GREEN MANURES AND AMENDMENTS FOR ORGANIC SYSTEMS FINDINGS FROM EASTERN CANADA

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Maintaining adequate soil fertility to sustain acceptable yields has long been regarded as one of the greatest challenges for organic producers. Organic farmers must adopt sound crop rotation that build fertility by promoting good soil health. This is achieved through the use of crop rotation including soil building crops and using organic soil amendments. Researchers in organic field production have been supporting producers in their efforts to develop farming systems that promote soil ecosystem health, reduce nutrients surpluses, and improve soil organic matter quality, while enhancing yields. This publication brings together findings from years of research on green manures and organic amendment management in organic cropping systems in Eastern Canada. The research discussed here was done mostly in potato and wheat systems in the Maritimes, QC and ON.

Topics explored in this bulletin:

- How green manures influence nutrient availability for wheat, potato, and forage crops
- Soil quality and soil health benefits of green manures
- How green manure management influences the soil ecosystem and biota

A green manure is a crop cultivated with the purpose of improving soil fertility. Although not seeded to be harvested, it may provide financial benefits for farmers, in addition to other non-monetary benefits. Green manures can reduce erosion, improve soil tilth, smother weeds, support pollinators, and reduce pest pressure.

Organic farmers are interested in the effects of green manure use on both nutrient cycling and the soil ecosystem. These effects depend on many factors including the rotation sequence, fertilization strategy, type of green manure, whether it is incorporated, tillage system, and farming intensity. Depending on the farm goals, different green manure crops offer the possibilities of growing full-season or partial-season crops, annual, biennial, or perennial crops, and as a pure stand or a mix of species.

Whereas N is typically the limiting factor for yields in organic field crop systems, legume green manures constitute an important source of N through biological fixation. Legumes can supply a part of the N fixed by symbiosis with soil microorganisms to the following crop. Some common legumes cultivated as green manures are peas, clovers, alfalfa, and vetches. In some cases, phosphorus (P) supply may also be limiting yields, and this bulletin discusses some P management options as well.

A green manure of buckwheat

ORGANIC AMENDMENTS – THE SWEET SPOT

Dr. Derek Lynch, a researcher at Dalhousie University, has been working to improve soil health and nutrient management within organic cropping systems. In 2008, he and his collaborators demonstrated that commercial dehydrated poultry manure (Nutriwave 4-1-2) was effective in promoting higher yields in potato crops at a rate of 300 kg N per ha, but could delay plant maturity and increase residual nitrate (NO_3) at higher rates (600 kg N per ha).

Another commercial product, hog manure-sawdust compost, with a high C:N ratio, could also provide yield benefits, but at a high rate of application. However, the apparent benefit from the compost was due to a non-nutrient effect on soil properties, stimulating mineralization.

Dr. Lynch and his team demonstrated that the application of moderate rates of N in amendments or organic matter could still enhance organic potato yields, while at the same time reducing the environmental impact from NO_3 leaching occurring between growing seasons (Figure 1).

