HYBRID POPLAR CROP MANUAL FOR THE PRAIRIE PROVINCES

Prepared by

Cees ("Case") van Oosten
SilviConsult Woody Crops Technology Inc.

For

saskatchewan forest centre

SilviConsult Woody Crops Technology Inc. (SilviConsult Inc.) is a company founded and incorporated in British Columbia in 1998. The aims of SilviConsult Inc. are to promote the establishment, management and utilization of hybrid poplar as a farm crop in Canada and in the US-PNW.

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Cees van Oosten,
Nanaimo, B.C.
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INTRODUCTION

Knowledge and expertise about hybrid poplar crop farming in Canada has not been readily accessible up to now to the farmer, land owner or corporation planning to grow this new crop in the Prairie region (Alberta, Saskatchewan and Manitoba and British Columbia's Peace River region). The 'Hybrid Poplar Crop Manual for the Prairie Provinces' (including British Columbia's Peace River region) aims to alleviate this and was produced in response to an increasing interest in growing hybrid poplar crops in Canada.

I.1 Hybrid Poplar Crop Manual for the Prairie Provinces

The "Hybrid Poplar Crop Manual for the Prairie Provinces" is a web-based 'How to' manual for farmers, land owners and corporations (collectively called 'farmer') interested in establishing a successful hybrid poplar crop on farmland. It provides the tools and knowledge to make informed decisions about this new crop.

The manual is designed for Internet access and consists of distinct modules (chapters) the user can access and use independently. The design of the manual allows it to be dynamic and thus suitable for updates and improvements over time.

I.2 Agronomic Crop Concept

Well-managed hybrid poplar crops on farmland will produce yields that are considerably higher than poplars grown in a forest setting. To meet yield expectations, hybrid poplar crops must be grown on good soils, and must be intensively managed like any other agronomic crop. This manual is aimed at the concept of growing this crop as an agronomic crop. This concept is generally referred to as 'SRIC hybrid poplar'.

I.3 SRIC Hybrid Poplar

SRIC is the acronym for 'short-rotation-intensive-culture'. The SRIC hybrid poplar crop, or simply SRIC hybrid poplar, denotes hybrid poplar grown as an agronomic crop on farmland on a short crop cycle or rotation, using intensive cultural practices. It is a multi-year farm crop.

The length of the crop cycle or rotation depends on the end product the farmer intends to grow and will vary depending on the location; i.e. the cycle will be shorter under more favourable growing conditions.

a) For biomass crops the crop cycle could vary anywhere from four to seven years; in some countries the cycle can actually be annual. Subsequent biomass crops are produced from the same root systems that coppice (re-sprout new shoots) following a winter harvest. This process can be repeated several times before the parent trees need replacing. This manual will not deal with biomass crops, as this requires a totally different approach.

b) For a pulpwood crop the expected crop cycle or rotation would last from 15 to 25 years, depending on the climate, location and the possibility of irrigation. A subsequent crop would be started with newly planted trees; the old stumps from the previous crops are either removed or killed.

c) For a solid wood crop, such as saw- or peeler logs, the rotation varies from 20 to 30 years, depending on the climate and location. As with the pulpwood crop, a subsequent crop would be started with newly planted trees; the old stumps from the previous crops are either removed or killed.

Another frequently used acronym for this type of crop in the US is SRWC, which stands for short rotation woody crop. It is the growing of trees as a crop using agricultural practices on a rotation generally less than 15 years.

I.4 Terminology

It is unavoidable for new terminology to emerge with the introduction of this new crop. To assist the user, there is a Glossary of Terms for easy reference. There are a few new terms and concepts that are discussed below, which are considered essential for ease of use of this manual.

I.4.1 *Populus* species

Both poplars and aspens belong to the genus *Populus* and are 'true poplar' species. The scientific name (in Latin) is always *italicized*. The genus covers many different poplar and aspen species and sub-species that occur naturally in the northern hemisphere, where they are the fastest growing tree species. The Latin naming of species follows a system of plant nomenclature generally accepted in the scientific world. It allows for a more precise description and identification of the various species. There are also many common names for these species that vary from country to country and even region to region, resulting in much confusion. There is ongoing debate in the scientific world about this and from time to time names are changed to reflect a better understanding of how species are organized.

In the introduction the common name is listed, followed by the scientific name (in brackets and italicized). In the remainder of the manual specific hybrid poplars will be referred to by common name or number. For a listing of clones currently available in the Prairie region, see Appendix A-2. Not all of these are suitable and more information can be found in 'Site requirements and clone selection' [see Module 2.2.1] of module 'Clone Selection and Deployment' [see Module 2].

❖ **Poplar**

Poplar is the common name for several of the native North American species:

- Balsam poplar (*Populus balsamifera*);
- Plains or eastern cottonwood (*Populus deltoides*) – three subspecies (see Variety).
- Black cottonwood (*Populus trichocarpa*) – two subspecies;

The balsam poplar occurs naturally in the northern regions of Canada, including the Prairie Region. The plains or eastern cottonwood occurs in the southern Prairie Region, mostly along riparian systems. Eastern cottonwood also occurs throughout southern regions of Ontario and Quebec. Black cottonwood occurs throughout coastal and interior British Columbia and into the Peace Region of northeast British Columbia and northwest Alberta.

The name 'black poplar' is sometimes also used for either the balsam poplar or the black cottonwood. Although this may be a localized name, it could cause confusion as the name black poplar applies to the European black poplar (*Populus nigra*), native to Europe, of which there are several subspecies. The familiar Lombardy poplar (*Populus nigra* 'Italica') is a subspecies of the European black poplar and has been widely used in North America as a landscape or windbreak tree.

To add to the confusion, lumber yards in North America sell 'poplar'; however, this wood comes from the so-called yellow poplar or Tulip tree, which is the *Liriodendron tulipifera* and is not a 'true poplar' or *Populus* species at all. Lumber from *Populus* species is marketed in North America as 'aspen' or 'cottonwood'[1].

One characteristic of poplars is the relative ease with which they can be reproduced vegetatively (asexually) through unrooted cuttings. Poplars grow best on rich, moist, but well-drained sites (e.g. river bottomland).

This manual will deal exclusively with poplars and their hybrids.

❖ Aspen

Aspen is the common name for another group of *Populus* species native to North America; these are also 'true poplars':

- Trembling or quaking aspen (*Populus tremuloides*) – five subspecies;
- Bigtooth aspen (*Populus grandidentata*) – two subspecies.

Trembling or quaking aspen is prevalent across all of Canada and is very common in the Prairie Region and the Rocky Mountains; in some areas it is known as 'popple'. Bigtooth aspen grows in southern Manitoba, Ontario, Quebec and the US Lake States. Unlike the poplars, aspens cannot be readily propagated from unrooted cuttings. They sucker vigorously from their root systems following harvest or forest fires. Aspens are much better adapted to drier upland sites, as opposed to poplars.

This manual will not deal with aspen. These *Populus* species have different requirements and can best be dealt with in a dedicated aspen crop manual in the future if the need arises.

I.4.2 Hybrid poplar

Poplar (and aspen) trees are dioecious, meaning they are either male or female. Other tree species, such as spruce, carry both male and female flowers. The white snow or fluff that flies around late in the spring is the seed from the female poplar trees.

1 Dickmann, D.I. 2001. An overview of the genus Populus. In Poplar Culture in North America. Part A, Chapter 1. Edited by D.I. Dickmann, J.G. Isebrands, J.E. Eckenwalder, J. Richardson. NRC Research Press, National Research Council of Canada, Ottawa, ON K1A 0R6, Canada. Pp. 1-42.

Hybrid poplar is created by crossbreeding two parents from closely related species of poplar, or by crossbreeding two parents with a different genetic makeup within a species of poplar. This can either occur spontaneously or artificially. Not all combinations are possible or compatible.

A hybrid is designated by the 'times' (x) symbol. For instance, a hybrid between the balsam poplar (*Populus balsamifera*) and the eastern cottonwood (*Populus deltoides*) is written as *Populus balsamifera* x *Populus deltoides*; the abbreviation for this hybrid poplar cross is BxD or BD. The female parent is always listed first. One such hybrid is a naturally occurring or spontaneous hybrid (see below) known as the '*Jackii*' or 'Jack's poplar' (*Populus* x*jackii*) in eastern Canada. In this case the extension '*xjackii*' means that this is a hybrid between two poplars that has been named 'jackii'. There are also naturally occurring Jackii poplars in Alberta

❖ Spontaneous hybrid poplars

Where compatible species of poplars have overlapping ranges, poplar hybridization can happen spontaneously. For instance, the female (symbol ♀) balsam poplar crosses fairly easily with the male (symbol ♂) eastern cottonwood to create a hybrid poplar (*Populus balsamifera* x *Populus deltoides*), also known as the 'Jackii' or 'Jack's poplar' *(Populus x*jackii); some of these have been used with good success. In the overlapping range of black cottonwood and balsam poplar in the Peace Region, hybridization is a frequent occurrence.

The balsam poplars (*Populus balsamifera*) and trembling aspens (*Populus tremuloides*) occur naturally in the Prairie region, where they have overlapping ranges, yet they are incompatible and cannot crossbreed. The same holds true for introduced hybrid poplars, such as the shelterbelt poplars. These are also incompatible and cannot crossbreed with natural aspen.

Introduced poplar species can also hybridize spontaneously with native poplars. There are several good examples of this in Europe between eastern cottonwood females (imported from North America) and native European black poplar males. These spontaneous hybridizations produced some economically important hybrid poplars in Italy for instance, of which *Populus* x*canadensis* 'I 214' is one of the better known hybrids. The designation *xcanadensis* is the name of this group of hybrid between eastern cottonwood females and European black poplar males. In Ontario the earliest plantings in 1925 consisted of the Carolina poplar[2] (*Populus* x*canadensis* 'Eugenei', also known as 'DN34'), which was also one of many spontaneous hybrids between an eastern cottonwood and a European black poplar. It was selected in France and subsequently imported to and widely planted in North America. Interestingly enough, the reverse combination of European black poplar females and eastern cottonwood males is incompatible and crossing does not occur.

❖ Artificial hybrid poplars

Parents from closely related species of poplar or parents with a different genetic makeup within a species of poplar are crossed artificially to create superior trees, using traditional crossbreeding techniques. Some combinations between closely

2 Boysen, B., Strobl, S. (Editors), 1991. A Grower's Guide to Hybrid Poplar. Ontario Ministry of Natural Resources. (Out of print).

related species are easily made and some only work with the female from one species crossed with the male from another species, but not the reverse.

Out of thousands of artificial crosses, only a handful of hybrid poplars will eventually be successful. Their success and acceptance are determined by a few important criteria, such as hybrid vigour, site adaptability and resistance to diseases and pests. Many hybrid poplars not meeting the final selection criteria will have to be eliminated from the selection process, for example when these hybrids are not resistant to diseases.

- **Is hybrid poplar a genetically modified organism (GMO)?**

Hybrid poplar is NOT a genetically modified organism (GMO). Hybrid poplars are created through classical or traditional crossbreeding techniques; they also occur through natural or spontaneous hybridization.

A genetically modified organism is a plant (or animal) that has been genetically engineered by transferring specific traits or genes from one organism into a different plant (or animal) species. With genetic engineering, genes from completely different species can be inserted into the targeted organism.

I.4.3 Why hybrid poplar?

- **Hybrid vigour or heterosis**

Hybrid vigour or heterosis is the general tendency of the hybrid tree to show qualities (e.g. growth rate) that are superior to those of either parent or parent species. This is the case with hybrid poplars that not only exhibit superior growth, but in some cases also superior resistance to pests and diseases. There are many parallels with agricultural crops, for instance hybrid corn or hybrid canola; these are used to improve yield.

I.4.4 Clone, variety or cultivar

Since poplars (both hybrids and non-hybrids) can easily be propagated through vegetative means from stem cuttings, an infinite number of genetically identical trees could be created from one (hybrid) poplar, with all trees having exactly the same properties.

Genetically identical trees are called a ‘clone’. For instance the clone ‘Walker’ is a well-known hybrid poplar used for farm shelterbelts and is now also used to establish SRIC hybrid poplar crops in the Prairie region.

Other terminology such as variety or cultivar (cultivated variety) is sometimes used incorrectly when referring to (hybrid) poplar clones; this can create confusion. This manual uses the word clone.

I.4.5 Monoclonal or clonal crops

The ability to easily propagate a vast number of individuals from one selected hybrid allows planting a field to just one clone. This is called a monoclonal crop or a clonal crop. The ability to do this can have some important advantages. This manual refers to a monoclonal crop when a crop consists of just one clone.

In SRIC hybrid poplar it is unusual to intentionally grow a crop consisting of a clonal mix. When it does occur, it is often the result of an unintentional mix-up of two or more clones at the nursery or of insufficient quality control during planting. A crop consisting of two or more clones planted as a mix is a polyclonal crop.

I.5 How Is This Manual Organized?

The content of this manual is based on operational knowledge and experience and follows, to some degree, the handbook 'A Grower's Guide to Hybrid Poplar'. This handbook was produced in 1991 by the 'Fast Growing Forests Technology Development Unit'[3] (also known as the 'Fast Growing Forests Group') of the Ontario Ministry of Natural Resources and associated partners. This handbook is out of print.

3 The Fast Growing Forests Technology Development Unit was located in Brockville, Ontario; however, it does not exist anymore. A Grower's Guide to Hybrid Poplar was edited by B. Boysen and S. Strobl.

The order of the modules or chapters follows the flow of decision making and planning of the farmer. Although the modules are intended as 'stand-alone' information on certain subjects, it is important to follow the flow of decision making that leads to a well-planned SRIC hybrid poplar crop.

I.6 Future Updates and Expansion and a Word on Marketing

This manual can and will be updated periodically, depending on the need and the availability of funds to make it happen. There are tentative plans for two future modules (chapters) that deal with harvesting and marketing. Harvesting systems for SRIC hybrid poplar crops have been developed elsewhere in North America and have proven to be viable. These systems are continually being improved. Since the first harvest in the Prairie region is quite some time into the future, writing a module about harvesting seemed premature. What about marketing?

I.6.1 Marketing

Information about marketing is critical to the success of this new crop. Farmers and potential farmers always ask about the potential market and who will buy the wood when it is ready. The dilemma with this new crop is that there is not yet enough of a sustainable and concentrated supply of consistent quality to attract a processing industry. Unless the farmer is under contract to an existing facility, such as a pulp mill, to grow and eventually produce the wood, there is no market until a sufficient supply is ready. It appears to be a Catch-22 situation.

In 1998 a major marketing study was conducted in eastern Oregon, where only a few SRIC hybrid poplar crops were grown beforehand, to determine what the market opportunities would be for these crops as solid wood products in the Pacific Northwest[11]. This study was implemented through a public-private partnership in eastern Oregon. One of the first things the study addressed was to identify and compare the wood characteristics of hybrid poplar through a review of technical literature and interviews with specialists in the industry. The major conclusions were that there was a "solid opportunity" to bring hybrid poplar wood into the solid wood products market; however,

11 Marketing Study for a Multi-Region Plantation Hybrid Poplar Project - Final Report, December 1998. Mater Engineering, Ltd., Corvallis, OR. - 101 S.W. Western Boulevard, P.O. Box 0, Corvallis, OR 97339 - Ph: (541) 753-7335.

the interest in the wood was likely to result in a demand for volume production that would be much higher than what farmers would be able to produce on short notice. Crop establishment continued in Eastern Oregon and a sustainable supply of hybrid poplar wood is now coming on line in the region. There is serious interest to construct a new saw mill within the next few years to process the wood.

In the meantime, important initiatives are underway in the Prairie Provinces to determine the suitability of the wood characteristics of existing hybrid poplar grown in the region for various uses, including veneer, OSB and solid wood products. These initiatives are funded through the Saskatchewan Forest Centre (SFC) and carried out by Forintek Canada Corp. The results are very encouraging and confirm what the Oregon marketing study concluded. To determine the suitability of the wood is the first and most important step in the marketing strategy of hybrid poplar grown in the Prairie Provinces.

For additional information, please see:
Web-SFC
Web-Forintek

I.7 Who Should Use This Manual?

- Farmers who intend to grow SRIC hybrid poplar crops for pulpwood, OSB, saw- or peeler logs;
- Contractors who see an opportunity to offer services to this emerging new crop enterprise;
- Nurseries and stoolbed operators, interested in supplying planting stock;
- Extension agencies who would like to offer some or all of the expertise of this manual to their clients;
- The poplar research and technology development community. Ideally the manual could serve as a two-way communication tool between farmers and developers of poplar research and technology, through a feedback loop;
- Forecasters and marketers. The manual serves as a tool to reach farmers, which could lead to a database on existing farmers, wood inventories etc.;
- End users such as saw mills, veneer mills, LVL mills, OSB mills, pulp and paper mills, organizations growing SRIC hybrid poplar in utilizing manure and municipal biosolids, or in the cleanup and rehabilitation of polluted sites through phytoremediation;
- Although this manual will not deal with biomass crops, the principles still apply and can form the basis for a dedicated crop manual that could benefit the ethanol and bio-energy industry;
- The manual only addresses the know how of growing a successful SRIC hybrid poplar crop. It does not offer expertise on any other crop that might be grown in conjunction with hybrid poplar (including cattle grazing).

I.8 Disclaimer

The author, associated experts and advisors, the Poplar Council of Canada and the Saskatchewan Forest Centre do not assume liability for crop losses, safety or environmental hazards caused by the use of practices or products listed in this manual.

The use of pesticides, fertilizers and other regulated materials is subject to Provincial and Federal laws and regulations. Although every effort is made in this manual to ensure recommended practices fall within the laws and regulations, the user assumes the full risk and responsibilities under these laws and regulations.

The mentioning and listing of products, services and contacts do not imply endorsement, but are intended to provide the user of this manual with the broadest possible choices and comparisons.

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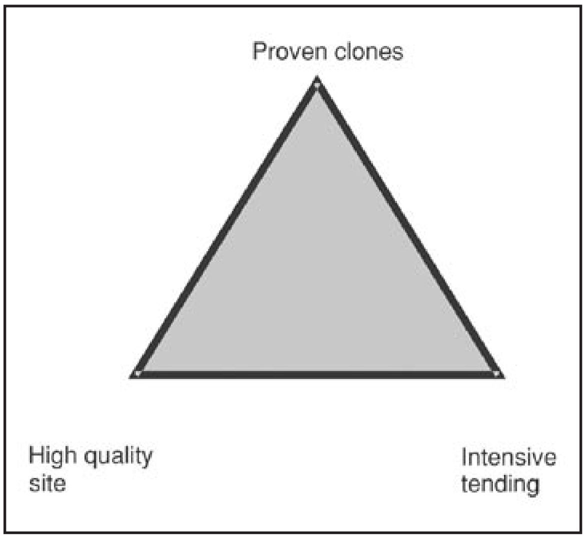
MODULE 1 : SITE REQUIREMENTS AND SITE SELECTION

Success of short-rotation-intensive-culture (SRIC) hybrid poplar crops depends on three main conditions (Figure 1-1):

a) Planting the best proven clones;
b) Planting the best quality sites;
c) Carrying out timely and appropriate cultural treatments.

Figure 1-1[4]



If the farmer cannot or will not commit to intensive crop tending following planting, then this crop is not for him.

To determine if a site meets the requirements for a successful crop, the following needs to be considered:

a) Are the soils suitable ? [see Module 1.1]
b) Is there sufficient precipitation during the growing season?
c) Are there environmental restrictions such as known drought or frost pockets? [see Module 1.2.11]
d) What was previously grown on the site and what weed population is currently present? [see Module 1.2.6]
e) Does the site meet operational requirements such as distance to potential markets, topography and suitability to work the soil etc.?

1.1 Site requirements

In general, optimum crop performance can be expected on soils that are a well-aerated, have sufficient moisture and nutrients, are of sufficient depth (> 1 m or 3 ft. to the water table), have a medium texture and have a soil pH in the 5.0 to 7.5 range. Poplars need high light intensity, warm temperatures and sufficient soil moisture during the growing season.

