Advancing Cover Crop Systems in Ontario -Focus on Soil Nutrients (N+P), Soil Health, Insects and Nematodes

Interim Report 2

(OSCIA Tier 2 – St. Clair)

Purpose:

Cover crops have numerous documented benefits including reducing soil erosion, increasing soil organic matter, inhibition of pests and altering nutrient availability. The popularity of using several cover crop species in a mix is increasing, thus this project was established to compare cover crop multi-species mixes to single species or simple mixtures in terms of various functions. The objectives of this project include;

1. To compare cover crop multi-species mixtures to single species or simple mixtures for biomass growth
2. To determine the nitrogen credit of selected cover crop mixtures to the following corn crop
3. To measure the impact of cover crops on phosphorus loss
    a. Determine the impact of variable freeze-thaw magnitude on dissolved reactive phosphorus (DRP) export
    b. Find candidate cover crop species which best resist the impact of freeze-thaw cycles (FTC)
    c. Determine the effect of early termination of cover crops (via glyphosate application) has on DRP export compared to leaving plants green
4. To study the impact of cover crops on insects, slugs and soybean cyst nematode (SCN)
5. To promote the use of cover crops and provide information on how to grow cover crops successfully

Methods:

Multi-species mixtures: This part of the project is co-led by Adam Hayes and Anne Verhallen, soil management specialists with OMAFRA. In 2015 and 2016, three small plot, intensive sites, were setup each year in Winchester, Ridgetown and Thamesville. In 2015 all three sites had four reps with 22 different treatments. Each treatment was 2m wide by 6m long. Treatments included a no cover check plot and 21 different cover crop mixes ranging from 2-14 species per mix. Additionally, at Ridgetown and Thamesville, 6 treatments were added to each rep for a total of 28 treatments. The additional 6 treatments were mixtures of radish, oats and crimson clover at varying ratios to determine if seed ratio had an effect on total biomass or individual species germination and growth. In 2016, all three sites had four reps with 20 different treatments. Treatments included a no cover check plot and 19 different cover crop mixes ranging from 3-14 species per mix. Certain mixes contained the same species but different ratios were used to determine if seeding rate had any influence on biomass. Mixes in 2016 were chosen based on results from the 2015 plots. Table 1 lists all the species used in the mixes while Tables 2 and 3 are the treatment lists by species and seeding rate for each of 2015 and 2016 respectively. Visit https://scscia.wordpress.com/ for a complete listing of species mixtures and seeding rates.

Table 1: List Of Cover Crop Species Used In Small Plot And Satellite Location Mixes

Species		
oats	berseem clover	peas
rye	sweet clover	Brassica (kale/turnip)
radish	lentils	annual ryegrass
hairy vetch	flax	sorghum sudan
crimson clover	phacelia	mustard
sunflower	mung bean	sunnhemp
red clover	buckwheat	barley
faba beans	triticale	chickling vetch
white clover	cowpea	chickpea

Table 2. Treatment List of Cover Crop Mixes and Seeding Rates 2015

Trt #	Total lbs	Cover Species Mix	Lbs/species
1	0	no cover	0
2	30	rye, vetch, radish	22,6,2
3	30	rye,clover, turnip	22,6,2
4	40	oat, pea, radish	20,18,2
5	35	oat, crimson clover, pea	14,6,15
6	30	oat, sweetclover, annual ryegrass	20,5,5
7	30	oat, red clover, annual ryegrass	20,5,5
8	45	oat, radish, crimson clover, sorghum sudan, sunflower, pea	10,2,4,4,2,13
9	45	oat, radish, crimson clover, faba bean, sunflower, pea	10,2,3,15,2,12
10	43	rye, hairy vetch, radish, oat, crimson clover, pea	10,4,2,10,2,15
11	45	rye, pea, turnip, oat, hairy vetch, faba bean	10,10,1,10,4,10
12	20	annual ryegrass, crimson clover, white clover, sweet clover, lentil, flax	5,4,2,2,5,2
13	40	rye, oat, triticale, pea, hairy vetch, crimson clover, radish, sunflower, kale/turnip	7,7,7,10,3,2,1,2,1
14	40.5	oat, sorghum sudan, barley, pea, faba bean, chickling vetch, radihs, sunflower, phacelia	7,2,7,7,7,7,1,2,0.5
15	40	rye, oat, hairy vetch, faba bean, pea, crimson clover, flax, turnip, sunflower	7,7,2,9,8,2,2,1,2

