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RESEARCH & INNOVATION CENTRE

State of the Industry Report on Soil Management

Ontario Field Tree Nursery Producers

October 2020

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1 A Note from Tony DiGiovanni

Soil is life! Think about this phrase for a minute. What does it mean?

Soil is the foundation of all plant life. Without plant life there would be no human life. Period.

Soil is the repository for the essential water that plants require. Water too is life!

The complex exchange of oxygen and carbon dioxide needed for optimum plant growth happens within the pores of the soil particles. Air too is life!

The nutrients required for plants to thrive also reside in the soil. The nutrients are unlocked by billions of microorganisms that magically break down the organic matter into soluble nutrients taken up by the plant. Organic matter too is life.

Additionally, soil is how plants hold themselves up. Somehow, they are able to anchor themselves by spreading their roots and grabbing hold of the soil particles. This can only happen in soil that is not severely compacted.

In a song by Bruce Cockburn, he writes, "If you stare at too much concrete, you forget the earth is alive." Soil is alive.

With such a direct correlation between soil and survival it seems most of us take soil for granted. Soil deserves more respect. It deserves more research. It deserves more of our attention. This is really what this study is about. It is about soil health for plant survival. Specifically, trees in this instance but the principles are the same for all plant growth.

Ultimately, this study is about human survival too. At the base, all nature is interrelated and interdependent. But it is also more. The benefits of plants are many. They provide aesthetic, environmental, health, spiritual, economic, recreational and legacy benefits. From an economic perspective, plants are the main economic driver for an 8 billion dollar living green infrastructure profession that employs over 100,000 people in Ontario alone. The industry feeds many families while improving and enhancing the quality of life for all (even those that are not even born yet). Soil is the foundation for all of this.

Vineland Research and Innovation Centre (VRIC) is committed to helping the horticulture industry thrive. As an association, Landscape Ontario Horticultural Trades Association is thrilled and proud to be involved with such an august and caring organization like Vineland who are truly making a difference. They are focused not on themselves but on improving the lives of those in the horticultural occupations and ultimately in making the world a better place for the larger community.

The information is this document is necessary. It is helpful. It provides data driven and relevant solutions to age-old problems. In particular, the case studies make the information accessible and real. On behalf of the horticultural community, I want to thank Vineland for taking on the burden and responsibility for making the horticultural profession better.

Tony DiGiovanni
Executive Director
Landscape Ontario Horticultural Trades Association

2 Ontario's Field Tree Nursery Industry

It is clear that the products of Ontario nurseries are important eco-service providers for our landscapes. Nurseries are well positioned to capture market opportunities related to increasing environmental concerns and a growing demand for green space, however, producers will also undoubtedly need to continue to meet sustainability targets on the farm. There is a growing expectation from society that agricultural and horticultural products are produced sustainably. In fact, the environmental sustainability of ornamental plant production nurseries are beginning to be assessed at regional scales to better understand how the sector stacks up against environmental sustainability targets[1].

The benefit to producers that effectively implement sustainable management practices is indeed multi-faceted. Of particular interest are the implications that various soil management cultural practices yield in terms of economic benefits for field tree nursery producers as well as the environmental benefits. In 2019, there were 6.3 million field-produced trees in Ontario nurseries and 1.2 million container-grown trees[2]. This means that a significant number of trees that ultimately contribute to the vitality of our landscapes, are produced and grown in fields in Ontario. Soil management is critically important for field tree nursery producers and *healthy soil* is the foundation upon which a sustainable agricultural production systems are built. Best management practices that improve soil health contribute to mitigating the effects of climate change by lowering greenhouse gas emissions, reducing nutrient input losses from fields, and improving resilience to drought or excessively wet conditions.

Although soil is the key ingredient for the success field tree nursery production, the impacts of different cultivation practices currently used by Ontario nursery tree producers have not been evaluated to understand their efficacy for improving soil health, tree growth or production costs. Greater understanding around producers' objectives for soil management, barriers to the use of different cultural practices and gaps in information and resources, are important to understand as a foundation on which support for the Ontario field tree nursery industry can grow.

The purpose of this report is to provide an evaluation on the current state of the industry with respect to soil management practices used by Ontario field tree nursery producers. As part of a collaborative project implemented by Landscape Ontario and Vineland Research Innovation Centre (Vineland), funded by the Ontario Ministry of Food Agriculture and Rural Affairs (OMAFRA), we administered a questionnaire to over 50 Ontario tree nursery producers in the summer of 2020. Of the 50 producers invited, 29 responded and completed the survey that sought to understand the range of soil management practices used by Ontario field nursery producers. Herein, we will report on the findings from the survey and describe the state of Ontario field tree nursery producers with respect to soil management and soil health.

[1] Giulio Lazzerini, Paolo Merante, Stefano Lucchetti & Francesco Paolo Nicese (2018) Assessing environmental sustainability of ornamental plant production: a nursery level approach in Pistoia District, Italy, Agroecology and Sustainable Food Systems, 42:8, 911-932, doi: 10.1080/21683565.2018.1466755

[2] Statistics Canada. Table 32-10-0031-01 Nursery tree and plant production.

