TREES AND DROUGHT

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INTRODUCTION

The 1998 growing season, in the Kitchener-Waterloo area was noticeably one of the driest years on record. This type of weather event normally occurs every 30 to 50 years and hasn't occurred since the 1960's. Such weather phenomena can have a profound effect on tree health and growth. The purpose of this report is to help landowners be aware of what effects may be evident in their woodlots due to the drought and how the trees may be impacted by the drought conditions. It also suggests some management strategies that may be adopted in order to increase drought resistance in their forest stands.

WATER IN TREES

Water absorption

Water is absorbed primarily into roots and translocated throughout the tree. However, not all root tissue absorbs water. Absorption takes place at the tips of roots, through root hairs which are thin-walled cells permeable to water. The mechanism of this absorption is affected by many factors. Plant factors are: the rate of water use and loss by the tree and the extent and efficiency of the root system. Environmental factors are: the availability of soil moisture, soil temperature, soil aeration, and the concentration and composition of the soil solution.

Internal competition for water

Within the tree, young leaves usually obtain water at the expense of older leaves, and the latter usually die first during a drought. Shaded leaves die before unshaded leaves. Growing regions obtain water at the expense of other tissues. Generally, leaves can obtain water at the expense of fruits and seeds. In extreme droughts, the tops of tall trees may experience water shortages and show signs of dieback.

PHOTOSYNTHESIS AND RESPIRATION

Plants produce their own energy source for growth. This process is called photosynthesis. Very simply, carbon dioxide is absorbed through the leaf through stomates, small openings in the leaf that open or close as water is absorbed or lost through guard cells that are placed on either side of them. The carbon dioxide is combined with water in the presence of chlorophyll and light to produce sugars with oxygen as a byproduct. Sugars are translocated throughout the tree to provide the energy the trees need for growth. When sugar is stored in the tree, it is converted and stored as starch.

While photosynthesis causes sugar to be manufactured and stored within the tree, respiration causes the sugar to be broken down into water and carbon dioxide, which are lost from the tree. The stomates allow this moisture to be lost from the tree as evapotranspiration. Respiration is the means whereby trees and plants use stored sugars to produce their energy for growth and other processes.

The balance between photosynthesis and respiration changes throughout the day, and throughout the growing season. There is also competition within the tree for the products of photosynthesis. Fruit and seed production take precedence over shoots. Shoots have precedence over cambium, the wood forming tissue of the tree. Cambium has precedence over root growth and storage in the root systems. This is determined by hormones within the tree and the relative rates of metabolic activity of the regions of the tree. The more active growth centres receive the bulk of the energy. Therefore in a year of lessened photosynthesis, roots will often suffer dieback before other parts of the tree.

TREE GROWTH

Height growth of trees depends on both stored food reserves and ongoing photosynthesis. Since height growth starts before leaves are functional, this growth must be fuelled by the previous years stored food reserves. Hence poor food production in one year will be evident in reduced height growth the following year. Conversely, diameter growth is dependent on food production of the current year, moved downward from the crown. Current photosynthesis is also used for the production of new roots.

EFFECTS OF WATER DEFICITS

Almost every process of the tree is affected directly or indirectly by a water deficit. The most obvious effect is to reduce vegetative growth. Growth is reduced directly by the loss of cell turgor (resulting in wilting) and indirectly by the closure of stomates, which reduces the supply of carbon dioxide for photosynthesis. One result is that under water deficits, photosynthesis can stop. However, since the tree must continue to function, some respiration continues and may even increase with higher temperatures. The result, at the end of the growing season, may be that the food reserves, sugars and starches, are depleted. The tree may end up with less at the end of the year than what it started with. If defoliation from insects occurs during the period of drought stress, the condition may be worsened, particularly if the tree is caused to re-foliate partway through the year. One of the common conditions identified in the period of tree decline in the 1980's was this reduction in stored food reserves, attributed to drought and defoliation.

When growth slows down, cell structure changes. Wood produced during drought has smaller, thicker walled cells. This can show up in the tree as narrower "spring wood" in the annual ring, and proportionally more "late wood".

Many trees survive best on moist but well-drained soils. These species may have fairly shallow root systems which absorb moisture and nutrients at shallow depths in the soil. Conversely, trees adapted to dry sites such as dry ridges, more typically have deep tap roots or roots that are more adapted to exploiting such soils for available moisture. In dry years, trees with shallow root systems may be susceptible to drought which results in dieback of root tips. This may result in dieback of branches within the crown in the current year, or in subsequent years. As noted above, dry years may have the added effect of causing root dieback due to the relative distribution of carbohydrates, the product of photosynthesis, within the tree. Roots and new root growth are dependent on current photosynthesis, and are low on the distribution priority scale.