4 Stanturf, J.A., van Oosten, C., Netzer, D.A., Coleman, M.D., and Portwood, C.J. Ecology and silviculture of poplar plantations. In Poplar Culture in North America. Part A, Chapter 5. Edited by D.I. Dickmann, J.G. Isebrands, J.E. Eckenwalder, J. Richardson. NRC Research Press, National Research Council of Canada, Ottawa, ON K1A 0R6, Canada. Pp. 153-206 (Fig 1. page 154).

1.1.1 Soil texture and drainage

Soil texture and drainage are two of the most important factors influencing the success of a hybrid poplar crop. In combination these two factors are main determinants of the suitability of a soil for poplar (Table 1-1). A general misconception is that poplar grows well on wet sites; however, like any crop, the best results with poplar are obtained on well and moderately well drained sites.

Table 1-1 The influence of soil texture and drainage condition on site quality for poplar. Ratings in brackets indicate potential with improved drainage.

Dominant Profile Textures	Symbol	Well and Moderately Well Drained	Imperfectly Drained	Poorly and Very Poorly Drained
Sand	S	Unsuitable	Fair	Unsuitable
Loamy Sand and Silty Sand	LS and SiS	Good	Fair	Unsuitable
Sandy Loam and Sandy Clay Loam	SL and SCL	Very Good	Fair (Good)	Unsuitable
Sandy Clay	SC	Fair	Unsuitable	Unsuitable
Silt, Silt Loam and Loam	Si, SiL and L	Good	Fair (Good)	Unsuitable
Clay Loam and Silty Clay Loam	CL and SiCL	Good	Unsuitable	Unsuitable
Silty Clay and Clay	SiC and C	Unsuitable	Unsuitable	Unsuitable

The texture of a soil refers to the size distribution of the mineral particles composing the soil. Particles are grouped into three main classes: sand, silt, and clay. The textural classes are based on the percentages of clay and sand in the main textural classes of soils; the remainder of each class is silt.

Clay plays an important role in soil fertility as the surface area of clay particles has the ability to attract and hold positively charged nutrient ions, which are available to the plant roots for nutrition; this is called 'cation exchange capacity' or CEC and is a measure of potential soil fertility. The structure of clay particles also allows clay to absorb water. For a more detailed description and understanding, the user can check the website of Agriculture and Agri-Food Canada [Web-CanSis texture]. Appendix B contains a diagram that the farmer might find useful to determine soil texture.

When soils remain waterlogged during the growing season, lack of soil oxygen negatively affects functioning of the roots. The poplar actually suffers from drought-like symptoms, with leaves turning yellowish-green and remaining very small. The tree becomes increasingly stressed as the growing season progresses and may die. Most poplar clones require well-aerated soils by the end of June to survive and grow well. Younger trees are generally more susceptible to poor soil drainage. In a wet growing season on a soil with insufficient drainage, the results are often quite visible in the tree crop; the leaves remain small and are pale green.

The finer textured soils still suitable for poplar, clay loam (CL) and silty clay loam (SiCL) (Table 1-1), are less favourable than coarser textured soils. The main problem on these finer textures is the difficulty of achieving good weed control. That is why the imperfectly drained clay loams (CL) and silty clay loams (SiCL) are deemed unsuitable. Besides the effects of poor drainage, mechanical weed control with a disk or cultivator is often ineffective when these soils are still wet. Equipment access may not even be possible, leaving the farmer without cost-effective options. Survival will be adversely affected and growth during the first few years can be disappointing. The lack of rapid growth will delay canopy closure, which is the point at which neighbouring trees start to form a closed canopy. A canopy that remains open cannot control the weeds through shading; that will adversely affect growth of the crop.

Drainage classes are defined in Table 1-2. Appendix C contains a chart that will help the user determine soil drainage on his land.

Table 1-2 Soil drainage class definitions (CDA, 1974)[7,8]

Class	Description
Rapidly drained	The soil moisture content seldom exceeds field capacity in any horizon except immediately after water additions (soils are free from gleying [Web-Soil Classification] throughout the profile).
Well drained	The soil moisture content does not normally exceed field capacity in any horizon (except possible the C) for a significant part of the year (soils are free from mottling in the upper 1 m or 3 ft.).
Moderately well drained	The soil moisture in excess of field capacity remains for a small but significant period of the year (soils are mottled in the bottom of the B and C horizons).
Imperfectly drained	The soil moisture in excess of field capacity remains in subsurface layers for moderately long periods of the year (soils are mottled in the B and C horizons).
Poorly drained	The soil moisture in excess of field capacity remains in all horizons for a large part of the year (soils are usually very strongly gleyed.
Very poorly drained	Free water remains at or within 30 centimeters of the surface most of the year (soils are strongly gleyed).

A study completed in 2002 by the Shelterbelt Centre concluded that “the factor determining height growth of Walker poplar was predominantly soil texture” and “the best sites for Walker poplar growth were found to be those with soils which were classified as sandy loam, sandy clay loam and loam. The second best sites for growth had soils classified as silty loam, clay loam and silty clay loam. The poorest sites were on sites with soil textures classified as sandy clay, clay, silty clay, heavy clay and loamy sand.” In other poplar handbooks well drained and moderately well drained loamy sands (LS) are considered very good for productivity[5,6] of poplar in general. This illustrates the variability between different clones.

Besides soil texture, other variables such as total precipitation, moisture deficit, depth of the A horizon and depth to water table were also considered, but their effects on growth performance were overshadowed by the importance of soil texture for clone Walker. This clone is a good example of the exacting requirements many hybrid poplar clones place on growing site. It is less flexible or plastic than others and is therefore a good and conservative model to describe site requirements.

7 Schroeder, W., Silim, S., Fradette, J., Patterson, J., and de Gooijer, H. 2002. Detailed Site Analysis and Mapping of Agroforestry Potential in the Northern Agricultural Zone of Saskatchewan. Funded by the Saskatchewan Forest Centre - Forest Development Fund.

8 Adapted from: Canada Department. of Agriculture (CDA), 1974. The System of Soil Classification for Canada. CDA Publication 1455. 155pp.

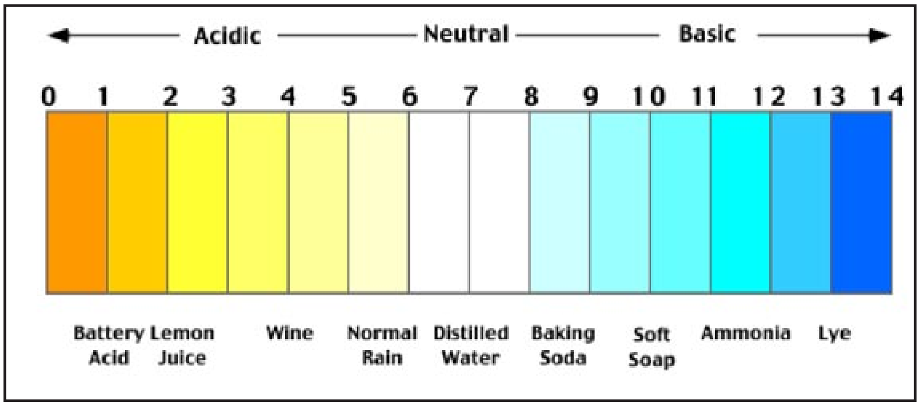
5 Stanturf, J.A., van Oosten, C., Netzer, D.A., Coleman, M.D., and Portwood, C.J. Ecology and silviculture of poplar plantations. In Poplar Culture in North America. Part A, Chapter 5. Edited by D.I. Dickmann, J.G. Isebrands, J.E. Eckenwalder, J. Richardson. NRC Research Press, National Research Council of Canada, Ottawa, ON K1A 0R6, Canada. Pp. 153-206 (Table 3. page 169).

6 Dickmann, D.I., and Stuart, K.W. 1983. The culture of poplars in eastern North America. Michigan State University Press, East Lansing. 168 pp.

1.1.2 pH and soil fertility

Soil pH is the scale used to measure the acidity or alkalinity of the soil by determining the concentration of hydrogen ions in solution. The acidity or alkalinity of soil is measured in pH units, at a scale of pH 0 to pH 14; the neutral value is pH 7. Figure 1-2 shows the pH range for several familiar substances.

Figure 1-2 (source: [Web- PhysicalGeography.net])



Distilled water for instance has a pH of 7.0 (neutral) as it does not contain any positively or negatively charged ions; i.e. it is pure water, without dissolved salts.

With an increase in hydrogen ions in the soil, the acidity increases and the pH value decreases; i.e. from pH 7 to pH 0 the soil becomes increasingly more acidic and from pH 7 to pH 14 the soil becomes increasingly more alkaline or basic.

Chemical reactions in the soil depend on the soil chemical properties and the most important one is the soil pH; it is the single most important factor affecting soil productivity.

The optimum pH range for poplar is pH 5.0 - 7.5, which is slightly acidic to neutral [see Module 1.1]. Table 1-3 shows interpretation of the acidity and alkalinity classes and also identifies the best range for most agricultural crops. There is substantial difference between various hybrid poplar clones in their sensitivity to a different pH level. In some cases this influences nutrient availability, to which different clones react differently.

Table 1-3

<table>
<tr><td colspan="7">Soil pH</td></tr>
<tr><td>5</td><td>5.5</td><td>6</td><td>6.5</td><td>7</td><td>7.5</td><td>8</td></tr>
<tr><td>Strongly
Acid</td><td>Medium
Acid</td><td>Slightly
Acid</td><td>Neutral</td><td>Neutral</td><td>Mildly
Alkaline</td><td>Moderately
Alkaline</td></tr>
<tr><td colspan="6">Optimum range for hybrid poplar</td><td></td></tr>
<tr><td></td><td></td><td></td><td colspan="2">Best range - most crops</td><td></td><td></td></tr>
</table>

There are 16 essential nutrients required for plant growth and reproduction. Three of these are carbon (C), hydrogen (H) and oxygen (O), which come from the atmosphere and from water. The remaining 13 nutrients come from soil or from fertilizers; of these, six are referred to as macronutrients, which include nitrogen (N), phosphorus (P) and potassium (K) and the remaining seven are referred to as micronutrients.

The soil pH influences availability of several nutrients, particularly phosphorus (P) and micronutrients. Soil biological processes are also influenced by pH.

The pH values for soils are a reflection of the soil parent material when soils were formed, the climate (rainfall in particular) and the type of vegetation that established itself on these soils. In the Prairie region many soils originated from calcareous rock (parent material), experienced moderate rainfall and were covered by either grassland or deciduous forest (aspen); frequent occurrence of fire maintained these ecosystems, which contributed to generally neutral to alkaline soils. Soils developed from a sandy parent material and soils developed under long term coniferous forest are generally more acidic.

Farming the land can also contribute to the acidifying process of soils over time. An example is the use of large applications of ammonium based (NH_4+) fertilizers, or the extensive use of legumes in crop rotations. Seepage of alkaline salts can raise the pH over time, making the soil less suitable for crops.

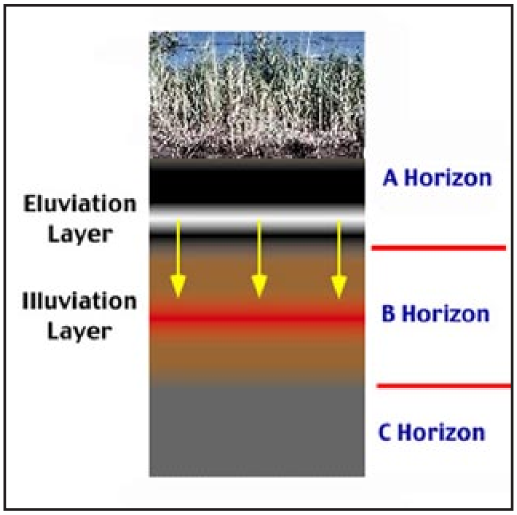
1.1.3 Soil profile, soil depth and soil water storage

In certain circumstances poplars can perform well on shallow soils less than 1.0 m (3.0 ft.) deep. Shallow soils can be caused by an impermeable soil layer, a high water table, bedrock etc. While trees can still be established under these conditions and may grow well initially, they run the risk of serious windthrow damage as the trees get taller. The risk of windthrow varies by clone and increases with increased crop density and age. In years with extended periods of drought, shallow soils could run out of soil moisture partway through the growing season, leading to poor crop growth and possibly crop damage or death.

❖ Soil profile

Soils consist of a number of horizontal layers, which are called soil horizons (Figure 1-3, following page). Each soil horizon has unique characteristics. There are three major horizons in an agricultural soil profile, the A, B and C soil horizons. Undisturbed soils, such as forest soils, would have a layer (called LFH layer) at the top, consisting of fresh undecomposed organic matter (branches, leaves etc.), just below it partially decomposed organic matter and finally at the bottom a layer of well decomposed organic matter. This well decomposed organic matter is incorporated into the top-most soil layer and forms the A horizon. Due to continuous cultivation of agricultural soils, this LFH layer at the top has disappeared.

Figure 1-3: The main soil horizons.



❖ Organic matter

Organic matter is one of the most important components of soil and contributes to its fertility. As with clay particles, organic matter also has a cation exchange capacity (CEC) and is a measure of potential soil fertility. Besides improving soil fertility, organic matter enhances soil structure, soil porosity and resistance to erosion.

Continuous cultivation depletes soil organic matter; however, there are several ways to replenish it. In crop rotation systems using a green manure cover crop is a method of adding back organic matter, nitrogen or other nutrients. Minimal tillage is also a technique that conserves organic matter.

❖ Predominant soil types used for SRIC hybrid poplar crops

SRIC hybrid poplar crops have been established on soils that were developed under grassland (Chernozems [Web-Soil Classification]), on soils that were originally developed under forested conditions and subsequently cleared and farmed (Luvisols [Web-Soil Classification]), or on soils that were frequently flooded or permanently waterlogged and were drained to make them suitable for farming (Gleysols [Web-Soil Classification]).

a) Chernozems
Chernozems are soils common to the grasslands. Soils are dark in colour (brown to black) and have an A horizon (Figure 1-3) that is rich in organic matter; this is called the Ah horizon. The organic matter colours the soil dark. They have a high cation exchange capacity (CEC) due to this rich Ah horizon.

b) Luvisols
SRIC hybrid poplar crops on Luvisols are mostly located in the Boreal Transition ecoregion or in the northern limits of the Aspen Parkland. They were developed under the influence of forest vegetation and are well to imperfectly drained. Soil profiles have a leached, light grayish A horizon, which is called the eluviation layer (Figure 1-3) and a B horizon enriched with clay, called the

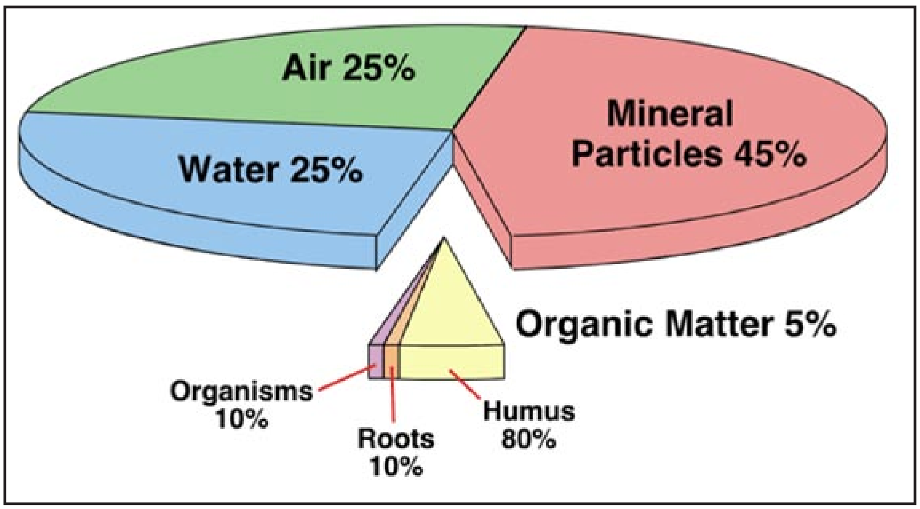
illuviation layer (Figure 1-3). These soils do not have the rich Ah horizons of the Chernozems and are therefore not as productive.

c) Gleysols
Gleysols often occur in depressions or at lower slope positions and are frequently flooded or waterlogged part of the year. The soil horizons show the chemical signs of oxidation and reduction, called gleying. These soils could be improved if drainage is possible and affordable.

❖ **Soil drainage**

Soil drainage is influenced not only by the soil texture, but also by the underlying layers, the depth, slope and structure of the soil. Soil consists of four components: mineral particles, air, water and organic matter (Figure 1-4). Organic matter improves the soil structure and soil fertility, and increases the soil water storage capacity [Web-Soil Water Storage].

Figure 1-4 (source:[Web- PhysicalGeography.net)



A very useful and educational document about soil can be downloaded free of charge from the website of the Canadian Mortgage and Housing Corporation [Web-Soil CMHC] (once at the 'Order Desk', click on 'About Your House Fact Sheets', then click on 'Landscaping' and click on 'Get to know your soil', publication #63486; either order the printed version or download the PDF version).

For additional information, please see:
[Web-Introduction to Soils]
[Web- Soil Formation]

1.1.4 Climate considerations and site suitability

A suitable site for a crop is not only defined by soil properties alone (such as texture, pH, fertility), but also by climatological factors, in particular the amount of rainfall during the growing season and the growing degree days, as well as by landscape factors.

❖ CanSis land suitability rating system

Agriculture and Agri-Food Canada (AAFC) published a technical bulletin in 1995: 'Land Suitability Rating System for Agricultural Crops [Web- CanSis-Manual]'. This is a crop suitability rating system for spring-seeded small grains; this publication and the two accompanying maps can be downloaded free of charge. It is basically a modified Canada Land Inventory (CLI) system [Web-CanSisCLI], which rates the various soil classes on their suitability to produce spring-seeded small grains, by assigning a suitability score that is based on growing degree days and moisture deficit.

There is a decreasing moisture deficit gradient going from the south to the north, while the values of growing degree days decreases, which can be seen on the two maps that accompany this bulletin. Both factors have a very significant impact on soil development and can partly explain the differences between related soil types in the southern and northern regions.

The significance of this technical bulletin for SRIC hybrid poplar crops is in the methods used to develop this rating system and the two maps, which could also be helpful to prospective poplar farmers.

For additional information, please see:
[Web-GGDandPPE]

❖ Poplar suitability mapping

In recent years several organizations have produced maps to combine soils information with climatological information that show various suitability classes for hybrid poplar. These must be considered as first attempts of putting together a crop suitability rating system for poplar.

a) The Northern Forestry Centre of the Canadian Forest Service (CFS) in Edmonton, Alberta produced such a map for Saskatchewan (Appendix D).

b) The Shelterbelt Centre of the Prairie Farm Rehabilitation Administration (PFRA) and the Saskatchewan Forest Centre (SFC) produced a map (Appendix E-1 with a legend in Appendix E-2) showing the suitability for hybrid poplar in the northern agricultural zone of Saskatchewan. This map also shows boundaries of the Rural Municipalities (RM) that are covered by this map. This work was field referenced.

c) The Northern Forestry Centre has also produced a similar map [Web-CFS poplar map] for the entire Prairie region, including Manitoba and the Peace River region in British Columbia. This effort was undertaken to "help assess the cost effectiveness of large-scale afforestation efforts" [Web-CFS poplar map]. The evaluated suitable sites have a growing degree days range of 1150-1300 and a precipitation range of 240-375 mm (Appendix F).

Although experts were involved in validating the map against the actual soils and sites, the development of a detailed suitability rating systems requires periodic upgrades and verifications to make them more meaningful for use on a farm-specific basis.

d) Agriculture and Agri-Food Canada (AAFC) produced a map for Alberta, based on the methods used in Saskatchewan, showing suitability for hybrid poplar (Appendix G [12]). More detailed maps were produced for selected Townships of Athabasca County #12 (Appendix G-1), selected Townships of Municipal District (MD) East Peace (Appendix G-2) and selected Townships of Grande Prairie County #1 and MD of Greenview #16 (Appendix G-3). This project did not include field referencing[18] the results and caution is urged when interpreting this information.

