EFAO
ECOLOGICAL FARMERS ASSOCIATION OF ONTARIO

# LIVING LABORATORIES INITIATIVE
## Advancing Reduced Tillage for Organic Vegetable Systems

**FARMER-RESEARCHER**
Ken Laing, Orchard Hill Farm

**FUNDING**
Agriculture and Agri-Food Canada as part of the Living Lab–Ontario project

## IN A NUTSHELL

To innovate systems that reduce tillage and keep the soil covered using cover crops for organic vegetable production in southern Ontario, Ken Laing tested 60+ combinations of crops and ground cover over three years. The most promising systems that emerged from his investigations included:

- Garlic no-till planted in the fall into a mown cover crop of sorghum sudangrass
- Potatoes no-till planted into winter rye, which is mown before potato emergence
- Winter squash no-till planted into hairy vetch or deep compost mulch
- Field tomatoes planted into winter rye and hairy vetch; with more trials needed to confirm

## MOTIVATION

The motivation behind Ken's Living Lab–Ontario project came from seeing the results of a soil health benchmark study he conducted in cooperation with EFAO in 2019. "It was shocking to see how much more organic matter we have in our undisturbed fence rows compared to our land in production," says Ken. "We've grown organically, with cover crops, for years, and the benchmark results showed me we have to do more if we want to build soil organic matter."

Determined to figure out how to reduce tillage in organic vegetable production systems for mid- to large-scale growers, Ken took on the extensive role managing EFAO's "Horticulture Division," as he calls it.

"Developing a horticultural system for vegetables with no tillage is very challenging because we often use tillage to terminate one crop and get another established, and then we come in again with tillage to control weeds," explains Ken.

## GUIDING PRINCIPLES

The principles guiding Ken's trials included:

1. Reduce tillage as much as possible
2. Mechanized, tractor-scale system suitable for mid-scale market gardening (i.e. 10-50 acres)
3. Use a 60" bed system
4. Avoid the use of agricultural plastics
5. No hand or mechanical weeding throughout the season


Ken Laing at the entrance of Orchard Hill Farm near St. Thomas. For more information about the Living Lab–Ontario project, see below.

## STRATEGIES FOR REDUCED TILLAGE

The strategies Ken chose to use to reduce tillage for organic vegetable systems included:

1. Planting or transplanting into winter killed cover crops
2. Planting or transplanting into green cover crops either before or after termination
3. Planting or transplanting into deep compost mulch (DCM)

With these principles in place, Ken used an iterative approach starting with a screening trial to identify promising systems, which he then compared in side-by-side demonstration plots, followed up by randomized, replicated trials.

### EQUIPMENT USED

For a list of the equipment Ken used in these trials, please visit: efao.ca/no-till-vegetable-trials-equipment/

# SCREENING TRIALS

## METHODS

### *2020*

In 2020, Ken utilized plantings of cover crops that were not designed as trial plots and performed a broad survey of many strategies and crops to narrow down promising combinations, as shown in **Table 1**. He performed no hand or mechanical weed control in any of the plots.

### *2021*

For 2021, Ken moved the plots to a better field and amended the fertility prior to planting cover crops. He experimented with more covers and combinations of covers, as shown in **Table 2**. He performed no hand or mechanical weed control in any of the plots.

## FINDINGS

### *WEED CONTROL*

Weed control offered by various cover crops differed greatly. In order of effectiveness of weed control:
**daikon < oats/barley/peas < sorghum sudangrass < rye < DCM (3⁄4 wood chips + 1⁄4 spent mushroom compost)**

Note that while DCM had the best weed control, it can be expensive. There can also be weed problems with DCM if weed seeds get scooped up with the compost when stockpiled at a dealer or when stored at the farm.

### *OTHER OBSERVATIONS FROM THE SCREENING TRIALS*

- Crops transplanted into cover crops were generally more successful than seeded crops. With seeded crops it was often difficult to get a good stand of plants.
- It is very important to adjust the fertility before the cover crop is planted. It is difficult to work in amendments after the cover crop is planted since it is not disturbed before planting.
- Winter-killed cover crops have limited weed control. For example: daikon radish leaves very little residue to control weeds the following season; and sorghum sudangrass residue breaks down enough for the weed control to start failing by mid-July. Even a early spring planting of oats/peas to roll before late planted crops makes for very late planting and poor yields.
- Waiting for green covers to mature enough to be terminated by rolling can delay planting.
- No-till soils become very firm which appears to make it a challenge for crop plants to explore the soil for water and nutrients.
- Having equipment that cuts through lots of residue is critical to allow for planting and for getting the planting trench closed. This need required Ken to modify equipment that was designed for conventional no-till, which does not require as much residue for weed control.
- Existing soil health may be a strong determining factor in the success of reduced tillage methods.
- No-till planting techniques can allow more leeway for row spacing because you do not need to design for tillage machines to control weeds. For example: You can plant 2 rows of potatoes 24” apart in a 60” bed because there’s no need to till for weed control or hilling.
- Cover crop strategies for successful no-till usually start at least one year before planting the cash crop; research trial time frames should account for this.