TREE RESPONSE TO INJURY

Trees can be injured mechanically by wind, ice, or tree tapping. They can also be injured environmentally by frost cracks or sun scald, and biologically by fungal pathogens or insects. When trees are injured, they do not heal. Trees combat injury by isolating the injury with barriers of mineral stain and other compounds, and then by growing new tissue to bury the isolated tissue. The process is called "compartmentalization". This results in: a depletion of the energy reserves of the tree as it combats the injury, and a loss of storage capacity of the tree as it loses a portion of its live tissue to the injury. Furthermore, tree vigour determines the speed with which the barrier is formed, and the strength of the barrier laid down to isolate the injury, and its eventual success in reducing the spread of any pathogens that may be present in the injury. A similar injury on trees of varying vigour may therefore have differing impacts to the tree. An injury to a low vigour tree will have much greater impacts than a similar injury to a vigorously growing tree. Furthermore, trees that are weakened by stresses such as drought become liable to attacks made by a range of pathogens (diseases) and insects that seldom harm healthy trees. Conversely, trees that are actually killed by a drought are usually those that have been subject to earlier stresses such as either injury or disease.

WINTERKILL

The imbalances that occur in trees during a drought year may predispose them to winterkill. In many plants, sugar concentrations in the tissues is one factor, among many, that can affect freeze tolerance. Generally, the higher the sugar concentration, the greater the freeze tolerance. Therefore, a drought which causes a net loss of carbohydrate reserves, where respiration exceeds photosynthesis, can result in winterkill. Repeated freezing and thawing results in a breakdown of cell tissue and dieback of the living parts of the tree; shoots, cambium and roots.

TREE VIGOUR

Vigorous trees generally have thin rather than heavy, corky bark, have full crowns with many small, vigorous branch tips, and have rapid diameter growth resulting in rapid healing of injuries. They are much more able to withstand periods of stress, or unexpected injuries, or attacks by insects and pathogens. Maintaining tree vigour is one of the most obvious ways to prepare trees to combat stress. This preparation can be accomplished in many ways:

Site

Flooding, drainage and soil compaction can result in conditions that stress trees by acting primarily on the root system. Grazing of woodlots increases soil compaction and results in root dieback and tree stress. Growth rates are reduced significantly. Fertilization of the wrong materials or at the wrong time can also predispose the trees to stress by upsetting nutrient balances in the soil or interfering with normal hardening off processes in the fall.

Spacing

Trees require adequate spacing from their neighbours. A rule of thumb for maple is:

- crown diameter in feet should be 20X the stem diameter in feet i.e. 1 foot diameter stem, 20 foot diameter crown.
- spacing in feet should be 2X the diameter in inches i.e. 12 inch diameter stem; 24 foot spacing.
- crown depth should be 40% of the total height of the tree, i.e. tree height is 80 ft., crown depth is 36 feet.

For conifer plantations, manage the stand so that 1/3 of the total tree height is live branches.

Stocking

Maintain your stand, through proper thinning, at optimum stocking levels. This is normally measured in basal area: square feet per acre or square metres per hectare. Excessively high stocking, or conversely excessively low stocking, are both tree stressing situations.

Thinning and harvesting

Avoid severe disturbance such as heavy thinning or harvesting in periods of stress: i.e. drought or wet years, or after heavy defoliation. Conversely, not thinning may result in stressed trees with small, narrow crowns and poor diameter growth, that are not well-equipped to deal with injuries or attacks of insects and diseases.

Monocultures

Stands of all one species are all competing at the same level for the same things at the same time. Stands of mixed species do not compete so much "head-to-head". Also, pathogens such as root fungi prefer, and spread faster, through monocultures.

TAPPING

Tapping causes periodic and repeated injury to trees. In healthy trees, this injury is rapidly isolated from the rest of the tree, and is buried by new wood. In low vigour trees, the injury is more long-lasting and results in more extensive loss of tissue. In addition, repeated tapping that contacts a previously injured or isolated zone breaks through the tree's protective barrier and causes the injured zone to expand. Therefore, tapping that contacts stained wood from a previous tap hole, or heartwood in the centre of the tree, results in additional loss of living tissue as the tree lays down another protective barrier. This process also causes an energy drain on the tree.

Cluster tapping can result in many injuries to a relatively small area of the stem. This can occur because of drop lines being too short, or a preference for tapping on one side of the tree, usually the south side. Research has shown that over the tapping season, taphole position in reference to the aspect on the stem, had no impact on total sugar production (as opposed to sap production).