16	40	oat, barley, pea, vetch, crimson clover, rape, lentil, flax, sunflower	7,7,8,8,3,1,2,2,2
17	45	pea, chickling vetch, spring lentil, chickpea, hairy vetch, crimson clover, oat, rapeseed, flax sunflower	9,8,4.5,4.5,4,1,11,0.5,2,1
18	45	pea, lentil, hairy vetch, crimson clover, oat, barley, sunflower, rape, flax	6.3,2.7,2.7,1.8,13.5,13.5,.9,.9,2.7
19	45	hairy vetch, lentil, cowpea, crimson clover, sunnhemp, oat, rye, pearl millet, sorghum sudan, radish, cabbage, turnip, buckwheat, flax, phacelia, sunflower	4.05,4.05,4.05,2.7,1.35,10.8,2.7,1.35 ,1.35,1.35,2.7,2.7,2.7,1.35,1.35
20	45	hairy vetch, mung bean, lentil, berseem clover, oat, barley, millet, flax, phacelia, sunflower	3.6,3.6,2.7,1.8,9.45,9.45,2.7,5.85,1.8 ,0.9
21	45	hairy vetch, lentil, berseem clover, barley, wheat, radish, mustard, flax, phacelia, sunflower, flower mix	4.5,4.5,5.4,7.2,4.5,0.9,1.8,5.85,5.85, 2.7,1.35,0.9
22	47.5	rye, oat, hairy vetch, phacelia, pea, crimson clover, sunn hemp, radish, faba bean, sunflower, sorghum sudan, flax, green pea	5,5,5,0.5,9,4,2,4,7,1,1,2,2
23	20	radish, oat, crimson clover	5,5,5,0.5,9,4,2,4,7,1,1,2,2
24	27	radish, oat, crimson clover	2, 8, 10
25	35	radish, oat, crimson clover	2, 12, 6
26	35	radish, oat, crimson clover	3.5, 7, 24.5
27	35	radish, oat, crimson clover	3.5, 14, 12.5
28	35	radish, oat, crimson clover	3.5, 21, 10.5

Additional to the small plot sites, eleven satellite locations were established in 2015 and four locations in 2016. These locations were strip trial plots with varying number of treatments and replications. The species used in these trials were the same as the small plots as listed in Table 1. The size of the plot and species used in mixes was at the discretion of the cooperator. Table 4 lists the locations and the type of trial being performed at each.

All locations were planted after wheat harvest between mid-August and mid-September. Counts of each species present in each mix were conducted at the small plot locations in September to determine germination and compare with expected ratios from the seeding rates. Counts were conducted by counting the number of each species present in two $0.25m^2$ quadrats per plot. Biomass harvest was done at all small plot and satellite locations between mid-October and the beginning of December. In 2016, the small plots

Table 3. Treatment List of Cover Crop Mixes and Seeding Rates 2016

Trt #	Total lbs	Cover Species Mix	Lbs/species
1		No cover	0
2	16	rye, hairy vetch, radish	10, 4, 2
3	21	rye, hairy vetch, radish	15, 4, 2
4	26	rye, hairy vetch, radish	20, 4, 2
5	16	oat, crimson clover, radish	10, 4, 2
6	21	oat, crimson clover, radish	15, 4, 2
7	26	oat, crimson clover, radish	20, 4, 2
8	31	oat, radish, crimson clover, sorghum sudan, sunflower, pea	10, 2, 3, 4, 2, 10
9	21.5	rye, hairy vetch, crimson clover, kale, sunflower, ARG	10, 4, 3, 0.5, 2, 2
10	31	oat, radish, crimson clover, sorghum sudan, sunflower, faba	10, 2, 3, 4, 2, 10
11	21.5	rye, hairy vetch, crimson clover, turnip, sunflower, winter barley	6, 4, 3, 0.5, 2, 6
12	38	oats, hairy vetch, red clover, pea, faba, berseem clover	10, 4, 2, 10, 10, 2
13	28	oat, rye, radish, sweet clover, buckwheat, faba	6, 6, 2, 2, 2, 10
14	40	buckwheat, sunflower, mustard, phacelia, flax, faba, sunnhemp, chickling vetch, oat	5, 2, 1, 1, 10, 4, 5, 5, 5
15	35	rye, oat, hairy vetch, faba, pea, crimson clover, flax, sunflower	5, 5, 8, 2, 2, 1, 1, 2
16	35	oat, barley, pea, lentil, radish, sunflower, faba, crimson clover	5, 5, 1, 10, 2, 8, 2
17	21	rye, winter barley, hairy vetch, kale, red clover, sunflower, crimson clover	5, 5, 1, 4, 2, 2
18	45	oat, barley, pea, lentil, radish, sunflower, faba, crimson clover	10, 10, 1, 10, 2, 8, 2
19	31	rye, winter barley, hairy vetch, kale, red clover, sunflower, crimson clover	10, 10, 1, 4, 2, 2
20	45	rye, oat, hairy vetch, phacelia, Pea, crimson, radish, faba, sunflower, sorghum, flax	5, 5, 5, 11, 4, 3, 7, 1, 1, 2

were sampled in early October and early November to compare growth between the two sampling time points. Two strip trial locations in 2015 were not sampled due to lack of adequate growth. Sampling was done by collecting all above ground biomass in two 0.25m^2 quadrats per plot (the same ones as used for plant counts) for the small plot

locations, and three 0.25m^2 quadrats per strip for the satellite trial locations. All biomass was dried to constant moisture and total dry weight biomass was recorded. In 2016, root biomass was collected from two treatments in each rep at the Ridgetown and Thamesville trials. From the 0.25m^2 used for collecting biomass, all root mass was dug from the area, washed and dried. Dry weights for these plots were recorded.