**Table 1.** The crops and reduced tillage strategies Ken trialed in 2020, along with the general success of each combination. The deep compost mulch was 3/4 poplar wood chips from the farm and 1/4 spent mushroom compost spread 3.5” deep at 175 tons/ac and $35/ton delivered. = good success; = fair success; = disappointment for various reasons including poor variety selection, poor soil conditions or fertility, or poor machine performance. Empty cells denote that Ken did not trial the combination.

| TREATMENT | BEANS | GARLIC | PEAS | SPINACH | SQUASH | SUNFLOWERS | SWEET CORN | TOMATOES |
|---|---|---|---|---|---|---|---|---|
| DAIKON (WK) | | | S | S | | | | |
| DAIKON (WK) + DCM | | | S | S | | S | S | |
| SSG (WK) | S | H | S | S | | S | S | |
| SSG (WK) + DCM | S | | S | S | | S | S | |
| OAT/BARLEY/PEAS (RC) | S | | | | T | S | T | T |
| RYE (RC) | S | | | | T | S | T | T |
| TILLED SOIL + DCM | S | | S | S | T | | T | T |

SSG = sorghum sudangrass; S= seeded; T= transplanted; H= planted by hand; DCM= deep compost much; WK= winter-killed; RC= rolled crimped

**Table 2.** The crops and reduced tillage strategies Ken trialed in 2021, along with the general success of each combination. The deep compost mulch was spent mushroom compost 3.5" deep at 175 tons/ac and $35/ton delivered. ▇ = good success; ▇ = fair success; ▇ = disappointment for various reasons including poor variety selection, poor soil conditions or fertility, or poor machine performance. + DCM indicates that Ken trialed the crop with DCM; +/- DCM indicates that Ken trialed the crop with and without DCM. Empty cells denote that Ken did not trial the combination.

| TREATMENT | BEANS | BROCCOLI | GARLIC | PEAS | POTATOES | SPINACH | SUMMER SQUASH | SUNFLOWERS | SWEET CORN | TOMATOES | WINTER SQUASH |
|---|---|---|---|---|---|---|---|---|---|---|---|
| DAIKON + DCM | | | | | | T | | | | | |
| SSG | | | +/- DCM H | | | | | | | | |
| SSG/SUNN HEMP | | | H | + DCM S | | | | | | + DCM T | |
| PEARL MILLET | + DCM S | | H | | | | | | | + DCM T | |
| PEARL MILLET/COW PEAS | | T | | + DCM S | | + DCM S | | | | | |
| HAIRY VETCH | | | | + DCM S | | | T | S | S | + DCM T | +/- DCM T |
| RYE/HAIRY VETCH (RC) | | | | | P | | T | S | | T | T |
| CRIMSON CLOVER + DCM | S | | | S | | S | | | S* | T | T |

* Ken also trialed sweet corn on tilled ground with DCM
SSG = sorghum sudangrass; S= seeded; T= transplanted; H= planted by hand; DCM= deep compost much; RC= rolled crimped


Green beans seeded into DCM on top of winter killed sorghum sudangrass


Sunflowers seeded into DCM on top of winter killed sorghum-sudan

## REDUCED TILLAGE TRIALS

From the 2020 screening trials, the crops that looked promising were garlic, potatoes, winter squash, and field tomatoes.

### GARLIC

In 2021, Ken planted unreplicated demonstration plots of a reduced tillage garlic system using sorghum sudangrass without tilled controls as shown in **Figure 1**. While we were unable to run statistics, it appears that the first location had higher yields than the second location, as shown in **Figures 2 and 3**. We are unable to attribute this to site location or the absence of DCM. Overall, garlic yields were promising and it appears that the addition of hen pellets did not greatly affect garlic yield as lbs/acre but did increase yield as head weight.

In 2022, Ken tested this garlic system in randomized, replicated plots of sorghum sudangrass and tilled controls. The land where Ken established these plots, however, ended up having a grass weed problem that resulted in low yields in the no-till plots. Curiously, Ken noted that the tilled plots did not have a higher yield, which perhaps can be explained by bare soil from planting to harvest in the tilled plots. Garlic is traditionally mulched at least on the scale that most organic growers operate.

Another cover crop option for reduced-tillage garlic that Ken tried was pearl millet that he seeded July 1st the year before garlic harvest at 30 lbs/acre, and mowed whenever it reached three feet in height. This cover crop also winter-killed.