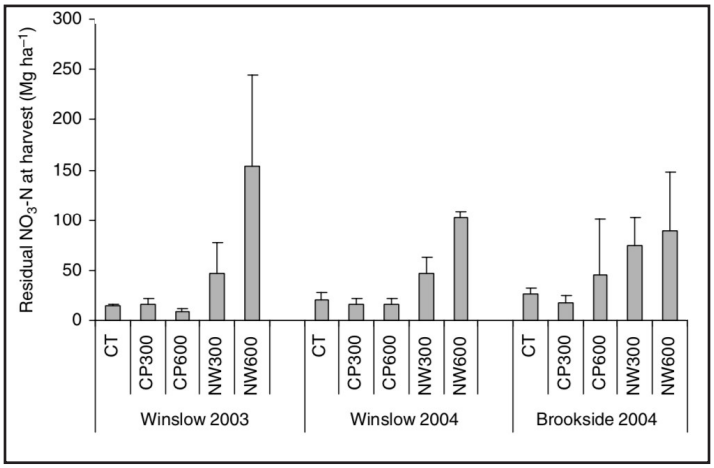

Figure 1: Soil (0–30 cm) residual NO_3^--N at harvest as affected by organic amendments over the three site-years (CT, un-amended control; CP300 and CP600, hog manure–sawdust compost applied at 300 and 600 kg total N ha^{-1}, respectively; NW300 and NW600, pelletized poultry manure 'Nutriwave' applied, at 300 and 600 kg total N ha^{-1}, respectively). [Lynch et al., 2008]

DEFINITION

The ratio between carbon and nitrogen (C:N) present in organic material determine its **rate of decomposition**. This rate is also affected by the carbon "quality" (lignin vs hemicellulose).

GREEN MANURES AND PEST PRESSURE

In a related 5-year cropping systems experiment, the Dalhousie research team examined nutrient cycling using different green manures combined with fertility treatments in organic potato production. This experiment also included cash crops with low nutrient demand (bean and carrot) in a 5-year rotation, and considered different green manure frequency (three times or twice) and types (red clover, oat/red clover, oat/pea/vetch). Similar tuber yields and dry matter contents were obtained for all cropping rotations as they all included a green manure prior to potato production. The results suggested that green manures provide a level of nutrients to allow acceptable organic potato yields (25 tonnes per ha compared to a national average of 31 tonnes per ha), considering the organic price premium. At the same time, average tuber size increased as soil N supply increased with green manures and amendments.

A green manure of oats, peas and vetch

DID YOU KNOW?

By decomposing and controlling nutrient cycling, soil organisms and microbes contribute to creating good soil structure and may prevent plant diseases.

Nevertheless, specific types of green manures in a rotation may favour certain pest insects in a subsequent crop. For example, greater wireworm damage or infestation of nematodes (*Pratylenchus* spp. and *Meloidogyne* spp.) are a concern in potato tubers following red clover. In the 5-year cropping systems trial described above, an oat/pea/vetch mixture was as an effective green manure substitute for red clover with respect to crop nutrient supply, while also reducing potato marketable yield losses due to wireworm damage in some years (Fig.2).

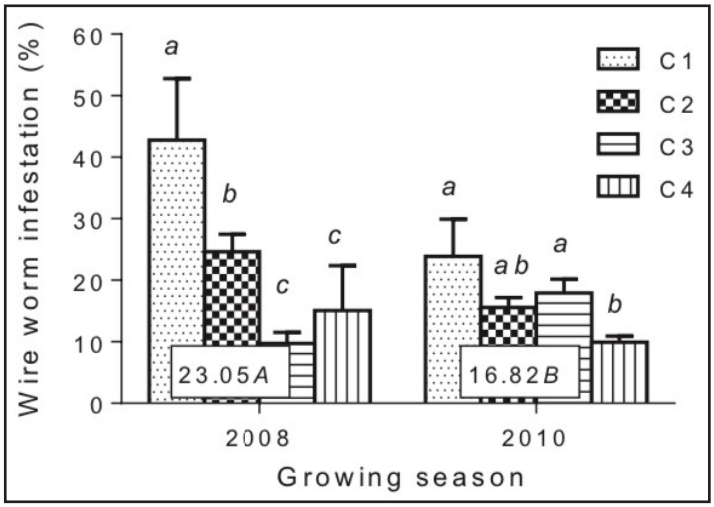

Figure 2: Wireworm infestations as influenced by crop rotation and growing season. (C1, oats/red clover (RC) – carrots - oats/RC - RC - potatoes; C2, oats/RC – RC – potatoes - beans/buckwheat (Bu) - carrots; C3, oats/RC - beans/Bu – carrots – oats/pea/vetch (OPV) - potatoes; C4, oats/RC – carrots - beans/Bu – OPV - potatoes. [Alam et al., 2016]