For additional information, please see:
[Web-CFS]
[Web-PFRA]
[Web-AAFC]

❖ **Precipitation**

It is important to check weather records for historic precipitation data, although these data may not always be available or easy to locate [Web-Climate data].

A study completed in 2002 by the Shelterbelt Centre of the PFRA reports that “Past studies have shown that areas with less than 375 mm annual precipitation or a moisture deficit of greater than -375 (mm) will have significantly restricted tree growth and are not suitable for large scale tree production unless supplemental moisture is available through irrigation or trees are able to access the water table. Availability of groundwater can mitigate the requirement for precipitation”[7].

A similar study for Alberta by Agriculture and Agri-Food Canada (AAFC) stated: “Areas with less than 300 mm of growing season precipitation, or 400 mm annual precipitation, or a moisture deficit of greater than -400 (mm) will have significantly restricted poplar growth and are not suitable for hybrid poplar production unless supplemental moisture is available through irrigation or trees are able to tap into the water table”[12]. This is in line with the Saskatchewan report.

1.1.5 Salinity

Salinity is the concentration of dissolved salts found in soil moisture. Saline conditions are not tolerated very well by many plant species, including poplar. The result is reduced growth and even death. Salt prevents uptake of water and nutrients by the roots; the tree displays drought symptoms, the leaves turn yellowish-green and remain very small. The condition worsens as summer drought sets in, frequently resulting in tree mortality. If salinity is suspected, the farmer should collect samples and send them to an environmental or soils labs for testing [Web-PFRA-3] [Web-Salinity-2].

12 Vanin C., Burgon, M., Development of Suitability Maps for Hybrid Poplar Production in Alberta. Agriculture and Agri-Food Canada - P.F.R.A., Edmonton, AB. July 2003

18 Personal communication with Candace Vanin, Agriculture and Agri-Food Canada - P.F.R.A., Edmonton, AB. February 2006.

7 Schroeder, W., Silim, S., Fradette, J., Patterson, J., and de Gooijer, H. 2002. Detailed Site Analysis and Mapping of Agroforestry Potential in the Northern Agricultural Zone of Saskatchewan. Funded by the Saskatchewan Forest Centre - Forest Development Fund.

Salinity is abbreviated as EC, which stands for 'electrical conductivity' with units of deciSiemens per meter (dS/m) or millimhos per centimeter (mmhos/cm). Both are equivalent units of measurement and give the same numerical value. Sometimes EC is reported as mS/cm, which is the same as dS/m.

The Shelterbelt Centre of the PFRA reports that values of electrical conductivity greater than 2.0 are likely to be limiting and values in excess of 4.0 will result in significant growth reduction, in some cases more than 25%, and tree dieback. Although these recommendations apply to the clone Walker[7], they are generally applicable to other poplar clones as well (Table 1-4).

Table 1-4 (modified) [7]

Salinity Rating - EC (dS/m)	0-2	2-4	>4
Crop Hazard - Suitability	Low - Suitable	Medium - Marginal	High - Unsuitable

Alberta data from 1991 indicates that the clone Brooks (not specified which one) would suffer 7.9% and clone Northwest 10.4% height growth loss respectively per dS/m increase in salinity [Web- Salinity-2]. Useful information from Utah State University can be found in a publication on high salinity levels [Web-Salinity-1]. For "poplars" and "cottonwoods" (eastern cottonwood) it lists an EC of 3-4 dS/m as the approximate tolerance range; this is in line with the information in Table 1-4. There will be clonal differences in salt tolerance; however, to be on safe side, the EC rating should not exceed 2 dS/m.

7 Schroeder, W., Silim, S., Fradette, J., Patterson, J., and de Gooijer, H. 2002. Detailed Site Analysis and Mapping of Agroforestry Potential in the Northern Agricultural Zone of Saskatchewan. Funded by the Saskatchewan Forest Centre - Forest Development Fund.

❖ Saturated soil paste method

The so-called saturated soil paste method is the standard method used by soils labs in Canada to determine the EC rates; Table 1-4 is based on this method. The farmer should check with the soils lab that they are using the saturated soil paste method.

1.1.6 Potential to improve the soil

In some cases, where soil problems exist, improvements are possible.

For poor drainage, installing drain tile, establishing ditches, subsoiling or ripping may be workable options, depending on the costs and the general features of the land. Subsoiling or ripping may be an opportunity to increase soil depth, break up plow pans etc. and thus improve water infiltration and water storage capacity, at least for one or two growing seasons. The jury is still out whether subsoiling or ripping has long term benefits. Subsoiling or ripping along the intended tree row is generally a good idea, if only to ease planting of the crop.

1.1.7 Soils mapping and soil samples

The Canadian Soil Information System (CanSis) is a soils database that can provide reasonably good soils data. The websites below give the user access to the soils reports and descriptions, as well as maps. Reports and maps are organized by region or administrative areas.

When interpreting the soils maps, the use of the technical bulletin 'Site Suitability Rating System for Agricultural Crops [Web-CanSis-Manual]', its two accompanying maps showing growing degree days and moisture deficit information, as well as the various maps available that delineate suitability for poplar might be a good start to determine if the land is suitable.

For additional information, please see:
[Web-CanSis Alberta]
[Web-CanSis BC]
[Web-CanSis Manitoba]
[Web-CanSis Saskatchewan]

Although most farmers probably know their land quite well, it is still recommended that they run soil tests to ensure the soil is suitable for an SRIC hybrid poplar crop. A good handout of how to take soil samples is provided in Appendix H , which was produced by Enviro-Test Laboratories [Web-Enviro-Test]. The information discusses several soil sample depths. Three sampling depths are recommended for each sample point: 0-15 cm (0-6 in.), 15-30 cm (6-12 in.) and 30+ cm (12+ in.) When sampling points fall into the same soil type, it is possible to make composite samples. For example, if three samples are taken in the same soil type, all the soil from the three 0-15 cm (0-6 in.) depth samples are put into a clean bucket and thoroughly mixed. From this mix, scoop enough soil into the sampling bag or container for the analysis. A sample the size of a baseball is necessary for full analysis. This should be repeated for the other two depths as well. Just ensure to thoroughly clean the bucket before processing the next batch of soil and not to mix soils from different soil types.

The lab can provide the farmer with a list of analyses that could be performed. If this is the first time soil samples are taken on the land, soil texture should always top the list for the first time. It is also recommended to measure pH and the main macronutrients. If salinity is suspected, check what sampling procedures must be used and ask that the sample be processed with the saturated soil paste method [see Module 1.1.5].

1.2 Operational Considerations

1.2.1 Location

The expression 'location, location, location' also applies to a poplar farm. What is the expected road distance to transport the wood to an existing or potential market? Rising transportation or haul costs have been reasons for several companies to consider establishing SRIC poplar crops as close to their mills as possible. This becomes more urgent as oil prices continue to rise, making transportation even more expensive. Since the farmer usually pays for the transportation cost to get his wood to the market, each dollar paid extra per m^3 in transport takes a dollar away from the bottom line. What the farmer can afford depends on the yield and the value of the wood he produces, since all his growing and management costs are by the hectare and are independent of transport distance.

1.2.2 Topography

The topography of a field determines what the limits are to the use of equipment and what the erosion (both water and wind) risks are as a result of soil management activities. The guidelines in Table 1-5 are suggested for evaluation of slope and length of slope.

7 Schroeder, W., Silim, S., Fradette, J., Patterson, J., and de Gooijer, H. 2002. Detailed Site Analysis and Mapping of Agroforestry Potential in the Northern Agricultural Zone of Saskatchewan. Funded by the Saskatchewan Forest Centre - Forest Development Fund.

Table 1-5 (modified) [7]

Slope Length	**Percent slope**		
	0-5%	6-10%	> 10%
< 50 m (150 ft.)	+++	+++	+
50-100 m (150-650 ft.)	+++	+	---
> 100 m (650 ft.)	+++	-	---
Highly Suitable (+++) to Highly Unsuitable (---)			

1.2.3 Access

Access is critical, not only to the farmer, but also to contractors and their equipment, from spraying the fields to harvesting and loading the wood. It is important to know what the load restrictions are that apply to the roads, bridges, road culverts etc., whether there are dangerous crossings or underpasses that are too low. Are the roads wide enough, are they passable and up to standard to carry the loads?

1.2.4 Pipelines, powerlines and other infrastructure

Pipelines pose potential problems when growing a tree crop. To avoid expensive problems and disappointments, check the rules and restrictions for buried pipelines. Are there differences between various pipelines, can you farm right over some pipelines, but not others etc.? What are their precise locations? Are there restrictions around well sites?

Similar concerns exist with other structures such as powerlines for instance. What is the right-of-way when planting a poplar crop? Whereas annual crops could be grown in powerline right-of-ways, right under the powerlines, that will not be possible or allowable with a tree crop. Powerlines can result in significant loss of growing site due to the width of right-of-ways.

It is best to check with the utility, oil- and gas companies to find out what is permitted and where the pipelines are located, especially when using deep-tillage equipment and when the need arises to bring in heavy equipment for the harvest. Advanced planning, in cooperation with these companies, will avoid problems later.

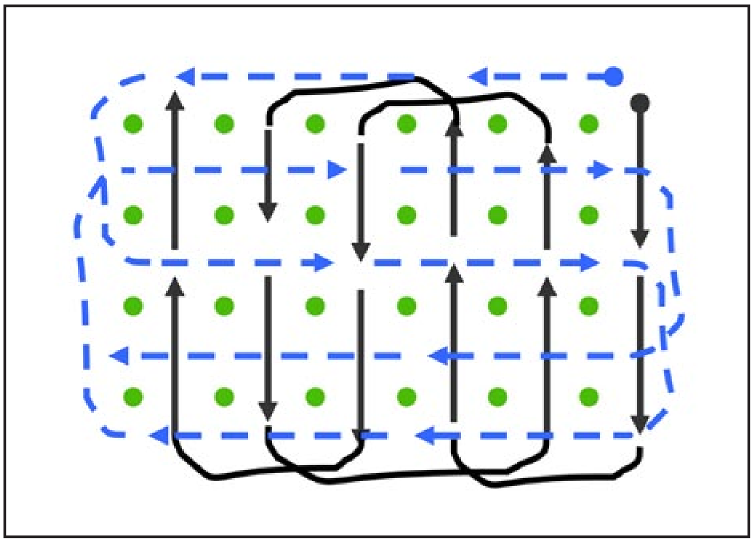
1.2.5 Field shape, size and crop layout

The field shape and size have a direct bearing on the efficiency of planting and subsequent crop management. What is the best crop layout? Is there enough allowance for headlands to allow equipment to turn around and gain access between tree rows? How best to lay out a field when planting two or more monoclonal crops?

Efficient crop management is achieved when the crop is planted in long and straight rows, enabling machinery to work between the tree rows. With the current lack of registered pre-emergent herbicides in Canada for SRIC hybrid poplar crops, it is best to carry out mechanical weed control and/or chemical weed control, with shielded sprayers, in two directions perpendicular to each other (the orchard approach). The tree rows therefore have to be parallel to each other in two directions [see Module 4.2] (Figure 1-5).

It is important to plan for the longest possible tree rows parallel to the travel direction of the large pieces of equipment needed during site preparation and spraying, such as the high-clearance boom sprayers.

Figure 1-5



1.2.6 Vegetation history

Effective weed control will be critical to the success of the crop. It is important to know what crops were grown previously and what weed control practices were used. This will determine the need for and cost of weed control treatments when preparing the land. Perennial weeds are usually the most problematic and require a different strategy than annual weeds [see Module 5.5].

1.2.7 Stoniness

Some stony sites can grow good hybrid poplar crops, but could severely restrict site preparation and subsequent weed control activities. If the stones are going to interfere with the equipment, the costs will increase. Is it feasible to use a rock picker and get the largest stones off the field? Is it feasible to remove stones as they become apparent and/or problematic during cultural activities?

On many poplar farms problematic stones and even boulders are removed as they are encountered.

1.2.8 Fish-bearing creeks and other riparian habitat concerns

The farmer must be aware of riparian habitat that may be impacted by crop management activities. For instance, there may be opportunities to participate in an Environmental Farm Planning (EFP) process, which is available to all agricultural producers. Provinces have organizations in place to deliver and manage EFP [Web-EFP-1.

Depending on the jurisdiction, there may be regulations regarding farming along or in riparian zones. Some herbicides require the user to incorporate herbicide-free zones along riparian areas. The added requirements will impact the cost of growing a crop and the farmer must assess how this will affect the bottom line.

1.2.9 Grazing conflicts

It is generally unwise to mix cattle, sheep and horses with trees, at least while the tree crop is still young and under intensive crop tending. Even when the crop is older, cattle, horses and sheep are known to cause damage to the trees. Although it appears attractive to manage cattle in an older hybrid poplar crop, as is done in several countries around the world (Photo 1-1), cattle needs to be managed to avoid overgrazing and direct damage to the lower stems of the trees. Cattle lean into young trees for a 'backrub', resulting in partly uprooted trees. Left alone, sheep can destroy an older hybrid poplar plantation by stripping the bark off the trees; horses do likewise. The damage is usually the result of overgrazing.

Sylvain Fortin, Quebec

Photo 1-1: Landowners in Argentina raise cattle in the poplar trees. Productivity is measured in m³ of wood per hectare and in kg per heifer.

Cattle need herding to avoid overgrazing and subsequent damage to the tree crop.

1.2.10 Wildlife problems

Wildlife and young poplar trees do not mix well. In areas with a high deer, elk or moose population the farmer is guaranteed to experience browse damage. Controlling access during the establishment phase is therefore critical to the success of the crop. Fencing a crop is expensive, although this has been done with success elsewhere. New electric fencing technology may offer a cost effective solution.

Beavers are extremely hard on the trees and can cause serious damage. They can harvest a large area of trees overnight, especially when the trees are only a few years old. Serious economic damage can occur when the trees are approaching marketable size.

Hares and rabbits can also wreak havoc in young poplar crops; porcupines can do serious damage to older trees and so can black bears.

Crop insurance records may reveal some of these risks to other, more traditional crops; it is worth checking this out.

Other rodents, such as voles [Web- Voles1] and gophers (Richardson's Ground Squirrel) [Web-Gopher1], can cause very serious damage in a tree crop, especially when weed control has been substandard during the site preparation and establishment period [see Module 7.1].

1.2.11 Weather anomalies

Some areas may be prone to weather risks such as frequent drought, hail damage, frost pockets and excessive wind during the growing season. Crop insurance records may reveal some of these risks as would weather records. The various crop insurance agencies keep records and are a good source of information.

For additional information, please see:
[Web-Sask crop Insurance]
[Web-Alberta Crop Insurance]
[Web-Manitoba Crop Insurance]

MODULE 2: CLONE SELECTION AND DEPLOYMENT

The selection of the hybrid poplar clones to be planted is one of the most important decisions a farmer has to make. No matter how good the cultural practices are, choose the wrong clone and all the work in the world will not transform a poor clone into a good one.

2.1 Monoclonal vs. Polyclonal Crop

Virtually all SRIC hybrid poplar crops are planted as monoclonal crops. There are several reasons for this and one is ease of management, which is not to be confused with easy management! Experts are divided over the benefits and risks of planting monoclonal crops vs. polyclonal crops.

2.1.1 Monoculture (monoclonal) vs. polyculture (polyclonal)

The growing of a single species, be it trees or peas, is referred to as a monoculture. In agriculture some of the most productive crops are monocultures and the same goes for SRIC hybrid poplar crops. In hybrid poplar a monoculture is a crop consisting of only one clone; it is actually a monoclonal crop and the two terms are sometimes used interchangeably.

The counterpart of monoculture is a polyculture, where a crop consists of more than one species or, in the case of hybrid poplar, more than one clone. A polyculture is actually a polyclonal crop. The two terms are sometimes used interchangeably. Polyclonal crops are recommended for a long crop cycle to minimize the risk of insects and disease that could cause a crop failure. According to some proponents of polyclonal crops, a long crop cycle or rotation is regarded as 10+ years[9], which is still considered short for an SRIC hybrid poplar crop, other than a biomass crop.

9 Mattson, W.J., Hart, E.A., and Volney, W.J.A. 2001 Insects pests of Populus: coping with the inevitable. In Poplar Culture in North America. Part A, Chapter 5. Edited by D.I. Dickmann, J.G. Isebrands, J.E. Eckenwalder, J. Richardson. NRC Research Press, National Research Council of Canada, Ottawa, ON K1A 0R6, Canada. Pp. 219-248 (page 243).

❖ Polyclonal SRIC crops

Based on examples in agriculture, monocultures are usually more productive than polycultures. That is also the case for SRIC hybrid poplar crops; monoclonal crops are generally more productive than polyclonal crops. Polyclonal crops can be very inconsistent and this is observable in poplar crops that were inadvertently established with a mix of clones. Inadvertent clonal mixes are caused by inadequate quality control at the nursery. Often the unknown clone is a worse performer than the intended one; however, sometimes it could be the opposite. If the clones in the mix happen to be compatible, the resulting crop will probably be OK and could be very productive, but frequently they are not and yield loss is the result. A mix up and the effect of it will not immediately be noticeable; it takes several years for the differences to show and by that time it is too late to correct it.

❖ Clonal differences

Large differences between clones can be observed in trials where individual trees of different clones are intentionally planted in a randomized trial design to evaluate and select superior clones. These differences really start to show from the time the trees reach canopy closure. Although many clones perform very well when planted as a monoclonal crop, purposely mixing up different clones in clone trials emphasizes growth differences between clones. Some become ‘aggressors’, while others become ‘subordinates’. The aggressor clone will start to dominate the neighbouring subordinate clone by occupying the growing space and taking up soil resources; it shades out the subordinate, which results in its suppressed growth. Planted as a monoclonal crop, the subordinate clone might actually do very well and even equal the growth of the aggressor, but in a mix is at a disadvantage.

This ‘aggressor’ characteristic could be an important selection criterion. It points to the clone aggressively taking over growing space and soil resources and is an important trait in being able to shade out competing vegetation. A very good example of this can be seen in a trial near Henribourg (SK) at the Weyerhaeuser Seed Orchard.

Rising 9 (or R-9, meaning in the 9th growing season) trees were originally planted as a monoclonal crop of clone Walker in a crop density trial (spacing at 2.4x2.4 m or 8x8 ft.), established by the Shelterbelt Centre of the PFRA. Two trees of clone Northwest were inadvertently mixed in. Even though clones Walker and Northwest grow reasonably well as a monoclonal crop, in this mix the Northwest is starting to show the trait of the aggressor, while Walker is slowly being relegated to the subordinate role. The live crown of Walker to the left in Photo 2-1 has lifted to well over 2 m (6.5 ft.), which is an indication that this clone does not thrive at this spacing.

Cees van Oosten, BC

Photo 2-1: An R-9 density trial of Walker, established in 1997 at 2.4x2.4 m (8x8 ft.) spacing. Note the crown lift in clone Walker on the left and that of the clone Northwest on the right, which is still all the way to ground level.

The location is near Henribourg (SK).

The crowns of the Northwest clone are still alive all the way to ground level and have spread out much wider than the narrow-crowned Walker. From this observation it appears that the clone Northwest could be a better competitor than the clone Walker. This could be used as a selection criterion.

Despite the best efforts, clonal contamination occurs often. Photo 2-2 shows the result of an inadvertent mixture and the impact wind has had on one of the clones planted, while the wind resistant clone remains largely unaffected. The tree with the smooth bark and larger diameter (on the right) has become the ‘aggressor’ and has dominated its neighbours (on the left and in the background). The smooth-barked tree was actually one of two or three unknown clones that were mixed in; it performed better than the originally intended clone with the rough bark, and it proved wind-stable. Wind stability is an important selection criterion, which is not apparent till relatively late in the crop cycle.