Garlic that was hand-planted into winter killed sorghum sudangrass in 4 rows 12" apart in a 60" bed, with plants 5-6" apart in the row. Yield was 7,500 lb/ac.

Planting garlic into mown sorghum sudangrass cover crop in fall 2020.

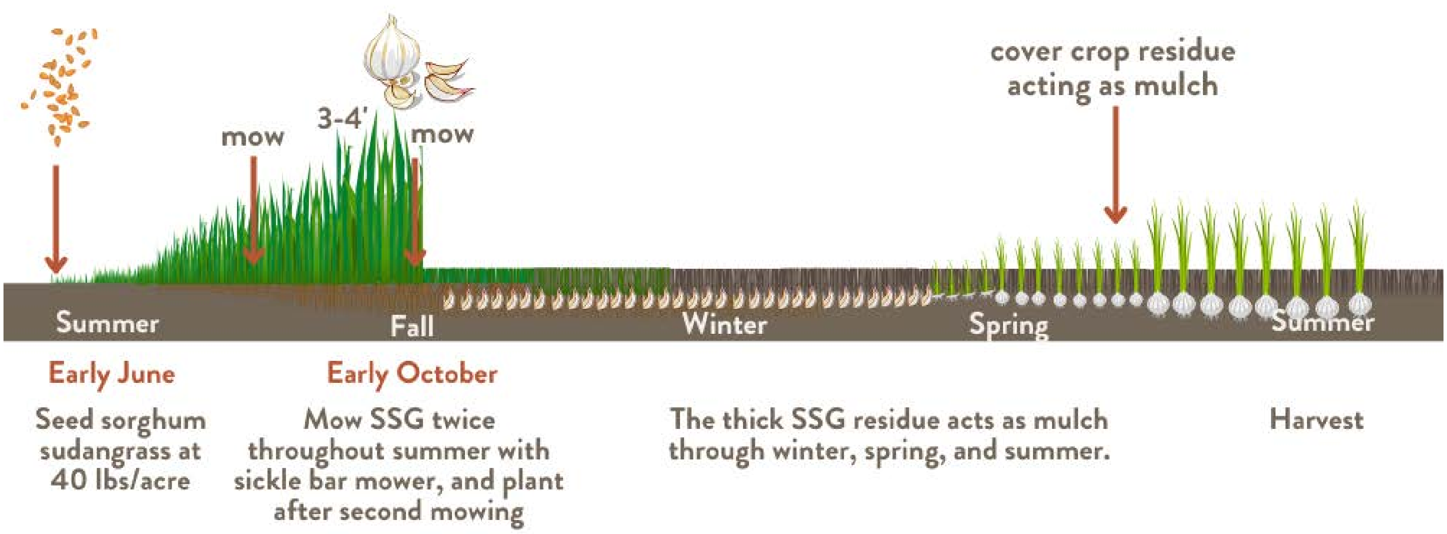


**Figure 1.** For the reduced-tillage garlic system, Ken seeded sorghum sudangrass the summer before garlic harvest (early to mid-July) at 40 lbs/acre, mowed it twice with a sickle bar mower when it reached 3-4 feet to increase biomass, and planted garlic into the mown cover crop in early October with a slightly modified RJ Equipment no-till carousel plug planter. The cover crop then winter-killed and left a thick residue to control weeds while garlic grew the following summer. Throughout the season, Ken did no hand or mechanical weeding and he harvested the garlic by hand with a fork.

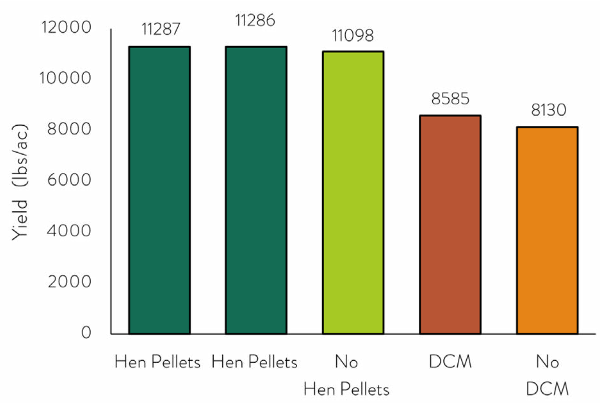


**Figure 2.** Garlic yields as a measurement of lbs/acre from Ken's reduced tillage garlic plots at two locations in 2021 using sorghum sudangrass. At the first location (light and dark green), Ken trialed plots with and without the addition of hen pellets for added fertility (1,000 lb/ac). At the second location (light and dark orange), he trialed plots with and without DCM. He measured yield weights after curing.

