Perennia

Managing Nitrogen Supply

in Mature, High-Density Apple Orchards in Nova Scotia

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Content

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1. BACKGROUND

1.1 Introduction

Soil fertility, including soil nitrogen supply, is an important aspect of orchard management that can significantly impact orchard profitability. It has a bearing on tree canopy development and vigour, precocity and biennialism, fruit quality (colour, storage, sensory), winter hardiness and nutrient reserve status.

With careful planning and execution during the soil preparation phase of orchard establishment, most soil fertility parameters are easily managed with ongoing soil and leaf analyses once an orchard reaches the mature phase. Soil pH and exchangeable acidity can be adjusted with applications of lime every two to three years. Phosphorus (P) and potassium (K) status, base saturation of the cation exchange complex (CEC, - Ca: Mg: K ratios), can be adjusted annually with spring applications of fertilizer which can include trace elements such as Zn, Cu and B if necessary. In some cases, foliar feeding can be used to address deficiency of these nutrients as well.

However, ease of management is not the case with soil nitrogen (N). This plant essential element has the most impactful effect of all plant nutrients on orchard performance. Managing soil N supply by establishing the optimum application rate for a particular orchard most often involves more complex decision making. While other soil chemical parameters are easily tested for in a representative soil sample, predicting soil N supply (SNS) from a soil test remains a tedious and challenging undertaking. This is due to the dynamic nature of soil N processes that govern availability and the vital roles of soil organic matter (SOM) and soil microbes.

The purpose of this fact sheet is to provide an educational guide and road map for growers to manage N supply in mature orchards. The reader is encouraged to use this guide in conjunction with other related Perennia publications: "Orchard Fertility," "BMPs for Apple Production," and "Planting and Care of Young Trees." Additional resources are also provided at the end.

1.2 Role and sufficiency of nitrogen in apples

Nitrogen is an essential nutrient for all plants including apples. Structurally, it is a key component of chlorophyll needed for photosynthesis and a building block for proteins and nucleic acids. It is essential in cell division and the development of roots, shoots, leaves, flowers and fruitlets. It directly supports vegetative growth and fruit development, making soil availability and quantity for uptake time sensitive. Early-season N applications are directed to current-year growth, whereas pre- and post-harvest applications can contribute to N reserves for the following season.

In Nova Scotia's short cool growing season, crop load management can be exacerbated by low C and N reserves going into the winter. Maintaining the health of the canopy together with effective pruning practices is the first line of defence in crop-load management.

Conversely, an over-supply of N in the orchard is most often observed as excessive vegetative growth with dark green colour and shading of fruit. Weakening of tissues at the cellular level increases susceptibility to diseases and negatively impacts fruit sensory quality and storability. In particular, the physiological disorder known as bitter pit is aggravated by high tree N status and excessive vegetative growth.

Moderate to severe nitrogen deficiency in Nova Scotia's apple orchards is rarely observed. A light to moderate under-supply results in less terminal shoot growth with smaller, uniform leaf chlorosis (lighter or yellowish green colour, Figure 1), reduced yield with small and highly coloured fruit, early leaf senescence and poor return bloom in the following season. Nitrogen is mobile within the tree and symptoms may appear on older leaves first, but trees can also be generally light coloured in appearance, especially in the post bloom period.

Figure 1. Nitrogen deficiency is rare in commercial orchards but when observed it appears as pale yellowish green leaves and short shoot growth. Permission to share photo granted by Dr. Eric Hanson, Michigan State University.

1.3 Dynamics of soil nitrogen supply

Nitrogen in soil exists within inter-changeable pools. Most N is bound in organic matter and unavailable

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for uptake by the tree (immobilized). The magnitude of this pool correlates with soil organic matter (SOM) content so that more SOM equates to more nitrogen. In a soil fertility analysis, SOM content is reported as percent organic matter (% OM).