Table 4: List Of The Eleven Satellite Locations And The Type Of Trial At Each

Year	Location	Type of trial
2015	Florence	comparing seeding rates of a 3-way mix
	Thamesville	Nitrogen trial
	Amherstburg	Nitrogen trial
	Chatham	comparing species ratios in 3-way mixes
	Lakeshore	comparing 3, 6, 9 and 12 -way mixes
	Watford	comparison of different cover crop mixes and no cover
	Kingsville	comparison of cover crop mixes that will not overwinter
	Highgate	comparison of cover crop mixes that will not overwinter
	Strathroy	comparing 3, 6, 9 and 12 -way mixes
	Chatham	comparison of different cover crop mixes and no cover
	Petrolia	comparison of cover crop mixes that will not overwinter
2016	Chatham	Comparing single species (grasses) to simple and complex mixes
	Chatham	Comparing five different mixes, including complex mixes of up to 15 species
	Kingsville	Comparison of four different mixes
	Essex	Comparison of four different mixes

Cover Crop Nitrogen Credit: Dr. Laura Van Eerd, University of Guelph, Ridgetown Campus is assisting with this part of the project. The three nitrogen trial sites were planted in August of 2015 and consisted of field-scale strips with check (no cover crop) strips and strips of a cover crop mixture (hairy vetch, red clover, crimson clover, rye, oats) replicated 4 times. In the spring of 2016, corn was planted with five nitrogen rates, in each cover crop and no cover crop block to determine the nitrogen credit if any from the cover crop. Due to the weather in the spring of 2016, one location was deemed inadequate for the purpose of the project and yield was only collected at two locations.

Biomass was collected from all three locations in the spring and weighed dry and will be analyzed for total N content as well as C:N ratio.

Phosphorus: This part of the project is led by Dr. Merrin Mcrae and her master's student James Cober is doing most of the lab and field work. In the winter of 2016, a laboratory experiment was conducted to examine the effects of cover crop species, type of freeze-thaw cycle, and the effects of termination prior to freezing on phosphorus export. These variables were tested for both phosphorus and nitrogen release. The work helped determine which cover crop species to include in the field work. A series of field trials were initiated on the University of Waterloo campus to determine an appropriate set of in-field instrumentation for the leaching studies.

The second portion of the project, a field study began in August, working with Aaron Stevanus in the Waterloo region. Six cover crop species and mixtures were planted in August 2016 with the help of Aaron Stevanus (Image 1). Three different types of water collectors were designed and installed in the field to collect surface runoff, shallow soil water (in the rooting zone) (image 2), deeper soil water and ground water (between the rooting zone and 90 cm). A weather station and sensors to monitor soil temperature and moisture were installed on the field (images 3 and 4). Plant and soil samples are being collected regularly to measure the effects of freeze-thaw cycles on phosphorus release from cover crops (image 5).

Image 1: Field Map Of Aaron Stevanus Cover Crop Field Trial

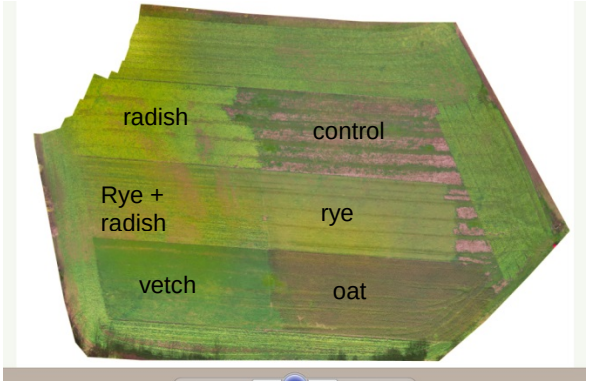

Image 2: Installing Lysimeter In Field

Insects: This part of the project is led by Tracey Baute, Entomologist – Field Crops, OMAFRA. In the spring of 2015 sampling was performed in cover crop trials at seven locations to assess insect presence. These locations had strips of cover crop mixtures and within each two 0.25m^2 holes were dug to a depth of 6". The soil from these holes was examined by hand and all insects were placed in 95% ethanol and transported to the lab for identification. In 2016, insect pitfall traps, rootworm bait traps and slug traps were set up at several locations in Southern Ontario to assess insect presence. These locations had strips of cover crop mixtures, as well as no cover strips. Within each strip at least 3 traps of each type were set up. The slug traps were boards placed on the ground and the number of slugs were counted each week. Pitfall traps were setup using a piece of metal inserted in the ground and a cup on the end of each piece to allow the insect to travel along the metal and fall into the cup. Pitfall traps were checked every 3-4 days and records of number and species of insect were collected. Insects were placed in 95% ethanol and have been sent to an accredited lab for identification. Bait traps were dug to a depth of 6" and a mixture of flour and water was placed in the hole. The whole was covered with the soil and a piece of black plastic to maintain moisture and temperature. Bait traps were checked every 7 days and the number of root worms found were recorded and collected for further inspection. The bait in the trap was also replaced with new flour every 7 days.

Image 3: Soil Temperature And Moisture Monitoring Equipment. Image 4: Weather Station

Image 5: Field In The Winter

SCN: This part of the project is led by Albert Tenuta, Pathologist – Field Crops OMAFRA. In 2015 and 2016, the same cover crop species listed in table 1 were planted in two locations (Highgate and Rodney) and assessed for suitability as a host for Soybean cyst nematode (SCN - *Heterodera glycines*) and root lesion nematode (RL-Pratylenchus penetrans) as well as the fungal disease sudden death syndrome (SDS- *Fusarium virguliforme*).

Promotion of Cover Crops: This part of the project is co-led by Adam Hayes and Anne Verhallen. Demonstration farms will be established to show different cover crops and their management. Presentations will be made at various soil and crop and other meetings.