Cees van Oosten, BC

Photo 2-2: An R-9 SRIC crop in the early spring. This was planted as a monoclonal crop, but turned out as a mix. Note the amount of windthrow in the smaller stems. The tree on the right has a larger stem and smooth bark and was wind-stable. The trees with the small stems and rough bark suffer from windthrow.

The location is in Whatcom County in Washington State.

❖ Clonal compatibility

Work done in Belgium shows that compatible clones could do very well when planted in a mix, but the clones the Belgian researchers worked with all descended from the same female parent and all but one also from the same male parent. Mixing clones to cut risk of diseases or insects is a gamble from a growth and yield perspective, unless the farmer uses proven clones that have shown good compatibility, and that takes time.

For SRIC hybrid poplar crops it is unpractical to mix clones as not enough is known yet about compatibility of the clones that are currently available. Risk management of diseases and pests is better achieved by increasing the number of available hybrid poplar clones from different parents and by limiting the percentage of area planted to any single one clone per farm or region, no matter how good it is [See Module 2.3].

2.2 Clone Selection

There is no 'one size fits all' hybrid poplar clone or 'super clone' that has superior performance wherever it is planted. The selection of a suitable hybrid poplar clone must be based on local knowledge or trial information. All too often poplar farmers want to plant 'hybrid poplar' without being specific as to which hybrid clone, as long as it is a hybrid. This is based on the perception that any hybrid will do well. Even in the case of well known hybrid clones, such as Walker and Northwest, these may get planted on inappropriate sites or in areas where there is a high risk they could be affected by diseases or insects. For example, Northwest is highly susceptible to the poplar bud gall mite (*Aceria parapopuli*) [Web- Poplar bud gall mite], especially in the southern prairies, whereas this may not be much of a problem in other regions. Both Walker and Northwest are also susceptible to Septoria stem cankers [Web-Septoria-1] (*Septoria musiva*; note that Septoria is also known as *Mycosphaerella populorum*).

The myth of the existence of a hybrid poplar 'super clone' is being promoted and maintained through various mail order catalogues and websites claiming spectacular results with a particular clone of hybrid poplar. Sometimes it might work, but most often it will not and there is no money-back guarantee! Some previously successful clones got a 'new life' in the mail order business. For example, hybrid poplar clone OP41 originated from the breeding program of the Oxford Paper Company in the 1930s. It was also known as 'Androscoggin, NE41 or HP510; it was marketed through a mail order catalogue as HP510 and was touted as a miracle clone – the elusive 'super clone'. It is buyer beware!

2.2.1 Site requirements and clone selection

In general, optimum crop performance can be expected on soils that are well-aerated, have sufficient moisture and nutrients, are of sufficient depth (> 1 m or 3 ft. to the water table), have a medium texture and have a soil pH in the 5.0 to 7.5 range. Poplars need high light intensity and warm temperatures during the growing season and require sufficient soil moisture during the growing season. Please refer to Module 1 'Site Requirements and Site Selection' for additional information [see Module 1].

The clone Walker (*Populus* x 'Walker') is a good model of the exacting requirements many hybrid poplar clones place on growing site. This clone is less flexible than most other clones, which may have a broader range of application. A list of suitable clones can be found in Table 2-1. The clones originating from the Shelterbelt Centre were originally selected for their performance in a shelterbelt setting and their hardiness to withstand the local climate. Their performance as SRIC hybrid poplar crops is largely untested and clonal testing in the various regions is definitely a requirement. Since no other poplar clones are yet available for SRIC crops, the shelterbelt clones are the only source of material for the time being.

❖ Characteristics of selected SRIC poplar clones

The suitability of various poplar clones was tested in a recent project completed by the Shelterbelt Centre of the PFRA [19]. The information came from "test planting records, lab tests and field observations during the project". The results are summarized in Appendix A-1 and Appendix A-2 for all clones reviewed. Table 2-1 is a summary of clones considered suitable for SRIC hybrid poplar crops. Although the results are applicable to Saskatchewan, they can be applied to the Prairie region in the absence of more specific information, with the possible exception of southern Manitoba.

19 Schroeder, W., Inouye, G. M. 2006 in Final project Report ADF project 200010048 - Hybrid Poplar Plantations for Farm Diversification in Saskatchewan (AAFC-PFRA Agroforestry Division).

Table 2-1

Clone	Tree Characteristics			Hardiness	Disease	Suitable for SRIC
	Growth	Form	Sex			
Brooks 6	2	1	Male	1	2	X
Hill	2	2	Female	2	2	X
Katepwa	1	1	Male	2	2	X
Northwest	2	3	Male	2	2	X
Walker	1	1	Female	3	2	X
WP-69	1	2	Male	1	1	X

a) Growth class 1 is a height growth rate of greater than 1.0 m (3.3 ft.) per year; class 2 is 0.8-1.0 m (2.6-3.3 ft.) per year[19].

b) Form class 1 has a 'straight and narrow' crown, with steep branch angles; class 2 has a 'moderately wide crown' and is spreading wider; class 3 has a 'wide spreading crown'. A good example of this was discussed in 'Clonal differences' of the section dealing with 'Monoculture (monoclonal) vs. polyculture (polyclonal) [see Module 2.1.1]). Photo 2-1 shows the clones Walker, with the narrow crown (class 1) and Northwest with the wide crown (class 3)[19].

c) Hardiness class 1 is 'not vulnerable' to low temperature damage and "the clone rapidly attains maximum cold hardiness and low temperature damage is extremely unlikely"; clone WP-69 stands out in it low vulnerability. Class 2 is 'slightly vulnerable' to low temperature damage and 'clones are very rarely affected by low temperatures". Class 3 is 'moderately vulnerable' to low temperature damage and "clones are periodically susceptible to low temperature damage." None of the clones in Table 2-1 rate in class 4, in which "clones have a high risk of yearly low temperature damage"[19].

d) Disease rating of 1(resistant), 2 (moderately susceptible) and 3 (highly susceptible) are for Septoria (*Septoria musiva*) [Web-Septoria-1] stem canker and Melampsora (various *Melampsora* species) leaf rust diseases[19]. Susceptibility of various poplar clones to Septoria stem cankers is a major concern. More information on diseases is available in module 'Diseases and Pests [see Module 9.1]'.

2.2.2 Clone names

Most clones in the Prairie Region have been given names, such as Walker, Northwest, Assiniboine, Hill etc. (Appendix A-2). Giving hybrid poplar clones names is traditional in Europe when the clones are released for commercial use and are entered in an official clone register. In some parts of North America naming a clone is also common when it is released for general use after having been tested for many years; however, there is no official clone register. Clones are sometimes also known by a number. In some cases this signifies that a clone is still under evaluation. For example, clone WP-69 (Walker poplar # 69) is a hybrid between the female *Populus* x 'Walker' and the male *P. xpetrowskyana*; it shows promise, but is still under evaluation before being released as a commercially viable clone. Some companies that do their own breeding usually assign numbers rather than names to their commercial clones.

2.2.3 Renaming clones and loss of clonal identity

In North America a real nuisance has been the tendency of some nurseries and companies to rename clones for marketing purposes. This practice is not illegal, but it can cause serious problems for the unsuspecting buyer. In Canada there is no regulatory oversight regarding sales of poplar stock, either by Government agencies or industry associations. With the loss of clonal identity the farmer takes a substantial risk in purchasing a clone to start his new crop, of which he knows nothing. An example of this was previously discussed in section 'Clone Selection' [see Module 2.2].

Only through DNA testing can the farmer be absolutely certain of the clonal identity. This will be discussed further in module 'Stock Procurement [see Module 3] in 'Clone identity [see Module 3.1.4]'.

2.3 Deployment of Clones

Since polyclonal crops of hybrid poplar are not practical [see Module 2.1.1] for SRIC crops, the way clones are deployed on the farm or in an area or region offers an opportunity to minimize risk of crop problems. Unlike with most agricultural crops, poplar farmers do not have the same access to pesticides to control insects and diseases for example. An ongoing spray program to control insects and diseases in a poplar crop is not desirable and is too expensive to repeat on an annual basis. This could only be justified if the value of the wood is very high, as might be the case for large and clear veneer logs for instance. In the long run poplar farmers must rely on a combination of integrated pest management strategies, improved new hybrid poplar clones and proper clonal deployment strategies.

2.3.1 Corn analogy

Although the deployment of hybrid poplar clones has similarities with many other agricultural crops, the comparison with corn illustrates this very strongly.

The following information was located in an Ontario publication 'Pub.811 - Agronomy Guide for Field Crops: Chapter 3 – Corn [Web-Corn-1]':

> "Corn hybrids are often classified as 'workhorses' or 'racehorses.' Hybrids that produce above-average yield under good conditions but below average under poor conditions are considered racehorses, while those that have relatively consistent yields in both low- and high-yielding conditions are considered workhorses. Most hybrids that are considered to be variable performers (racehorses) have specific defects that cause them to yield lower than average when exposed to certain conditions. Farmers can avoid some of the risk associated with hybrid selection by taking time to find out as much as possible about a hybrid's past performance. Select hybrids that complement each other because they have different specific weaknesses."

This is good advice and applies to hybrid poplar clones just as much. The strategy is one of 'not putting all your eggs in one basket'. There are plenty of examples where farmers have not heeded that important message. This is also the case with farmers in the Prairie region; everyone wants the best and wants to plant Walker, as this clone has a reputation as a 'racehorse', to borrow the phrase from the example in corn farming. As a result it will have a "yield lower than average when exposed to certain conditions" (such as less optimal soils, lower moisture etc.). It is true for corn and true for hybrid poplar. Without planning and developing a risk strategy, the planting of favourite 'racehorses' will only get out of control and is guaranteed to cause insect and disease problems. When the farmer sees a nice crop of hybrid poplar on his neighbour's land, it is awfully tempting to plant the same clone on his own land. This would probably be OK to a point, but the farmer should also consider putting in some of the 'workhorses', just in case! In the poplar world the 'workhorses' are known as 'plastic' clones; these have the plasticity or flexibility of being able to grow under varying conditions.

2.3.2 Deployment strategy

There is no science yet behind a sensible deployment strategy for SRIC hybrid poplar crops, only common sense. An easy rule of thumb is to plant a field to a maximum of 20 hectares (50 ac.) to a single clone. If the field is larger, consider splitting it in two, three or even four blocks. Avoid mixing the clones, lay out the field in blocks from end to end and assign each clone to its own block, or use logical breaks in topography or other features, such a an access road cutting across a field or a pipeline right-of-way, to delineate the area for each clone.

❖ Crop maintenance flexibility

By planting clones in distinct blocks, crop management can be geared to each clone in case there are different requirements for crop tending. For instance, clone A requires additional weed control, or additional fertilization, whereas clones B and C do not. It also allows scheduling a harvest of one clone without impacting the other clones in the field. In case of the need to harvest one clone early or to start a new crop in case of a crop failure, the farmer can easily restart a new crop. For maximum efficiency, lay out the blocks parallel to the longest boundary or use logical breaks in topography or other features to delineate the block. Try to avoid breaking up the block to accommodate two or more clones. For more information about crop layout, refer to 'Crop layout [see Module 4.3]' in module 'Crop Density, Spacing and Layout [see Module 4]'.

❖ Guidelines for deployment

If the farmer decides to grow two clones in two distinct blocks in a field that is 20 hectares (50 ac.) or less, that is fine too. The limits are only guidelines and are meant to resist the temptation to plant all of a quarter section (65 ha or 160 ac.) to one clone for instance. Table 2-2 provides guidelines for deployment.

Table 2-2: Deployment of clones

Field size	Minimum # of clones	Maximum per clone
Up to 20 ha (50 ac.)	1	n/a
20 ha (50 ac.) - 40 ha (100 ac.)	2	50%
40 ha (10 ac.) - 60 ha (150 ac.)	3	35%
60 ha (150 ac.) or more	4	20 ha (50 ac.)

If the farmer plants SRIC crops over several years, he should consider switching to a different clone the next year and the year after. Plant more of the 'workhorses' for relatively consistent yields in both low- and high-yielding conditions. This way the farmer minimizes the risk of a disappointing crop (Table 2-3).

Table 2-3: Example of maximum deployment by clone over 4 years

		'Racehorse'		'Workhorses'							
	Planted Ha	A		B		C		D		E	
		%	ha	%	ha	%	ha	%	ha	%	ha
Planting - Year 1	15	100%	15		-		-		-		-
Planting - Year 2	26	20%	5	50%	13	30%	8		-		-
Planting - Year 3	51		-		-	35%	18	35%	18	30%	15
Planting - Year 4	67	30%	20	30%	20		-	25%	17	15%	10
Total planted	159	25%	40	21%	33	16%	26	22%	35	16%	25

The example of Table 2-3 adhered to the guidelines in Table 2-2 and planting of the 'Racehorse' (clone A) has been limited to no more than 25% over the full four years. 'Workhorses' make up the balance; it is like a balanced investment fund. This is a good strategy and the farmer has not put all his eggs in one basket.

❖ Clone availability

At present the limited selection of clones for the Prairie region makes it a challenge to accomplish a good spread of risk. The fact that the current clones have been selected for shelterbelt purposes, rather than for use in SRIC poplar crops, makes choosing a good clone difficult. There simply are not enough good clones yet and an aggressive and ongoing production breeding program is needed for the Prairie region to rectify that.

MODULE 3: STOCK PROCUREMENT

3.1 Clone Selection

The Prairie Farm Rehabilitation Administration (PFRA) Shelterbelt Centre is currently the only organization in Canada that has selected and released several clones of hybrid poplar for outplanting in the Prairie region (Alberta, Saskatchewan and Manitoba and British Columbia's Peace River region). The selection is based on their performance as shelterbelt poplars. Testing of these clones under short-rotation-intensive-culture (SRIC) hybrid poplar crop conditions is ongoing, but preliminary recommendations can be made based on performance under shelterbelt conditions.

For additional information, please see:
[Web-PFRA-1]

3.1.1 Clone deployment

In 'Deployment of Clones [See Module 2.3]' the recommended guideline is to plant a single clone to a maximum of 20 hectares (50 ac.) per field. If the field is larger, consider splitting it in two, three or even four blocks and planting each block to a single clone. Table 3-1 can be used as a guideline in deciding how many clones to plant in any one year.

Table 3-1: Deployment of clones

Field size	Minimum # of clones	Maximum per clone
Up to 20 ha (50 ac.)	1	n/a
20 ha (50 ac.) - 40 ha (100 ac.)	2	50%
40 ha (10 ac.) - 60 ha (150 ac.)	3	35%
60 ha (150 ac.) or more	4	20 ha (50 ac.)

Growth performance differs between clones and although it is tempting to plant everything to the best clone, spreading the risk by planting a few other clones is highly recommended. Some clones are very good performers, but they may have some very exacting demands on site quality and would perform well below their potential when planted on marginal sites. The clone Walker is such a clone; if conditions are not perfect, it will disappoint. Planting a few additional all-round and flexible clones is a good strategy.

3.1.2 Clone selection

Table 3-2 contains clones that are recommended for usein SRIC hybrid poplar crops in the Prairie region. Few of the hybrid poplars selected elsewhere in Canada and the US Lake States have proven suitable for the climate in the Prairie regions of Canada. The only poplars that have proven to be adapted to the climate are those selected by the PFRA (Appendix A-1)[19]. Additional information on these clones can also be located in 'Site requirements and clone selection [See Module 2.2.1]'.

Table 3-2: Suitable clones for SRIC crops

Clone
Brooks 6
Hill
Katepwa
Northwest
Walker
WP-69

19 Schroeder, W., Inouye, G. M. 2006 in Final project Report ADF project 200010048 - Hybrid Poplar Plantations for Farm Diversification in Saskatchewan (AAFC-PFRA Agroforestry Division).

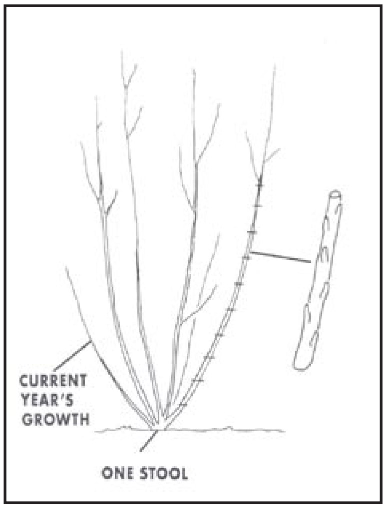


Figure 3-1: A stool is an individual plant in a stoolbed that gets repeatedly cut back in the winter to produce additional shoots the following growing season. The shoots are cut into segments that are called cuttings.

The very tip and bottom end of the shoots are not used.

Source: Boysen, B., Strobl, S. (Editors), 1991. A Grower's Guide to Hybrid Poplar. Ontario Ministry of Natural Resources. (Out of print).

3.1.3 Source of stock

The Shelterbelt Centre's mandate does not include breeding and selecting poplars for use in SRIC hybrid poplar crops; however, the Centre will make propagation material of suitable clones available to commercial nurseries interested in growing planting stock.

Commercial nurseries have to multiply this material through vegetative propagation of small cuttings to increase the availability of so-called starter stock in order to grow a new nursery crop in the greenhouse or outdoors.

❖ Open market sources

Only a few nurseries manage stoolbeds (Figure 3-1) to produce starter stock or planting stock of clones adapted to the Prairie region. Most produce stock under an existing contract.

Commercial nurseries that are currently producing or are capable of producing poplar stock are listed in Appendix I. This is not an all-inclusive listing and there may well be other nurseries on the horticultural side that would also be capable of producing stock. Please note that some nurseries are using alternate names for some of the clones. A listing of clone names and alternate names is provided in Appendix A-2.

❖ Contract sources

It is unusual in the nursery business to grow a tree crop without a contract. Nurseries typically require 1.5 years or more lead time prior to the intended spring planting season to secure the starter stock and to grow a nursery crop. A few nurseries may have starter stock of their own to start a nursery crop for a farmer, but most require the farmer to provide this.

3.1.4 Clone identity

When the nursery provides the starter stock, it is recommended that the farmer request proof of genetic identity. If the farmer provides the starter stock, it is equally good practice for him to provide proof of clonal identity to the nursery before entering into a contract to have the nursery grow the planting stock. Both farmer and nursery manager must be certain of the clonal identities as mix-ups do occur and could lead to complications down the road. Although it may not seem important at first to many farmers, the need to confirm genetic identity of the clone is to:

a) Avoid a possible crop failure as a result of planting the wrong clone;
b) Avoid possible disagreements between farmer and nursery in case the SRIC hybrid poplar crop turns out to be of a different or mixed genetic nature.

An experienced person could quickly spot a problem in a stoolbed, nursery bed or in a field crop around the time when trees start to change colour in the late summer and early fall or in the early spring when trees break bud and start to grow new leaves. If there is a clonal mix, it can be spotted fairly easily (Photo 3-1).

During the growing season it will be much more difficult to spot a mix. When a problem is noted, especially in a stoolbed, it is important to immediately flag the different trees with hi-visibility flagging tape for verification with a DNA test and subsequent removal, if needed.

❖ DNA testing

The best method for testing identities is through the DNA test, also known as genetic or DNA fingerprinting . Costs of these tests have come down substantially in the last few years, making it more affordable. Several facilities offer this service for a fee. One such lab is GenServe Laboratories [Web-GenServe] of the Saskatchewan Research Council (SRC). The lab publishes a pricelist on its website and provides a list of 24 clones for which it already has a DNA database (fingerprint file).

DNA is extracted from leaf tissue, which can easily be collected during the growing season or in the winter by forcing tree branches into bud flush in a warm indoors environment. The DNA is then compared with the DNA database to verify its identity, if the record already exists in the DNA database. If no records exist, the lab can at least verify that the submitted samples are identical or not.

A single sample for a batch of starter stock, a stoolbed, a nursery bed or a greenhouse crop is not sufficient. Ensuring the purity of starter stock is the most critical, as a contaminated batch is quickly multiplied into a major contamination problem, which will be very costly to clean up later on. Although sampling and DNA testing may still be pricey, cleaning up a contaminated crop after the fact will be many times more expensive for the nursery and the farmer. Samples from a number of cuttings in the starter stock or stoolbed will provide better confirmation of purity. The testing labs would be able to advise on sampling protocol.