At any given time, approximately 98% of total soil N is bound in SOM. A small portion of the N in this pool can be converted to a usable mineral form (mineralized) by microbial processes. The principal mineral forms of N used by plant roots are ammonium and nitrate ions. As soil temperatures rise in spring, there is a flush of mineral N that becomes available to the tree from the SOM pool. Summer and fall mineralization occur to a lesser extent.

Soils with low or high OM contents are often considered "infertile" or "fertile" respectively, because most of the naturally occurring soil N that the tree will eventually use over the life of an orchard, is delivered from this source. As the major source of soil nitrogen, organic matter plays a pivotal role in soil nitrogen supply and in consequence, tree N status.

Tree response to an increase in N fertilizer rate is most rapid within the first growing season, when soil nitrogen supply (SNS) is low and when there is little or no competition from laneway vegetation for water and nutrients (N). In mature, high-density orchards, a rapid response to N will most often occur when a relatively wide weed-free strip is maintained under the tree row. The response of overly vigorous trees to a decreasing N application rate can be delayed (two or more seasons) in soils with a naturally high N supply (high % OM) and little competition from laneway vegetation for water and nutrients. In these situations, it is advisable to limit the width of the weed free strip to 25% or less of the orchard floor to increase competition (3 ft width or less in a 12 ft row spacing).

Bear in mind that while banding fertilizer as a practice is likely to encourage the concentration of apple feeder roots under the weed-free strip, field investigations most often reveal a significant presence of apple roots in the grassed laneways. For this reason, tree vigour can be influenced by root architecture, not only with regard to the vertical distribution of roots but also, the proportion of roots in the two distinctly different soil ecosystems of the orchard floor.

There are unfortunately no publications or reports summarizing historic averages and ranges of % OM values from soil fertility analyses for Nova Scotia's agricultural or orchard soils. A value of 3.8% OM for an average NS orchard soil is suggested here as a good starting point (see section 3.2). Such a soil could make available approximately 70 kg N / ha in a growing season. While this mineralized N is subject to similar constraints of usage as fertilizer N, it serves to reduce the amount of supplemental fertilizer N required to meet the tree demand for a healthy N status. For further discussion on the principles related to the estimation of fertilizer N rate, see Appendix I.

2. INTEGRATION OF N MANAGEMENT WITH OTHER FERTILITY PRACTICES

2.1 Maintenance liming

Nova Scotia's orchard soils are naturally acidic due to the region's high annual precipitation (approximately 1150 mm). Base cations calcium (Ca), magnesium (Mg), potassium (K) and sodium (Na) released from weathering minerals are rapidly leached from the soil profile with downward movement of drainage water. This acidifying process is compounded by the use of synthetic fertilizers, making maintenance liming a critical orchard management practice for balanced tree nutrition and a fertility source for Ca and Mg. In the case of nitrogen, maintaining a soil pH above 5.5 serves to increase availability of N from the soil organic matter pool. With regular maintenance liming (normally every two to three years based on soil analyses), optimum use of applied N is not dependent on the timing of lime applications in a particular season. Consult Perennia publication: "Orchard Fertility" for detailed guidance on effective orchard liming practices.

2.2 Phosphorus (P) and potassium (K) nutrition

Since soil levels of P and K in orchards are less dynamic when compared with N, the timing of their application is less sensitive. If soil or tissue analyses indicate a need for P and/or K, these nutrients are best applied together with N for cost effectiveness. In rare cases of an observable deficiency, a spring application will also be the most effective time to obtain a response. Always avoid spreading fertilizers on snow or frozen ground.

2.3 Sulphur and trace elements

Sulphur and micro-nutrient (trace elements) deficiencies are not widespread in Nova Scotia apple orchards. Boron deficiency is perhaps the most common and is most likely to appear on sandy soils with low OM contents and/or in rain-fed plantings, during dry growing seasons. Deficiencies of zinc,

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manganese and iron are characteristic of calcareous or high pH soils and are not likely to occur.