Results:

Multi-species mixtures: In 2015, total dry matter varied between 790-13875 lbs/ac for the three small plot locations. In 2016 total dry matter varied between 2349-4449 lbs/ac for the three small plot locations. Through combining the two years of data, as well as using the two collection time points of data from 2016, it was determined that there was no significant difference in total biomass between number of species in the mix when the data was collected in November. The seeding rates for the different mixtures were not all the same. Early harvest of biomass resulted in the species with higher number of species in the mix having increased total biomass (Figure 1). Furthermore, the biomass in the mixes with ten or more species was comparable to November biomass, whereas in mixes with fewer than 10 species, biomass values in October were significantly lower than the biomass values in November. If a mix is to be terminated early, the higher number of species in the mix would increase total biomass. Allowing the cover crop mix to continue to grow into November negates the effect of the number of species on total biomass, and all mixes have comparable value.

Additionally, analysis of the cover crops mixes was done based on winter survivability. Cover crop mixes were designated either “winter kill” (predominately oats based mix) or “winter survivable” (predominately rye based). Winter kill mixes had higher biomass in the fall (at both October and November harvest) as compared to winter survivable mixes (Figure 2).

In the spring of 2016, crop residue was measured at the two small plot locations in Southern Ontario for an average percent cover. The range of residue cover was similar for all treatments ranging from 52-82% cover (Figure 3). Treatment 10, a 6 way mix of rye, vetch, radish, oats, clover, and pea, had the highest percent residue cover and was significantly higher than two of the three way mixes of radish, oat and crimson clover.

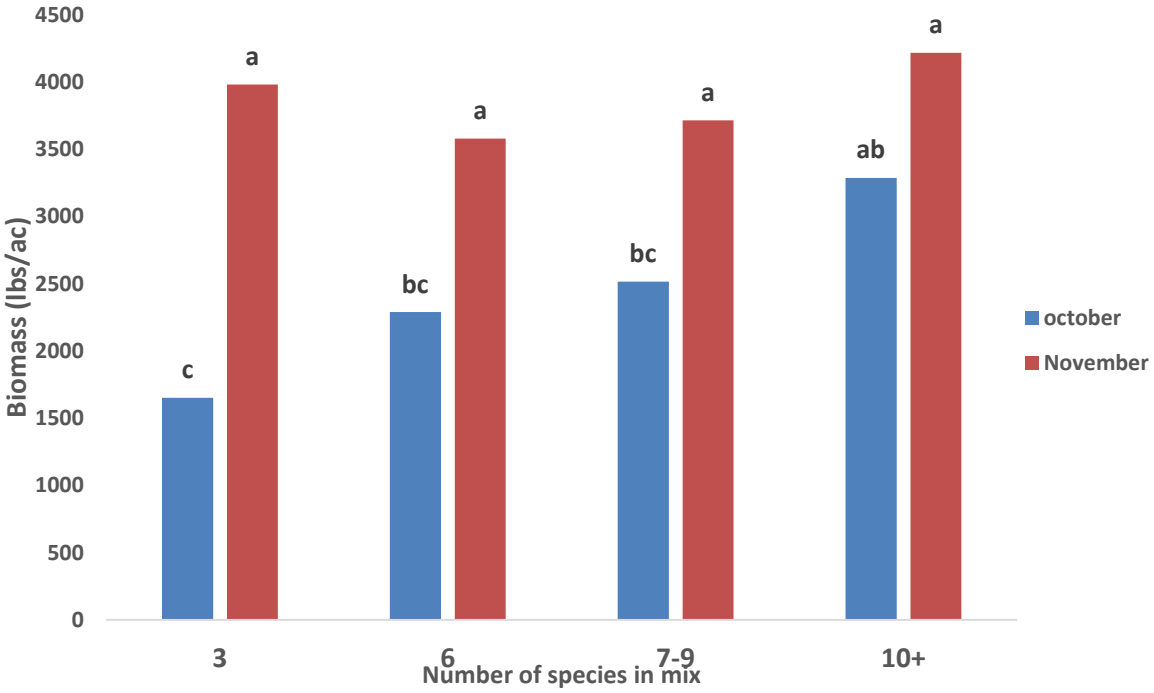

Figure 1: Average cover crop dry weight biomass for mixes with varying number of species collected in October and November from three small plot locations over two years. Biomass values followed by the same letter were not significantly different at the 5% level.

All sites had some level of cover crop establishment by late November; however stand quality and total growth varied widely. The variable growth, as well as difficulties in establishment could be in part due to the lack of moisture seen at and after planting. At the three small plot locations (Ridgetown, Thamesville and Winchester) total dry matter varied between 790-13875 lbs/ac. While at the eleven satellite locations total dry matter varied between 852-9625 lbs/ac.

At one location in 2016 weed biomass was collected as well as total cover crop biomass. The following figures (figure 4) compare weed biomass with cover crop biomass for the different mixes. Treatment 1 is the no cover treatment. Treatments 2-7 consist of various 3-way mixes. Treatments 8-13 are 6-way mixes and treatments 14-20 are 7-10-way mixes.