3 The State of Soil Management and Soil Health

3.1 What is the difference between soil management and soil health?

Farmers are demonstrating a growing interest in soil health and understanding how to improve the quality of their soils through changing management practices. **Soil management** is the suite of operations, practices, and treatments that can be used to protect, improve or enhance soil performance. It can include beneficial soil enhancing conservation practices, or the active restoration of soil qualities through the use of cover crops or the addition of amendments. Soil management, however, can also include practices like clean cultivation that degrade soil health. **Soil health** is a measure of the capacity of a soil to provide ecosystem services. Therefore, soil management are the operations or practices that can be used to enhance soil health. A major challenge of soil management is to support agricultural/horticultural productivity without jeopardizing other ecosystem services[3].

Soil health refers to the capacity of soil to function as a complete ecosystem capable of supporting the myriad of organisms that live in the soil and by extension sustain plant, animal, and human life. Soil health is assessed using a set of indicators that encompass physical, chemical, and biological soil properties. Healthy soils provide regulating and supporting ecosystem functions such as nutrient cycling, water infiltration and retention, gas exchange, pest and disease regulation, biodiversity, and storage of carbon, many of which highly impact agricultural productivity. Soil management strategies that have been suggested to promote soil health relate primarily to increasing crop diversity, avoiding mechanical soil disturbance, and adding organic amendments[4].

Figure 1. Strategies inherent to building soil health.

3.2 What are the primary soil management challenges affecting soil health?

Despite growing interest amongst tree producers, soil health can often be a secondary consideration when faced with other management needs. Where the vast majority of nurseries prioritize soil health in their current field management, 54% of growers surveyed indicated that soil health is often superseded in practice by other management requirements. The day-to-day demands of field management can easily detract and defer efforts to build and improve soil health in favour of response and mitigation activities that are required to manage the various soil level challenges associated with field production. The three primary challenges

[3] Williams, H., T. Colombi, T. Keller. 2020. The influence of soil management on soil health: an on-farm study in southern Sweden. Geoderma, 360. http://doi.org.10.1016/j.geoderma.2019.114010
[4] Kibblewhite M.G, Ritz K and Swift M.J. 2008. Soil health in agricultural systems Phil. Trans. R. Soc. B363685–701 http://doi.org/10.1098/rstb.2007.2178

affecting soil management as identified in the Vineland survey of Ontario tree nursery field producers are weed management, soil compaction and loss or difficulty building organic matter.

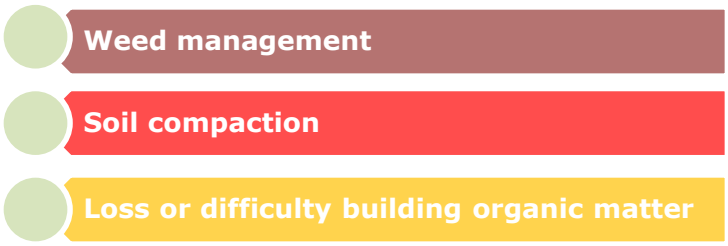

Figure 2. Top three soil management challenges affecting field production as identified in the Vineland survey of Ontario tree nursery producers.

Together, these challenges contribute toward the development and persistence of field conditions that demand continuous spraying, tilling and fertilizing to support tree growth[5]. The practices that are fundamental to navigating common soil level challenges can be costly, time consuming and self-perpetuating in nature. Practical, stepwise interventions designed to collectively manage weeds, decrease compaction and build organic matter - while simultaneously building soil health, are needed to support the development and achievement of soil health goals and objectives throughout the industry. Where there are vast resources designed to support soil productivity and health across agricultural, orchard and commercial forestry operations, Ontario field tree producers are in need of data driven strategies and guidelines that are specifically tailored to field tree production.

The current research and upcoming Nursery Soil Health Report seeks to support the industry by collecting, interpreting and presenting new and existing data related to soil management and soil health in a way that is relevant and applicable to the tree nursery industry. The Report will additionally present resources and information generated in partnership with Ontario nursery field producers, according to the demonstrated needs and interests of the industry.

4 The State of Field Management

4.1 What are the common management practices implemented for field production?

Adapting field management to build soil health requires a fundamental understanding of the common practices that characterize field management throughout the production cycle as well the consequences of those practices with respect to soil chemical, physical and biological function. Below, we provide an overview of the most commonly identified soil management practices used by Ontario tree nursery field producers between, prior to and during production. These foundational practices have defined the state of nursery soils and should thus be evaluated with respect to soil health, so as to begin to understand how current management contributes toward maintaining, improving and degrading soil health.