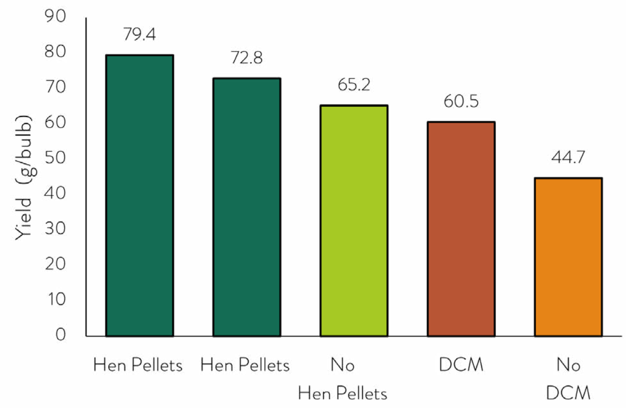


**Figure 3.** Garlic yields as a measurement of head weight from Ken's reduced tillage garlic plots at two locations in 2021 using sorghum sudangrass. At the first location (light and dark green), Ken trialed plots with and without the addition of hen pellets for added fertility (1,000 lb/ac ). At the second location (light and dark orange), he trialed plots with and without DCM. He measured yield weights after curing.


Planting garlic into standing rye/vetch or millet/cowpeas to avoid too much residue on the surface, fall 2021. The standing residue was mowed after it was killed by frost.

No-till garlic plots in April 2021.

Garlic plots at harvest time in summer 2021.

## POTATOES

In 2021, Ken planted demonstration plots of a reduced tillage potato system using winter rye and hairy vetch, as shown in **Figure 4**. Yields ranged from 25,289 lbs/acre with greening of 9,206 lbs/acre, to 37,301 lbs/ acre with no significant greening, as shown in **Figure 5**. The five year average for potato yields in Ontario is 21,700 lbs/acre. His reduced tillage system resulted in a 58% reduction in field passes associated with tillage, cultivation, weeding, mowing, irrigation, spraying Entrust, and harvesting.

In 2022, Ken tested this potato system using Orchard Hill Rose and Gold Rush potatoes in randomized, replicated plots of winter rye and tilled controls. The land where Ken established these plots, however, ended up having a grass weed problem that resulted in low yields in the no-till plots. Nevertheless, the tilled plots provided good evidence of the productivity of Gold Rush and Orchard Hill Rose under organic tilled production.

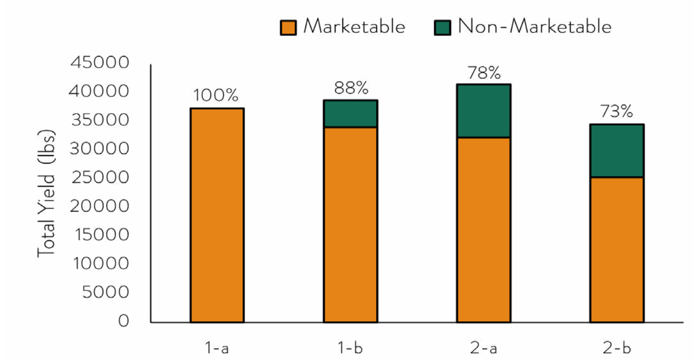


**Figure 5.** Yields from Ken's four reduced tillage potato plots in 2021. Bars represent total weight in lbs, with the orange section representing marketable weight and the green section representing non-market weight, usually due to greening. Per cent marketable is indicated above each bar. These plots did not have control plots.

Planting potatoes into standing rye/hairy vetch April 21, 2021, in 2 rows 24" apart in 60" beds. They had to make seed pieces smaller than optimum to prevent plugging in the opener shoe. They were aiming for 12" spacing in the row.

Planting potatoes May 14 into more advanced rye/hairy vetch.