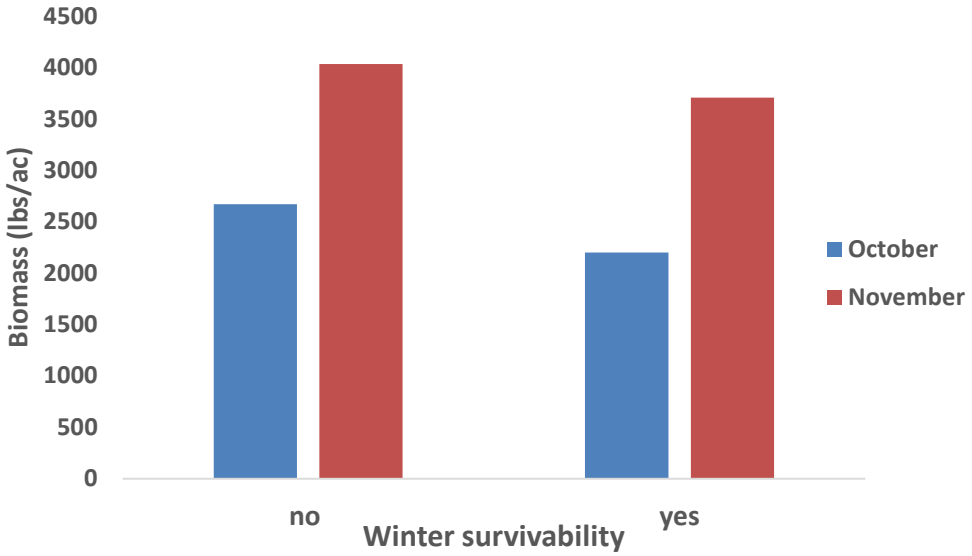

Figure 2: Average cover crop dry weight biomass for mixes in October and November that can either overwinter or will winter kill.

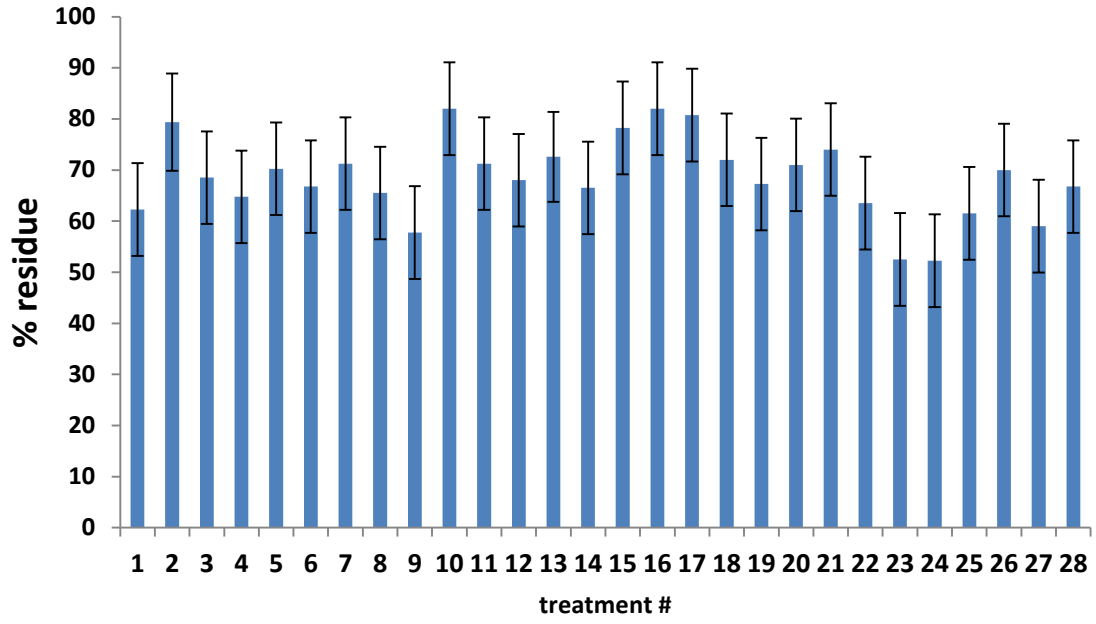

Figure 3: Average percent residue cover in spring 2016 at the two small plot locations in Southern Ontario