Best practices:

- Be aware that nitrogen management should be fully integrated into your nutrient management program.
- Consult Perennia publications on general orchard fertility and liming.
- Two minds are better than one—consult with a nutrient management specialist if you are in doubt.

3. TREE N STATUS INDICATORS AND THEIR INTERPRETATION

3.1 Tree appearance

Trees with a low N status generally exhibit a slight chlorosis (pale green or yellowish leaves) with unusually highly colored, smaller apples. Shoot extension is sometimes less than desired (10–20 cm after terminal bud set, depending on variety). Of note though, is that significant extension growth can be obtained at low N status if all other conditions for growth are optimum.

Honeycrisp tends to cease terminal shoot growth a little earlier in the season when compared with varieties like Royal Gala, Ambrosia and Minneiska. The annual pattern of off-colour leaves (zonal leaf chlorosis) characteristic of Honeycrisp trees should not be seen as an indicator of N supply. In addition, growers should be aware that the use of growth retardants such as prohexadione calcium, will shorten terminal shoot growth of overly vigorous orchards without significantly affecting leaf colour or photosynthetic capacity.

In situations of poor vegetative growth, additional N will not compensate for other growth limiting factors such as poor soil aeration/drainage, moisture stress, other nutrient deficiencies, replant disease, rootstock vigour, etc. These orchards should not then be classed as moderately or low vigor for the purpose of adjusting the N fertilizer rate.

In healthy orchards, increasing N status from low to moderate levels will increase shoot growth and yield. Applying nitrogen in cases of low SNS will also increase fruit size provided thinning is used to avoid overset. Excessive nitrogen applications can result in poor fruit color, sensory quality and storability.

3.2 Soil testing

As stated above, while other soil chemical parameters are easily tested for in a representative soil sample, predicting soil nitrogen supply in a soil test remains a tedious and challenging undertaking. For this reason, it is not included in the NSDA's Plant Lab F1 soil fertility analysis package. A strong indicator of SNS that is included, however, is soil organic matter (SOM), reported as % organic matter (% OM). A strong positive relationship exists between SOM and naturally occurring soil nitrogen supply.

Data provided by the NSDA's Animal and Plant Laboratory obtained from the analysis of 2,700 orchard soil samples between 2014 and 2024 point to an average OM content in NS orchards of 3.8%, with 33.3% of analyses being lower and higher than 3.3 and 4.0% OM respectively. In the absence of frequent, large additions of organic amendments or tillage, soil organic matter contents can be expected to remain fairly stable in orchards from season to season. Soil testing is recommended every second or third year. Analysis of a carefully taken, representative soil sample can provide the grower with a valuable starting point in determining N fertilizer rate (see sections 4.2 and 5.0).

3.3 Tree leaf N tissue status

During the growing season, aerial tissues can be sampled and analysed as a means of gaining insight into soil N supply and tree N status. These tissues (buds, flowers, petioles, leaves, fruitlets, etc.) differ in their nutrient concentrations at any given phenological stage. In addition, the nutrient concentrations vary across the course of the growing season, making timing of sampling important.

Figure 2. Tree nitrogen status can be assessed by mid-season testing of the median leaves of extension growth.

An approach pioneered years ago is to use mid-season leaf tissue analyses to assess tree N status as a medium to long term approach to optimizing N fertilizer rate. For mature orchards, this research showed that a mid-season window (end July/early August, approximately

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eight weeks after petal fall) offers an opportunity to sample leaves while leaf nutrient concentrations, including N, are relatively stable. Leaf nutrient ranges were developed for all plant essential nutrients at this phenological stage. To sample, leaves should be collected from the current season's extension growth, targeting the middle leaf between the shoot base and tip (Figure 2). Permanently mark three or four representative rows across the orchard and five to six trees per row to be sampled each year. Sample five leaves per tree for approximately a 100-leaf sample (see also soil sampling section 3.2).

