CHAPTER 3. FERTILIZING THE SOIL

Feed the soil, not the plants!

INTRODUCTION

Through their roots, plants get essential nutrients from the soil. To grow healthy turf, then, requires that the right nutrients are present in the soil and that they are available to the roots. This chapter discusses basic soil chemistry, including liming to correct soil pH, the role of major plants nutrients and the different types and timing of nitrogen applications. Soil chemistry is a complex subject; therefore this chapter reviews only the basic principles as they apply to turf. More detailed information is available from the references listed at the end of the chapter.

The Importance of Soil Tests

A soil test is an all-important tool for managing turf. It tells you the current condition in the soil, and usually recommends nutrient and pH changes that will improve results. This helps you tailor product applications to overcome deficiencies, while eliminating unnecessary applications. Take soil tests now, and repeat every two to three years. Save money and lessen the impact on the environment at the same time!

Where to Get a Soil Test
Low-cost and accurate tests are available from most Provincial agriculture departments.

New Brunswick Department of Agriculture, Fisheries and Aquaculture
Lincoln Road, P. O. Box 6000 Fredericton, NB E3B 5H1
(506) 453-2666 http://www.gnb.ca/0179/01790003-E.ASP

Newfoundland and Labrador Department of Forest Resources and Agrifoods
Soil and Land Management Division, Provincial Agricultural Building,
Brookfield Road Box 8700, St. John’s, NL A1B 4J6
(709) 729-6734 http://www.gov.nf.ca/agric/soils/sl164.htm

Nova Scotia Department of Agriculture and Fisheries,
Quality Evaluation Division, Laboratory Services,
P.O. Box 550 Truro, Nova Scotia B2N 5E3
(902) 893-7444 http://www.gov.ns.ca/nsaf/qe/labserv/soilsamp.htm

PEI Agriculture and Forestry Agriculture Resource Division
Research Station, University Avenue, Box 1600, Charlottetown PE
(902) 368-5600 http://www.gov.pe.ca/af/ard-info/index.php3

How to Take a Soil Sample

A soil test is only as good as the sample!
A lab needs about 500 ml (2 cups) of soil to make an analysis. For the most accurate assessment of soil nutrients and pH, the soil sample must be representative of the turf root zone all across the lawn. Since most roots are in the top 5-10 cm (2-4 in) of soil, samples should be taken from this depth.
Take a couple of tablespoons of soil from 2 to 3 locations for every 100 m^2 (100 yd^2) of lawn. This is 6 to 10 sample locations for an average front yard. For more detailed instructions see the Nova Scotia website: http://www.gov.ns.ca/nsaf/qe/labserv/soilsamp.htm

SOIL pH

The pH of the soil is the measure of hydrogen ion activity (or concentration) in a soil solution. This is a key element of soil chemistry that determines how available most nutrients are, both to plants and to the soil micro-organisms. A neutral soil has a pH of 7.0—it is neither too acidic or too alkaline. As the concentration of hydrogen ions increases, the soil becomes more acidic (due to the way it is denoted scientifically, it actually means that the pH number decreases). At a pH of 5.0, which is quite acidic, less than half of the major nutrients are available to the plants.

The little p in pH

In math, "p" is used to denote the negative log of…

In this case, it is the negative log of hydrogen ion (H) concentration in the solution.

Pure water contains some molecules that have broken apart into individual ions, either hydrogen (H^+) or hydroxyl (OH^-).

water (H_2O) = H^+ + OH^-

In pure water, there is an equal amount of hydrogen and hydroxyl ions, and the pH is neutral. If you were to count the number of $H^=$ ions in pure water, you would find

$\frac{1}{10,000,000}$ moles of H^+ ions per litre of water

In scientific notation, this is 10^{-7} $H^=$ ions, and the negative log of this number is the positive value of the little number on top or 7. As the concentration of hydrogen ions increases, the value of the pH decreases and the solution becomes more acidic.

Source: Reid, K., (ed). *Soil Fertility Handbook*. 1998. Queen's Printer for Ontario, Toronto.

Soils in most of the Atlantic region range from pH 4.5 to 5.5. They are naturally acidic for several reasons:

- the mineral and organic matter composition of the soil,
- the generous rainfall in our region, and
- the increasing acidity in that rainfall over the region.