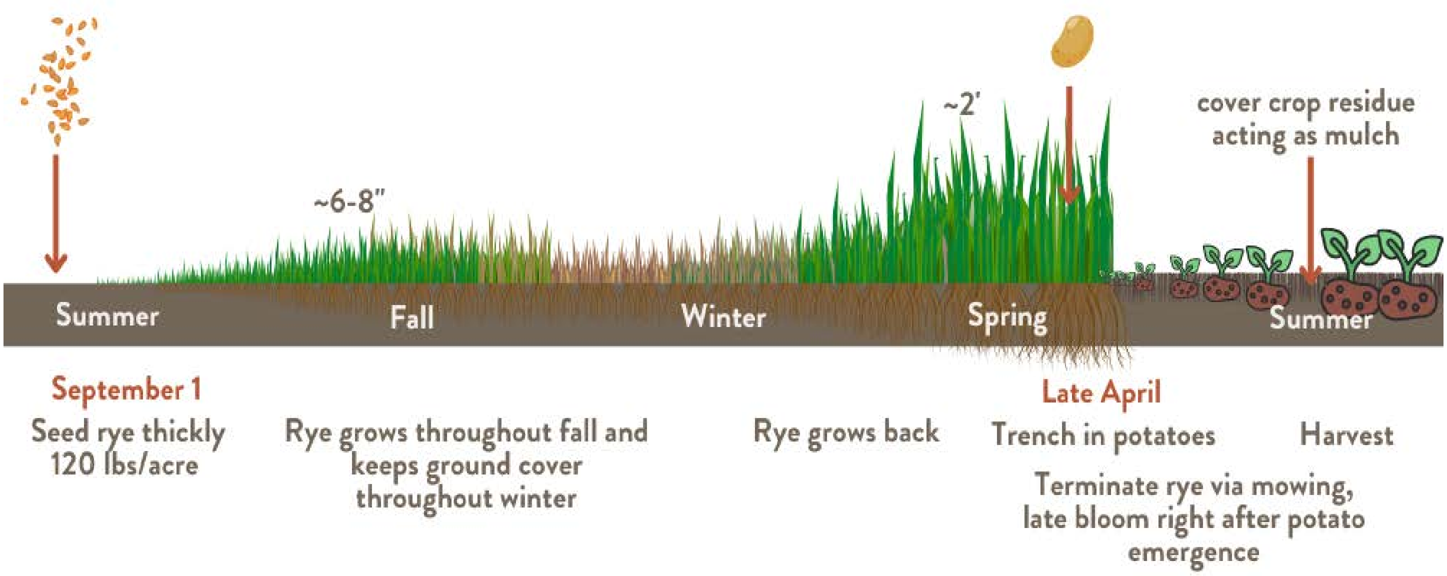


**Figure 4.** For the reduced tillage potato system, Ken seeded a winter rye cover crop September 1st the year before potatoes at 120 lbs/acre. Ken planted the potatoes into the standing cover crop in late April or early May and terminated the rye via flail mowing at first potato emergence. Ken notes you could roll the cover crop but mowing gets better termination. Ken did not hill or weed the potatoes throughout the season. In 2021 Ken planted Orchard Hill Rose, a leafhopper resistant potato that he and his family selected in cooperation with The Bauta Family Initiative on Canadian Seed Security, into a cover crop of winter rye and hairy vetch. He side dressed the plots with 1200 lbs/acre organic hen pellets, and applied the organic pesticide Entrust for Colorado potato beetles once.


Flail mowing rye/hairy vetch cover crop May 24 for potatoes planted on April 21.


Late planted potatoes on June 30.


It is time to flail mow the cover crop when the first potatoes emerge.


Digging potatoes from an early planted plot on August 30.


The development of a potato seed piece at time of mowing.

## WINTER AND SUMMER SQUASH

In 2021, Ken planted demonstration plots of reduced tillage squash systems using winter rye, hairy vetch, and deep compost mulch, as shown in **Figure 6**. Yields ranged from around 13,000 lbs/acre to over 49,000 lbs/acre, as shown in **Figure 7**.

Note that although the DCM resulted in the highest yield in these unreplicated plots, it may be less profitable due to the cost of quality deep compost mulch (2" of compost requires 100 tons/ac; the compost Ken used was spent mushroom compost, 3.5" deep at 175 tons/ ac at $35/ton delivered).

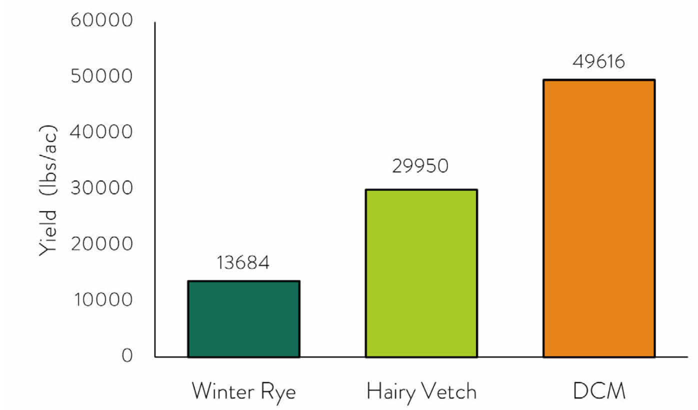


**Figure 7.** Winter squash (Butterscotch) yield for plants transplanted into winter rye, hairy vetch, or DCM.

Reduced tillage plots of winter squash in rolled rye, both seeded and transplanted, did very poorly in 2020..