Power tapping can sometimes result in: additional injury to the tree from high speed bits, poor taphole location, and tapping in too cold a weather when tree injury is increased.

It is important to be aware of how trees grow in diameter. In small trees, diameter growth on well-spaced trees can be fairly rapid. In unmanaged stands, 20 year diameter growth can be as low as 2.0 inches (20 rings per inch). Through thinning trials, trees starting at 6 inches in size grew up to 7 and 8 inches (5.7 to 5.0 rings per inch) during the 20 years of the study. 12 inch trees grew from 3.6 to 7.1 inches (11 to 5.5 rings per inch) , and 18 inch trees grew from 4.2 to 5.8 inches (9.5 to 6.9 rings per inch). Therefore, it can be seen that although large trees have a larger tappable circumference, their ability to bury the injury with new wood declines as the trees age.

Most tapping rules are based on only the diameter of the tree to be tapped. It is important to be aware of how fast the tapholes are being covered over by new wood, and important to base tapping intensity on the vigour of the tree. George Buzzell, Orleans County Forester, Vermont Department of Forests, Parks and Recreation, suggests the following tapping guidelines. These have a factor built in for minimum diameter increment, and therefore can reflect growth declines resulting from events such as drought.

Firstly, taps should be placed at least six inches to the side and two feet above or below any old taps that are still open. His guidelines are based on:

1. Tree growth as determined by measuring thickness of growth rings in fractions of an inch. These are obtained by using an increment borer on a few trees of each size class in each soil type. Trees are only bored one inch deep to minimize injury.

2. Available tappable area determined by measuring the net or live circumference of the tapping band. Tapping band refers to the tappable shell or live circumference of a maple tree which is available for tapping. Taps should be properly distributed over as large an area as possible, both vertically and horizontally.

The measured live (or usable) circumference can then be used to figure adjusted tree diameter. Each tree should be closely inspected and adjusted tree diameter determined by measurement. For example, a cluster of open tapholes should not be considered part of the tappable shell. The nontappable shell should include this cluster and an additional six inches on each side of the cluster.

This tapping guideline is based on the minimum tree growth necessary to seal over tapholes and produce new wood for future taps. It also separates usable shell of the tree from the unusable shell of the tree and relates this shell or circumference to adjusted diameter.

1 tap: 12" to 18" diameter for a healthy tree or... usable circumference of 36" to 54". Outside growth rings at least 1/8 inch thick (8 rings per inch or less) - if not consult a forester for possible thinning.

2 taps: 18" diameter for a healthy tree or....usable circumference of 54" and over. Not over 2 taps for any size tree. Growth ring at least 1/8 inch thick (8 rings per inch or less). If growth rings are less than 1/8 inch, (9 rings per inch or more) reduce number of taps and consult a forester for possible thinning.

Example:

A 20 inch diameter tree has had two taps per year for five years on one face. Many of the taps are still open, and occupy a face about 10 inches wide. These taphole injuries (compartments), may combine, compounding injuries and speeding up decay. This 20 inch diameter tree has a total circumference of 60 inches. Reducing this total circumference by the overtapped 10 inch face, plus the necessary horizontal offset of 6 inches on each side of this face, equals a usable shell or circumference of 60 inches minus 22 inches = 38 inches. Since the diameter of this tree is 1/3 of the circumference, the adjusted usable diameter of this tree is now 1/3 of 38" or about 13 inches. At best, a 13 inch diameter tree can handle one tap per year. If a shell of new wood covers the taphole cluster, the tree could be re-evaluated for more than one tap per year.

CONCLUSION

Drought can have serious consequences for trees. Trees can be pre-disposed to drought injury through site problems, injury, or management practices. Conversely their resistance to drought and stresses can be increased in the years prior to a drought, by some management practices. There is therefore opportunity for forest managers to adopt practices that are beneficial to trees and stands and which reduce risks due to environmental anomolies. These management practices should be developed with some knowledge of the physiological processes that result in injury to trees as a result of environmental stresses. Some of the physiological processes are:

- the function and competition for water within the tree,
- the photosynthesis and respiration balance within the trees and the tree's use and translocation of sugar and starch reserves.
- the tree's normal response to water deficits.
- the tree's normal response to injury.
- the tree's normal relationship to the site it is growing on.
- secondary injury such as winterkill.

Some recommended management practices are:

- protecting the site from damage and alteration.
- maintain tree vigour through proper thinning, spacing, and stocking control.
- maintaining a mix of species appropriate to the site.

In addition, tapping of trees for maple syrup should be conducted with the knowledge:

- how trees respond to injury and stress.
- normal expected growth rates in response to management practices.