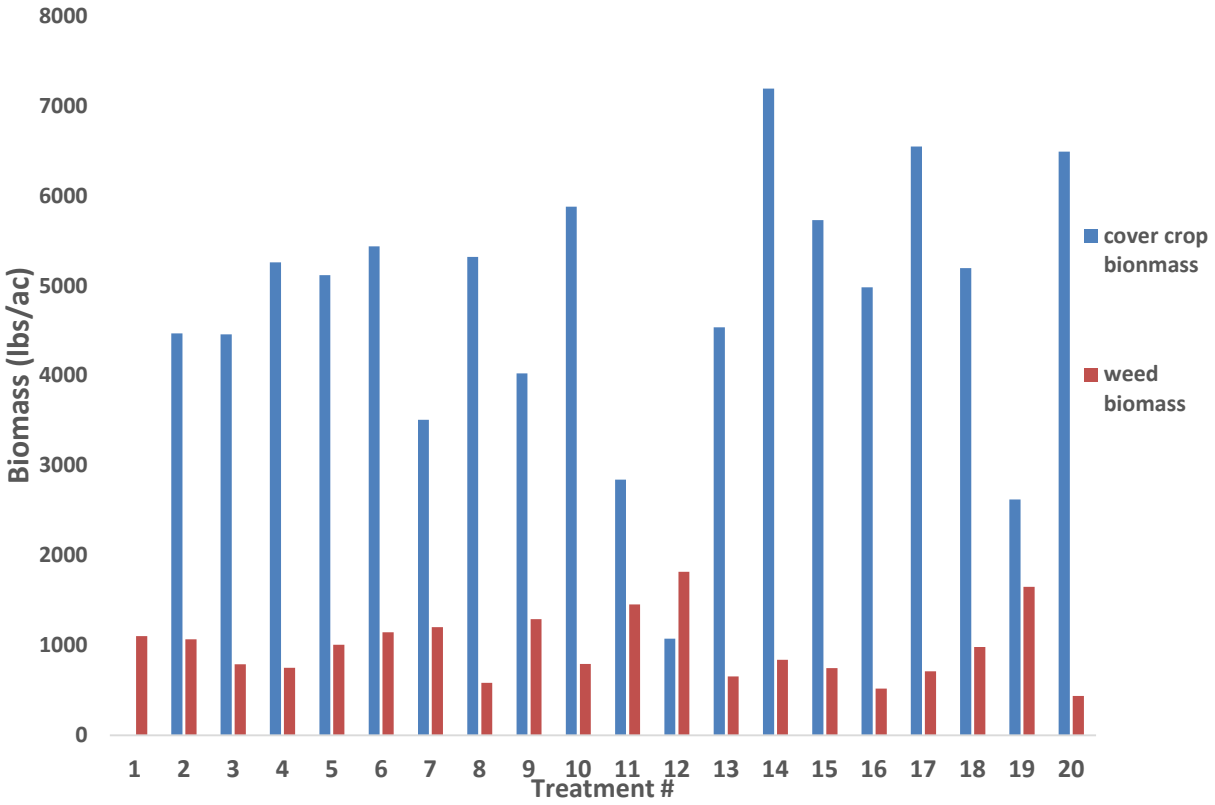

Figure 4: Average cover crop and weed dry weight biomass for mixes at the Ridgetown plot in November 2016.

Two mixes were analyzed closely at the Ridgetown and Thamesville location. Mix 7 (3-way mix of oat, crimson clover and radish) and Mix 14 (multimix of buckwheat, sunflower, mustard, phacelia, flax, faba, sunnhemp, pea, chickling vetch and oat), were compared for root biomass and canopy structure. Due to the fine root structure of some of these species it is difficult to collected the entire root biomass, additionally, when washing the roots, small root hairs are lost and are not included in the final dry weight. Regardless of the complications with root biomass collection, the biomass in mix 7 across the Ridgetown and Thamesville locations was higher (1129 lbs/ac) compared to mix 14 (913 lbs/ac).The average above ground biomass for mix 7 was 2495 lbs/ac, while mix 14 had an above ground biomass of 4450 lbs/ac. Combining the above-ground and root biomass, the multimix (mix 14) had higher total biomass (5363 lbs/ac) compared to the 3-way mix (3624 lbs/ac). Table 5 shows examples of the differences in canopy structure between the two mixes at 2 and 6 weeks after planting.

The satellite trials were all set-up slightly differently due to grower preference. Consequently it was difficult to compare total dry weight biomass across locations. Furthermore, harvest times varied between locations with at least 6 weeks separating the earliest harvested location and the latest. This increases the difficulty in accurately comparing cover crop growth across locations. Analysis is ongoing to compare the results from the small plots to the strip trials.

Table 5: Canopy Structure In Mix 7 (3-Way Mix) And Mix 14 (Multimix) At 2, 6 And 12 Weeks After Planting.

	Mix 7	Mix 14
2 weeks after planting		
6 weeks after planting		
12 weeks after planting		

Nitrogen Credit: Due to management differences between the location in Winchester and the two locations in Southwestern Ontario, biomass and soil N sampling was only conducted at the two Southern Ontario locations (DS and DF). One location (DS) had low corn emergence across the entire site and could not be used to assess N credit. The yield calculations were done on the Winchester and DF site.

Dry weight biomass at DF and DS ranged from 2869-6897 lbs/ac (Figure 5). Additionally soil nitrogen was sampled for nitrate and ammonium, comparing spring nitrogen levels with and without cover crops. The plots with cover crops had 45.7 lbs/ac of nitrogen in the soil in the spring compared to 26.2 lbs/ac in the no cover plots. Though the value in the cover crop plots is higher, this was not significant at the 5% level.

