INCORPORATING COVER CROPS IN GREENHOUSE SOILS

A summary of Perennia's winter webinar series, brought to you through the On-Farm Climate Action Fund. More details available at **ofcaf.perennia.ca**

COVER CROPPING IN GREENHOUSE SOILS

Greenhouse soils are cropped intensively to maximize the use of these highly productive spaces. This level of intensity in cash crop cycling can degrade the chemical, ecosystem, and physical health of the soil through compaction, loss of soil structure, build-up of salts (ex. calcium, magnesium) and increase in pH over time. It is important to be aware of the challenges surrounding soil health in protected spaces in order to implement the appropriate preventative and curative measures.

Cover cropping is commonly practiced in field settings but is a relatively new concept when it comes to implementation in protected agriculture. Cover crops offer many advantages to greenhouse soil health. Cover crops can fix nitrogen in the soil, build organic matter, outcompete weeds, break up soil compaction and facilitate movement of water through the soil. Certain cover crop species have also been proven to reduce pest populations, reducing farmer intervention required to successfully grow crops. They support diverse microbial communities through the off seasons and can protect against soil erosion for tunnels where the plastic is removed during the winter. The benefits of cover cropping are intertwined, so it is important to consider this practice as a holistic approach to soil health as opposed to a targeted one. Combined with proper nutrient management, protected soils can remain productive and resilient well into the future.

Why use cover crops in protected spaces?

- Nitrogen fixation
- Build organic matter
- Support diverse microbial communities in the soil
- Promote soil aggregation
- Pest, disease and weed management

Figure 1. An example of a tunnel cover crop implemented in Nova Scotia through the 2022-2023 winter. This photo was taken at the end of March following five months of growth.

Judson Reid is an extension specialist from Cornell University specializing in high tunnel production of soil-based vegetables. He is well versed in the complexities of managing soil health in protected spaces and participated in three webinars in 2023: two sessions discussing nitrogen management and one discussing the use of cover crops to improve and maintain soil health. Below is a summary of the discussion on cover cropping in protected spaces.

NITROGEN FIXATION

Nitrogen (N) is typically provided to the crop using fertilizers and bulk amendments (ex., compost). This is the most direct and accurate way to deliver fertility to a cash crop, however there are ways to reduce the amount of nitrogen that needs to be added into the system to meet the needs of the target crop. Certain species of cover crops (ex., peas, clover, vetch) can fix nitrogen throughout their growing cycle. In many legume species, nitrogen is removed from the root zone and incorporated into the above-ground biomass. Once the cover crop is terminated and incorporated into the soil, the plant tissue breaks down

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over time and serves as a slow-release source of nitrogen for future crops. The more biomass a legume generates, the higher the amount of nitrogen (pounds per acre) is produced for cash crops without contributing to salinity or excess nutrient banks in the soil.

Categorizing nitrogen as 'slow release' means that it will not be immediately plant available. With a healthy soil microbiome, this nitrogen will slowly mineralize into usable forms (nitrates, ammonium) on an ongoing basis. The rate of mineralization is difficult to quantify due to its dependence on many environmental factors (soil temperature, moisture, microbial communities present, etc.). Based on trial work done at Cornell, Judson's team found about a 25% increase in the rate of N mineralization to nitrate where cover crops were planted compared to bare soil. Subsequent cash crops will still need supplemental nitrogen throughout the growing season, but less compared to soil without legume cover crops.

Figure 2 shows the result of an experiment conducted at Cornell. The graph quantifies the amount of potential nitrogen generated in the soil following a variety of cover crop treatments. An early planted triticale +pea mixture, combined with the use of row cover, showed the highest estimated nitrogen contribution at 102 lbs/acre. Notice that the treatments that had an additional layer of protection from the cold produced more biomass compared to those that did not receive row cover through the winter.

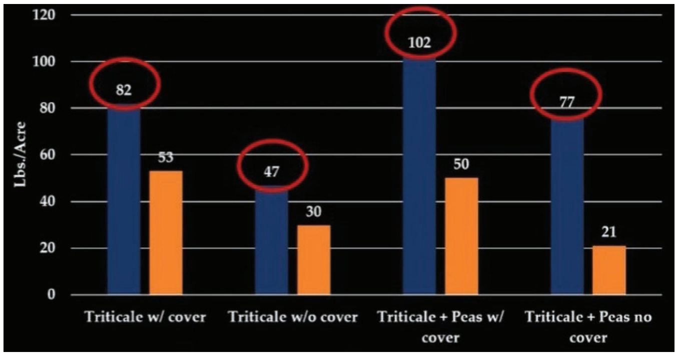

Figure 2. This graph demonstrates the estimated nitrogen contributions by the following cover crop treatments. The blue bar represents data collected from tunnel #1, and the orange collected from tunnel #2.