[5] Calkins, J.B., and B.T. Swanson. 1998. Comparison of Conventional and Alternative Nursery Field Management Systems: Soil Physical Properties. Journal of Environmental Horticulture. (2): 90–97. doi: https://doi.org/10.24266/0738-2898-16.2.90

4.1.1 Field Practices between Production Cycles

The practice of resting fields between production cycles is sufficiently prevalent across the industry to be considered an established practice. Approximately 86% of tree producers surveyed rest fields, many of which use annual single, multispecies or cash cover crops for 1 to 3-years between tree production cycles. Resting fields, particularly with the use of a cover crop, can contribute toward notable soil health benefits, ranging from increased soil organic matter content, to improved tilth and the establishment of beneficial soil macro and microorganisms. Resting bare fields although effective in reducing demand on the soil for the duration of the rest period, can degrade soil where exposed soil is more readily susceptible to weed pressure, erosion and nutrient leaching. The duration for which a rested field in in cover is critical to maintaining the soil health benefits accrued by resting. Although 88% of growers who rest their fields use a cover crop for some portion of the rest period, 52% are doing so for half the allocated rest period (approximately 6 months of each calendar year). Only one of the 29 surveyed tree producers noted the use of a single perennial cover crop, year round during the rest period. Increasing the diversity and duration of cover crops between production cycles is a primary mechanism by which tree nurseries can begin to expand upon existing soil management practices to improve and build soil health across field operations.

4.1.2 Field Practices prior to Production

Primary soil management practices implemented prior to production include tillage and the application of weed sprays. Secondary practices, implemented by 55% and 45% of the tree producers surveyed include the application of an organic amendment and mechanical decompaction, respectively. Tillage and the application of weed spays are largely soil health degrading practices that can contribute toward increased compaction and reduced soil aggregation[6]. Alternatively, the use of organic amendments and mechanical decompaction contribute toward improving soil health by increasing soil organic matter content and building physical, chemical and biological resilience that allows the soil ecosystem to collectively develop, function and adapt in response to environmental change[7]. These four central practices implemented by tree producers prior to field production; reflect the top three previously identified soil management challenges of (1) weed management, (2) soil compaction and (3) loss or difficulty building organic matter, reiterating the need for comprehensive management strategies to transition the focus of pre-production management from reactive actions toward more continuous and sustainable soil-building practices. Where soil management strategies central to building soil health include, minimizing mechanical disturbance, maximizing diversity and increasing organic amendments, pre-production practices present an opportunity for growers to incorporate the range of soil health building strategies into their standard practice.

4.1.3 Field Practices during the Production Cycle

Use of fertilizers, weed sprays and tillage are amongst the dominant management practices implemented by field producers during the production cycle. More than 70% of the Ontario

[6] Calkins, J.B., and B.T. Swanson. 1998. Comparison of Conventional and Alternative Nursery Field Management Systems: Soil Physical Properties. Journal of Environmental Horticulture. (2): 90–97. doi: https://doi.org/10.24266/0738-2898-16.2.90
[7] Magdoff, F. (Ed.), Weil, R. (Ed.). (2004). Soil Organic Matter in Sustainable Agriculture. Boca Raton: CRC Press, https://doi.org/10.1201/9780203496374

tree nursery producers surveyed identified these practices as being central to soil management during production, demonstrating the persistence of the three top ranked soil management challenges (weed management, soil compaction and loss or difficulty building organic matter), despite concerted efforts to build and improve soil health outside of production.

Case Study

Experimenting with best practices to support the optimal use of organic amendments in building soil organic matter

Where rest periods between production cycles are widely allocated toward restoring soil function and building soil health, a characterization of best practices related to the use of organic amendments and cover crops is fundamental to optimizing strategies for improving organic matter content in post-production field soils.

The characterization of soil health impacts associated with the use of cover crops with variable rates of organic amendment, can inform practices implemented between production cycles to maximize soil building during the rest period. In August 2020, a multifaceted trial was established at Kobes Nurseries to capture the effects of cover crops and organic amendments on soil health between production cycles. A cover crop of sorghum-sudan grass was established with a 0, 1 inch or 2-inch application of nursery produced compost, to gain a detailed understanding of the variable benefits associated with increasing rates of applied organic amendment. A comprehensive analysis of soil health, evaluating soil physical, chemical and biological function; will be used to quantify and characterize changes in field soil and optimize the use SOM building practices to maximize improvements to soil health.

KOBES NURSERIES INC.

Clean cultivation, constitutes the primary form of cultivation in tree rows where 86% of tree producers surveyed identified the use of either clean cultivation or weed spray as being central to the management of trees rows during production. Clean cultivation and cover crops were the dominant forms of cultivation used in drive rows during production. Unlike the time between or directly prior to the production cycle, which is largely allocated toward building soil physical, chemical and biological health, production is inherently centered on optimizing

the growth and performance of trees and requires that soil health be sufficiently established and sustained to maximize productivity at the tree level.