AMENDMENTS AND GREEN MANURES – JOINING FORCES

In Nova Scotia (Dalhousie University) and Quebec (CEROM - Centre de Recherche sur les Grains Inc.) a 2014-2016 study evaluated nutrient cycling effects of different combinations of annual legume green manures and organic amendments in organic wheat systems. A positive wheat yield and grain protein response was obtained following all green manures (hairy vetch/oat, common vetch/oat, and red clover) compared to a pre-crop of soybean (Fig.3). By testing four rates of a commercial organic fertilizer (Actisol 5-3-2), the study showed that a legume green manure was equivalent to the application of 800 kg per hectare (40 kg N per ha) of dehydrated poultry manure (DPM). The wheat yield obtained from a combination of DPM at a rate of 40 kg N per ha with a pre-crop of hairy vetch/oat green manure was similar to the yield provided with 120 kg N per ha DPM applied without a legume green manure as a pre-crop. Overall, among the green manures, N supply was greatest from the hairy vetch/oat green manure, and supported the highest wheat yield and protein content.

Spring wheat trial assessing response to dehydrated poultry manure and different green manure pre-crops in Nova Scotia.

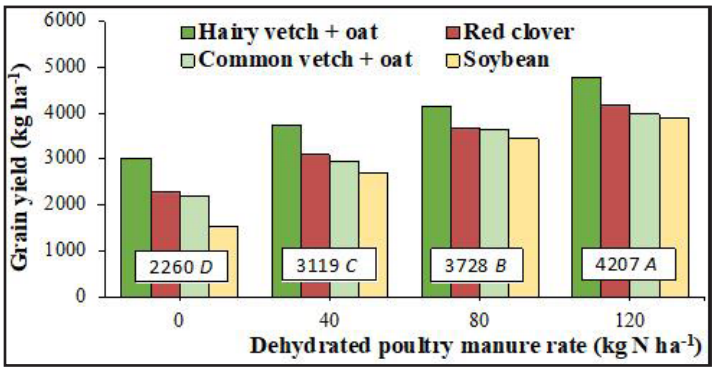

Figure 3: Crop rotation and poultry manure application impact on wheat yields at the Nova Scotia site (sandy loam). Values in boxes represent the average wheat yield across the four crop rotation at each rate of poultry manure. [Alam et al., 2018]

DID YOU KNOW?

Hairy vetch can produce as much as 7 tonnes of dry matter per ha, capturing about 250 kg of N per ha, of which 40-60% may be available to the next crop.

CAN NITROGEN SUPPLY BE PREDICTED?

Organic amendments and crop residues contribute to soil organic matter, which supplies between 20 to 80% of crop N requirement. Nevertheless, rapid changes of soil mineral N are common in Eastern Canada due to loss of residual N in the late fall and winter. Climatic conditions are an important source of variation for N supply to crops and may vary among years. Insufficient spring soil N supply will limit yields, especially for crops that have high N demands for long periods, like corn and potatoes. Alternatives to standard lab extraction procedures are needed to better predict the supply of N provided by mineralization of soil organic matter (and soil amendments).

Plant Root Simulators probes (PRS®) are a soil analysis tool made of ion-exchange membranes used to measure the supply of nutrients from soil under field or lab conditions. Unlike chemical extraction techniques in the lab, the probes are buried in the soil and collect nutrients onto their + or – charged membranes as they are released from the soil, much as they would become available to a plant. In 2009, this tool was assessed in organic potato systems by Drs. Mehdi Sharifi, Derek Lynch and colleagues, to see if it could help optimize N management. The PRS® probes were effective in measuring the supply of N from spring applied soil amendments with a C:N ratio of 15:1 or lower (e.g. dehydrated poultry manure). PRS® probes could help limit the consequences of an unbalanced N supply by predicting how much N is mineralized early in the season.

While the PRS® probes have helped to better understand the timing and amount of nutrient supply in the soil, further research is needed to explore this tool in developing nutrient management plans for Eastern Canada.