Turf grasses grow best in soils with a neutral pH of 6.5 to 7.0 through the entire root zone. When higher rates of nutrients are added to acidic soils in an attempt to get the expected growth, it:

- increases costs,
- can reduce soil microbial activity (due to higher salt concentrations from fertilizers), and
- can cause environmental problems as excess nutrients contaminate surface and groundwater.

Weed problems are also worse in low pH soils. This is because many weeds thrive in acidic soil, and because the turfgrass is less competitive. Weed species adapted to a lower pH can use more of the available nutrients and grow more aggressively. By raising the soil pH, the weeds become less competitive. The vigour and density of the turfgrass also improves, which suppresses weed germination and growth.

Correcting Low Soil pH

Applying agricultural lime adds calcium to the soil, which raises the pH. The lime (pelletized or powdered) can be mixed with the soil or added as topdressing, according to rates recommended by soil tests. Powdered limestone formulations are relatively slow acting. Some of the pelletized products contain a portion that is faster-acting calcium hydroxide or quicklime. Dolomitic lime contains a significant proportion of magnesium as well as calcium.

How Much Lime Does it Take?

To raise the soil pH one point, from pH 5.5 to pH 6.5, takes 4-5 tonnes of lime per hectare in average soils.
For smaller areas this translates into:

- ½ kg per square metre
- 1 lb per square yard
- 50 kg per 100 square metres
- 100 lb per 100 square yards

It can take a lot of lime to raise pH (see text box). It is estimated that lime moves downward about 13 mm (about ½ in) per year in loam soils. (It moves faster in sandy soils and slower in heavier silt or clay soils). This means that it can take 10 to 15 years to change the pH in a 15 cm deep root zone, using surface applications of lime.

It is common practice to apply the full amount of lime topdressing in one or two applications. The maximum recommended single application is 25 kg/100 m^2 (50 lb/100 $yd^{2)}$. It may be more effective, however, to divide the total amount into smaller portions and apply it over a longer period. For example: applying lime at a rate of 5 kg/100 m^2 (10 lb/100 yd^2) each time. This is desirable because it assures a more uniform pH profile through the root zone. Lime can be applied any time during the operating season. However, it will move into the soil more rapidly if it applied it before the periods of highest rainfall.

Table 3-1. Beneficial effects of raising pH on availability of nutrients (NPK) and on fertilizer efficiency.

Soil pH	Nitrogen Efficiency	Phosphorous Efficiency	Potash Efficiency	Fertilizer Wasted
pH=7.0	**100 %**	**100 %**	**100 %**	**0 %**
pH=6.0	**89 %**	**52 %**	**100 %**	**20 %**
pH=5.5	**77 %**	**48 %**	**77 %**	**33 %**
pH=5.0	**53 %**	**34 %**	**62 %**	**54 %**
pH=4.5	**30 %**	**23 %**	**33 %**	**71%**

Adapted from Adrian Gallant[1].

Fertilizer is used most efficiently at a pH of 7.0 (see Table 3-1), however; it takes very high rates of lime to maintain this target. Given that turfgrass performs well at pH 6.5 and nutrient losses are also minor at pH 6.5, this is the generally recommended target.

When calculating lime requirements, the fact that the nitrogen (N) component in fertilizer is an acidifying agent must be taken into account. Most of the common nitrogen sources or carriers 'consume' (require the neutralizing value of) about 2 units of lime per unit of nitrogen.[2] For example, turf fertilized at the rate of 1.5 kg of N per 100 m^2 (3 lb N/1000 ft^2) will require about 3 kg of lime per 100 m^2 (6 lb/1000 ft^2), every year, to counter the effect of the nitrogen on pH. This works out to 300 kg/ha (250 lb/acre). Natural rainfall, which is somewhat acidic, is estimated to consume about 150 kg of lime per hectare (125 lb/acre) per year.

A Rule of Thumb for Applying Lime

To maintain pH and compensate both for nitrogen applications and the effects of acid rain in this region:

- determine the total weight of fertilizer applied to an area for the year, and
- apply the same weight of lime during the season.