The leaf sample tissue N analyses target lies between 1.8 and 2.6% N for apples. This is a broad range! Of relevance to Nova Scotia is the detailed guide for apple leaf tissue N standards for New York State orchards adapted in Table 1 (Cheng et al. 2015, after Stiles and Reid, 1991). A practical rule of thumb that can be adopted is that a 10% increase in the fertilizer N rate is reflected in a 0.1% increase in leaf nitrogen content.

Table 1. Optimum mid-season apple leaf tissue levels for nitrogen

Tree Type	Leaf nitrogen %
Young non-bearing trees	2.4–2.6
Young bearing apples	2.2–2.4
Mature soft apples, including Honeycrisp	1.8–2.2
Mature hard apples, processing	2.2–2.4

Best practices:

- An orchard soil fertility or leaf tissue analysis is only as good as the sample that is sent to the lab. Spatial variability in soil fertility parameters, including SOM, is a reality, as is the variability in N content of leaves from different shoot/spurs positions. Make sure your sample is correctly taken.
- Mark three or four representative rows spaced across the orchard and sub-sample at five to six trees along the row. Combine the 100-leaf sample for submission. Always return to these rows. Sampling leaves from marked trees at these positions is an excellent way of tying your soil and leaf analyses together.
- In most orchards, the topsoil layer is darkened by OM to a depth of approximately 25 cm. Sampling to this depth is more representative than the standard of 15 cm for a fertility analysis. However, you may want to stick with 15 cm if you have historical records at that depth. Target the weed free strip under the canopy which receives most of your fertilizer. Record the sampling depth and keep it consistent from block to block.
- SOM content is a great starting tool to home in on your N fertility rate—use it!

4. APPLICATION OF NITROGEN FERTILIZERS

4.1 Timing

To maximize uptake efficiency, N applications are best timed to coincide with the start of the peak period of tree root growth which occurs in the pre- to post-bloom period (late April to mid-June). Recommended time for N application is therefore from late April to early May, shortly after laneway grasses start to show new growth. Watch the forecast for a good (15–25 mm) rainfall event post-application, if possible, to move the nitrogen into the root zone. Application ahead of heavy rainfall will reduce your N utilization efficiency.

In growing regions with long summers where leaf conditions remain healthy for a considerable period after harvest, there is an opportunity to apply additional N to build tree reserves, should soil mineral N status be low. More recent studies have confirmed that this timing has little to no effect on fruit N status and quality — N taken up remains in the roots and/or is translocated and stored in branches and shoots, contributing to the N reserve status of the tree.

Foliar application of low-bi-urette urea is an additional tool that can be used to maintain adequate tree N status in cases of cool, wet spring weather and/or on coarse textured soils with low OM when mineral N concentrations in the root zone are inadequate for sufficient uptake. Two to three applications 10 days apart at 3.6 kg per 1,000 L (3lbs per 100 gallons) in the post-bloom period, tank mixed with B and Zn if necessary, should suffice. Be aware that higher concentrations in the post-bloom period have been known to cause fruit russeting on rare occasions, especially under slow drying conditions.

Fall mineralization of N from OM in most orchard soils as well as a relatively early leaf senescence, generally obviates the need to apply additional nitrogen after spring under local conditions. Late season or fall application of N in the Annapolis Valley with its relatively short growing season would therefore be the exception rather than the rule.

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4.2 Rate

Traditionally, the recommended range of nitrogen fertilizer application rates for apples in the Atlantic provinces is 30–60 kg N per ha per year (Table 2). The range has been intentionally left wide to accommodate different scenarios related to tree N demand. While there are numerous factors influencing nitrogen demand, "the big three" are:

- removal of N in the apple crop
- soil N supply
- fertilizer N utilization efficiency

Table 2. Guide for estimating nitrogen fertilizer rate* (kg N / ha) using soil organic matter (OM) content and cropping potential in mature, high-density orchards.