DID YOU KNOW?

Plants feed microbes! The zone of the root's influence on the soil is called the rhizosphere. Ten to hundred times mores microbes are present in that zone as root exudates (organic compounds) stimulate fungi and bacteria.

An oat, pea, and vetch mulch in the spring.

WHAT ABOUT PHOSPHORUS?

Few phosphorus fertilizer sources are available to organic growers, and those that are available have a low availability of P for plant uptake. Much of the phosphorus that organic crops use are released from the decomposition of organic matter. Buckwheat is known to have a high P uptake ability. Ms. Arcand, Dr. Lynch, and collaborators explored whether buckwheat could influence soil P fertility when used as a green manure crop by enhancing P availability alone, or in combination with either supplemental rock P of igneous or sedimentary origin. It was found that buckwheat obtained P more easily from the sedimentary type, but the following crop yield was not increased by the residues of the green manure crop or by the addition of either type of rock P.

The researchers also found that soil microbial biomass was positively affected by green manure residues in the 2nd year of the experiment, but the green manure residues did not successfully affect crop yield through enhanced bioavailability of soil P. PRS® probes were able to detect that the P concentration contained in buckwheat tissue increased soil P available to the crop more than the rock P treatments, but the differences were not large enough to increase annual Italian ryegrass yields.

This study was conducted in Ontario at a site with high soil pH and Ca concentrations; conditions which lower P availability. Thus, simply applying rock P or growing buckwheat for one year will not result in higher yields of the following crop. Ultimately, soil P fertility

A field of buckwheat green manure.

management requires long term soil management possibly with the support of mycorrhizal inoculants.

IMPACTS ON SOIL QUALITY

To assess green manure impact on soil quality, the Dalhousie research team assessed potentially mineralizable nitrogen, microbial enzymatic activity, and microbial biomass as indicators of soil quality. In a 2014 experiment, they tested green manures in different crop sequences combined with off-farm composts. They wanted to know how these combinations maintained soil quality while fulfilling organic potato N requirements. Annual legume (oat/pea/vetch mixture) and biennial legume (red clover) had similar effects on soil physical properties when included in 5-year crop rotations. A biennial red clover green manure can considerably improve nitrate levels in soil but can also increase nitrate leaching in certain conditions. The results revealed that inclusion of an oat/pea/vetch mixture, plus a low demand cash crop like carrots or beans in the rotation was a good replacement for 2 years of red clover. This alternative gave a financial return for potato growers, and in the meantime, provided environmental benefits linked to soil quality.

A field of oat/pea/vetch green manure at the Dalhousie research center.

GREEN MANURE TERMINATION: IS NO-TILL WORTH IT?

In 2018, Drs. Carolyn Marshall and Derek Lynch experimented with no-till termination of green manures using a roller-crimper. They found that the practice increased soil organic carbon (SOC) pools, compared to a tilled green manure system. The effect was long-lasting: the increase in SOC was still detectable 3 years after the green manure termination. Also, a higher concentration of particulate organic matter (or 'active' SOC) at the soil surface was observed following no-till termination. Although SOC can be more concentrated in the surface layer of the soil under a conservation or zero tillage system, similar overall soil profile SOC levels are generally found in both conventional and conservation tillage. However, the soil organic matter C:N ratio was increased in no-till plots suggesting different rates of decomposition, but also, that N losses possibly occurred in the no-till treatment. Further

No-till wheat emerging in an oat/pea/vetch mulch.

investigation on SOC distribution at deeper soil depths is needed to fully determine SOC fate when green manure are terminated using organic no-till.