Note: this application rate does not correct for low pH conditions. It only balances the acidifying effects of fertilizers and rainfall.

CATION EXCHANGE CAPACITY

It's important for soil particles to be able to hold essential elements, yet release them into a water solution so they can be taken up by the roots of plants. In solution, these elements become positively charged (called cations). Soil particles are negatively charged, therefore they attract the cations. The capacity of the soil to attract cations is called the cation exchange capacity (or CEC). It a measure of the capability of soil to release elements, such as calcium, magnesium, and potassium, into soil solutions. The smaller the soil particles, the more surface area is available to hold and exchange nutrients. This is why clay soils and those with higher organic matter content have a higher CEC. Experience shows that a clay content of 5% or higher, and OM content of at least 2%, have enough exchange capacity to provide acceptable results.

In good soil, CEC tests commonly show ranges of 10 to 20 meq/100 g.[*] Readings below 10 meq/100 g may indicate sandy or low OM soil conditions.

The CEC reading is an indicator of soil quality that responds slowly to cultural practices. It will increase over time in most new lawns, as nature, turf roots and favourable management practices restore the soil structure and raise soil OM levels.

Corrie Almack has written a very readable description of this soil characteristic.[3]

PLANT NUTRIENTS

Turfgrasses need 16 elements for growth and development. Thirteen of these are available in the soil, some as a result of microbial activity. The other three (carbon, oxygen, and hydrogen) come from air and water. Nitrogen, phosphorous and potassium are three main elements that have a major impact on plant growth. Trace elements such as magnesium, calcium and sulfur, and micronutrients (barium, chlorine, copper, iron, manganese, molybdenum, and zinc) also play a significant role in turfgrass growth, but are required in far smaller amounts.

Most topsoil and subsoil found in the region have sufficient levels of trace elements and micronutrients to support satisfactory turf growth. It is nitrogen, phosphorus and potassium that can be deficient and that are commonly corrected by adding fertilizer. How much of each to apply depends on the results of soil tests and on management decisions, such as the level of nitrogen fertilization. Use soil tests to determine what fertilizer formulations your soil needs, rather than advertising!

PHOSPHORUS AND POTASSIUM

Phosphate is the common name for phosphorous (P) carriers (products supplying the elemental form of phosphorous to plants). Potash describes potassium (K) carriers. Both elements are important for

[*] CEC test results are reported routinely in soil tests carried out by the New Brunswick Department of Agriculture, Fisheries and Aquaculture Soil Laboratory.

healthy growth. In simple terms, phosphorous is generally recommended for growth of roots, fruit and flowers, and potassium promotes healthy stem and cell growth.

While not yet supported by research, observations of lawns and nursery sod production in New Brunswick over the past 25 years have shown that medium levels of P and K (as reported by soil tests) have given satisfactory results. The recommendations accompanying soil test reports often suggest adding enough P and K to raise levels to ‘high’ ranges. However, the medium levels of both elements may be an appropriate target, given the concern over environmental impacts and the added costs of excess or unnecessary fertilizer use. Both P and K are considered reasonably stable in most soils once target levels have been reached (unless they are depleted by continuous removal of clippings).

It is a common assumption that the addition of potassium to the soil will enhance plant winter hardiness. Although high potassium “winterizer” fertilizers are common turf formulations, the author has not yet observed cases where turf injury could be correlated with low P and K levels in New Brunswick lawns. Therefore, it is questionable whether higher rates of these elements are necessary. While they probably won’t hurt (there is little evidence of problems with potash leaching off the site), they haven’t been shown to help significantly, either, and they cost money.

Since most fertilizers contain some P and K, using formulations with the lowest levels of these elements (e.g., a 4:1:1 or 5:1:1 ratio) would be sufficient, once target levels of P and K have been achieved. It is possible to buy nitrogen-only formulations (such as SCU 32-0-0, ammonium nitrate 34-0-0 or urea 46-0-0), however, they are risky to apply with common push type fertilizer spreaders. Their actual application rates are so low that too much of these products may be applied, causing damage to the lawn.

NITROGEN

Of the three major nutrients, nitrogen is required in the highest amounts. Nitrogen fertilizer is a primary turf management tool because it has a major impact on turf growth and colour – the more N the plants take up, the greater the growth and deeper the colour. It is the most expensive ingredient in most fertilizers. It also has the greatest potential to damage the turf and the surrounding environment, if not used correctly.