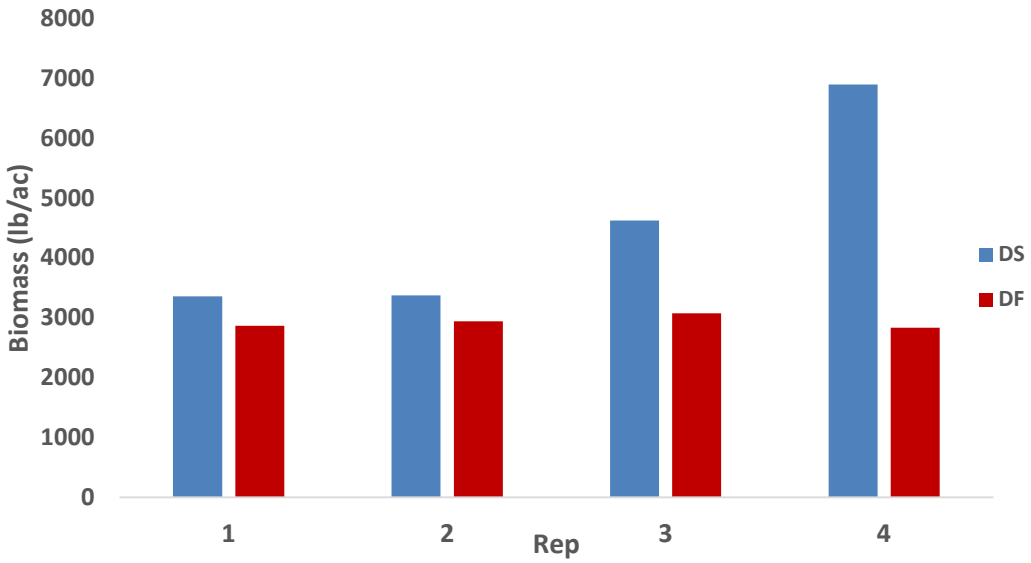

Figure 5: Dry weight biomass of cover crop N mix at two locations in the spring prior to planting

At harvest there was no significant difference in corn yield between the no cover plots and the cover crop plots, or between the different N rates. This could be in part due to the lack of moisture during the growing season resulting in lack of differences in N availability. The recorded yields are presented in figure 6.

Phosphorus: Two conference presentations were given on the lab results. The lab study showed that more delicate species such as oat and oilseed radish have a greater tendency to release phosphorus following freezing in comparison to hardier species such as cereal rye and hairy vetch.

For the field portion of the project, with a relatively dry autumn season, water collectors remained empty through December, and have since captured rain fall and snow melt with reasonable success. Very little phosphorus was lost from plants in the early fall

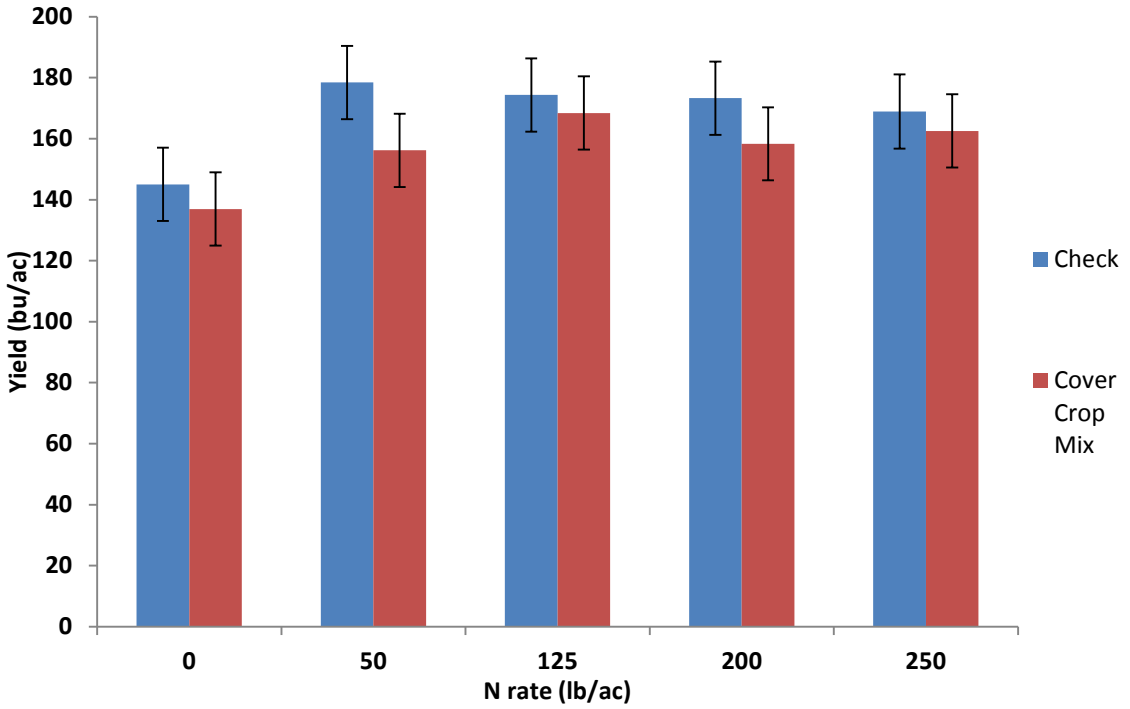

Figure 6: Corn yield after cover crop mix and no cover at Winchester and DF locations in 2016.

given the warm and dry conditions. We have been collecting samples throughout the freeze-thaw cycles in December and January and expect to see greater losses during these events.

Insects: Analysis of pest by treatment from 2015 has not been completed yet but some general observations can be stated. Millipedes made up the vast majority of the specimens found at the research sites. Millipedes can be considered both beneficial for breaking down organic matter and as pests, choosing to feed on crop seeds if conditions are ideal.

Wireworm specimens were sent to Wim van Herk, Agriculture *and Agri-Food Canada,* Agassiz, B.C. for species identification. All seven locations had wireworms present at varying degrees of infestation. A total of sixty-five wireworm specimens collected (Figure 4). Interestingly, each location was made up of predominately one wireworm species instead of a combination of wireworm species. Overall, the most abundant wireworm found was the eastern field wireworm, *Limonius agronus.*

As for other insects or pests found, slugs were next most abundant, though populations were below damaging levels and a few (n=3) predatory ground beetles or larvae were captured.