Cropping potential (tonnes / ha)**	---Soil Nitrogen Supply---		
	Low (< 3.3% OM)	Med (3.3–4.0% OM)	High (> 4.0% OM)
Bumper: 50 (56 bins/ ac)***	60	50	40
Average: 40 (45 bins / ac)	55	45	35
Meager: 30 (33 bins / ac)	50	40	30

* rate range of 30 to 60 kg N / ha based on Webster & Craig (1993) Orchard Fertility guidelines for NS (see references); ** a three-season average can be used; *** based on 800 lbs per bin

Other factors that play a role are tree vigour, pruning practices, variety, orchard floor management practices such as the addition of organic materials from time to time and the presence/use of legume crops such as clovers in the laneways, etc. A common situation encountered in the rolling topography of Annapolis Valley orchards is a tendency for trees in a block to be less vigorous in crested positions and more vigorous in depressed areas. Soils in crested positions quite often are coarser in texture and have lower SOM contents (depth and %) when compared with their counterparts. These two soil parameters directly impact moisture availability and SNS, especially during the hottest, driest part of the growing season. In these situations, consider using a variable N rate above or below your target rate in these areas if resources allow.

Best practices:

- Synchronize your N application to coincide with the peak period of root growth (the pre- to post-bloom period).
- Monitor leaf N status, tree vigour and colour carefully in orchards with very high (> 4.5%) soil organic matter contents, especially in the case of sensitive varieties like Honeycrisp—these orchard soils have the potential to meet the N demand of the tree without supplemental fertilizer N applications.
- Remember, when all other growth limiting factors are addressed, apple trees require little additional N for sufficient growth when compared with other crops.
- Band your fertilizer on a weed free strip—this is the best compromise for efficient uptake.
- Use information from observations that represent the greatest area of the orchard block to determine N fertilizer rate (Figure 3).
- Use a variable N rate above or below your target rate to address localized areas with trees of low or excessive vigour if resources allow.
- Avoid the use of additional N to compensate for growth-limiting factors such as poor drainage, replant disease, too dwarfing a rootstock and other nutrient deficiencies.
- Strive to adopt a medium to long term approach to meeting the N demand of the orchard. If you are continuously making changes to your N rate from year to year, there is something wrong!

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- Active and effective crop load management (pruning, thinning) from season to season will help you "home in" on your orchard's N requirements.

Figure 3. Examples of orchard cropping potential in mature, high-density orchards. A. Low cropping potential: trees have not filled their allotted space (canopy gaps between trees) and never reached the full height of the trellis (effectively a smaller bearing surface); B. Medium cropping potential: some gaps between trees but trees have good height and bearing surface; C. High cropping potential: trees crowded to a hedge row, grower limits further height growth to adhere to the maximum tree height rule of 90% of row spacing.

4.3 Source

Mineral fertilizers: The nitrate form of nitrogen is more rapidly available than either the ammonia or urea form because it is more readily leached into the root zone, but it is also more readily lost from the root zone by leaching under excessive rainfall. In the rain-fed orchards of Nova Scotia, a fertilizer that supplies approximately half of the nitrogen in the nitrate form and half in the ammonia (or urea) form is recommended. Ammonium nitrate or blends such as 17-17-17 (17% N) with most of the nitrogen supplied as ammonium nitrate (34% N) are examples of such fertilizers. Other commonly available sources of nitrogen are urea (46% N) and diammonium phosphate (18% N).

A common misconception is that an additional benefit to fruit quality can be obtained with the use of nitrogenous fertilizers containing calcium (Ca), either calcium nitrate (15.5% N) or calcium ammonium nitrate (27.5% N). While the latter two are effective N sources, in a correctly limed soil with a calcium saturation of approximately 80% of the soil CEC (cation exchange capacity), the additional Ca added in a nitrogen fertilizer is negligible. In addition, low fruit Ca status is caused by low allocation rather than low uptake.