BUILDING ABOVE-GROUND BIOMASS

Cover crop establishment and growth are key in maximizing the impact that they have on protected soils. More cover crop biomass hinders weeds establishment, increases nitrogen production and pest-deterring substances, as well as supports root systems in breaking up compaction, supporting soil aggregation, and microbial communities.

For producers implementing winter cover crops, it can be difficult to maximize the amount of biomass created while simultaneously maximizing crop yield. Unheated structures with a double layer of inflated plastic are not sufficient when it comes to maintaining an internal temperature above zero degrees through late fall and winter. While certain cover crop species have increased tolerance to cool weather compared to others, some additional protection is needed to keep these crops growing through the winter months. Row cover is a cheap and easy way to protect cover crops against extreme cold temperatures throughout the winter. The addition of one or two layers of fabric makes a significant difference in the quality and quantity of the crop grown. Notice in Figure 3 that the 'without ground cover' portion of the row has bare patches of soil and poor survivability of the cover crop, compared to the survival rate and health of the crop in the 'row cover' treatment. Row cover increases the heat units experienced by the crop, helps to retain soil moisture, and can buffer major fluctuations in air temperature as well.

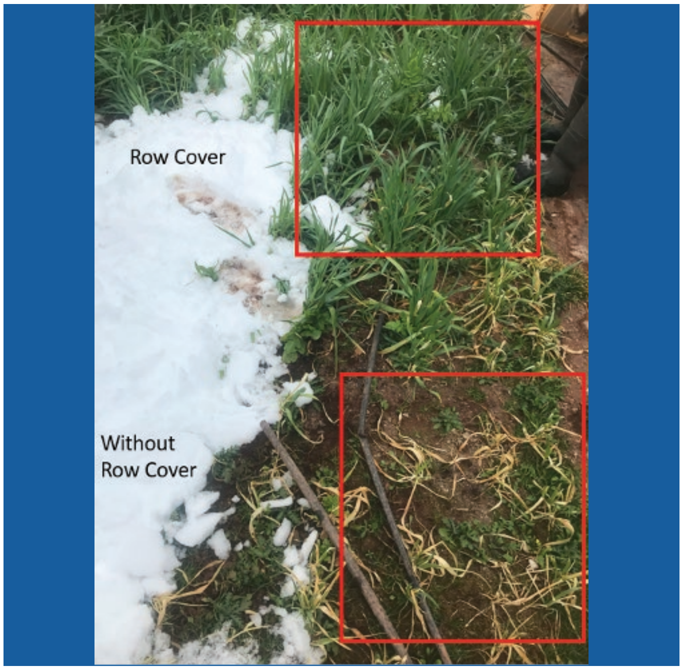

Figure 3. A side-by-side comparison of a cover crop which had row cover overtop of it throughout the winter, compared to one grown without row cover.

The impact that row cover can have on biomass production was well quantified in a study done by Cornell. Figure 4 illustrates the difference in biomass produced when including row cover over a winter cover crop. When comparing the triticale+ field pea treatments, the most conservative increase in biomass with the addition of a row cover translates to 2,000 lbs dry weight/acre. The most dramatic increase in biomass production due to the addition of row cover took place across triticale treatments, with an additional 9000 lbs dry weight/acre in tunnel 2.

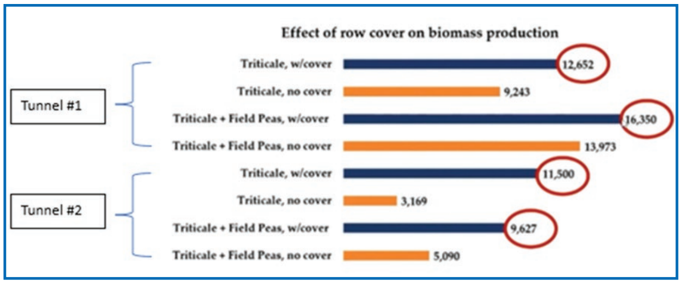

Figure 4. A side-by-side comparison of biomass (lbs dry weight/acre) produced by various cover crops in two different tunnel spaces. The top 4 treatments took place in greenhouse #1, and the bottom 4 treatments took place in tunnel #3 in order to replicate the study and identify trends.

> Row cover is best installed following a few days of freezing temperatures in the tunnel, which should knock back some annual weeds and pests that may be hiding in the space post-season. In Nova Scotia, that tends to happen around December/January, depending on the year.

