly associated with the temporal niche provided by small grains for underseeded red clover or alfalfa. Crop diversification strategies increased the probability of harnessing favorable growing conditions while decreasing the risk of crop failure. In hot and dry years, diversification of corn-soybean rotations and reduced tillage increased yield by 7% and 22% for corn and soybean respectively. Given the additional advantages associated with cropping system diversification, such a strategy provides a more comprehensive approach to lowering yield variability and improving the resilience of cropping systems to multiple environmental stresses.
2016 precipitation
May - 1.7”
June – 1.4”
July 1-13 – .4”
July 14-24 – 1”
July 25-31 – 1.5”
August – 5.8”
Sept – 2.6”
• No-till not associated with increased soil carbon (Deen and Katak, 2003, Meyer-Aurich et al., 2006)
Corn and soybean yield: Elora rotation trial, 2016

2016 precipitation
- May - 42 mm
- June - 36 mm
- July 1-13 - 11mm
- July 14-24 - 23mm
- July 25-31 - 37 mm
- August - 146 mm
- Sept - 64 mm
Overall, our results show that no-till reduces yields, yet this response is variable and under certain conditions no-till can produce equivalent or greater yields than conventional tillage. Importantly, when no-till is combined with the other two conservation agriculture principles of residue retention and crop rotation, its negative impacts are minimized.
Ridgetown College researcher David Hooker says interseeding cover crops in corn is nothing new. He unearthed a sign from a 1980s interseeding research trial at the college.
Cover crops interseeded to corn (Jackie Clarke (MSc student, U. of Guelph) Mehdi Sharifi (Trent University) Bill Deen, Dave Hooker, Laura VanEerd (U of Guelph)

- 3 sites: Elora, Ridgetown, Trent (2 seasons)
- 2 harvest treatments: silage corn & grain corn
- 5 cover crop treatments
  - Control
  - Annual Ryegrass drilled
  - Red Clover drilled
  - AR + RC drilled
  - AR + RC broadcast

Objectives

1. Quantify impact of interseeding cover crops on silage corn, grain corn or soybean yield.
2. Analyze above ground biomass achieved by cover crops singly and in combination, as well as drilled and broadcast.

Funded by: Grain Farmers of Ontario
Measurements & Management

- Cover crops drilled/broadcast V4-V6
- Overwintered, chemically terminated
- No-till soybeans planted the following spring
- Measured: silage DM, grain yield, cover crop and weed biomass, soil parameters
Preliminary observations

• Cover crop biomass (above ground) in the fall following grain corn is low and highly variable (0-1000 kg ha\(^{-1}\))
• Cover crop biomass (above ground) in the spring is also low and highly variable
• Establishment and biomass is improved by drilling
• Greater biomass in silage corn
• Greater biomass with mixtures
• No impact on corn yield
Elora - 2015
Preliminary Results: Biomass

- Season 2: Ridgetown – October 24th 2016

Grain corn, drilled, mixture
Silage corn, drilled, mixture
Grain corn, broadcast, mixture
Silage corn, broadcast, mixture
- Season 1: Elora - April 15th 2016

- Season 1 – Ridgetown– April 22nd 2016

Drilled  Broadcast  Silage

Drilled  Broadcast  Grain corn
Cover crops into soybean (Bill Deen, Dave Hooker U of Guelph)

- 2 sites: Elora, Huron (3 seasons)
- 6 cover crop treatments
  - Cont. soybean
    - No cover crop
    - Fall rye broadcast pre-soybean leaf drop
    - Fall rye drilled immediately after soybean harvest
  - Annual ryegrass broadcast pre-soybean leaf drop
  - Annual ryegrass drilled post soybean harvest
  - Soybeans following corn in a 2-year rotation
    - no cover crop
• In three years (with cooler, wetter falls) fall biomass (above ground) was low and variable (0-500 kg ha\(^{-1}\)).
• Drilling was more consistent
• Fall rye more consistent and greater biomass
• Spring biomass determined by planting timeliness, winter survival, date controlled,
Challenges of Cover Crops in CS

• Biomass production of cover crops in CS rotation is low and variable, particularly when interseeded to corn, particularly in shorter season regions