For additional information, please see:
[Web-SRC]

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Photo 3-1: This imposter is clearly visible in the early spring when trees are about to flush. This is a very common problem and can only be solved through good quality control, starting with the starter stock.

Location is Snohomish County in Washington State.

3.2 Stock Type Selection

The best results are obtained with dormant stock and the predominant stock types used to date in the Prairie region are dormant, unrooted cuttings, rooted cuttings (known as BR or bareroot) and container-grown stock (also known as plugs). The choice of stock type depends on the expected field conditions where the poplar crop will be planted and the nurseries' capability to produce it. The ability to easily grow roots from an unrooted cutting varies between clones and is dependent on the temperature of the soil. Due to the risk of drought at the time of planting, rooted stock is preferred. It is more expensive than unrooted cuttings, but is more reliable.

In planting stock 'size matters'. The larger the caliper (diameter) of the stem, the better the results will be. The upper limit to size depends on what the farmer can afford. In a biomass crop, planted at very high crop densities, planting stock would consist of relatively small unrooted, dormant cuttings to keep the costs as low as possible and to ease machine planting. If a certain percentage of the planting stock fails, there are enough other plants to compensate for the loss.

When planting a pulpwood crop, unrooted or rooted cuttings are the norm. A small amount of loss is tolerable, but should not exceed 10%. In Quebec much taller stock is used, called a 'steckling' or rooted whip. It is a good choice where chemical weed control is not an option and deer browse is a threat in the first season (Photo 3-2). This stock type is also used for OSB crops in Quebec.

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Photo 3-2: Rooted one-year old whip, just after harvest at the nursery. This stock is used in Quebec.

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Photo 3-3: Unrooted two-year old whips are planted in many countries in South America and Europe. This location is Chile.

In the case of a saw log or veneer log crop, which is typically planted at 5x5 m (16.5x16.5 ft.) to 8x8 m (26x26 ft.) spacing in many European, South American and Asian countries, every tree 'counts' and must survive and thrive; there is no tolerance for loss. The stock is usually much larger, as can be seen in Photo 3-3 ; sometimes this stock is also rooted and thus much more expensive to grow and to plant.

To produce outdoor grown bareroot (BR) stock or to start a new stoolbed, dormant unrooted cuttings are preferred. The size requirements are listed in Table 3-3 in 'Stock standards – Summary [See Module 3.2.4].' These standards are ambitious, but physical size in unrooted cuttings is critical to success. It ensures an even development of the plants. Each cutting will form abundant new roots near the bottom of the cutting, and a new shoot from a live bud near the top of the cutting.

3.2.1 Unrooted and dormant

The two types of unrooted, dormant stock types are the cutting and the whip. Fat cuttings or whips will always be superior to thin ones. The limit placed on the maximum length and caliper of planting stock is for practical reasons only, such as planter productivity and cost.

❖ Cuttings

Cuttings used in the Prairie region as planting stock have typically been 20-30 cm (8-12 in.) in length, with fairly small calipers. To ensure better survival and performance in unrooted cuttings, the recommended standard for top caliper is 1.0-2.0 cm (3/8-3/4 in.), with at least one live bud within approximately 2.5 cm (1.0 in.) of the top; a second live bud within 5.0 cm (2.0 in.) of the top would be optimal. This is regarded as an ambitious standard, but for unrooted cuttings 'size matters'. Cuttings should be free of any branches and show no sign of damage or disease. These cuttings can also be used to start a new stoolbed crop or a new bareroot crop.

Cuttings used as propagation material for bareroot nursery beds and container-grown stock are discussed in 'Rooted and dormant [See Module 3.2.2]'.

Cuttings not meeting the recommended minimum top caliper of 1.0 cm (3/8 in.) standard should not be considered for planting a crop; they do not have sufficient food reserves to support the growth needed for a successful crop. With a doubling of the top caliper, the volume of the cutting increases fourfold! That means it has 4x the food reserves of a cutting with half the caliper. That is why it is so important to insist on meeting the stock standards. Photo 3-4 shows the dramatic differences between the small caliper and the large caliper cuttings from an experiment carried out on a poplar farm on Vancouver Island (B.C.). The results of this and several similar trials led to exacting stock standards for unrooted cuttings.

The standards for the top caliper of unrooted cuttings at 1.0-2.0 cm (3/8-3/4 in.) are the same as published in a poplar handbook 'The culture of poplars in eastern North America' at Michigan State University[6].

Can the whole shoot be used for cuttings? The answer is no. Figure 3-2 shows a typical stool in a stoolbed. The shoot on the right is shown in segments of cuttings. Viable cuttings from these shoots exclude the very top section and the cutting at the very bottom of the shoot.

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Photo 3-4: The relationship between cutting caliper and the performance of the poplar plant several months after planting unrooted dormant cuttings. The small caliper cutting on the right shows few roots and has a small top; the large caliper cutting on the left shows a mass of roots and a large top. The two intermediate cuttings in the centre show intermediate results.

The black line near the top of the cuttings represents the soil level.

These trees were excavated from a trial site on Vancouver Island (B.C.)

6 Dickmann, D.I., and Stuart, K.W. 1983. The culture of poplars in eastern North America. Michigan State University Press, East Lansing. 168 pp.

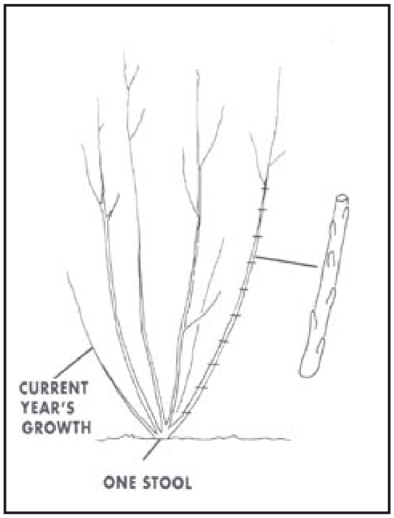

Figure 3-2: Viable cuttings are produced from about 60-70% of each shoot of the stool. The very bottom and top portions are rejected for cutting material.

Source: Boysen, B., Strobl, S. (Editors), 1991. A Grower's Guide to Hybrid Poplar. Ontario Ministry of Natural Resources. (Out of print).

Cutting caliper decreases from the bottom to the top, while bud size increases. As long as the cuttings meet the 1.0-2.0 cm (3/8-3/4 in.) top caliper standards, they will perform similarly.

❖ Whips

Whips can also be used to plant a crop. The size is usually 1.5-2.0 m (5.0-6.5 ft.) in length, with a top caliper of 1.0-2.0 cm (3/8-3/4 in.) and a bottom caliper not exceeding the diameter of the planting tool (steel rod, dibble), approximately 2.5 cm (1.0 in.). There is little experience with whips in the Prairie region and this stock type may not be suitable given the risk of drought. To improve the success rate of whip planting, the lower buds and branches are removed, leaving just 4 to 6 live buds near the top. This avoids excessive moisture loss when the whip starts to grow in the spring.

❖ When and where to plant cuttings

Given the frequent drought spells on the Prairies the last few years, cuttings could be a risky stock type to establish a crop. There are differences between various clones on how well they grow roots when planted as an unrooted, dormant cutting. The condition of the stock has to be perfect and it needs to meet the size standards; thin cuttings (less than 1.0 cm or 3/8 in. at the top) simply do not measure up for field planting!

The condition of the planting site also determines the success rate of cuttings. They will be more successful in coarser textured soils that warm up much faster than fine textured soils, especially when there is a lot of soil moisture. Rising soil temperature creates good conditions for root growth; this is discussed in 'Soil temperature [See Module 6.7.1]'. For finer textured soils, rooted stock is a better choice, as soil temperature is probably not as critical as for unrooted cuttings.

3.2.2 Rooted and dormant

A rooted and dormant plant is the most versatile stock type for the Prairie region.

There are two choices of rooted stock: Bareroot (BR) and container stock (plug). Both bareroot and container stock types are grown using short cuttings as starter stock. The performance of the trees in the nursery not only depends on the cultural practices, but also very much on the initial health and size of the starter stock.

❖ Bareroot stock

Bareroot stock is grown in an outdoor nursery bed. The nursery uses unrooted dormant cuttings for starter stock. Sometimes cuttings that do not meet the standards for regular planting stock could be used as starter stock, provided they meet the standards for starter stock (Table 3-3). Good sorting standards should apply here just as much as for regular planting stock.

For starter stock unrooted cuttings are used with a top caliper of 1.0-1.5 cm (3/8-5/8 in.) and a length of 15 cm (6 in.) with one live bud within approximately 2.5 cm (1.0 in.) of the top; a second live bud within 5.0 cm (2.0 in.) of the top would be optimal. They need to be precision planted in bareroot nursery beds. Depending on the size requirements for the stock, spacing within the nursery bed usually varies from 15-25 cm (6-10 in.) apart within the row and about 25 cm (10 in.) between the rows. The spacing between the rows depends on the equipment used at the nursery. Spacing in the row needs to be fine tuned to the specific clone and stock size required and that takes experience and time to determine.

The aim should always be to grow the maximum possible caliper, measured at about 2.5 cm (1 in.) above the top of the starter cutting. Height is not that critical and cutting it back to a certain height when processing the stock before packaging is possible; growing a large caliper certainly is critical. A good choice would be to grow the stock as tall and fat as possible (Table 3-3) and then cut the main stem back to about 20-30 cm (8-12 in.) above ground level when the stock is being processed for sorting and packaging. This is a size that is easy to plant and the remainder of the shoot could be processed into new starter stock for bareroot, stoolbeds or container grown stock. The decision to what height to trim the shoots depends on the farmer's requirements.

During processing, the roots can be pruned back to ease storage, handling and planting. The great advantage of BR stock is its capacity to grow coarse roots[17]. The volume of the coarse roots adds to the total food storage of the tree (Photo 3-5 and Photo 3-6).

The recommended target standard for caliper, measured about 2.5 cm (1.0 in.) above the top of the starter cutting, should be 1.0-1.5 cm (3/8-5/8 in.); this is an ambitious target standard that bareroot nurseries should be aiming for once enough experience has been gained with respect to the cultural practices required to achieve it. A currently achievable interim target standard is for a caliper of 0.7-1.0 cm (1/4-3/8 in.), measured about 2.5 cm (1.0 in.) above the top of the starter cutting.

Cees van Oosten, BC

Photo 3-5: A typical Quebec steckling or rooted whip on the left. In the centre the whip is processed by trimming the root system. Note the heavy coarse roots. This stock exceeds the long term target standard for the caliper of 1.0-1.5 cm (3/8-5/8 in.)

Cees van Oosten, BC

Photo 3-6: A rooted cutting produced in Alberta. This BR cutting would easily meet the interim target standard of 0.7-1.0 cm (1/4-3/8 in.). Note the nice coarse roots; these are trimmed well.

17 Martens, L.A., Response of aspen (Populus tremuloides Michx.) seedlings to cold storage, root aeration, and watering regime. Master of Science thesis 2006. University of Alberta.

❖ Container stock

Container-grown stock, or simply called container, PSB or plug stock is started in a greenhouse and subsequently finished outdoors, or with the greenhouse roof removed, to make use of natural light conditions.

Most container stock is grown in the Styroblock® tray system developed in Canada by Beaver Plastics Ltd. of Edmonton, Alberta. The designation for this stock type is PSB, followed by a number and sometimes a letter (e.g. PSB415D). PSB stands for ‘plug styroblock’ and the number designation 415 indicates a top diameter of the root cavity of approximately 4 cm (1.6 in.) and a depth of 15 cm (6 in.). There are several different types and sizes (Appendix J).

Another container type is the Spencer Lemaire Rootrainers™ system. This system has not been widely used for poplar in Western Canada. Jiffy peat pellets and peat pots and Finnish paper pots are rarely used to grow poplar stock.

The PSB415D and PSB412A are the most frequently used plug stock types for hybrid poplar to date. The 415D is 15 cm (6 in.) deep and the 412A is 12 cm (4.6 in.) deep. The 412A is suitable for planting in cooler soils, where the bulk of the roots are closer to the soil surface and benefit from warmer soil temperature to initiate root growth.

There are other suitable container sizes as well, such as PSB512A, PSB515A and PSB615A. These have progressively larger root cavity volumes and are thus increasingly more expensive.

Small 7.5 cm long (3 in.) starter cuttings are set in each of the soil-filled cavities of a styroblock (Photo 3-7), which is then placed in a greenhouse (Photo 3-8).

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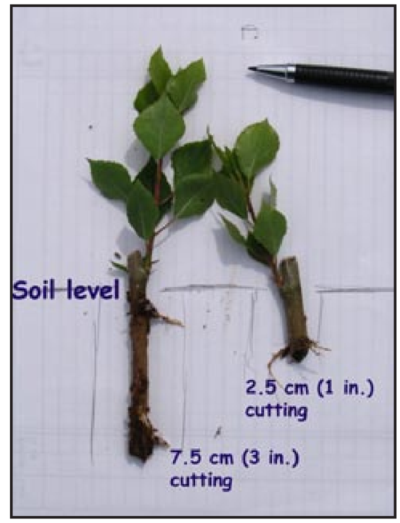
Photo 3-7: Starter cuttings are set in a PSB415D styroblock and moved into a greenhouse at Smoky Lake Forest Nursery of Coast to Coast Reforestation Inc. in Alberta.

Cees van Oosten, BC

Photo 3-8: A greenhouse filled with PSB415D styroblocks loaded with small starter cuttings at Smoky Lake Forest Nursery of Coast to Coast Reforestation Inc. in Alberta.

The timing of starting a greenhouse nursery crop varies depending on nursery space and logistics, but is recommended to be in the April – May period. Starting this stock type in June is not recommended. After a good start in the greenhouse, the stock is moved outdoors in late June to be exposed to full sunlight. Many nurseries have polyhouses (plastic walls and roof), where the poly (plastic) roofing can be removed to expose the crop to full sunlight. The trees grow to the required standard that summer, are lifted, packaged and stored in November or December and are ready for planting the following spring as a dormant plug stock, hence the alternate name of OWD (over-wintered dormant).

Most roots develop near the bottom of the cutting and quickly occupy the bottom half of the container. The initial root development is clearly visible for two small starter cuttings of different lengths that were set in styroblocks (Photo 3-9). By the end of the summer the longer cutting on the left would have formed a solid root plug in the bottom half of the container, while the top half of the plug remains soft and without much structure. When the trees get extracted from the container the following winter for packaging and storing, the root plugs can lose their firmness and have the tendency to fold or hinge about halfway down at the slightest resistance. This makes planting more difficult the following spring. By using smaller 2.5 cm (1 in.) single bud cuttings, shown on the right, this problem can be avoided. Since most roots originate from the bottom of this short cutting, there will be more roots in the top half of the root plug, adding to its firmness by the end of the summer. An added advantage of using the single bud cuttings is that it 'stretches' the supply of scarce starter stock. Although a longer starter cutting has the advantage of additional food storage in its stem over the single bud cutting, the benefit of this needs to be weighed against the disadvantage of the loss of firmness of the plug.



Cees van Oosten, BC

Photo 3-9: New stock set in early June in an outside compound on a trial basis at the PRT Nursery near Prince Albert (SK).

7.5 cm (3 in.) cutting stuck in a PSB 410 (112 cavities per block) on the left and a single bud cutting 2.5 cm (1 in.) set in a PSB313B (160 cavities per block).

Note the initial root development.

Size of the container stock is also a critical issue. The nursery would like to fill every cavity in the styroblock with a starter cutting. Due to poplars' extreme intolerance to shade, a density this high will result in a small caliper. Sometimes shading can be so severe that it actually damages the trees physiologically. This crowding can be avoided several ways.

The nursery manager can use cultural practices to control the growth of the crop by carefully managing irrigation and fertilization. The aim should always be to grow the maximum possible caliper. As with bareroot stock, height is not that critical and can be trimmed back at time of processing and packaging. To avoid excessive crowding, the nursery manager can adjust the crop density, as will be discussed next.

The choice of cavity size also matters and the way cavities in a styroblock are utilized will influence the physical size of the trees. The PSB415D and PSB412A (Appendix J) styroblocks offer a good compromise between size and price. In a greenhouse crop nurseries use an 'oversow' factor to allow for mortality and for stock that cannot meet the target standard for caliper. Since poplars are extremely intolerant of shading and crowding leads to stress, properly spacing trees in the nursery is an important management strategy. The shade intolerance of poplar in a nursery setting is often underestimated and standard practices used for the production of conifer crops do not fit poplar. To fill every cavity of a styroblock, in


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Photo 3-10: A nice single-bud cutting produced this PSB 415 tree in 1995 by one of PRT's Nursery near Tsawassen (B.C.)

This tree is about two months old and was started in the greenhouse. It was placed outside after initial establishment. Every cavity in the styroblock was filled, which resulted in a high a crop density.

This tree is at or near the target standard of 5-7 mm (3/16-1/4 in.) for caliper and is approximately 50 cm (20 in.) in height. These trees were transplanted into a stoolbed in early June, but had they continued to grow in the containers, they would have needed more room for proper development and balance between caliper and height.

order to maximize the number of plants per unit area, could be counter productive in the 415D or 412A stock types.

One strategy nurseries can use (and are using) is to leave a certain number of cavities empty (e.g. leave one in every four cavities empty) thereby allowing sufficient space for the remaining tree crop to grow. An example of this can be seen in Appendix K, where cavities are systematically left empty in a diagonal pattern. This results in approximately 58 trees per block vs. the 77 in a completely filled 415D (or 412A) styroblock. With 1/3 more above-ground space, the trees experience less above-ground competition and will respond by adding caliper. An added advantage is the extra ventilation the empty cavities can provide, which will help the watering regime.

The target standard for container stock should be a caliper of 5-7 mm (3/16-1/4 in.). That is an ambitious target standard for PSB415D and PSB412A styroblocks, but is possible (Photo 3-10), especially when providing the trees more above-ground space.

Another approach is to choose the next container size up, for instance the PSB 515A (or 512A) (Appendix J). This styroblock has 60 trees per block vs. 77 trees for the 415D styroblock. Growing trees in the 515A size would result in better calipers than growing in the 415D size if all cavities were to be filled. The trees would be more expensive to grow, store, transport and plant.

It is unlikely that 58 evenly spaced trees grown in a 415D size styroblock have the same size as 60 trees grown in a 515A size. Although all the trees would have the same above-ground space for their foliage, the root systems in the 515A styroblock have 45% more soil volume than trees in the 415D styroblock (Appendix J), which will result in 'fatter' trees.

For additional information, please see:
[Web-Beaver]
[Web- Spencer Lemaire]

3.2.3 Rooted and active

Planting of actively growing rooted stock in the late spring, summer or early fall is known as hotplanting. It is not a recommended practice of planting or fillplanting a crop.

Hotplanting during the late spring and early to mid summer, when the weather can be warm and sunny, carries a high risk of trees shedding most of their foliage due to transplant shock. There can be several causes. Light levels may be too intense for the trees when they come from a crowded nursery into an open field; their response is to shed foliage to protect reserves. High heat levels can cause damage; the leaves turn black in a matter of hours and are subsequently shed. In the late spring and early summer there is no terminal bud yet and the tree continues to grow new foliage at the very tips of its terminal leader and uppermost branches. Since the old foliage to support this growth is gone, trees dip into their stored reserves to continue growing new foliage. They have to have very favourable growing conditions during the rest of the growing season to maintain this growth, rebuild reserves, set a terminal bud and get ready for dormancy. Under the most favourable circumstances trees will recover, provided moisture conditions are good and the planting was early enough in the summer.

Trees that have already set a terminal bud in late summer and are hotplanted late summer to early fall, may also be at risk of prematurely shedding foliage due to transplant shock, especially when it is warm and sunny. This could jeopardize the conditioning of the trees to start the normal dormancy cycle, leaving them vulnerable to cold damage over the fall, winter and spring period.

Hotplanting does have a place in nurseries and in breeding operations where stock needs to be transplanted to the field, as long as there is the capability to provide overhead irrigation and it is early enough in the summer.