Biomass generated through the off-season will contribute to the overall percentage of organic matter within the soil. Organic matter is critical for plant growth. It enhances soil structure by maintaining air and water spaces throughout the top layer of the soil while protecting against erosion. It also improves overall soil fertility by buffering soil pH and supporting soil microbes. These soil microbes impact the release of energy and nutrients to the plant roots and play a crucial role in the nitrogen cycle, which sees the transition of unusable forms of N into compounds that are readily plant-available. While organic matter accumulation takes time, implementation of regular cover cropping will contribute to that accumulation significantly more than bare soil does.

SEEDING DATE

Good establishment winter cover crops is highly dependent on the seeding date. The earlier the seeding date in the fall, the more biomass can be produced before light becomes a limiting factor to growth. The impact of using a legume cover crop is maximized with an earlier planting (ex., early to mid-September) combined with the use of row cover, where it can create more above-ground biomass. Later planting dates (ex., October) and row cover are going to favour winter grain productivity as they can germinate and grow in cooler temperatures (wheat, winter rye, barley, triticale). In either case, most of the cover crop growth will take place in the fall/early winter and late winter/early spring.

Figure 5 shows the result of a seeding date demonstration implemented in the fall of 2022. The tunnel can be broken into four seeding dates, with the first strip on the left side of the image planted mid-September. A weekly planting was installed following the initial seeding date, ending mid-October. The final seeding date strip can be seen on the right side of the image. The trial clearly demonstrates the advantages of getting the cover crop in early to help generate biomass and exclude weeds that could be growing in these soils.

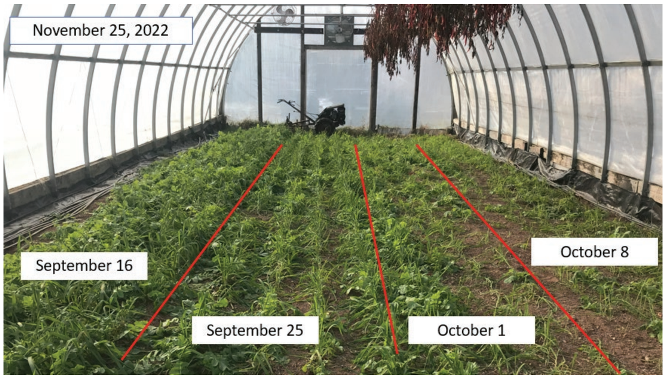

Figure 5. A comparison of four seeding dates for a cover crop mix consisting of oats and tillage radish.

Throughout Judson's trials, cover crop maintenance was quite basic. Following the application of the cover crop seed, the research team provided sufficient water to the protected soil space to encourage the germination of the cover crop, as well as provide an opportunity to leach excess salts from the top layer of soil down and out of the production space. Following this watering event, cover crops were left for the remainder of the season. Early spring applications of moisture would help boost biomass production and plant productivity but can be difficult depending on irrigation infrastructure in those early months.

COVER CROP TERMINATION

Overwintered cover crops should be terminated and incorporated about two to three weeks before transplanting in a warm season cash crop (ex., tomatoes, peppers, cucumbers). The best termination method is going to depend on the farm – no-till would have to rely on mowing, tarping or winter kill to terminate living plants in protected space, whereas those who do use tillage are able to mow and incorporate that material. The recommended amount of time between cash crop planting and cover crop termination is going to vary depending on the species used, the volume of biomass produced, and the termination method – those who are no-till planting may require more time to break through the root masses of the cover crop to make room for new transplants. Regardless of the termination method, allowing a rest period will prevent any accidental nitrogen tie-up caused by the introduction of a large amount of biomass onto the soil. The soil biology is going to require some time to begin breaking down the terminated cover crop tissue before the nutrients are available to the target crop.

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LIVING VERSUS DEAD MULCHES

When it comes to amending the soil with nutrients and building the organic layer, what is the difference between growing the plants in the protected space versus bringing in outside materials that have been harvested elsewhere? The answer lies beneath the soil.

What is aggregate stability?

Primary soil particles (sand, silt, and clay) form secondary soil particles called aggregates. Soil forming processes, biological activity, soil wetting/drying, freezing/thawing, and mechanical manipulation of the soil impact soil aggregates. Aggregate stability refers to the ability of these aggregates to resist breaking apart with forces acting upon the soil (ex., heavy rains, winds, human activity). It is important for these aggregates to be stable because poor soil structure or instability can leave the soil more prone to erosion and compaction. Stable aggregates help promote carbon sequestration by physically protecting soil organic carbon from microbial breakdown and improving water infiltration and drainage.