Nitrogen is found in soil in a number of forms, but is only available to plant roots in two water-soluble forms: as nitrate (NO_3^-) or ammonium (NH_4^+). Other forms of N must be converted into these available forms by Nature’s food factory – the soil’s microbial population.

Turfgrass roots are very efficient at trapping nitrogen. Under a normal fertilization program, when turf is actively growing, the plants take up all (or most) of the water-soluble N in the root zone.[4] This rapidly improves the appearance of a lawn by stimulating growth and enhancing the green colour. High rates, however, are not healthy for the turf (*see* Nitrogen Application Rates, below).

Although complex forms of N are relatively stable in the soil, the fast release, water-soluble forms are the most mobile of the nutrients in the soil. Water-soluble N is subject to leaching through the root zone and can also be lost to the environment through volatilization or evaporation. Such losses occur when water-soluble N is available, and the roots are unable to take it up. This can happen when the N is applied:

- in a period of turf dormancy or slow growth (e.g. mid summer, or late fall),
- in excessive amounts, or
- when excessive rainfall or irrigation washes it down through the root zone.

Environmental tip:

If you're applying fertilizer containing fast-release nitrogen components, be sure to get it on at least 4 weeks before the grass goes dormant (mid-summer or fall). This way, the grass gets most of the nitrogen, rather than the environment!

Sources of Nitrogen

Nitrogen in turfgrass fertilizers is grouped into two broad types: fast release (or water-soluble), and slow release.

Fast Release Products: Nitrogen is usually present in water-soluble fertilizer formulations as soluble nitrate (NO_3^-) or ammonium (NH_4^+). It is readily available for uptake by the roots and gives a rapid growth response. Common nitrogen sources are ammonium nitrate and urea. The effect of these formulations generally lasts up to 30 days after application. These products must be applied carefully. Higher concentrations, of over 0.5 kg/100 m^2 (1 lb/1000 ft^2), can damage (chemically burn) turf.

Water-soluble nitrogen is quite mobile in the soil. It is not analyzed in New Brunswick soil tests because levels in the soil will have changed significantly by the time test results are received.

Slow Release Products: Slow release nitrogen is available in two forms: chemical and organic. Both types safeguard the environment by reducing the amount of N that can leach off site.[5] The nitrogen in most common slow release formulations must be broken down by soil micro-organisms into the water-soluble form before it is available to roots. The conditions that support the highest microbial activity (warm soils and adequate moisture) are also optimum for turf growth. This means the actively growing plants take up water-soluble nitrogen as it is converted, leaving little or no N lost into the environment. There is also little loss of the remaining N in periods when the turf is dormant in summer (when it is dry) and in winter (when soils are cold), because the soil microbial activity is not producing it.

Chemical Sources of Nitrogen: The chemical formulations of slow-release fertilizers consist of water-soluble nitrogen in resin or sulphur based capsules. As the capsules break down in the soil, usually through soil microbial activity, the nitrogen is released. The product most commonly found in turf fertilizers is sulphur-coated urea (SCU™). The effects of SCU generally last about two months under active growing conditions. Products with longer lasting N formulations (such as Methydure™) are also available.

Organic Sources of Nitrogen: Organic materials, such as compost, animal waste, blood meal, feather meal, and grass clippings, release nitrogen as micro-organisms break them down in the soil. Nitrogen can continue to be released from these materials for a few weeks up to several years. For example, it has been shown that compost releases only 10-15% of its nitrogen content each year. The advantages of using organic materials are:

- they make N available in the root zone over a long period of time,
- the N is less likely to leach off site and contaminate ground water, and
- there is little chance of chemically injuring the turf.

Compost is gaining in popularity for use on turf. Anecdotal reports suggest that compost may provide benefits beyond the supplying nutrients and organic matter. These may include: improving soil structure, increasing disease and insect resistance, and reducing the requirement for other nutrients. These benefits may be due to increased activity of soil micro-organism, but this requires more research.