Spring planting with dormant stock is still the best way to maximize survival and growth. Planting dormant stock allows the farmer some flexibility when using a directed or shielded herbicide application with a glyphosate herbicide before bud break to control newly emerged weeds. This may be needed to clean up a field where the previous herbicide application was not totally effective in controlling (perennial) grasses and broadleaf weeds. When the crop is in a dormant state, it is less susceptible to herbicide damage.

- **Fillplanting needs**

There are proponents of hotplanting stock in full foliage in a fillplanting operation during the early fall to fill in the gaps in a crop. The observations are that if the stock is planted in the early fall season it sets a terminal bud and sheds its leaves in the normal fall cycle, together with the other trees. Not enough is known yet about the consequences of hotplanting in the early fall and trials are needed to validate this practice.

3.2.4 Stock standards – Summary

Table 3-3

Unrooted stock			Top Caliper		Height	
	End use	Type	Target standard			
			cm	inch	cm	inch
	Planting stock	Cutting	1.0-2.0	3/8-3/4	20-30	8-12
	Starter stock stoolbed	Cutting	1.0-1.5	3/8-5/8	15	6
	Starter stock Bareroot	Cutting	1.0-1.5	3/8-5/8	15	6
	Starter stock Container	Single bud	0.8-1.2	5/16-3/8	2.5	1
		Cutting	0.8-1.2	5/16-3/8	7.5	3
	Planting stock	Whip	1.0-2.0	3/8-3/4	150-200	60-78

Rooted Stock*			Top Caliper		Height	
	End use	Type	Target standard			
			cm	inch	cm	inch
	Planting stock	BR cutting**	0.7-1.0	1/4-3/8	varies	
	Planting stock	BR whip (set)	1.0-2.0	3/8-3/4	150-200	60-78
	Planting stock	PSB415D	0.5-0.7	3/16-1/4	varies	
	Planting stock	PSB412A	0.5-0.7	3/16-1/4	varies	

* Caliper is measured at about 2.5 cm (1 in.) above the top of the starter cutting

** Interim Target Standard - Future target: 1.0-1.5 cm (3/8-5/8 in.)

3.3 Stock Logistics and Sourcing

3.3.1 Suppliers

Most nurseries do not grow a tree crop without a contract and typically require 1.5 years or more lead time prior to the intended spring planting season to secure the starter stock and grow the nursery crop [See Module 3.1.3]. Almost all nurseries have specialized in growing conifer stock for the forest industry and growing a hardwood crop is not as common yet. That is likely to change as demand for poplar stock increases. There are several nurseries that have the capability and experience to grow planting stock. They are listed in Appendix I.

3.3.2 Prices

Depending on the nursery, prices may or may not include costs for the starter stock and cold and/or freezer storage in standard boxes. Stock pricing is related to the expected recovery of acceptable stock per unit area (per m^2 or $ft.^2$). This is especially important for container grown stock that depends on the limited space and expensive infrastructure of a greenhouse, and inputs such as heat and extra lighting. The nursery is aiming at a certain amount of revenue per m^2 of space.

Outdoor grown stock, such as bareroot (BR) and completely outdoor grown container stock should be cheaper than greenhouse grown stock. It is really important that greenhouse grown stock gets exposed to full sunlight as soon as the stock is well established and the risk of frost has passed. Nurseries move the stock outdoors or remove the plastic roofs of the greenhouse; however, growing outdoors is more risky due to unexpected cold spells, hail damage etc.

In some instances it may be a good idea to have a nursery crop grown in a more favourable climate, which could lower costs of production and thus prices, but would inevitably lead to higher transportation costs. These are some of the options a farmer should explore with the nursery. Since prices fluctuate, there will not be any price information in this manual. It is best to approach the nurseries directly (Appendix I).

3.3.3 Packaging and storage, transportation and delivery

Unrooted cuttings can be harvested during the winter, provided the shoots of the stools have not been exposed to desiccating weather. The shoots must retain sufficient moisture to yield healthy cuttings. Harvesting too early in the winter may lead to reduced viability of the stock due to the length of storage.

Container grown stock should be moved indoors just before freeze up to avoid solidly frozen styroblocks, so it can be lifted, packaged and stored. This should take place as late as possible to shorten the length of storage.

Once the bareroot stock is dormant in late fall (to early winter) and before freeze up, it is lifted and processed for packaging and storage. The impact of storage length of bareroot poplar stock needs to be evaluated. Work done on aspen stock storage indicates that lengthy storage (beyond two to three months) decreases stock viability[17].

❖ Packaging

Normally nurseries provide storage boxes with liners as part of the growing contract. The cost should be included in the stock price. For relatively small amounts and regular stock sizes, standard seedling boxes work well. For special sizes, such as whips or large bareroot stock, the nursery and farmer need to agree on alternate ways to package and store the stock if standard boxes do not work.

Packaging should fit the storage and transportation methods, but above all, it should be geared to ease storing and handling in the field. Since much of the stock will be planted manually, packaging or wrapping in units of 50, 75, 100 etc. trees would be an easy way to keep track of production by and payment for the planters. It is also an easy way for the farmer to keep track of which stock and how much goes where. That will be covered in 'Planting Project Record Keeping [see Module 6.9]'.

Using sturdy plastic bags that can be sealed off using twist ties or ladder ties is a good method of packaging cuttings and whips. With varying stock sizes a roll of polytube can be cut to measure and can be sealed at both ends once the stock is inside. Make certain that the plastic has sufficient thickness ('mil') to withstand handling and avoid puncturing. This is a very good and flexible way to package stock. Clear plastic allows the farmer to easily see the condition of the stock. Some people promote black plastic to exclude any light from reaching the stock; this is unnecessary. It has the disadvantage that it absorbs heat, even on a cloudy day, heating up the stock inside.

17 Martens, L.A., Response of aspen (Populus tremuloides Michx.) seedlings to cold storage, root aeration, and watering regime. Master of Science thesis 2006. University of Alberta.

When packaging cuttings or whips, ensure they are all oriented in the same direction, i.e. all the tops at one end and the bottoms at the other. This avoids mistakes in planting. One nursery paints the tops of the cuttings with a latex paint and uses unique colours for each clone. This makes quality control easy as the trees are easily spotted in the field after planting; the paint may also seal the cut surface of the cutting top to prevent moisture loss. It is a nice option and easy to do. Cuttings and whips can either be stored horizontally or vertically, whatever is easiest.

Packaging of plug stock in cardboard boxes, with water tight liners or plastic bags, works well. If the stock fits upright in the box, it could be stored vertically. If the stock is too tall, it can be stored horizontally. If the farmer agrees, the tops could be trimmed back to fit the box. Trimming the tops to an even size would work well; however it might impact the growth form after planting. The root plugs should be wrapped in cellophane in bundles of 10, 15, 20 or 25 trees, or whatever works best. Just ensure the bundles hold the same number of trees; it makes administration in the field a lot easier.

For bareroot stock the packaging becomes a bit more complicated. The ease of packaging depends on how many roots are retained. It is not necessary to leave all roots on the tree; it would be very costly to plant. One nursery in Quebec trims most of the roots and the tree looks like a rough bottle brush (Photo 3-5). Polytube works well, provided it has sufficient thickness ('mil') to prevent puncturing.

When packaging stock, the nursery must ensure that leaf litter is removed. Leaf litter can be a source of disease that spreads through the crop during storage.

❖ Storage

Most commercial nurseries have storage facilities.

For long term storage, freezing of stock is recommended at temperatures between -2° and -4°C. For shorter storage (several weeks), a cooler would do fine between 0° and +4°C. If the farmer wants to store his own stock, he could rent commercial storage space, or use a (good) fridge to store a limited amount of stock for a short while. Avoid storing at temperatures below -10°C. Some nurseries have reported that storing at temperatures below -10°C works well for certain clones. That takes knowledge of individual clones.

The risk of storing at colder temperatures is losing an excessive number of frozen buds that get easily knocked off the stems during handling.

When stock is delivered to the field, keep it cool by storing it in the shade of a building, or in the trees next to the field. Always use a 'Silvicool' tarp to keep the sunlight out and the cold in. This will be discussed in 'Storage on site [See Module 6.8.2]'. It is advisable to take delivery of one day's planting stock at a time to minimize the amount of stock stored outside. Keep the stock out of direct sunlight, even on an overcast day. Storing it short term in a shed with ample ventilation is also a good idea, but still use a Silvicool tarp.

❖ Transportation and delivery

Most nurseries can provide advice on or assist with the transportation and delivery of the stock; however, the price of the stock does not normally include this service. If the transport involves a large number of trees, a reefer van may be the answer. Check with local transport and trucking companies to see what service they can offer. A direct delivery is best; it avoids the stock being routed through central truck yards where the transport is combined with a load of lumber for instance. Once this happens, no one has control over the condition of the stock.

MODULE 4: CROP DENSITY, SPACING AND LAYOUT

In agriculture the term seed spacing is used to identify the spacing of seeds in a crop row (in-row) in relation to the spacing between the crop rows. That determines the number of crop plants per hectare or per acre, which is called crop density. This is no different for an SRIC hybrid poplar crop.

- Crop density is the number of crop plants per hectare or per acre.
- Crop spacing is how individual trees are spaced within and between crop rows or tree rows.
- Crop layout is the placement and direction of the tree rows in relation to the conditions of the field in which the crop will be planted.

Please see Appendices L and M for conversion tables. Note that conversions from metric to imperial measures and imperial to metric are approximate and rounded off.

4.1 Crop Density

Many poplar farmers do not have a good rationale for choosing a crop density, other than being able to fit the tractor between the tree rows. Frequently the choice is made without consideration for the potential value of the future crop. This is not surprising as no one is able to predict what the market will be like [see Module I.6.1].

4.1.1 Various measurements

It is important to discuss measurements and measurement units used in this business.

❖ **Diameter**

The diameter of a tree is measured at 1.30 m (4.3 ft.) height, which is a convenient height for most people. It is about breast height, hence the name 'diameter at breast height' or simply DBH. The measurement of the DBH always includes the bark; that is called 'diameter outside bark' or dob.

The diameters used for log specifications always exclude the bark and is called 'diameter inside bark' or dib.

❖ **d/h ratio**

The d/h ratio is the DBH (in cm) of a tree divided by its height (in m); it is referred to as the 'd/h ratio' or 'diameter over height ratio' (Appendix N). For a tree with a DBH of 19 cm (7.7 in.) and a height of 18 m (59 ft.), the d/h ratio is: DBH 19 (cm) divided by height 18 (m) = 1.06, which is a excellent ratio for a dominant tree in a pulpwood crop, planted and grown at 1,000-1,100 stems per hectare (spha) or 400-450 stems per acre (spac).

Although log markets in Canada buy and trade logs in metric units (tonnes, cubic meters), many people in the industry still use imperial units to define the log sizes and grades. Wood studs are still sold in imperial units as 2x4's (2 in. by 4 in.) of 8, 10, 12 ft. (etc.) in length, sheets of plywood as sheets of 4x8 ft. and in thicknesses of 3/8th, 1/2, 5/8th inch etc. Sawmills use the foot board measure (fbm), or simply called board foot or board feet; it is a unit of cubic measure for lumber, equal to one foot square by one inch thick.

4.1.2 End product considerations

❖ Volume or value?

The choice of crop density is a compromise between the end product the farmer is interested in producing and the methods and their costs required to achieve it. A high crop density will yield a high volume of small trees. A low crop density yields large trees, but a lower volume per hectare (Table 4-1) with a longer crop cycle.

Table 4-1[30]

Crop	Yield	Value	Crop cycle or Rotation – Years	# of Harvests	Stems per hectare – spha	Stems per acre – spac
Biomass	+++++	+	4-7	4-5	> 2,000	>800
Pulpwood	++++	++	15-25	1-2	1,000-1,100	400-450
OSB	++++	+++	15-25	1-2	1,000-1,100	400-450
Saw log	++	+++++	20-30	1	625-816	250-330
Peeler log	++	+++++	20-30	1	625-816	250-330

30 van Oosten, C. 200501 - Crop Density for Hybrid Poplar. Project 200501 - Saskatchewan Forest Centre, March 2006.

Biomass crops will not be discussed in the Manual, as this requires a totally different management approach.

To be economically successful, farmers should aim for a crop that offers some flexibility to respond to developing markets. For example, there can be greater risk to a farmer in just growing a pulpwood crop, unless the farmer is under contract with a pulp company to grow this crop. Pulpwood crops are typically planted at 1,000-1,100 spha (400-450 spac) for a crop cycle or rotation of 15-25 years. Although this option results in a high volume, the percentage of saw- or peeler logs would be low and of a low grade; there will not be enough merchantable volume to respond to and benefit from a saw- or peeler log market as stem sizes will be marginal.

❖ Thinning

In several countries around the world poplar crops that are planted at a higher crop density are thinned partway through the crop cycle. The rationale is that the increased space created benefits the remaining trees. Thinning is an expensive treatment, with few opportunities to market the small material. To benefit the remaining trees, thinning would have to take place at a very young age and at a time when the trees barely meet minimum merchantable size requirements. Prices for thinned material will always be low, unless a specialty market exists close by that is willing to pay an attractive price. In that case thinning a poplar crop might be appropriate. If market opportunities for small material are uncertain or sporadic, it is a better option to manage the crop for saw- or veneer log production right from the start.

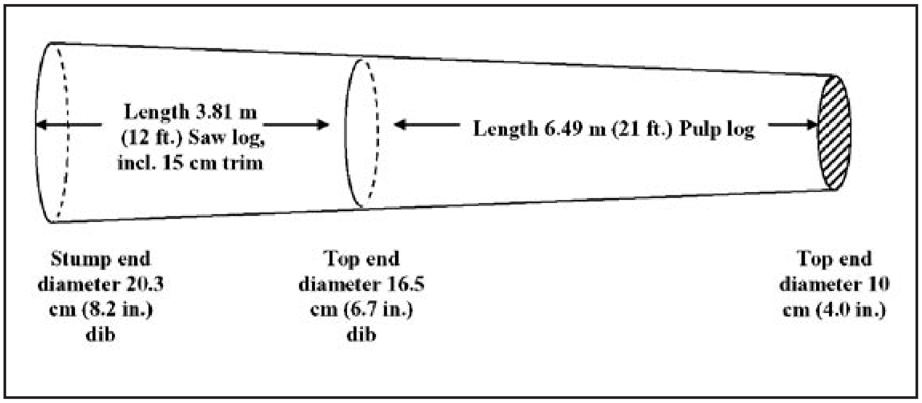
❖ Pulpwood production

For example, in a pulpwood crop planted at 1,100 spha (450 spac, in 15-20 years an average tree might grow to a height of 18 m (59 ft.) and a DBH of 19 cm (7.7 in.) dob. Saw logs are produced in lengths of 2.44 m (8 ft.), 3.05 m (10 ft.), 3.66 m (12 ft.) and 4.88 m (16 ft.), with a minimum diameter at the top end of 15 cm (6.0 in.) dib (Figure 4-1).

Figure 4-1 shows one saw log with a length of 3.81 m (12 ft.), which includes 15 cm (6 in.) trim, that could be produced from the average tree in this pulpwood crop. Using the 'Volume table Quebec - inside bark' (Appendix O-2[29]), developed for hybrid poplar production clones in Quebec, this tree of 18 m (59 ft.) in height and 19 cm (7.7 in.) DBH would have a volume of approximately 0.16 m^3 per tree (inside bark). The volume of the saw log portion is approximately 0.10 m^3 or almost 62% of the total tree volume. It is a low grade saw log in terms of its dimensions.

29 Popovich, S. Hybrid poplar - The first form factor and volume tables for Quebec. Information Report LAU-X-71E, Laurentian Foretsry Service - Canadian Forestry Service, 1986

Figure 4-1: Only the bottom 3.81 m (12 ft.) can be graded a saw log (including trim); the remainder of the log and the rest of the tree would be pulp grade.



In this example, the minimum top diameter for pulpwood is 10 cm (4 in.) dib, which is currently an industry standard. As technology develops and suitable wood becomes scarcer, the top diameter of useable pulpwood will probably decrease, especially when wood is debarked and chipped right on the farm rather than being transported to the mill in log form.

❖ Saw and veneer log production

In order to produce a large proportion of saw- or veneer logs of a high grade, the farmer must aim for a larger average DBH. That requires a d/h ratio well in excess of 1.0, and preferably 1.1 to 1.2, which would be possible with a density range of 816 spha (330 spac) on the high end, to 625 spha (250 spac) on the low end. This is substantially lower than 1,000-1,100 spha (400-450 spac) for a pulpwood crop.

The data in Table 4-2 demonstrates how much more saw log volume is possible with a slightly larger tree. Choosing a lower density will result in a lower overall yield (volume) per hectare, but the proportion of saw log volume may well be worth it. The grade will increase with an increasing tree size. The farmer needs to compare the increase in overall crop value at a lower crop density with the value of a higher volume of small stems at a high crop density. The economics of the crop density choices will be discussed in more detail in module 'Economic Analysis [see Module 10]'.

Table 4-2 : Estimated % and volume of saw log grade for an 18 m (59 ft.) tall tree

Crop	Crop density	d/h		DBH		Volume	Saw log	
	spha	spac	ratio	cm	in.	m^3/tree	%	Grade
Pulpwood and OSB	1,100	450	0.9	18.0	7.1	0.15	40-45%	lowest
	1,100	450	1.0	20.0	7.9	0.18	55-65%	↓
Saw log	816	330	1.1	22.0	8.7	0.22	70-75%	
	625	250	1.2	24.0	9.4	0.27	75-80%	highest

Please note that there are no relevant data yet for the Prairie Provinces. The example in Table 4-2 is an estimate based on information from other regions.

4.1.3 Mortality of trees

The mortality rate of trees will have to be incorporated when deciding on a crop density. When using top of the line planting stock [see Module 3.2], 85-95% survival (Table 4-3) should be the norm for pulpwood and OSB crops, without need to compensate by fillplanting. If historical levels of survival are much lower, the farmer could adjust the number of trees upward; however, this would cause potential problems in the crop spacing by impeding the ability to cross cultivate.

In low density saw- or peeler log crops of 500-800 spha (200-325 spac), every tree counts and a higher survival rate is required. The survival rate should be at least 95% (Table 4-3). If survival drops below this level, a fillplant with good quality dormant and rooted stock should be considered immediately after the first survival survey [see Module 8.1] following planting.

Table 4-3

Crop	Stems per hectare – spha	Stems per acre – spac	Survival target
Pulpwood and OSB	1,000-1,100	400-450	85-95%
Saw log	625-816	250-330	>95%
Peeler log	625-816	250-330	>95%

4.1.4 Crop stability and density

Inter-tree competition is when neighbouring trees compete for growing space (light, soil moisture and nutrients). When a crop is planted too densely, inter-tree competition forces trees to maintain their position in the canopy, otherwise the tree will be shaded out by its neighbours and will eventually die. Height growth becomes a higher priority for the tree than diameter growth and the d/h ratio drops to a level where the trees become structurally weak. The entire crop structure is weakened and the trees are at risk of wind throw during a heavy wind storm. Since individual trees do not have the structural strength to withstand a severe wind storm, they lean into their neighbours, causing a domino effect that can flatten an entire crop (Photo 4-1).

Crop stability becomes a concern when trees approach a d/h ratio of 0.9 or lower. The trees become too tall for their height and the roots systems are not developed enough to provide support; trees become unstable and topple easily.

Alternatively, it could also be a poor clone from a genetic perspective. Some clones are not wind firm.

Cees van Oosten, B.C.

Photo 4-1: Windthrow damage of a hybrid poplar crop in its 8th growing season. This crop was planted too dense at 1,360 spha (550 spac).

The d/h ratio was at or just below 0.9, signaling serious inter-tree competition at too young an age.

The location is in Snohomish County in Washington State.