Case Study

Experimenting with cover crops for weed control

Where over 75% of field producers surveyed identified weeds as being a top soil management challenge affecting production, alternate strategies for managing weed pressure are widely needed to minimize the use of costly, labor-intensive herbicide applications and transition toward more sustainable, soil building practices. Where cover crops are readily used throughout the industry to build soil organic matter, best practices for the use of cover crops to additionally control and manage weeds is of increasing interest. Information on how to select, apply and manage cover crops for weed control is needed to support the multifaceted use of cover crops in tree nursery field production.

In Fall 2020, an experimental cover crop trial was established at Connon Nurseries CBV, whereby two different cover crop mixes were seeded into tree and drive rows during production. The first of the two mixes was a standard orchard mix, selected to maximize establishment under intensive production practices, while the second low-mow mix, was chosen as a robust, low maintenance, low-growing cover to minimize the need for cover crop management during production. A comprehensive analysis of soil health, evaluating soil physical, chemical and biological function; will be used to quantify and characterize changes in field soil and comparatively assess the value of cover crop based weed management with respect to soil health.

Where tillage and weed spays can contribute toward increased compaction, reduced soil aggregation and loss of soil chemical and biological function[8], the addition of fertilizers is needed to maximize the availability of key nutrients and resources needed to support tree

[8] Calkins, J.B., and B.T. Swanson. 1998. Comparison of Conventional and Alternative Nursery Field Management Systems: Soil Physical Properties. Journal of Environmental Horticulture. (2): 90–97. doi: https://doi.org/10.24266/0738-2898-16.2.90

growth, of which field soils are often lacking on account of the aforementioned soil degrading practices. Understanding how soil management during production can actively contribute toward tree growth is essential to establishing and prioritizing best practices that function to build productivity at both the soil and tree levels. 45% of tree producers surveyed identified the use of cover crops as a primary practice during production, demonstrating the integration of soil building strategies traditionally implemented outside of the production cycle into active production practices. The extension of between and pre-production soil building practices into the production cycle establishes a continuous and holistic approach to soil management, by which investments in soil health are not only sustained, but consistently grown at the field level.

5 The State of Soil Organic Matter

5.1 What is soil organic matter?

Soil organic matter (SOM) has profound effects on almost all soil properties – chemical, physical and biological - which is why scientists and farmers interested in improving soil health are focused on management practices that enhance SOM content[9]. While plants cannot consume soil organic matter directly through their roots, the activity of soil biota make nutrients within organic matter available over time. SOM is composed of living microorganisms and plant residues, organic debris in various stages of decay, as well as more stabilized forms of debris, traditionally called humus. More recently, the importance of humus has been called into question as scientists learn about the nature of soil organic matter, where current research suggests that microbial access to SOM is likely more important in determining the level and persistence of SOM in soil than it's perceived stability [10]. SOM is widely understood as an important building block for properties like soil structure and aggregation[11]. Other factors central to tree production that are positively influenced by SOM include water retention and infiltration, soil aeration, nutrient retention and availability and the overall function and stability of diverse assemblages of soil organisms.

SOM ranges have been established in agricultural soils to describe the provision of several soil functions and associated benefits for crop production [e.g. the **Cornell Assessment of Soil Health (CASH)**]. However, there is less information on critical SOM thresholds for tree growth and productivity[12]. Research has demonstrated that increasing soil organic matter to certain levels in urban soils reduces compaction and improves tree growth[13]. Compost-based soil amendments and surface mulch applications can increase organic matter content and available nutrients over time[14]. In the Vineland survey of Ontario tree nursery field producers, 83% of growers indicated having a target organic matter range between 3 and 7%. Only two tree producers identified SOM targets greater than 7% for field production.

[9] Magdoff, F. (Ed.), Weil, R. (Ed.). (2004). Soil Organic Matter in Sustainable Agriculture. Boca Raton: CRC Press, https://doi.org/10.1201/9780203496374
[10] Lehmann, J., & Kleber, M. (2015). The contentious nature of soil organic matter. Nature, 528(7580), 60-68.
[11] Gregorich, E.G., M.R. Carter, D.A. Angers, C.M. Monreal, B.H. Ellert. 1994. Towards a minimum data set to assess soil organic matter quality in agricultural soils. Canadian Journal of Soil Science, 74, 367-385.
[12] Oldfield, E.E., A.J. Felson, S.A. Wood, R.A. Hallett, M.S. Strickland, and M.A. Bradford. 2014. Positive effects of afforestation efforts on the health of urban soils. Forest Ecology and Management, 313, 266-273.
[13] McGrath, D., J. Henry, R. Munroe, C. Williams. 2020. Compost improves soil properties and tree establishment along highway roadsides. Urban Forestry & Urban Greening. 55. https://doi.org/10.1016/j.ufug.2020.126851
[14] Scharenbroch, B.C. 2009. A meta-analysis of studies published in Arboriculture and Urban Forestry relating to organic materials and impacts on soil, tree, and environmental properties. Arboriculture and Urban Forestry. 35(5):221-231.