Winter squash transplanted into DCM on top of tilled soil in 2020. Yield was 70,489 lb/ac.

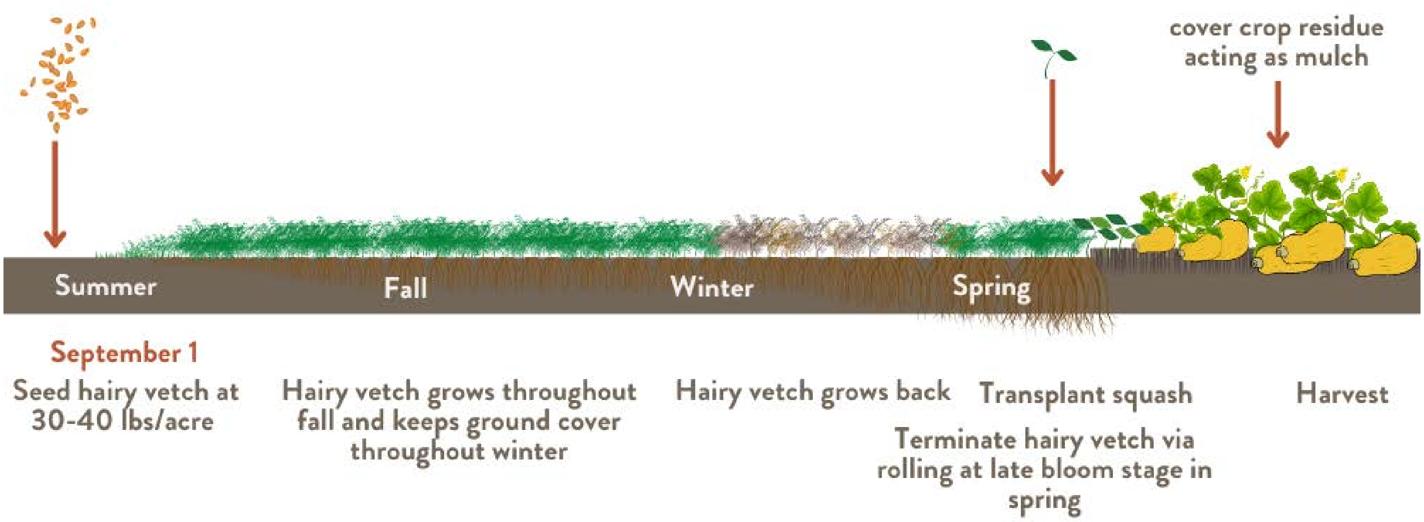


**Figure 6.** For winter squash, Ken setup demonstration plots of squash no-tilled planted into rye/hairy vetch, hairy vetch alone (depicted), and 2" of DCM on top of rolled hairy vetch. For the hairy vetch, he seeded at a rate of 30-40 lbs/acre on September 1st the year before the squash crop, and rolled the cover at late bloom of vetch the following spring. Overall, he found weed control and yield were acceptable for organic production in Ontario with both the hairy vetch and DCM systems. The DCM was spread at least 2" deep or 100 tons/ac. The hairy vetch system might be preferable because of the cost of mulch for the DCM system. The summer squash also grew and produced well but Ken did not measure yields.

Winter Squash transplanted into deep compost mulch.

Left row in rolled hairy vetch, right 2 rows in rolled rye/hairy vetch.

Winter squash transplanted into rolled hairy vetch.

Left row winter squash transplanted into rolled hairy vetch; right 2 rows had the same planting date and variety (Butterscotch) but transplanted into DCM on top of rolled hairy vetch (middle row) and on top of crimson clover in right row.

## ABOUT LIVING LAB–ONTARIO

The Living Laboratories Initiative is an integrated approach to agricultural innovation that brings farmers, scientists, and other partners together to co-develop, test, and monitor new practices and technologies in a real-life context.

Funded by Agriculture and Agri-Food Canada (AAFC), the 2020-2023 Living Lab–Ontario project was led by the Ontario Soil and Crop Improvement Association (OSCIA). Living Lab–Ontario project collaborators for the 2020-2023 project included five farmers; Ecological Farmers Association of Ontario, Innovative Farmers Association of Ontario, Ontario Soil Network; scientists and researchers from Agriculture and Agri-Food Canada and Environment and Climate Change Canada; and Essex Region Conservation Authority, Lower Thames Valley Conservation Authority, and Upper Thames River Conservation Authority. Together, our research focused on reducing the soil and nutrient runoff from agricultural land into Lake Erie, improving water quality, conserving soil health, and increasing biodiversity on agricultural lands in Ontario.

EFAO joined the Living Lab–Ontario project to support on-farm research and innovations to reduce tillage in organic vegetable and organic field crop production systems. This work focused on two farm sites including Ken's looking at vegetables and another site looking at field crop production managed by Brett Israel at 3Gen Organics near Wallenstein.