4.1.5 Clonal differences and density

The way trees compete with each other in a monoclonal crop differs from clone to clone. The question that is often raised is: "Could trees with a narrow crown be planted at a higher density than trees with a wider crown?" The answer is a definite "maybe"! There simply is not sufficient information on the various clones to recommend clone-specific crop densities and it is doubtful there ever will be as clones will be taken out of production to be replaced by newer and better ones as time goes on.

There are narrow-crowned clones that are not doing well at a high crop density. One such clone is Walker, a well known shelterbelt clone that is now frequently used for SRIC poplar crops. The following illustration is from module 'Clone Selection and Deployment [See Module 2.1.1]' in a trial near Henribourg (SK) at the Weyerhaeuser Seed Orchard.

Trees of the clone Walker were planted at three different densities by the Shelterbelt Centre of the PFRA in a crop density trial. In one of the plots, planted at the density of 1,700 spha (680 spac) and a spacing of 2.4x2.4 m (8x8 ft.), a few trees of clone Northwest were inadvertently mixed in. The live crowns of all the R-9 (or rising 9, meaning in the 9th growing season) Walker trees on the left and the background (Photo 4-2) have lifted to well over 2 m (6.5 ft.), which is an indication that this clone is suffering from inter-tree competition and does not thrive at this crop density.

Cees van Oosten, B.C.

Photo 4-2: An R-9 density trial of Walker, established in 1997 at 2.4x2.4 m (8x8 ft.) spacing. Note the difference in crown lift in clone Walker on the left and that of the clone Northwest on the right, which is still all the way to ground level.

This trial is located near Henribourg (SK).

The crowns of the intruder clone Northwest are still alive all the way to ground level and have spread out much wider than the narrow-crowned Walker. From this observation it appears that the clone Northwest is a better competitor than Walker. At the density of 750 spha (300 spac) and a spacing of 3.7x3.7 m (12x12 ft.) the crowns of Walker were still alive all the way to ground level. At the intermediate crop density of 1,100 spha (450 spac) and a spacing of 3x3 m (10x10 ft.), the live crowns of Walker were intermediate and had started to lift. Since clone Northwest has a much wider crown, which extends all the way down to ground level, it is much more effective in shading out competing vegetation than clone Walker.

The inability of Walker to compete well at a high density is also visible at the nursery site operated by Pacific Regeneration Technology (PRT), located near Prince Albert (SK). The R-6 Walkers (Photo 4-3) were established at a spacing of approximately 3x2.4 m (10x8 ft.) or a density of 1,345 spha (545 spac). The trees have a narrow crown and there is no crown closure. Lots of light still reaches the ground, which has benefited the weeds. Walker has not fully occupied the site, yet the live crown has already lifted to about 2.5 m (8 ft.) on a tree that is 6-7 m (19-23 ft.) tall. That is an indication this clone is a poor competitor. Walker of the same age that was established as an outside buffer row (Photo 4-4) still has a full live crown due to lack of competition from the road area to the right.

Cees van Oosten, B.C.

Photo 4-3: Density of this R-6 Walker trial is 3 m (10 ft.) between rows and 2.4 m (8 ft.) in row. Note narrow crowns, which are typical for Walker. The live crown has lifted quite high. The location is near Prince Albert (SK).

Cees van Oosten, B.C.

Photo 4-4: This row of R-6 Walker was established as an outside buffer row. Note the full live crown on this tree due to lack of competition. The location is near Prince Albert (SK).

Elsewhere are similar examples of trees that perform poorly at high densities, but appear to do quite well at much lower crop densities. The clone Walker grows quite well in row plantings as a shelterbelt tree (Photo 4-5), where it experiences less inter-tree competition.

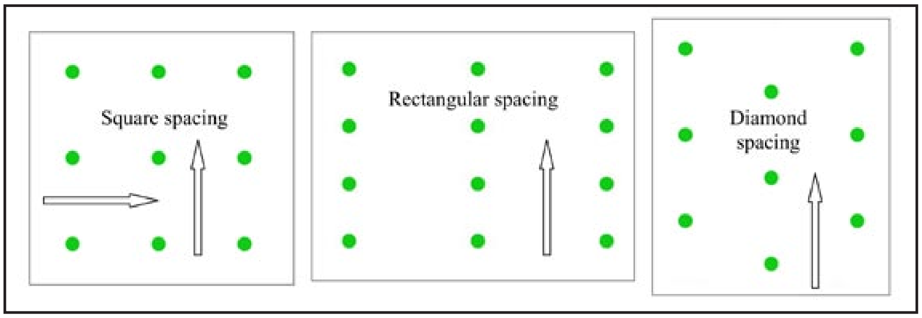
Cees van Oosten, B.C.

Photo 4-5: Walker shelterbelt poplars at the Conservation Learning Centre near Prince Albert (SK). The poplars were established in 1981 and are now R-25. Very nice and tall trees.

4.2 Crop Spacing

Once the farmer has selected a crop density he needs to decide on the spacing of the individual trees. For example, at the crop density of 1,100 (450 spac), each tree will have 9 m^2 (approx. 100 $ft.^2$) of growing space (one hectare is 100x100 m or 10,000 m^2). This can either be in the form of a square, a rectangle or a diamond (Figure 4-2).

Figure 4-2



In this case the square spacing would be 3x3 m (10x10 ft.), the rectangular spacing 4.5x2 m (14.8x6.6 ft.) and the diamond spacing 3 m (10 ft.) between tree rows and 3 m (10 ft.) in the rows (in-row). All three options would result in 9 m^2 (100 $ft.^2$) of growing site per tree.

The choice of spacing is mainly determined by the need for weed control. Poplar farmers in Canada do not have access to some of the more effective pre-emergent herbicides compared to their US colleagues. Their best option is to cross cultivate to control the weeds. Square spacing offers that opportunity.

Standards and allowances for in-row crop spacing depend on the need for cross cultivation and the choice of planting methods. That is discussed in the section 'Choice of Planting Methods [see Module 6.3]' of module 'Crop Planting' [see Module 6].

4.2.1 Square spacing

For a pulpwood or OSB crop density of approximately 1,100 spha (450 spac), choosing a square spacing at 3x3 m (10x10 ft.) is the best option. It allows for enough room between the tree rows and the in-row trees to move equipment in two directions. This spacing allows cross cultivation during the first years of crop growth, which is a critically important option for the farmer for effective weed control.

Cross cultivation requires headlands on all four sides of the field to turn equipment. This may result in some loss of net growing site; however, that loss will be more than offset by the benefits of better and more complete weed control.

For cross cultivation the trees need to be in perfect alignment in both directions to avoid equipment damage (Photo 4-6), especially at this narrow spacing of 3x3 m (10x10 ft.). There is no margin for error. A decrease in crop density with a corresponding increase of in-row spacing and tree row spacing result in more flexibility.

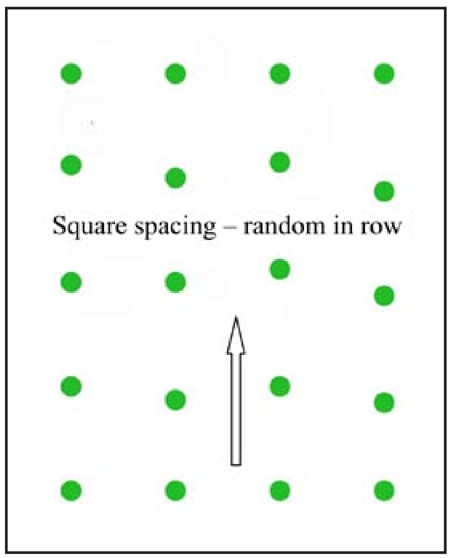
Cees van Oosten, B.C.

Photo 4-6: Cultivation caused damage to this R-2 hybrid poplar.

Note that a serious quackgrass problem is developing. The location is near Athabasca in Alberta.

In a situation with insufficient room for headlands, or where a field has numerous potholes or swampy low spots, cross cultivation may not be possible or practical and one-way cultivation is the only option. Tree rows should still be perfectly aligned, but the spacing in the rows (Figure 4-3) is not as critical. The choice is between 3 m (10 ft.) tree row spacing and rectangular spacing (see next). If the farmer sticks with 3 m (10 ft.) spacing between tree rows, the spacing within the tree row could vary somewhat, as long as there are some standards applied. For instance, on average the spacing in the row needs to be 3 m (10 ft.), but a slight variation is allowed. Experienced planters are very good at estimating planting distances and can come very close to an average distance of 3 m (10 ft.). As can be clearly seen in Figure 4-3, this spacing will not allow cultivation in the east-west direction.

Figure 4-3



4.2.2 Rectangular spacing

Rectangular spacing allows a bit more room for cultivation in one direction. In the 1,100 spha (450 spac) crop density example, instead of 3x3 m (10x10 ft.), spacing could go to 4.5x2 m (14.8x6.6 ft.). This will still result in 9 m^2 (100 $ft.^2$) of growing space per tree. Only one-way cultivation (Figure 4-2) is possible, but the farmer could use slightly wider equipment to get the job done, or make two passes, each ‘hugging’ one row on the way up and the other on the way down. Control of the weeds in the rows now becomes harder and requires a herbicide approach, the use of equipment that can weed in the row or a combination of mechanical and herbicide use.

In the case of a saw- or peeler log crop at a density of approximately 800 spha (325 spac), each tree gets 12.5 m^2 (134 $ft.^2$) of growing space. At square spacing that would mean about 3.5x3.5 m (11.5x11.5 ft.), which leaves plenty of room for cross cultivation. The equivalent in rectangular spacing would be approximately 4x3 m (13x10 ft.). Either situation would allow cross cultivation.

4.2.3 Diamond spacing

This is a variation on the square spacing. Odd rows are started one half tree spacing earlier (or later) than the even rows. The benefit of this more intricate pattern has not been demonstrated and it is more complicated to lay out.

If the farmer does decide to proceed with this pattern, the result would look very good (Figure 4-2); however, at the density of 1,100 spha (450 spac) it would be difficult to cultivate in multiple directions. Theoretically three-way cultivation would be possible, but practically it is difficult to do. That may be different when the density decreases with a corresponding increase in spacing.

4.2.4 Random in-row spacing

If cross cultivation is not a requirement for the farmer, in-row spacing could be random, but would still have to meet in-row spacing standards and tolerances. The main disadvantage of random in-row spacing is that in-row weed control will be harder to do and will be more expensive. From an esthetic viewpoint, this crop layout is the least attractive to look at.

4.2.5 Rectangularity

What is rectangularity? Rectangularity is the ratio between the long and short sides of a rectangle. In the example above, a 4x3 m (13x10 ft.) spacing has a rectangularity of 4:3. A spacing of 8x6 m (26x20 ft.) has the same rectangularity of 4:3 etc.

Does rectangularity result in different yields than perfectly square or diamond spacing? The short answer is no[13,14]. Rectangularity does not appear to affect yield as long as it does not exceed 3:1.

Does rectangularity affect the shape of the stem; i.e. would the shape of the stem become elliptical rather than circular? This has not been identified as a concern.

There are research reports that concluded rectangularity in biomass crops, planted at very high densities, benefits yields. For pulpwood, OSB, saw- and peeler log crops rectangularity does not impact yield either positively or negatively.

See Appendices L and M for conversion tables.

13 Johnstone, Wayne - Unpublished - The effects of initial spacing and rectangularity on the early growth of hybrid poplar plantations. Note: This is to be published in 2006; the author provided me the draft text and conclusions.

14 van Oosten, C. Plantation density - Literature review and trial design. 2000. Internal unpublished report.

4.3 Crop Layout

4.3.1 Operational considerations

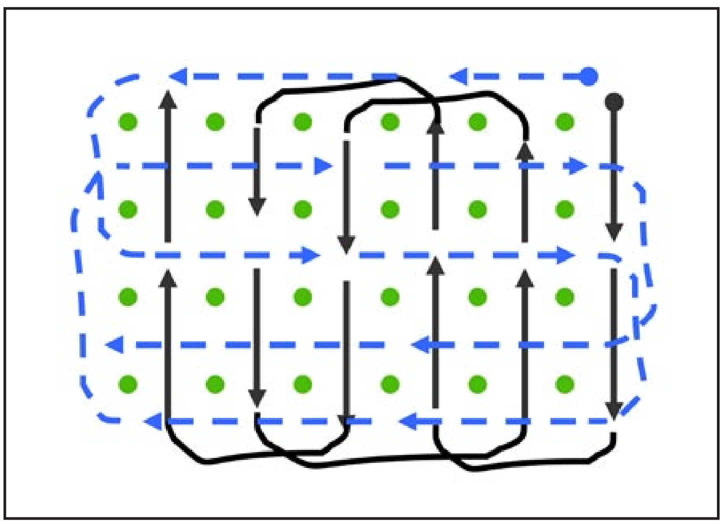
Some of the points raised below have also been discussed in module 'Site Requirements and Site Selection' under operational considerations [see Module 1.2].

❖ Field shape, size and crop layout

The field shape and size have a direct bearing on the efficiency of planting and subsequent crop management. What is the best crop layout? Is there enough allowance for headlands to allow equipment to turn around and gain access between tree rows? How can the number of turns be minimized? How best to lay out a field when planting two or more monoclonal crops?

The most efficient crop management is achieved when the crop is planted in long and straight rows, enabling machinery to work between the tree rows. With the current lack of registered pre-emergent herbicides in Canada for SRIC hybrid poplar crops, it is best to carry out mechanical weed control and/or chemical weed control in two directions perpendicular to each other. The tree rows therefore have to be perfectly parallel to each other in both directions (Figure 4-4) [See Module 4.2].

Figure 4-4



The importance of perfect tree row and in-row spacing cannot be stressed often enough. It offers the ability to achieve or approach a standard of 90% weed control [see Module 7.1] that otherwise would only be possible with the use of herbicides that are not available to Canadian poplar farmers. Not paying attention to this spacing will prove to be costly in subsequent crop maintenance.

It is very important to plan for the longest possible rows parallel to the travel direction of the large pieces of equipment needed during site preparation and spraying, such as the high-clearance boom sprayers. This is only possible if the topography of the field allows it.

When the farmer opts to use plastic mulch to control the weeds in the tree row, cross cultivation is not required or even possible. To protect the integrity of the plastic mulch, the tree rows need to be perfectly aligned, especially when using cultivating equipment between the tree rows.

The layout of the tree rows is called row marking and cross marking; this will be discussed in detail in module 'Crop Planting [see Module 6]'.

❖ Topography

The topography of a field determines what the limits are to the use of equipment, what the erosion risks are as a result of soil management activities and how the tree rows can be laid out to achieve maximum efficiency. Safety is paramount! The following guidelines in Table 4-4 are suggested for evaluation of slope and length of slope.

Table 4-4[7].

	Percent slope		
Slope Length	0-5%	6-10%	> 10%
< 50 m (150 ft.)	+++	+++	+
50-100 m (150-650 ft.)	+++	+	---
> 100 m (650 ft.)	+++	-	---
Highly Suitable (+++) to Highly Unsuitable (---)			

On highly suitable ground there are few restrictions on the layout of the crop, especially when planning a square spacing to ease weed control activities. There are few concerns for water erosion and slopes are gentle enough to allow safe tractor travel in all directions.

On less suitable ground slope, conditions may dictate how to lay out the tree rows. If the longest possible rows run along the contours of the slope, assess the risk of tractor roll. If it is too steep to safely operate a tractor, consider running the tree rows perpendicular to the contours of the slope and forget about cross cultivation. This may shorten the rows, but safety concerns must prevail.

Another concern of rows running along the contours of the slope is tractor drift towards the row on the low side of the tractor. The driver must constantly steer the tractor slightly uphill to avoid running into the tree row. Any abrupt steering correction to the uphill side immediately results in the attached equipment swinging into the tree row on the low side, damaging or burying the trees. This is especially true when the cultivator or disk is mounted on a three-point hitch and/or when the soil is too slippery for good traction. This would also be a concern when using herbicides in a shielded application; the risk of running the spray nozzles too close to or over the trees is real.

If the risk of soil erosion (wind or water) is too large for cultivation, maybe the site is only suitable for 100% herbicide weed control. If a cover crop is used, the soil is better protected, but the crop will suffer from the competition. These are all trade offs.

7 Schroeder, W., Silim, S., Fradette, J., Patterson, J., and de Gooijer, H. 2002. Detailed Site Analysis and Mapping of Agroforestry Potential in the Northern Agricultural Zone of Saskatchewan. Funded by the Saskatchewan Forest Centre - Forest Development Fund.

❖ Clone deployment

There is no science yet behind a sensible deployment strategy for SRIC hybrid poplar crops, only common sense. An easy rule of thumb is to plant a field to a maximum of 20 hectares (50 ac.) to a single clone. If the field is larger, consider splitting it in two, three or even four parts and planting one, two or three additional clones in distinct areas of the field. Avoid mixing the clones, lay out the field in blocks from end to end and assign each clone to its own block, or use logical breaks in topography or other features, such as an access road cutting across a field or a pipeline right-of-way, to delineate the area for each clone. More details can be found in ‘Deployment of clones [see Module 2.3]’.

❖ Pipelines, powerlines and other infrastructure

Pipelines pose potential problems when growing a tree crop. To avoid expensive problems and disappointments, check the rules and restrictions for buried pipelines. Are there differences between various pipelines? Can you farm right over some pipelines, but not others etc.? What are their precise locations? Are there restrictions around well sites?

Similar concerns exist with other structures such as powerlines for instance. What is the right-of-way when planting a poplar crop? Whereas annual crops could be grown in powerline right-of-ways and right under the powerlines, that will not be possible or allowable with a tree crop. Powerlines can result in significant loss of growing site due to the width of right-of-ways.

It is best to check with the utility, oil- and gas companies to find out what is permitted and where pipelines are located, especially when using deep-tillage equipment and heavy equipment for the harvest. Advanced planning, in cooperation with these companies, will avoid problems later.

❖ Fish-bearing creeks and other riparian habitat concerns

The farmer must be aware of riparian habitat that may be impacted by crop management activities. Depending on the jurisdiction, there may be regulations regarding farming along or in riparian zones. Some herbicides require the user to incorporate herbicide-free zones along riparian areas. The added requirements will impact the cost of growing a crop and he must assess how this will affect the bottom line.

MODULE 5: SITE PREPARATION

The site preparation phase consists of a combination of mechanical and chemical methods to prepare the land for the short-rotation-intensive-culture (SRIC) poplar crop. Site preparation can take place from one to two years to just before the actual planting of the crop.

As stated in 'Site Requirements and Site Selection [see Module 1]', the success of short-rotation-intensive-culture (SRIC) hybrid poplar crops depends on three main conditions:

a) Planting the best proven clones;
b) Planting the best quality sites;
c) Carrying out timely and appropriate cultural treatments.

The ability to carry out efficient and cost-effective cultural treatments depends on how well site preparation is carried out. The most important cultural treatment involves weed control and site preparation is the first step. If the farmer fails to do a good job here, he will be paying for it in subsequent treatments. Poor or incomplete site preparation cancels out most of the benefits of planting good clones on good sites!

Effective weed control, as part of the site preparation effort, allows the farmer to anticipate and prevent problems later. An ounce of prevention is better than a pound of cure! In this respect an SRIC hybrid poplar crop does not differ from any of the more traditional agricultural or horticultural crops.

Assuming that the site generally meets the requirements outlined in 'Site Requirements' [see Module 1.1] and 'Operational Considerations' [see Module 1.2], the important issues now will be the current land use and the vegetation history, which determine the choice and timing of weed control and actual soil preparation methods to be used.

This module will be dealing with current land use [see Module 5.3], vegetation history [see Module 5.2] and weed control [see Module 5.3] in general terms only. This will be followed by a discussion on soil preparation [see Module 5.4] and a planning and decision chart [see Module 5.4]. This module will also deal with registered herbicides [see Module 5.6] for use in site preparation. The last section 'Site Preparation Scenarios [see Module 5.7]' will illustrate the site preparation planning for three of the most likely scenarios: Conversion of pasture, forage and crop to SRIC hybrid poplar.