Organic Buyers Beware

Note that the Canada Fertilizer Act allows *organic based* fertilizer products to contain up to 85% chemical fertilizer. Since chemical fertilizers are considerably less expensive per unit of nutrient than organic products, such blended formulations are cheaper to produce. Users who need organic products that meet certified organic standards or personal preferences must check the labels carefully to ensure the products meet their requirements.

Nitrogen Application Rates

How much N to apply generally depends on the preferences of the end users. In the quest for deep green lawns and rapid growth, nitrogen fertilizers have become the primary turf management tool. As Beard and Green point out[6], however, these deep green lawns are not healthy lawns. Furthermore, there are increasing concerns about the cost and environmental impact of high fertility programs.

If the uniformity of green colour, rather than depth of colour, is acceptable as a criterion for turf appearance, the turf manager can focus on maximizing the health of the turf, rather than on maintaining a deep green colour. This gives considerably more flexibility in adjusting nitrogen application rates and timing to:

- reduce workloads and costs,
- improve pest resistance and reduce pesticide requirements,
- minimize environmental risks from nutrient leaching, and
- enhance the image of the industry or individual as environmentally responsible.

The N requirement for lawn areas varies depending on the soil base, pH, levels of P and K, the types of plants in the lawn, and whether or not the clippings are left to decompose on the lawn (s*ee* Grasscycling, Chapter 6). For example:

- Lawns on a ‘sustainable’ soil base (i.e., deep soils with uninterrupted capillary movement of moisture) perform well with lower rates of N than those on only 100 mm (4 inches) of soil over gravel.
- Lawns with higher populations of clover need less added nitrogen because the clover makes nitrogen available naturally.

- Bluegrass-fescue blends require less N than pure bluegrass turf, because the fescue grows well at lower N levels.[7] (New selections of Kentucky bluegrasses with lower N requirements exist, but are not yet generally available).

How Much Nitrogen is Enough?

Many lawns in our region perform acceptably without annual fertilizer applications. However, the addition of fertilizer will likely improve turf health. The question is: how much? The decision about the how much and when to apply N will depend on the site's unique soil and turf conditions, as well as the user's expectations and budget.

Provincial recommendations vary for nitrogen use on general use turf (home lawns and parks). For example:

- New Brunswick recommends that total N for the season should not exceed 1.5 kg/100 m^2 (3 lb/1000 ft^2), [8] with no single application greater than 0.5 kg of soluble nitrogen/100 m^2 (1 lb /1000 ft^2). (Some slow release formulations have higher recommended single application rates because of the reduced potential for burning).
- Nova Scotia recommends not more than 1 kg/100 m^2 (2 lb/1000 ft^2 [9].)

Most published recommendations are for higher annual application rates, but these are for regions with longer growing seasons. For example, recommended rates for Kentucky bluegrass, (the species with the highest N requirement), start at about 0.2 kg/100 m^2 (0.4 lb. of N/1000 ft^2) per growing month[7]. In Ontario, Eggens suggests using 1 to 1.75 kg/100 m^2 annually (100-175 kg/ha) on medium maintenance turf.[10] Using these figures as a guide, the New Brunswick and Nova Scotia figures above give reasonable upper ranges for the 5 to 6 months of active growth in our region.

When calculating the amount of nitrogen required, it is important to realise that leaving clippings on the lawn will reduce the need for added N by one-third to one-half.[11, 12, 19] Applying properly matured composts can produce the same result. A healthy turf on a sustainable soil base, using mulched clippings, will perform well with an annual N application rate of 0.5 kg/100 m^2 (1 lb/1000 ft^2) or less.

Nitrogen Drives Clipping Production

Applying increased rates of nitrogen to turf generates a large amount of leaf tissue. A Winnipeg study showed an average of 90% increase in the yield of clippings with an increase of 0.5 kg/100 m^2 (1 lb/1000 ft^2) in the N application rate.[13]

Recent studies in Fredericton showed that lawns yield an average clipping mass of about 12 kg per 100 m^2 (26 lbs/1000 ft^2, wet weight).[14] This means a typical 500 m^2 home lawn could produce about 1.2 tonnes of clippings annually; a hectare would generate over 24 tonnes. Assuming the Winnipeg findings are transferable, a 0.5 kg increase in nitrogen application rates would almost double clipping production—to over 22 kg/100 m^2. That is a lot of extra mowing! On the other hand, reducing nitrogen application rates is a way to significantly reduce clipping yields, workloads and landfill pressures.