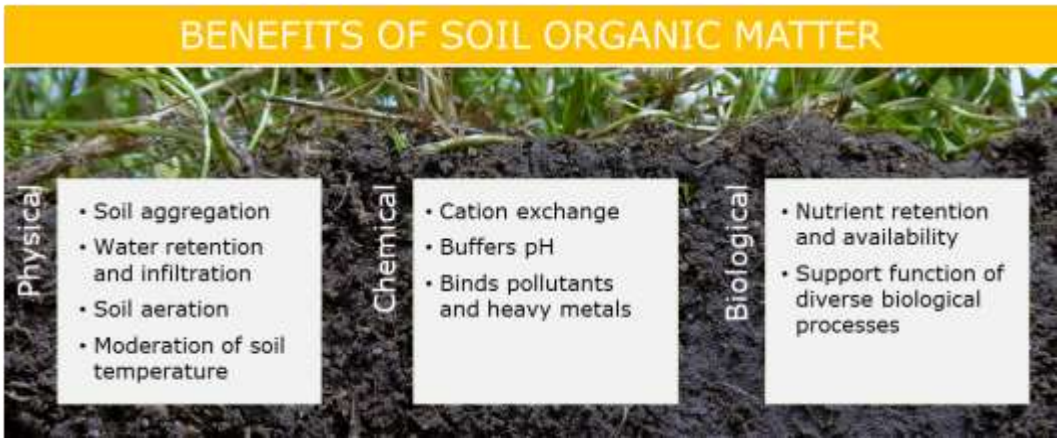

Figure 3. Overview of physical, chemical and biological benefits associated with increased soil organic matter.

5.2 What practices contribute toward building soil organic matter?

Figure 4. Overview of relevant soil organic matter fractions.

SOM in its totality includes (1) soil organisms, (2) simple organic compounds, (3) large, stabilized humic substances and (4) fresh residue in various stages of decomposition. Standard field management practices contribute toward changes in the relative quantity, quality and function of SOM across all four fractions. Addition of organic amendments such as composts, manures and live and incorporated cover crops can influence concentrations of simple organic compounds, nutrient availability for soil organisms and the reservoir of stabilized humic substances and variably decomposed residues in soil. Mechanical decompaction, tillage, planting techniques and rotation, contribute toward the distribution and function of soil organic matter throughout the soil profile while fertilizers, and herbicides can influence the diversity of soil organisms, and simple organic compounds as well as the persistence and stability of organic residues. Understanding the impacts of management practices on the range of SOM fractions would allow for an increasingly comprehensive and holistic approach to building SOM and by extension soil health.

Our understanding of how soil management practices contribute toward building and maintaining SOM is continually evolving with novel research findings and first-hand experiences of scientists and producers at the field level. Farmers are increasingly demonstrating that SOM levels can improved and sustained through the integration of multiple soil health building practices, as opposed to isolated, one-off actions that offer limited returns in the long term. Although the addition of organic amendments will increase SOM levels initially, soil-degrading practices such as continuous tillage and lack of cover crops can limit the overall longevity of organic matter in soil. Although some organic inputs will naturally

break down faster than others, the persistence of SOM is largely contingent on soil level associations between organic matter and the existing chemical, physical and biological systems and structures that work to protect and store SOM in soil. In the absence of these integral systems, SOM is consumed and released into the atmosphere as CO_2, contributing toward loss of SOM as well as reduced carbon capture. Current research suggests that unlike monocultures, diverse communities of plants, such as cover crop mixes; can create a greater abundance of pores within soil that are associated with higher microbial activity and by extension greater soil carbon storage capacity[15]. These pores are not only important for building and maintaining SOM, but are additionally critical for the infiltration, water storage and aeration underlying tree health and productivity. By increasing organic inputs, using cover crops to keep a diversity of living roots in the soil, reducing tillage and keeping the soil covered, producers can gain access to significant and lasting increases in SOM.

In the Vineland survey of Ontario tree nursery field producers, SOM was identified as the most important soil characteristic influencing tree production. Although 64% of producers noted the importance of SOM, only 43% indicated having a defined target or optimal SOM range for field operations. Where a widespread understanding of the benefits of SOM does not coincide with an increased likelihood of having a defined optimal SOM content for field production, guidelines and decision-making tools are needed to support growers in identifying and achieving targets that are specific, feasible and timely within the larger context of tree production.

5.3 How are Ontario tree nurseries using organic amendments to build OM?

Our understanding of the use of organic amendments in field production is centered on the individual and combined uses of manures, composts and mulch. Although the majority of Ontario tree producers surveyed identified SOM as the most important soil characteristic influencing tree growth and productivity, approximately 40% of growers indicated that they do no use any organic amendments in the field. Cost and availability of organic amendments were the primary factors limiting their widespread use in field production. Availability was simultaneously identified as the top contributing factor influencing use of organic amendments amongst the 60% of tree producers who do currently apply organic amendments across their field operations. Where increasing organic amendments is one of the central mechanisms by which tree nurseries can improve and build soil health at the field level, integrative strategies are needed to increase availability and access to affordable, organic amendments throughout the industry.