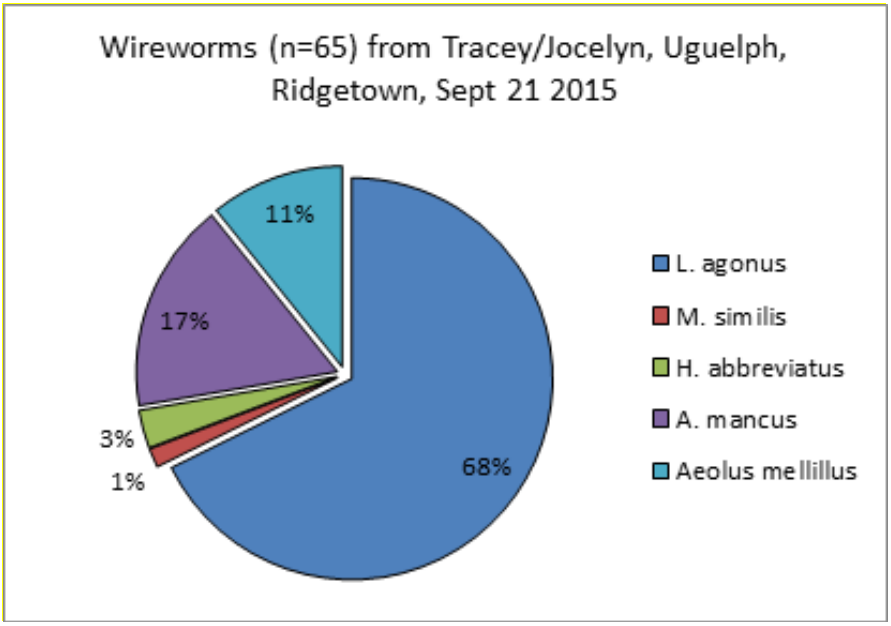

Figure 7: Wireworm species collected from cover crop sites in 2015

The results from 2016 are still coming back from the lab and will be analyzed once is has all been received.

SCN: At both locations (Highgate and Rodney), SCN reproduction was only observed on the broadleaf legume, crimson clover and at very low levels. Roots were also processed to determine the average number of SCN larvae (juveniles) in the root. Hairy vetch had the highest number followed by red clover. The other clovers (sweet yellow, crimson and white) along with faba beans had the low levels of SCN larvae in the roots. No SCN larvae were found associated with brassicae and grass cover crop roots. Although these results from this one year study show low or little risk for SCN reproduction it is important to note that broadleaf legume cover crop species such as hairy vetch, red clover, field pea, crimson clover, white clover, sweetclover and faba beens have been reported to be SCN hosts. Besides planting SCN resistant varieties growers who use these species should routinely take a SCN nematode sample to note changes in nematode population levels.

Root lesion nematodes were detected in all 26 cover crop species ranging from a high of over 15,000 nematodes per gram of root to a low of 75 nematodes per gram of root. Seven cover crop species had root lesion numbers averaged above 1000 nematodes per gram of root. The highest by far was Sunn Hemp which was over 15,000 nematodes/g root followed by Field peas (7352) and Faba Beans 4072). Four other cover crop species hairy vetch, white clover, red clover and oriental mustard ranged from 1921 to 1429 root lesion nematodes per gram of root whereas the remaining 19 cover crop species were all below 1000 nematodes per gram of root. Sunn Hemp has been shown to be effective against various nematode species particularly those nematodes which stay and feed in one place in the root system (sedentary endoparasitic nematodes) such as root knot nematode (Meloidogyne spp) and SCN.

The results from 2016 are still coming back from the lab and will be analyzed once is has all been received.

Promotion of Cover Crops: Presentations were made at Essex, Kent and Lambton Soil and Crop annual meetings in 2015 and 2016. No demonstration farms were established but the multi-species plots will be used for tours. These plots were signed and people were invited to walk through. The St Clair Region Conservation Authority Soil and Water tour visited one site. A tour of several of the plots was arranged to show cover crop researchers what was being learned from the plots and to facilitate discussion amongst the researchers and encourage future research. Information gathered from the project has been fed into promo/information cards and plot tours are planned for spring of 2017. The information was also presented at many meetings in 2016.

Summary:

Cover crop mixes planted after winter wheat harvest can produce variable amounts of biomass depending on moisture, timing of planting and time of harvest. Fall harvest biomass ranged from 790-13875 lbs/ac. It is difficult to determine optimal mixes. Two years of study indicate small differences between mix composition and number of species, however if the cover crop is not terminated early, there are no significant differences. Nitrogen credits were not calculated due to the lack of difference in corn yield between the no cover and cover crop plots as well as the different N rates.

Next Steps:

Data and laboratory analysis is ongoing for samples collected in the fall of 2016. SCN counts from collected soil samples are currently being done. Analysis of plant counts is ongoing to evaluate cover crop mixes. In the spring of 2017 cover crop residue will be recorded, as well as biomass for specific plots and trials.

Acknowledgements:

Thanks to the co-operators for their commitment to planting these plots. The funding for this project was provided by the OSCIA Tier II grant, a regional grant from the Southwest Agricultural Conference and from Innovative Farmers of Ontario. Thank you to Speare Seeds (2015) and General Seeds (2016) for supplying the seed at a discounted price. Thanks also to Claire Coombs for her assistance with project design, data analysis and biomass harvest. Also thanks to the many summer students who helped with the field work and data entry.

Project Contacts:

Adam Hayes, OMAFRA, adam.hayes@ontario.ca