Organic amendments: A host of organic materials including non-composted or composted animal manures and plant materials, biochars and other amendments can potentially be used as an N fertility source, either directly by releasing N into the soil or indirectly by improving soil health via the addition of a carbon source (Figure 4). Some of the benefits of their use over time may include:

- Improved soil health (carbon sequestration and improved microbial biodiversity)
- Improved aeration and water infiltration
- Moisture conservation during the hottest/driest part of the growing season
- Soil temperature modulation
- Increased activity of soil fauna such as arthropods

Disadvantages include:

- Slower and less predictable supply of N even when analysis is known
- Could lead to nutrient imbalances if the material contains appreciable amounts of other nutrients, in particular P and K
- Requires additional equipment, time and energy use to spread effectively
- N contents are most often low, leading to high rates of application
- Can be a haven for pests and diseases if applied heavily under the tree canopy
- Can encourage undesirably shallow feeder root systems

Best practices for organic amendments:

- Consider using if you have access to a reliable supply of an organic amendment with a known and consistent nutrient profile and at least 3% N

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- Use in conjunction with soil and leaf analyses and orchard observations
- Be prepared to supplement with mineral fertilizers if the organic source cannot meet the tree's N demand
- Be aware that ongoing use of organic amendments as an N source can lead to excessive levels of soil P and K, for example by using certain livestock manures.
- Consult Perennia publications: "Taking a Compost and a Solid Manure Sample," "How to Interpret a Manure Analysis Report" and "How to Interpret a Compost Analysis Report."

Figure 4. Clippings from laneway mowing are blown onto the weed-free strip as a mulch to improve soil health and nutrient cycling, a potential best practice which together with accurate fertilizer placement can lead to improved nitrogen usage efficiency.

4.4 Placement

Placement of N and other applied fertilizers in the orchard has a direct bearing on the uptake efficiency of the trees and in turn, orchard productivity and the cost effectiveness of a grower's nutrient management program. To better understand how to spread fertilizer N in a particular orchard system, growers should consider two contrasting placement options:

- A uniform broadcast across the entire orchard floor
- A very narrow banding along the tree line.

Traditionally, growers maintain a weed-free strip along the tree row. The width and area of the weed-free strip under the tree canopy, varies from 50–60% of the orchard floor at older, wider spacings, to as little as 20% in the highest density orchards. It is important to remember that the roots of laneway vegetation (grasses and broadleaves) compete aggressively with apple roots for water and nutrients. The width of the vegetated strip can therefore be seen as a tool to manipulate tree vigour. Growers should band fertilizers based on a management width of weed-free strip to ensure effective placement and use of N.

5. PRACTICAL GUIDE TO DETERMINING YOUR N FERTILIZER APPLICATION RATE WITH EMPHASIS ON MATURE HONEYCRISP ORCHARDS

- Be realistic about the cropping potential of your orchard. A common mistake is to strive for an unrealistic yield level.
- Don't change your N application rate if you consider your mature orchard to be in good vegetative/reproductive balance.
- From Table 2, select one of the nine scenario N rates that best approximates your soil N supply as measured by the % OM in your soil analyses and the cropping potential of the orchard. Examples: If both soil OM content is "high" and cropping potential is "Bumper", your estimated spring N rate is 40 kg N per ha; if soil OM content is "Low" and cropping potential "Average", your estimated N rate is 55 kg N per ha.
- Take leaf samples at the recommended time during the growing season (see section 4.3). If leaf N content is in the normal range (2.0–2.2%, Table 1), it is an indication that you are close to the optimum fertilizer N rate for the orchard.
- Add or subtract 5 kg N / ha based on the previous season's leaf N analyses, if your leaf N content was lower than 2.0% or higher than 2.2%, respectively. In the example, this would increase/decrease the rate to 45 or 35 kg N per ha, respectively.
- Consult your soil and leaf analyses to determine if your orchard has a P, K, S, Ca, Mg requirement and work with a nutrient management specialist to determine the correct fertilizer blend, maintenance lime requirement, etc.
- Be aware of "hidden hunger", a condition where slight but yield limiting micronutrient deficiencies are visually masked by an ample supply of the macro-elements. While not prevalent in Nova Scotia's orchards, there are cases where B and/or ZN can be added to a prescription blend for more balanced nutrition.
- Consider foliar nutrition as an exception rather than the rule and make sure the decision to adopt a foliar program is evidence based.