Timing of Nitrogen Applications

Past practice has been to apply the first feed of N at or before the first mowing, with additional applications through the season. Research has found, however, that early spring applications of N to healthy turf cause a decrease in root growth and plant nutrient reserves.[15] The additional N appears to stimulate excessive tissue growth at the expense of root growth.

The best time for a single nitrogen application is the beginning of the September-October growth period.[16, 17] This is a relatively new concept in turf nutrient management. Turfgrass uses nutrients most effectively during this period to build up reserves for over-wintering. This also prepares the turf to begin the next spring flush with healthy nutrient levels.

The second best time to apply N is immediately after the spring growth flush, which is about mid-June in this climate. The timing of June applications of fertilizers containing water-soluble N is critical both from the point of view of plant health and environmental impact. This is because grass growth generally slows down by mid-July and may stop all together by the third week of July as soil moisture is depleted. When fertilizer is applied too close to this summer dry period, it can produce high nitrogen levels in the plants and increase plant stress. (The stress from high N levels in the dry period shows up as a greyish green sheen on the turf.) Any remaining soluble nitrogen, not taken up by the plants, dissipates into the environment. In most of the region, N can be applied between June 10th and 20th with a reasonable assurance that there will be 30 days of active growth to fully use the soluble nitrogen. Of course, individual sites may vary, depending on the soil base, climate, and irrigation practices.

Fertilizing turf in late fall, after top-growth ceases, is recommended in many regions, however, this practice is not recommended for our region. This is because there is a risk of soluble nitrogen remaining in the soil at the time the ground freezes up. It has been recognized for some time that this N can potentially leach off site over the winter.[18] To avoid this problem, apply the last N fertilizer at least four weeks before mowing stops in the fall.

Table 3-2: Suggested fertilizer application schedule for the Atlantic region.

Applications per Year	Timing of Applications			
	Early May	June 10 to 20	Mid-September	Mid-October
1			X	
2		X	X	
3		X	X	X
4	X	X	X	X

Multiple applications are recommended if annual nitrogen application rates are higher than 0.5 kg/100 m^2 (1 lb/1000 ft^2). When using up to 3 applications per year, the total annual application rate should be divided evenly into the number of applications desired. A fourth (May application) might be desirable for young turf (e.g. planted last season and just becoming established) or where turf shows excessive winter injury. In these cases, a reduced N rate is suggested – about half the rate of the other applications.

To minimize streaking or overlapping that might burn the turf, spread half the total amount in two applications, made at right angles to each other. Check the spreader delivery rate, and adjust as necessary, taking care to spread the fertilizer on the turf, not on sidewalks or driveways.

ENVIRONMENTAL STEWARDSHIP

There are several ways a turf manager can move further toward environmentally friendly practice, while providing healthy turf. These include:

- Consider the impact on the environment when choosing the type of nitrogen fertilizer, the application rate and timing. There are direct impacts, such as leaching of excess nitrogen off site, and indirect impacts, such as energy wasted on excess mowing, removing clippings, and transporting them to landfills or other disposal sites.
- Avoid fertilizing in the early spring, near the time of the first mowing, because this accelerates top-growth. Not only does this increase mowing and clipping disposal costs, but it can also have a negative impact on the health of the turf, and significantly increase the risk of nitrogen loss to the environment.
- Reduce the need for fertilizers by adjusting the soil pH to 6.5 and by leaving grass clippings on the lawn.
- Make sure fertilizers are applied only to the lawn and not to the surrounding driveway or sidewalk where rain will wash it into watercourses.
- Schedule applications of soluble nitrogen products at least 4 weeks before turf dormancy begins, both in summer and late fall.