More recently, Dr. Marshall and Dr. Lynch continued their research on organic green manure termination practices, this time investigating the impacts on soil biota population dynamics. Different timing of tillage (fall or spring), and green manures (hairy vetch/oat and red clover) were tested. Hairy vetch/oat increased the overall soil microbial biomass, with the no-till and fall tillage treatments, but the effect only lasted 2 months in the spring. Longer lasting effects observed from the green manure management practices varied depending on which soil organisms were being observed. Earthworms were the most sensitive to tillage of a green manure (Fig.4) but recovered after 2 years. Negative impacts on earthworm populations could therefore be mitigated if occasional tillage was used in the context of a long organic rotation. Moreover, divergent effects on predators were noted: more spiders were captured in no-till than in spring tilled plots (Fig.5) while fewer beetles were captured in the no-till plots. It is therefore difficult to draw a clear conclusion for no-till benefits to soil biota, as it largely depends on type of green manures, soil organism taxa, and climatic conditions.

WHAT IS A "HEALTHY" SOIL?

Soil can be considered to be a vital living system within an ecosystem. It supports the health and productivity of plants and therefore also the productivity and health of livestock. A healthy soil consists of good physical, chemical and biological properties. These can require numerous measurements. However, many soil organisms such as bacteria, fungi, and nematodes live in the soil and their populations respond to the soil environment. Soil health assessment can be made by measuring the abundance and diversity of these populations, since they are sensitive to human disturbance of soil environment.