[15] Kravchenko, A. N., Guber, A. K., Razavi, B. S., Koestel, J., Quigley, M. Y., Robertson, G. P., & Kuzyakov, Y. (2019). Microbial spatial footprint as a driver of soil carbon stabilization. Nature communications, 10(1), 1-10.

Case Study

Experimenting with alternate forms of cultivation

Where established practices suggest that time be allocated toward resting fields to rebuild soil function following intensive production activity, there is growing interest in a more continuous and holistic approach to building soil health at the field level. The active and targeted use of cover crops as an alternative to clean cultivation in tree and drive rows, particularly in conjunction with the use of organic amendments, presents a unique opportunity to prepare fields that are in production for subsequent production cycles. Multifaceted data on the diverse physical, chemical and biological impacts associated with alternate forms of cultivation can inform soil management practices to maximize soil function both during and prior to tree production within a single field.

In the Spring and Summer of 2020, a comprehensive trial was established at NVK Nurseries to capture the soil level impacts derived through the combined used of cover crops, organic amendments and targeted management practices. A series of alternative cultivation practices were implemented across a subset of tree and drive rows, allowing for the assessment of soil health with respect to current and future tree production. Tree row treatments included mechanically tilled clean cultivation, amendment with nursery-produced compost and amendment with nursery produced compost with a two species cover crop. Drive row treatments included a two species permanent cover crop and amendment with nursery produced compost with a two species cover crop. A comprehensive analysis of soil health, evaluating soil physical, chemical and biological function within the context of associated management activities; will be used to quantify and characterize changes in field soil and comparatively assess the value of alternative cultivation strategies with respect to soil health.

Case Study

Experimenting with a multifaceted approach toward building soil organic matter

Where soil organic matter content is recognized by Ontario Tree Nursery field producers as one of the most important soil level variables driving tree production, strategies for maximizing organic inputs are of particular interest to field producers. An understanding of the diverse physical, chemical and biological impacts associated with the individual, as well as combined use of cover crops and organic amendments, can inform pre-production soil management practices to maximize soil function prior to tree production.

In 2020, a multifaceted trial was established at Winkelmolen Nursery to capture the individual as well as combined effects of cover crops and organic amendments on soil health prior to production. A summer cover crop of sorghum-sudan grass was grown and then incorporated with poultry manure, livestock manure or a compost-manure mix and was either left uncovered or seeded with a Fall/Winter oat cover crop. Detailed soil chemistry as well as a comprehensive analysis of soil health, evaluating soil physical, chemical and biological function; will be used to quantify and characterize changes in field soil and comparatively assess the value of various SOM building practices with respect to soil health.

WINKELMOLEN NURSERY LTD.

Compost and livestock manure are the top two organic amendments used in field production. Alternatively, mulch is not readily applied throughout the industry, where only 18% of nurseries surveyed actively use mulch as part of their field management practice to moderate soil temperature and suppress weeds during production. The remaining 82% of Ontario tree producers do not use mulch as part of their field practice on account of high cost, limited availability and uncertainty surrounding the efficacy of the product in the field.

Although compost is one of the more widely used organic amendments, the application of compost is by no means prevalent amongst field nursery producers. Of the 29 tree producers surveyed, 57% indicated that they do not currently apply compost, nor do they intend to apply compost in the future. The 43% of tree producers who identified compost as part of their current management practice, indicated using nursery produced compost, purchased

compost or some combination of the two. Where cost and availability were again the primary limiting factors affecting the use of compost to build to soil physical, chemical and biological function, on-farm composting presents an opportunity for growers to incorporate compost into their standard management practice. The central barriers to on farm composting as identified in the Vineland survey of Ontario tree nursery field producers are (1) composting set up and logistics, (2) information on compost quality parameters for trees and (3) lack of information to support monitoring and maintenance of a composting operation. Technical guidelines and comprehensive resources are needed to inform the production, management and use of nursery-produced compost throughout the field nursery industry.

Case Study

Experimenting with on-farm composting

Given growing interest in the use of compost to build and sustain soil organic matter, on-farm composting presents a unique opportunity for tree producers to repurpose waste materials produced at the nursery and generate sustainable organic amendments on site at a relatively low cost. An understanding of the physical, chemical and biological processes characteristic of composting with tree nursery feedstock's is required to support the development of on-farm composting operations using resources that are readily available at the nursery.

Sensors measuring moisture, temperature and bulk electrical conductivity were installed into composting windrows at Hillen Nursery between July and October 2020 to capture detailed data pertaining to compost pile conditions for the duration of the composting process. This data, in conjunction with chemical nutrient and maturity analyses, are being used to support the development of on-farm composting guidelines and resources for tree producers, providing insight into the unique composition, management and applications of nursery-produced compost.