• Interseeding/drilling results in higher and more uniform biomass than broadcasting BUT increased cost may not be justified

• Mixtures also result in higher and more uniform biomass BUT
  – may increase cost
  – will increase/reduce risk of herbicide injury
  – may increase difficulty to control
Challenges

• “Planting green” is a method to increase spring biomass BUT
  – In a dry year may reduce moisture
  – In a wet year may delay control and planting
  – Residue may interfere with planting
  – May make control more difficult (eg ARG, RC)
  – Will increase management and may not be as scaleable

• Delayed planting to increase spring cover crop biomass a questionable strategy
Challenges of Cover Crops in CS

• Cover crop benefits for soil health and erosion reduction associated with overwintering and spring growth. Inclusion of fall tillage will negate these benefits. No-till less effective in a CS rotation....strip tillage??
Value of adding wheat to rotation

• Provides a proper niche for cover crop
• Enables no-till/reduced till (... and associated benefits)
• Increases yield and yield stability (...and associated benefits)
• Increases weed resistance management options
• Reduces N requirement
Wheat improves nitrogen use efficiency of maize and soybean-based cropping systems

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\textbf{ABSTRACT}

Integrated nitrogen (N) management strategies could make significant contributions to improving the efficiency of N use in the northern Corn Belt, particularly for maize, which has high N requirements. Using legume cover crops has been shown to increase both the soil’s capacity to supply N and nitrogen use efficiency (NUE), through the reduction in the amount of N fertilizer that must be applied to the following crops. However, the impact of non-legume crops such as winter wheat (\textit{Triticum aestivum} L.) on the diminishing return function between crop yield and N supply and its influence on N fertilizer use remains unclear. We hypothesized that maintaining wheat in short maize and soybean-based rotations is instrumental to improve cropping system performance and increase N fertilizer use efficiency while decreasing N requirements for maize. Seven maize and soybean rotations with different frequency of winter wheat with or without underseeded red clover (\textit{Trifolium pratense} L.) were grown in two tillage systems (conventional and zone-tillage) and four long-term N regimes in Ridgetown, ON, Canada (2009–2013). Wheat in the rotation increased maize and soybean yields, negated crop yield lags due to zone-tillage, and decreased maximum economic rates of fertilizer N (MERN). The benefits of wheat in the rotation on maize yield were negated by high N rates; however, similar yields were obtained with lower N levels in rotationally grown maize, resulting in a 17% (conventional till) to 21% (zone-till) increase in partial factor productivity for N fertilizer at MERN (PFP\textsubscript{MERN}). While N benefits to crops following wheat alone may be attributed to a higher indigenous plant available soil N, underseeding red clover further increased the agronomic efficiency (AE) of N fertilizer (AE\textsubscript{MERN}) up to 32%. Maize yields were also less limited by N supply and less responsive to N fertilization when grown in rotation with wheat, especially in the zone-till system. These results highlight the value of wheat as a system component of dominant maize/soybean short rotations of Ontario and its potential to increase both maize and soybean productivity using less N input.

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Economic Justification for Wheat in Rotation

- 4% increase in corn yield: $7 bu/ac @ $4.50/bu = $32/ac
- 12% increase in soy yield: $5.5 bu/ac @ $12.50/bu = $69/ac
- Increased drought tolerance/yield stability = ??
- Reduction in N requirement: 26.4 lb/ac @$0.55/lb = $14/ac
- Cover crop N (eg red clover): 50 lb/ac @$0.55/lb = $27/ac
- Reduced tillage requirement = ??
- Ability to sustainably sell crop residue = ??
- Other eg. herbicide resistance management = ??
- **Added profit attributed to wheat** >$143/ac

- Wheat straw sale (1.2 t/ac net value in winrow $.03/lb) $79/ac
- Double crop forage (2-3 t/ac net value in winrow $??/lb) ??
• Benefits to farmers of rotation diversity (e.g. addition of winter wheat) may increase
  – Climate change
  – Increased yield potential
  – Biomass removal
  – Herbicide resistance

• Other stakeholders are increasingly recognizing importance of rotation diversity and may provide incentives to farmers
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