KEY POINTS

- Take soil tests now to determine soil pH, P and K levels; repeat every two to three years to review the results of your management program. Let your soil, rather than advertisers, tell you what fertilizer to use!
- Aim for a pH 6.5 target. Consider splitting lime applications over several years.
- Recycle clippings wherever possible (grasscycling).
- Balance nitrogen applications with lime, to keep the pH up.
- Use fertilizer ratios required to correct P and K deficiencies, then switch to products with high N and low P and K content (4:1:1 or 5:1:1 ratio).
- Evaluate current nitrogen application rates and reduce rates where appropriate.
- Consider using only fertilizers with controlled release N formulations.
- Consider timing fertilizer applicators for mid-September and mid-June.
- Where more than one application is scheduled for the season, split the N rates equally (with a reduced rate for May if applicable).
- Check the spreader delivery rate, and adjust as necessary
- Spread the fertilizer on the turf, not on sidewalks or driveways.
- To minimize unevenness, spread half the total amount in two applications at right angles to each other.

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[3] Almack, Corrie. *Understanding Soil Tests and Correcting Soil Problems*. Handout of presentation at Atlantic Turfgrass Conference, Halifax NS, March 26, 1996. Almack and Associates, 375 Carlisle, Waterdown ON, L0R 2H0.

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[7] Beard, J. B. *Turfgrass: Science and Culture*.1973. Prentice-Hall Inc. Englewood Cliffs, N. J. Table 13-11, p.446.

[8] Anon. Lawn Establishment and Maintenance. *Garden Facts*, Plant Industry Branch, New Brunswick Department of Agriculture. Agdex No. 273.21.

[9] Anon. *Lawn Care Through the Seasons.* Nova Scotia Department of Agriculture and Marketing, Plant Industry Branch. p.2.

[10] Eggens, J. L. *Turf Management – Principles and Practices.* Study Guide. 1998. University of Guelph, Guelph ON. Chapter 4 p.7.

[11] Eggens, op. cit. Chapter 4 p.17.

[12] McDonald, D. K. *Ecologically Sound Lawn Care for the Pacific Northwest*. 1999. Seattle Public Utilities. Seattle, WA. p.36. Available on-line at: http://www.ci.seattle.wa.us/util/lawncare/LawnReport.htm; hard copies available from New Brunswick Horticultural Trades Association; cost $15 plus postage.

[13] Platford, H. *Effect of Clipping Disposal, Fertilizer Rate and Mowing Frequency on Cool-Season Turfgrass Growth To Determine Impact on Waste Disposal.* 1998. Natural Resources Institute, University of Manitoba. p.135.

[14] Unpublished data. Analysis of tissue yield samples collected as part of studies in progress by the New Brunswick Horticultural Trades Association and the New Brunswick Department of Agriculture, Fisheries and Aquaculture. Samples were collected through the 2002 growing season from different turf areas, with fertility programs ranging from 0 to 1.5 kg/100 m^2 nitrogen application rates. Three studies were involved: Compost Performance Evaluation, Fertility Trials in Turf, and Weed Suppression through pH.

[15] Eggens, op. cit. Chapter 4 p. 30.

[16] Emmons, Robert D. *Turfgrass Science and Management, Third Edition*. 2000. Delmar Publishers, Albany NY, p.189.

[17] Stahnke, Gwen K. Washington State University. Quoted in McDonald, op. cit., p. 36.

[18] Beard, J. B, op. cit. p. 449-450.

[19] Eggens, op. cit. Chapter 4 p.7.

FURTHER READING

Eggens, J. L. *Turf Management – Principles and Practices Study Guide*. 1998. University of Guelph. See: Fertility, Chapter 4. pp.17–39. Provides an excellent description of nutrients and their impact on turf growth.

Anon, *Recommendations for Turfgrass Management*. Ontario Ministry of Agriculture and Food Publication 384, 1990. Queen's Printer for Ontario. See: Soil Management and Fertilizer Use, pp. 10-14, for discussion of nutrient recommendations based on different levels of turf use.

McDonald, David K. *Ecologically Sound Lawn Care for the Pacific Northwest*. 1999. Seattle Public Utilities. Seattle, WA. 79 pages. See: Fertilizing for Lawn Health, starting p.35. Contains an excellent description of turf management to meet plant requirements. Application rates and timing apply to West Coast; therefore they should be adjusted to our climate. Available on-line at: http://www.ci.seattle.wa.us/util/lawncare/LawnReport.htm; hard copies available from New Brunswick Horticultural Trades Association; cost $15.

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