6 The State of Soil Testing for Field Production

6.1 Why is soil testing important?

Testing field soil to evaluate physical, chemical and biological properties can allow for a comprehensive understanding of soil function as it relates to tree production. Even the most basic soil tests can provide insight into the state of soil health, identifying areas of interest as well as those in need of improvement. Access to timely, reliable and easy to interpret soil testing can allow tree producers to optimize management, between, prior to and during production. Many of the available soil testing resources focus on recommending fertilizing rates to meet the needs of a particular crop. The **OMAFRA Guide to Nursery and Landscape Plant Production and IPM**, provides useful information on how, what and when to sample soils, but is again primarily focused on soil chemical analysis. Although soil chemistry and nutrient requirements are important factors influencing soil productivity, there are countless benefits to be gained by tree producers who choose implement a more comprehensive soil testing regime on their farms. Soil testing and analysis should be conducted with a clear objective, or suite of objectives, to answer specific questions and gain targeted insights into soil physical, chemical and biological function. With consistent and representative soil testing, farmers can characterize and identify trends in their field operations, giving them the information they need to make targeted management decisions.

6.2 Understanding the range of soil testing options

With a growing number of soil testing packages available that offer moderate or comprehensive analyses of the state of field soils, the ability to understand and thereby use soil test results to build and improve practices, is paramount.

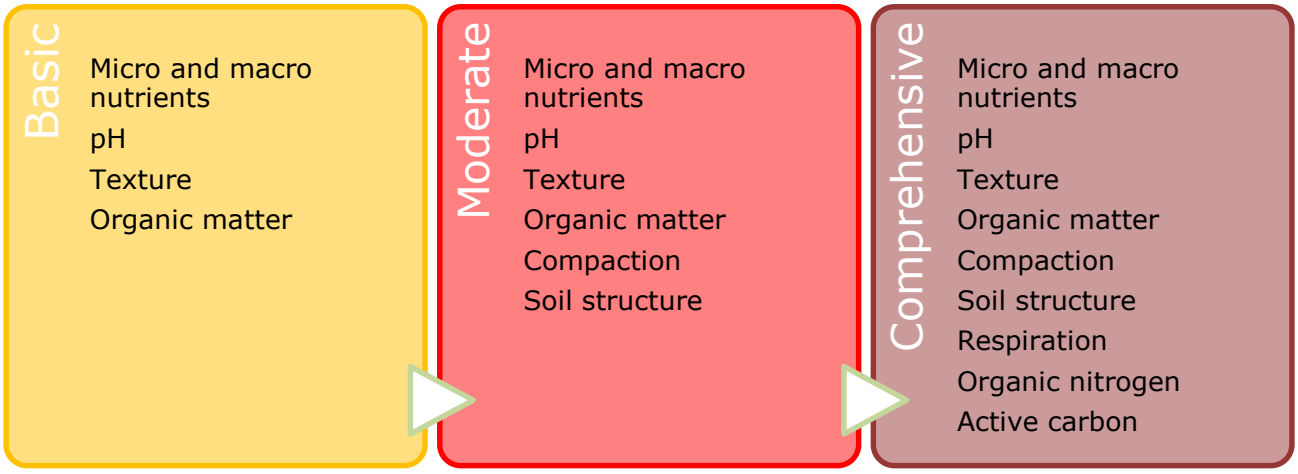

Figure 4. Overview of soil testing options

Basic soil testing packages will typically offer analysis of soil chemical parameters (e.g. micro and macro nutrients) as well as some physical parameters, like texture and organic matter content. Moderate soil testing packages offer those parameters as well as additional soil physical parameters like compaction and/or structure. The most comprehensive soil testing takes a "soil health" approach and service providers seek to provide multifaceted information on the intricacies of soil function with respect to plant survival, growth and productivity [i.e. **Cornell Assessment of Soil Health (CASH)**]. In addition to chemical parameters and

physical parameters, these types of assessments also provide analysis on constraints affecting the complex biological processes inherent to soil health. The more comprehensive approaches serve to build upon the basic and moderate approaches, which have been foundational to agricultural productivity by informing nutrient management since the early 1900s[16]. Where trees are long-lived perennial species that in nature, form complex, integrated relationships with soil microbiological communities, many basic soil analysis packages do not capture the complex nuances of the soil-tree relationships that may be offered by more comprehensive soil testing options. Key to Ontario tree nursery producers' use of new analysis will be complementary resources and training on testing purposes and interpretation of the results.

6.3 Soil testing in Ontario field tree production

In the Vineland survey of Ontario tree nursery field producers, 64% of growers surveyed indicated that they conduct soil testing, predominantly during production or when preparing a new field for production. Of the producers who do conduct testing, 78% noted basic testing as their preferred level of analysis, capturing micro and macronutrients, pH, texture and organic matter data. Basic soil testing packages were preferred on account of their widespread availability and ease of interpretation, whereas moderate and comprehensive soil testing approaches were preferred by only 4 of the 29 tree producers surveyed, likely on account of the limited availability and cost of these types of tests.