For more information about EFAO's involvement with the Living Lab–Ontario initiative, please visit efao.ca/living-lab.

# OTHER POTENTIAL SYSTEMS

## FIELD TOMATOES

Ken also had success no-till transplanting field tomatoes (Plum Regal) into winter rye and hairy vetch, which he seeded September 1st the year before tomatoes at a rate of 120 lbs/acre rye and 20 lbs/acre hairy vetch. He rolled the cover crops to terminate and transplanted the tomatoes at the late pollen shed stage of rye. He noted that it is better to be a little late terminating the rye as it will more likely coincide with late bloom stage of hairy vetch.

# RAPID REGENERATION PLOTS

In addition to his reduced tillage trials, Ken trialed different methods to regenerate degraded ground for organic vegetable production. For these trials, he compared one plot each of:

- Cover crop with compost and mineral amendments
- Cover crop with compost
- Wood chips with compost and mineral amendments
- Wood chips with compost
- DCM with no additional compost and mineral amendments
- DCM with no additional compost
- Weeds with compost and mineral amendments
- Weeds with compost

Ken tilled the cover crop plots on May 8, 2020 and planted them to buckwheat on May 27, 2020. He then terminated the buckwheat with tillage on July 6, 2020, and replanted to rye/hairy vetch/crimson clover on Sept 1, 2020. Note that the cover crop treatment was the only treatment tilled with a rototiller. He applied coarse poplar wood chips 3.5” deep on May 8, 2020. The compost was spent mushroom compost, 3.5” deep, applied May 8, 2020 at 175 tons/ac at $35/ton delivered. The weeds were red clover, grasses, and annual and perennial weeds remaining after a rye crop.

For the plots with mineral amendments, Ken applied S at 50 lbs/acre for 52 g/plot; KCl at 200 lbs/ac for 20 g/plot; B at 3 lbs/ac 10% B for 31 g/plot; and CalPhos at 500 lbs/ac for 522 g/plot.

In June 2022, Ken rototilled the plots three times and planted sorghum sudangrass at a rate of 40 lbs/ac. The sorghum sudangrass acted as an “indicator crop”, to show how well the treatments performed in terms of growing aboveground biomass.

## RESULTS

### *ACTIVE CARBON*

We measured permanganate oxidizable carbon (POXC, or active carbon) in May 2021 and in June 2022, using A&L Laboratories services. The analysis uses permanganate to react (oxidize) labile carbon, which are carbon compounds that are readily decomposed by soil microorganisms. The oxidation process produces a pink/purple colour, the intensity of which is measured on a spectrophotometer. The darker the colour, the greater the amount of labile carbon in the sample. While not a complete picture of labile carbon or soil health, Ken and other EFAO members have shown that active carbon can be a reliable and sensitive indicator of soil health on organic farms in Ontario (**1**).

From the single plots with and without mineral amendments, DCM followed by wood chips and compost (“woody compost”) produced higher AC, while the mowed weed treatment (“cut and come again”) had the lowest. With only two plots of each treatment, however, we were unable to run statistics and assign a probability and confidence level to these differences.

Using a paired t-test, we tested the effect of mineral amendments on active carbon. There was no statistical difference in AC between plots with and without mineral amendments (P=0.28); although plots without amendments had consistently higher AC values.

These trends are in contrast to farmer-led research conducted by Eric Barnhorst in cooperation with EFAO. Eric’s research showed a diverse cover crop mix more greatly influenced AC and biomass of a sorghum sudangrass indicator crop over wood chips and chicken manure (**2**). Differences between these two “rapid regeneration” trials could be due to the diversity in Eric’s cover crop mix contributing to the AC response. While Eric’s trial didn’t test no-mineral controls, the results from Ken’s trials indicate a replicated comparison with and without mineral amendments might be worthwhile.

### *BIOMASS*

During the 2022 growing season, we took samples of the sorghum sudangrass indicator crop from each of the plots. From the single plots with and without mineral amendments, we observed the DCM had the most biomass while the wood chips and compost (“woody compost”) treatment had the lowest—and the plants in these plots were yellowed or chlorotic. With only two plots of each treatment, however, we were unable to run statistics and assign a probability and confidence level to these differences.

Using a paired t-test, we tested for the effect of mineral amendments on biomass. There was no statistical difference in biomass between plots with and without mineral amendments (P=0.88), and no observable trend.