A soil with good aggregate stability will have different sizes of aggregates, often resembling a cottage cheese-like texture (Figure 6). Aggregates can also be identified on the roots; if the soil sticks to the roots, the aggregate stability is likely better compared to soil where it falls off the roots when pulled out of the ground (Figure 7).

Figure 6. An example of a soil with good aggregate stability.

Figure 7. Indication of good aggregate stability by looking at the root systems.

While the amount of clay in the soil cannot be changed, biological activity and root action can be promoted to improve aggregate stability. Cover cropping provides plant residues for organisms to break down and release biological glues; the root system itself can also help improve aggregate stability.

THE FLIP SIDE

Despite the benefits noted regarding cover crops in protected spaces, there are some drawbacks:

- Incorporating cover crops can translate to increased tillage. It is possible to incorporate cover crops into no-till systems, but it just requires careful selection of species (those that winter kill, for example) and some added time for decomposition before coming through with the next crop
- Reduces the amount of time the greenhouse can be used for cash crops
- Cover cropping needs to be viewed as a long-term investment, as benefits are not necessarily noticeable from year to year.
- Pests and diseases are more likely to survive in a cover crop compared to bare soil. Some cover crops can even help propagate pests and diseases, depending on compatibility. It is not as simple as switching out crops - cover crops need to be carefully selected.
- Field machinery may be too big for protected spaces, meaning more tedious and labour-intensive seeding and termination compared to implementing a similar crop outdoors. This will vary on a case-by-case basis.

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While this factsheet mainly focuses on cover cropping through the winter months, this practice can be implemented year-round. Early producers of beans, for example, can see a tunnel sit empty from mid-July until the following spring, which presents an opportunity to introduce a summer cover crop to build the soil and manage pests (Table 1). Finding the most suitable cover crop species will vary depending on the main goals of the farm and the timing of implementation. For a no-till farm, for example, selecting a crop that will winter kill gives the crop plenty of time to break down before the next round of plants go in the ground in the spring. Where clover is slow to establish, a longer timeline will be required to see the benefits of the cover crop, which is not always possible depending on the cropping schedule. Execution gets a bit more complicated when the primary goal is breaking a disease cycle. Some diseases and pests have wide host ranges, meaning the act of changing the crop may not be enough to stifle population growth. It's also important to consider the mode of action of the cover crop. For example, brown mustard can effectively reduce populations of wireworm, nematodes, fusarium and pythium but it needs to be mowed and incorporated into the soil to act as a biofumigant. If the mustard is grown strictly as a cover crop without being incorporated, it will not reduce pest and disease populations and can act as a host for pests such as nematodes. With such a new practice for protected spaces, there is still much to learn about cover cropping and the best ways to incorporate them into cropping schedules. Understanding the benefits and risks is a good place to start in deciding how it can best be included on farm, to promote carbon sequestration and support soil health into the future.

Table 1. A list of suitable high tunnel cover crops, broken down by group and ideal implementation time. Much of this table was generated by the University of Minnesota (Perkus, Pfeiffer, Thurston, Li and Grossman: https://eorganic.org/node/25214).

Implementation Target	Legumes	Grasses	Brassicas	Other
Winter Kill	Cowpea	Oats Japanese Millet	Tillage Radish	Buckwheat
Overwintering	Hairy Vetch Red Clover Austrian Winter Pea Crimson Clover	Winter Rye* Winter Wheat	Most cover crops are not reliably winter hardy in Northern Regions	
Summer Planted	Cowpea Sunn hemp	Sudangrass Sorghum Sudangrass Pearl millet	Tillage Radish	Buckwheat
Spring Planted	Hairy Vetch Clovers (red, white, sweet, crimson, berseem)	Winter Rye* Spring Wheat Oats	Tillage Radish	
Intercrops/Pathway Crops	Clovers (red, white, sweet, crimson, berseem)	Fescues Perennial Ryegrass Winter/Cereal Rye Italian Ryegrass		
Disease/pest (nematodes, wireworm) suppression		Sorghum Sudangrass Pearl Millet	Brown Mustard	Buckwheat

*** It has been documented that winter rye can cause inhibition of plant growth. If your next cash crop is direct-seeded into the soil, this may not be the best option.**

Interested in learning more about managing soil health in protected spaces? Check out the following resources or reach out to Perennia's Protected Crop Specialist.

'Greenhouse Playlist' on Perennia's YouTube Channel

'Protected Crops' Commodity Information located on **perennia.ca**

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