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7. ACKNOWLEDGEMENTS

Funding for this project has been provided by Agriculture and Agri-Food Canada through the Agricultural Climate Solutions (ACS) – On-Farm Climate Action Fund (OFCAF).

Larry Lutz (Lutz Family Farm, Rockland, NS) and Dr Laliang Cheng (Professor, School of Integrative Plant Science, Horticulture Section, Cornell University) for their constructive reviews and insightful comments.

Amy Sangster (Manager, NSDA Animal and Plant Laboratory) for her cooperation in providing information related to the organic matter contents of orchard soils in Nova Scotia.

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This publication was produced by Keith Fuller (AAFC Soil Scientist, retired) and Michelle Cortens (Perennia Tree Fruit Specialist) for Perennia Food and Agriculture Corp. as an ongoing initiative to support the NS tree fruit industry.

APPENDIX I

Several publications on N cycling and management in apple and other woody perennials refer to the following parameters required for estimating annual fertilizer N requirement:

- removal of N in the apple crop
- N that is built into the vegetative framework of the tree
- an estimate of the N utilization efficiency of N fertilizer
- the soil nitrogen supply

In high density orchards, there has been a trend in recent years to mulch prunings in the laneway rather than remove them, a good practice that has potential to contribute to carbon sequestration and nutrient (N) cycling in orchards. It also simplifies the empirical estimate of the N fertilizer requirement (FR) by removing less N from the system:

FR = [(CR + S) / FUE] - SNS Units: kg N / ha

CR (crop N removal): Research shows that harvesting removes approximately 0.5 to 0.6 kg N per 1,000 kg (1 tonne) of apples harvested. As an example, this equates to 20 to 24 kg of N / ha for a 40 metric tonne crop / ha.

S (structural N): Nitrogen taken up and allocated to the permanent structure of the tree. In mature, stable orchards, this is a small amount when compared with crop N removal and SNS, since an almost equal amount of tree N is shed annually in root mortality, leaf fall and prunings.

FUE (fertilizer use efficiency fraction): A wide range of utilization efficiencies for fertilizer N in woody perennials, including apple, have been reported, most well below 50% (0.5 fraction). In humid climates with high precipitation, including a short, rain-fed growing season in many cases, nitrate leaching from the root zone and to a lesser extent denitrification losses including (nitrous oxide, N2O) are the most likely environmental reasons for low efficiency.

SNS (soil N supply): Nitrogen made available to the crop from all non-fertilizer sources, including:

- soil mineral N already present at the start of the season,
- mineralization of naturally occurring SOM (often 50–90% of total SNS),
- mineralization of incorporated tree debris (fruitlets, leaves, prunings, uncollected drops, mower clippings),
- biological fixation (e.g. if legumes present in the vegetated laneways),
- atmospheric deposition (~ 2 kg N/ha/yr),
- irrigation water (e.g. dissolved N in irrigation ponds).

Assuming a use efficiency of 0.25 for this equation translates to a fertilizer requirement of 88 kg N / ha. From this we must subtract the soil nitrogen supply which is arguably the most variable of "the big three" factors mentioned above and subject to similar use efficiency constraints as fertilizer N.

It should be noted that apart from N leaching and denitrification losses, another important reason for low N use efficiency in mature apple orchards is that a significant portion of the tree root system extends into the competitive environment of the vegetated laneway, beyond the reach of fertilizer banded on the weed free strip. This issue confounds the estimation of N requirement using empirical formulas such as eq.1 above, but formulas do help us understand the associated principles for woody perennial row crops.

Funded under Agricultural Climate Solutions (ACS) – On-Farm Climate Action Fund (OFCAF) by Agriculture and Agri-Food Canada.

FCAF ON-FARM CLIMATE ACTION FUND for Nova Scotia

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