Agriculture and Agri-Food Canada Researcher Dr. Xueming Yang also studied Ken’s rapid regeneration plots to ask questions about carbon cycling, specifically as it relates to particulate organic matter, or POM. POM is biologically and chemically active carbon that is part of the labile pool of soil organic matter. It acts as a food or energy source for microbes and other organisms in the soil food web. Overall, POM enhances aggregate stability, water infiltration and soil aeration; and more POM in soil means nitrogen and other nutrients are being stored vs being prone to loss from leaching. EFAO will share the results of this study when they are available.

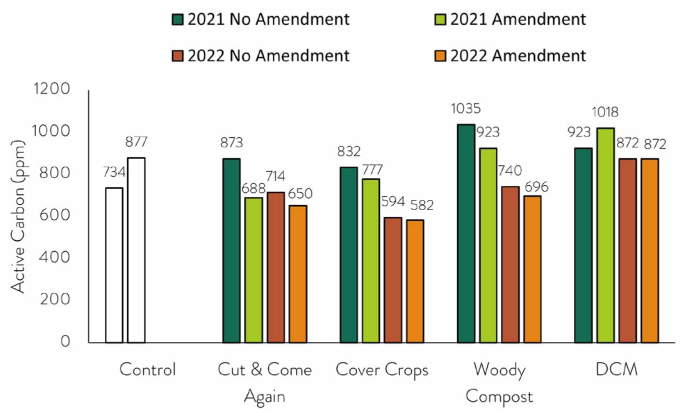


**Figure 8.** Active carbon in the rapid regeneration plots, including plots treated with mowing of weeds (cut and come again), cover crops, wood chips and compost ("woody compost"), and deep compost mulch; with and without mineral amendments, in 2021 and 2022. Control plots are from the untreated area between plots in 2021, and we did not take control samples in 2022.

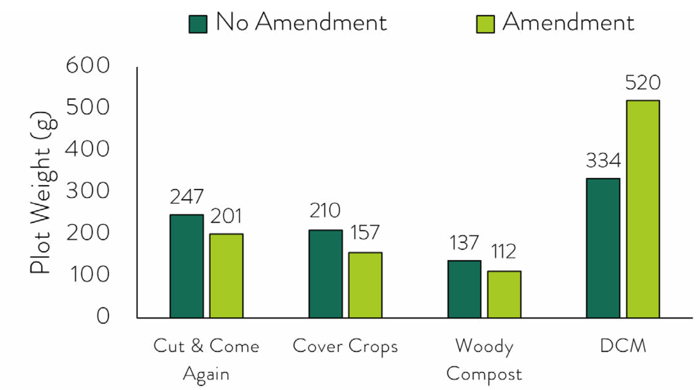


**Figure 9.** Biomass weight of the sorghum sudangrass indicator crop in the rapid regeneration plots, including plots treated with mowing of weeds (cut and come again), cover crops, wood chips and compost ("woody compost"), and DCM; and with and without mineral amendments, in 2021 and 2022.

## SHARING WITH OTHER FARMERS

Over the course of the project, Ken hosted three field days on the farm, presented at six agricultural conferences in Ontario, and presented at the PASA Conference in the US.

## REFERENCES

1. Hargreaves, SK, P DeJong, K Laing, T McQuail, and LL Van Eerd. Management sensitivity, repeatability, and consistency of interpretation of soil health indicators on organic farms in southwestern Ontario. 2019. Canadian Journal of Soil Science 3 October 2019. https://doi.org/10.1139/cjss-2019-0062.
2. Barnhorst, E. 2020. Regeneration of fallow fields for vegetable production, https://efao.ca/wp-content/uploads/EFAO-Barnhorst-2020-final-audio.pdf.

## ACKNOWLEDGEMENTS

We thank the Living Lab–Ontario project team, including Tracey Ryan, Pam Joosse, Eric Page, Natalie Feisthauer, Andy Van Niekerk, and all of the other team members across organizations.

## TAKE HOME MESSAGE

After many years of working with cover crops on his farm, and three years in cooperation with the Living Lab–Ontario project, Ken notes these important considerations when using cover crops and working to reduce tillage in organic vegetable production:

- Farming with cover crops for weed control requires long-term planning since the cover crop is often planted the season before the cash crop(s);
- It is critical to make adjustments in soil fertility the year before the cover crops are planted because the opportunities to amend during the cash crop year are very limited;
- Any persistent and/or perennial weed problems need to be controlled before the cover crop is planted;
- Waiting for cover crops to reach the best termination date can delay planting and harvest dates so that must be taken into consideration;
- Special equipment is required to deal with the residue and opening and closing a trench in soil fully occupied by roots of the cover crop;
- Flail mowing as a termination strategy for cover crops is more forgiving than rolling especially when dealing with cover crop combinations.

From the rapid regeneration plots, preliminary analysis shows that DCM, although expensive, might result in the fastest regeneration.