Although the majority of nurseries conduct soil testing, 10 of the 29 producers surveyed indicated that they do not currently test their soils. Soil testing is central to active soil management, where an understanding of the state of soil health can allow for more targeted and effective field management practices. Where most of the soil testing conducted throughout the industry is centered on basic soil level parameters, the vast majority of producers indicated that soil tests were generally accessible and easy to interpret. However, when asked about the needs of the industry, 50% of Ontario tree nursery field producers indicated the need for more comprehensive, accessible and easy to interpret soil testing to support the advancement of soil management across field operations. Access to more comprehensive testing, as well as resources to manage and utilize results are needed to allow nurseries to maximize their use of soil analyses to inform soil management as it pertains to tree production.

7 Building Knowledge to Support Ontario Tree Growers

Although soil is inherent to field production practices, relevant information, tools and data pertaining to soil management for tree nurseries are scarce. A comprehensive review of the existing literature identified only 10-15 articles and reports directly concerned with soil management practices for tree nursery production, published between 1970 and the present. Many of the tree related resources that have been developed are focused on seedling-sized trees and associated production practices, as they pertain to commercial forestry operations. Detailed data designed to support the production of larger, caliper-sized nursery trees, in the form of peer-reviewed articles, technical reports or other relevant resources; are limited and therefore difficult to obtain.

[14] Schindelbeck, R.R., H.M. van Es, G.S. Abawi, D.W. Wolfe, T.L. Whitlow, B.K. Gugino, O.J. Idowu, B.N. Moebius-Clune. 2008. Comprehensive assessment of soil quality for landscape and urban management. Landscape and Urban Planning, 88(2-4), pp.73-80.

Where there is limited access to relevant resources, the majority of Ontario tree nursery field producers rely on traditional practices and first hand experiences to inform their soil management. Although first-hand knowledge and experience obtained at the field level is invaluable, it can over time become highly specific and particular to a given farm or field operation. Where tree nurseries have only their own experience to guide soil management, the innovations, insights and knowledge gained by other producers, experts and scientists are not accessed and utilized to advance the industry as a whole.

As researchers, we have noted the lack of information and resources tailored to support the unique operational needs of the tree nursery industry. Field nursery production, which requires the disturbance of soil during field preparation and digging, would benefit from soil management practices that are customized to address the operational aspects of producing and harvesting trees with and without soil balls. In the Vineland survey of Ontario tree nursery field producers, the top two resources identified as being needed to support soil management were (1) information pertaining to cover crop selections and timing and (2) more comprehensive, accessible and easy to interpret soil testing. Where our own research interests currently include:

i. Developing tools to guide cover crop selection and management
ii. Defining optimal organic matter targets and characterizing the effective use of organic amendments
iii. Developing cost-effective methods for producing and using on-farm organic amendments
iv. Maximizing the use of soil testing at the field level

We intend to support Ontario tree nurseries by collecting, interpreting and presenting new and existing data related to soil management and soil health in a way that is relevant and applicable to the industry. In order to effectively develop resources for producers that can be used to build and expand upon existing soil management practices, we identified the key factors that would facilitate change in the industry. In the Vineland survey of Ontario tree nursery field producers, the top three factors that would motivate producers to change their current practices were (1) improved tree performance, (2) reduced use of chemical pesticides, herbicides and fertilizers and (3) increased soil organic matter content. By promoting soil health tree producers will ultimately accomplish these targets as well. Soil health frameworks are comprehensive approaches to production and provide integrated and ancillary benefits.

Having worked alongside and in collaboration with Ontario tree field producers, we have experienced the industry's commitment to improving soil management for the benefit tree health and productivity. Where 57% of tree producers surveyed believe that their current practices simply maintain soil health - we hope to provide the information, resources and support needed to transition toward extending soil management practices so as to actively build and improve soil health across field nursery operations in Ontario.

8 About the Greening the Landscape Program

The Greening the Landscape Research Program is centered on conducting scientific research to support the success and productivity of trees in urban landscapes. The establishment and survival of plants and trees to improve environmental performance, counter climate change pressures while increasing the competitiveness of the nursery landscape sector is the foundation of Vineland's Greening the Landscape research program.

Working with partners across Canada, Vineland develops models and specifications to improve the performance of vegetation and green infrastructure design to ensure impact for the industry.

Plants are the fundamental components of a living green infrastructure that delivers environmental, economic and social benefits. Cities recognize plants and trees as integral to climate change mitigation strategies and have set ambitious canopy cover targets.

Research and the application of that research to understand plant stress tolerance to extremes can inform plant selections and developing tools and production methods is improving plant establishment and survival. Providing clear, industry-ready recommendations backed by solid science and validated methodologies helps the sector capture a market opportunity to engage with cities, developers and others to deliver on climate change targets.

For more information and to stay up to date on current and upcoming research, visit and register at greeningcanadianlandscape.ca.

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