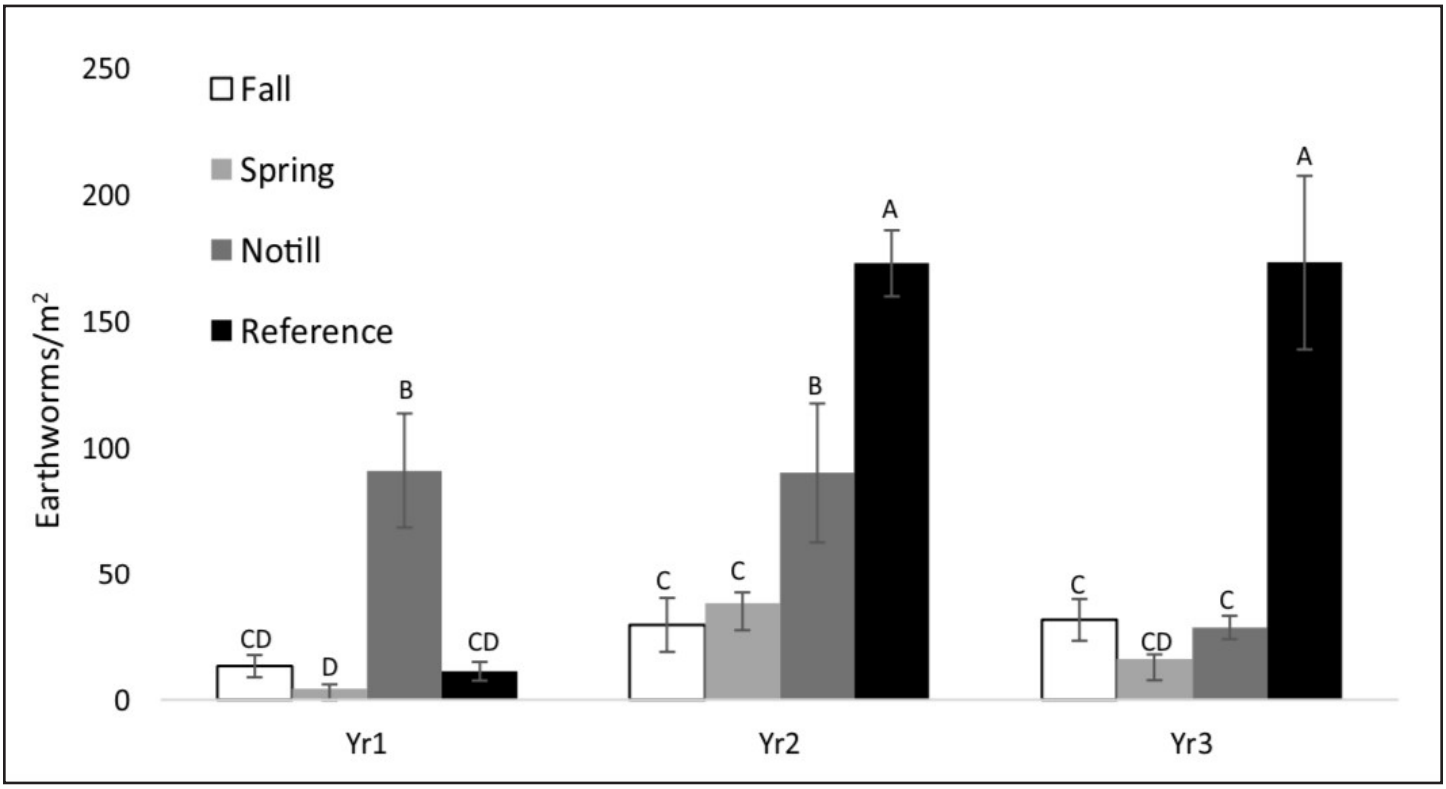

Figure 4: Earthworm abundance (per m2) in Bible Hill, NS by year after green manure termination. Treatments are (i) fall (tilled in fall), (ii) spring (tilled only in spring), (iii) no-till (rolled only), and (iv) reference (undisturbed field margin). Yr1 is the wheat phase, the year following green manure termination, Yr2 is the partial fallow/fall rye phase, and Yr3 is the soybean phase. Different letters indicate significant differences. [Marshall and Lynch, 2020]

From years of experimentation, the researchers conclude that green manures promote crop yield by providing both nutrient and non-nutrient benefits through their effect on soil properties and organic matter. Nutrient cycling and soil ecosystem functioning are more influenced by specific cropping practices, such as the rotations, amendments and tillage practices discussed in this bulletin. Improved understanding of the effects from green manure management in organic farming can be useful beyond organic – various farming systems can use green manures to sustain and enhance the soil and ecosystem health. Further analysis to value green manure benefits may help further recognize their contribution to yields, and their diverse benefits to agroecosystems as a whole.

DID YOU KNOW?

According to the ecological laws, including green manures in cropping systems favors diversification and allows a larger diversity of the soil biota in the ecosystem.

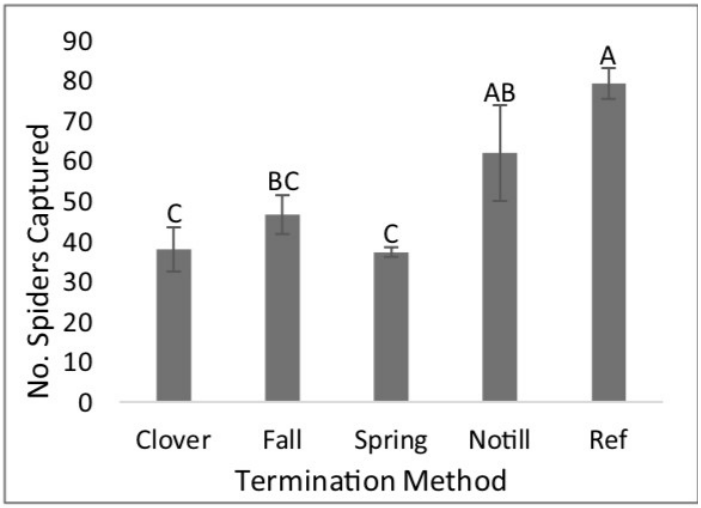

Figure 5: Cumulative spider captures in Yr1 and Yr2 combined. Treatments are (i) clover (2 years of red clover fall tilled), (ii) fall (HVO tilled in fall), (iii) spring (HVO tilled only in spring), (iv) no-till (HVO rolled only), and (v) reference (un- disturbed field margin). Different letters indicate significant differences. [Marshall and Lynch, 2020]

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Earthworm sampling in no-till mulch, June 2016.

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ABOUT THE ORGANIC SCIENCE CLUSTER

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