5.1 Current Land Use

The most effective way to control competing vegetation is to start the work in the summer before the next spring planting season. Since SRIC crops will be established on land that was in recent pasture, forage or crop production, the start of site preparation treatments varies with the land use. If the land is in pasture, it may simply be a matter of moving the cattle off the land to start site preparation. If it is under forage production, the farmer may have to forego the last cut to allow enough time to prepare the land. If it is under crop, harvest time will generally be too late to allow site preparation to start that same year. In that case a summerfallow strategy with cultivation in the following year would be an option prior to planting the year after.

5.2 Vegetation History

The vegetation history of a field will identify some of the challenges the farmer will likely face. It is important to know what crops were grown previously and what weed control practices were used. Perennial weeds are usually the most problematic and may require a different strategy than annual or biennial weeds. As part of this planning process the farmer needs to do field scouting to determine the current weed species, their coverage, distribution and their state of development.

5.3 Weed control

To improve survival and yield, weed control must be close to complete. A practical target is a 90% or better weed control at time of planting. This is an acceptable level in agricultural crops and is also appropriate for an SRIC poplar crop as well.

5.3.1 Herbicide-free weed control?

Some poplar farmers would like to grow an herbicide-free poplar crop. For ease of planting and to ensure a reasonable survival rate of the trees, the minimum that must be done is to mechanically prepare the tree row locations. When a field that was in pasture or forage is converted to a crop, the live root systems and rhizomes of especially the creeping perennials will be next to impossible to control when not using any herbicides.

The chance of success in an herbicide-free approach to weed control will be low. Weeds do not stop growing and use of labour to keep up and control them is time consuming and cost-prohibitive. This may work fine for a very small area, but when the farmer wants to get into growing several to many hectares of poplar, an integrated weed management approach is needed and herbicide use in site preparation is therefore strongly recommended.

To control weeds in the tree rows, mulches could be effective. These include plastic mulches, which require disking and cultivating of the tree rows the summer prior to planting, in order to break up the soil and sod of the killed vegetation [see Module 7.1.4]. Various rodents, some of which can harm the trees, use the plastic cover to move around without falling prey to raptors. Woodchips or sawdust is also an option, but needs to be applied on a weed-free soil and in a fairly thick layer to be effective [see Module 7.1.4]. Other forms of mulches, such as straw, may also be used but could also be a safe haven for rodents that can harm young trees. Landscape fabric is very effective, but the cost will be prohibitive to use on a larger scale.

5.3.2 Integrated weed management

A well thought out integrated weed management approach will lead to lower production costs, with the likely spin-off of reduced use of and costs for herbicides. The key is to 'do it right the first time' in the site preparation phase.

Weed control is a process that takes place in all crop phases and will be reviewed throughout this Manual in 'Crop Planting [see Module 6]' and 'Crop Maintenance and Improvement [see Module 7]'; some repetition will therefore be unavoidable.

- **Integrated weed management**

The Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) define integrated weed management [Web-IWM] as follows: "Integrated Weed Management (IWM) uses all available weed control strategies in the best possible way to manage weed populations. Such strategies include cultural, mechanical and chemical methods of weed control."

OMAFRA further states: "All these practices are components and none of these control measures on their own can be expected to provide acceptable levels of weed control. Therefore, instead of relying on only one particular method of weed control, an IWM system uses a combination of methods to control weeds. By following the principles of an IWM system we can reduce the use of herbicides and at the same time provide optimum economic returns to the grower."

Cultural practices include clone selection and deployment [see Module 2], choice of stock type [see Module 3.2], selection of crop density, spacing and layout [see Module 4], and fertilization [see Module 7.2].

Mechanical methods include use of cultivation equipment to various depths, or mowing equipment when using a cover crop or when setting up perennial weeds for a subsequent herbicide application [see Module 7.1.9]. They are used in the site preparation and crop maintenance phases.

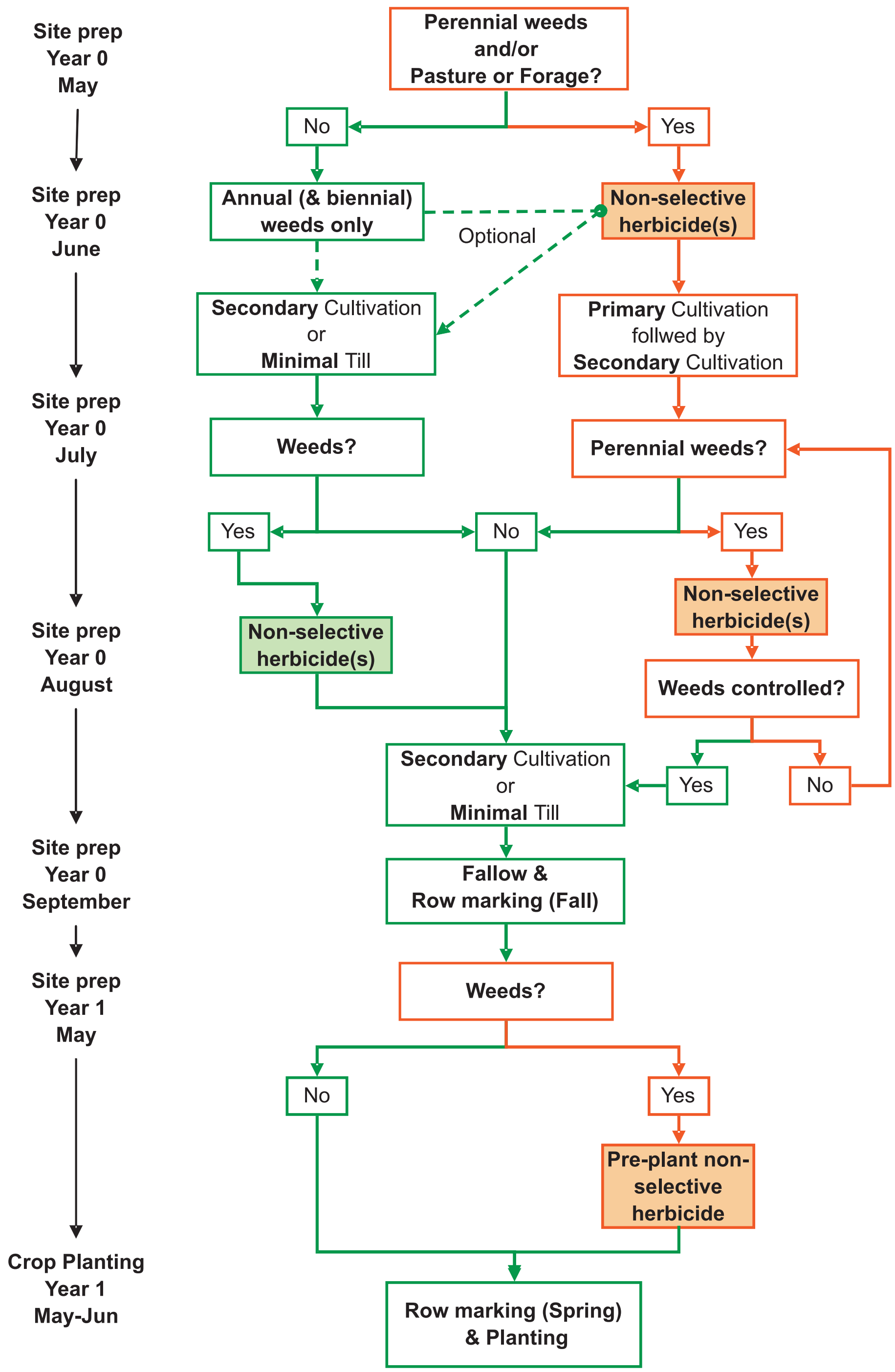
Chemical methods are used in the site preparation phase, during the dormant period in the crop planting phase and in the crop maintenance phase. Use includes selective herbicides for crop maintenance and non-selective herbicides in site preparation, the dormant period in the crop planting phase and in a directed or shielded crop maintenance situation.

All these methods have to work in harmony to be effective.

5.4 Planning and Decision Chart

The planning and decision chart (Figure 5-1) is a schematic overview to help the farmer plan the site preparation.

Figure 5-1



5.4.1 Pre-plant non-selective herbicide

The pre-plant herbicide application in the spring of year 1, with a non-selective herbicide (most likely a glyphosate-based herbicide), is a critical treatment. It is very effective if applied anywhere from one day to one week prior to planting. Planting into the dying weed vegetation has been reported to be very effective in controlling the weeds for a six week period.

5.4.2 Row marking and cross marking

Figure 5-1 indicates two possible opportunities to complete row marking. Ideally row marking would take place in the late summer or early fall of the year prior to planting. This allows the farmer an opportunity to more effectively control newly germinated and emerged weeds in a pre-plant herbicide application [see Module 5.4.1] the following spring. However, at this time it is still uncertain whether or not row marks and cross marks established in the late summer will remain sufficiently visible by the following spring. There is not enough experience yet with this practice to make a general recommendation to complete row and cross marking in the (late) summer or early fall of the year prior to planting.

5.5 Herbicides - Site Preparation

The 'Planning and Decision Chart' in Figure 5-1 identifies perennial weeds as the starting point of decision making. These weeds are the hardest ones to control and failure to do so can lead to crop failure.

5.5.1 Weeds

Weeds are classified using definitions from 'Weeds of the Prairies'[15]:

a) Annual: A plant that germinates in the spring, sets seed in the same year and then dies.
b) Winter annual: A plant that germinates in the fall and survives the winter as a dormant rosette. It resumes growth in the spring, sets seed in early summer and then dies.
c) Biennial: A plant that germinates in the spring of the first year, producing a rosette that survives the winter in a dormant state. It resumes growth in the second year, flowers, sets seed and then dies.
d) Simple perennial: A plant that survives for three or more seasons. Each spring the plant re-grows from stored root and crown reserves. Seed production may occur in the first season and in each subsequent year. Spread of a simple perennial weed species is primarily by seed.
e) Creeping perennial: A plant that survives for three or more seasons and, in that way, is similar to a simple perennial. However, a creeping perennial has a specialized method of vegetative propagation (rhizomes, stolons, budding rootstocks) in addition to seed production.

The creeping perennials are the most difficult weeds to control. These include such species as quackgrass, field bindweed, Canada thistle etc.

15 Bubar, C.J., McColl, S.J., and Hall, L.M., 2000 in Weeds of the Prairies

Appendix P is a comprehensive list of weed species and herbicides registered for site preparation and poplar crop maintenance.

Below are several good references that are accessible on the Internet or in print to help identify weeds.

For additional information, please see:

[Web-MB Weeds]
[Web-SK Weeds]
[Web-BC Weeds]
[Web-CWSS]
[Web-ON Weeds]
[Web-USDA Weeds] (this site can search by common and scientific names).
[Web-AB Weed Book] (to order the book).

5.5.2 Herbicides

For weed control during site preparation non-selective herbicides are the most effective. In most cases it would be best to enlist the help of licensed spray contractors, who are in a good position to provide the farmer with the advice and services required. There are several good references available to help the farmer choose; these are listed at the end of this section. Some of these also list crop protection companies and weed specialists.

It is important to realize that there are not many herbicides registered for use with poplar crops. To illustrate, one of the last site preparation phases in Figure 5-1 is to fallow the field in 'year 0' after the last secondary cultivation in August-September. To prevent new weed growth the following spring, several pre-emergent herbicides could effectively be applied in the August-September period, or even in the spring prior to planting the crop. The problem is that none are currently registered for growing a poplar crop and use of these herbicides is therefore not legally permitted.

The use of pesticides is subject to Provincial and Federal laws and regulations. Although every effort is made in this manual to ensure recommended practices fall within the laws and regulations, the farmer assumes the full risk and responsibilities under these laws and regulations.

The mentioning and listing of products do not imply endorsement, but are intended to provide the user of this manual with the broadest possible choices and comparisons.

❖ Product labels and MSDS

For complete information the user needs to review the respective product labels, where application rates, mixing and application instructions are listed, as well as safety instructions. Application rates differ for annual and perennial weeds and the glyphosate-based herbicides list special instructions for some of the more difficult to control annual and perennial weeds. For a more complete reference of registered herbicides in Canada, the Pest Management Regulatory Agency (PMRA) in Ottawa maintains a label-search [Web-PMRA Labels] website for easy access by product, active ingredient, PCP number, manufacturer etc. Other resources include the references listed at the end of this section and in Appendix Q, where websites for the chemical companies can be found with a lead to their herbicide labels and safety data sheets (MSDS). It lists products registered for site preparation, pre-plant applications (all crops) and summerfallow, as well as for the few products that are registered for use in a poplar crop during the poplar crop maintenance phase.

❖ Metric and imperial units – cause for concern

Product labels in Canada list application rates in metric units, e.g. liters per hectare (L/ha), or kilograms per hectare (kg/ha). Many guides and Internet sites list rates in a confusing mix of metric and imperial units; rates are listed in liters per acre (L/ac.), or kilograms per acre (kg/ac.). This is a cause for concern, especially when application rates from the product labels, which are in L/ha, are misinterpreted as L/ac., and kg/ha as kg/ac. etc.

There are approximately 2.5 acres in each hectare and 0.4 hectare in each acre.

❖ Glyphosate-based herbicides

The only option open to poplar farmers is to use non-selective post-emergent herbicides that can be applied to newly emerged weeds in the spring, before planting, such as several glyphosate-based herbicides; these are registered for use as site preparation for all crops and are widely in use.

❖ Tank mixes with glyphosate-based herbicides – summerfallow only

Several glyphosate-based herbicides permit the use of tank mixes with:

a) 2,4-D (Amine or Ester) – several manufacturers;
b) Bromoxynil (Pardner®);
c) Dicamba (Banvel® and Banvel® II).

The tank mixes are for extra effectiveness in a summerfallow treatment only during the site preparation phase. These compounds do not have a residual effect on subsequent crops when planted the following season[16]; that includes poplar. Appendix R lists several of the current herbicides, including the glyphosate herbicides registered for use in poplar (as a crop). Please note that the table is not a complete listing of all the glyphosate-based herbicides and more herbicides are available.

There are several pre-mixed products available of glyphosate and 2,4-D (Amine or Ester), glyphosate and bromoxynil, and glyphosate and dicamba for use in summerfallow only. A PMRA label-search [Web-PMRA Labels] will list these products.

16 Residual Herbicides, Degradation, and Recropping Intervals. Kansas State University - Agricultural Experiment Station and Cooperative Extension Service. Report C-707; April 1992.

❖ A word of caution on tank mixes

Tank mixes of glyphosate-based herbicides is permitted for use in summerfallow only. Although a tank mix of one of these herbicides with 2,4-D (Amine or Ester), applied just prior to spring planting, would also be effective, its use is not legally permitted according to the various glyphosate labels.

❖ Other herbicides

Besides the glyphosate-based herbicides, other potentially suitable herbicides may also be available for use in summerfallow or chemical fallow during the site preparation phase. The 'Herbicide Selector [Web-Alberta Herbicide Selector] or the PMRA label-search [Web-PMRA Labels] (choose 'Search Else') is a good starting point to check out the possibilities.

❖ Pre-emergent herbicides

Pre-emergent herbicides are applied to clean soil and prevent germination or early growth of weed seeds. Unfortunately poplar farmers in Canada face a major obstacle in the lack of registered herbicides with pre-emergent properties that can legally be used in the site preparation, crop planting or crop maintenance phases. The only registered pre-emergent herbicide for poplar is a product with the active ingredient dichlobenil (Casoron 4G – Appendix Q), which is a soil-active herbicide that is taken up by the weed seedlings. According to its label, it should be applied post-planting only (the crop maintenance phase), when the trees are established for at least six months. It is therefore not of much use in the site preparation or crop planting phases. It is a prohibitively expensive herbicide.

Herbicide-tolerant crops, such as several lines of herbicide-tolerant canola, are turning into a source of weed problems for poplar farmers. Farmers have access to several post-emergent glyphosate-based herbicides, including several tank mixes (summerfallow only – see above), to deal with volunteer canola after it has germinated; however, there are no registered pre-emergent herbicides to deal with the canola seed bank in the soil when planting or planning to plant a poplar crop. Although farmers can use several glyphosate-based herbicides in a directed or shielded application in the crop maintenance phase, these products are not effective against the glyphosate-tolerant volunteers and tank mixes are not permitted at this stage.

Currently there are two initiatives to obtain registration of several pre-emergent herbicides for use with and in a poplar crop. The possible registration of any one of these herbicides is not expected till 2007 at the earliest. Once registered for use, it is important to ensure the soil is completely bare of weeds when these herbicides are applied. The presence of actively growing annual or perennial weeds would render the use of some of these products ineffective and thus costly.

For additional information, please see:

[Web-SAF Crop Guide]
[Web-MB Crop Protection]
[Web-Blue Book]
[Web-Greenbook] – Note: The Greenbook lists both US and Canadian labels; however, its Canadian content may not always be accurate.
[Web-PMRA]

5.6 Soil Preparation

5.6.1 Cultivation

Hybrid poplar performs best in a sod-free field. Any field that has been in pasture or forage production should be first be sprayed with non-selective herbicides and then cultivated to break up the sod or root masses in the soil.

There are several intensities of cultivation:

a) Primary cultivation

Primary cultivation cuts the sod and root mass in the soil, breaks up heavy soils and compact layers with tools that penetrate 15-50 cm (6-20 in.) deep. This activity leaves a rough surface texture and requires further secondary cultivation. Examples of implements used are mouldboard plows, breaking disks (Photo 5-1) and heavy rotary tillers;

b) Secondary cultivation

Secondary cultivation breaks down the rough surface texture, levels, and firms the top 5-15 cm (2-6 in.) of soil. This smoothes the soil and eases subsequent weed control activities. Cultivating disks (Photo 5-2), disk harrows, cultivators, and rotary tillers are the main implements used for secondary cultivation.

5.6.2 Reduced tillage

Tilling leads to superior results over a no-till or minimal till option for SRIC hybrid poplar crop performance. Although this is a well-established fact, some land owners insist on minimal tillage for valid reasons, e.g. when soil erosion is of primary concern. There are some sites in Alberta where both approaches are used, which will permit an assessment of the differences in crop establishment and performance (Photo 5-3); however, results will not be available for several years.

The reduced tillage option should allow for a form of primary cultivation of the tree row locations for best results, as poplars need to be planted substantially deeper than most agricultural crops.

Cees van Oosten, B.C.

Photo 5-3: Zero-till vs. deep-till at a new poplar farm site Alberta in May 2005 near Athabasca, (AB).

On the left a zero-till field (just sprayed).

On the right a deep-tilled field (break disk), followed by a cultivating disk (2x)

Previous treatments: Roundup/2,4-D mix.

This field was planted in 2005.

Cees van Oosten, B.C.

Photo 5-1: Breaking disk at work on a new farm at Alberta-Pacific Forest Industries Inc. (Alberta) in May 2005 near Athabasca (AB).

This 350 hp International tractor pulls a Rohm breaking disk. Normal practice is one pass with a breaking disk as a subsoil treatment, followed by two passes with a cultivating disk as a secondary cultivation.

Phil Leduc (PAMI), SK

Photo 5-2: A tandem disk used as a cultivating disk for a secondary cultivation.

5.7 Site Preparation Scenarios

The site preparation scenarios discussed in the following sections are examples only. They illustrate possible approaches to site preparation and these can be modified depending on the soil types and climatic factors prevalent in the area of interest. Some of these issues were discussed in 'Site Requirements and Site Selection [see Module 1]'.

In all three scenarios the final herbicide treatment (if required) is a pre-plant application of a non-selective herbicide. In 'Pre-plant non-selective herbicide [see Module 5.4.1]' this was identified as an important opportunity control weed vegetation following planting.

To illustrate the planning, decision and execution process of various site preparation scenarios, this section will focus on conversion of fields that are currently in pasture [see Module 5.7.1], forage production [see Module 5.7.2] and crop production [see Module 5.7.3]. The assumption is that these sites are suitable for a SRIC hybrid poplar crop and that other operational aspects have been addressed.

5.7.1 Pasture conversion

Figure 5-2 is an example of the site preparation required to convert a pasture to an SRIC hybrid poplar crop. The sequence of events follows the planning and decision chart (Figure 5-1).

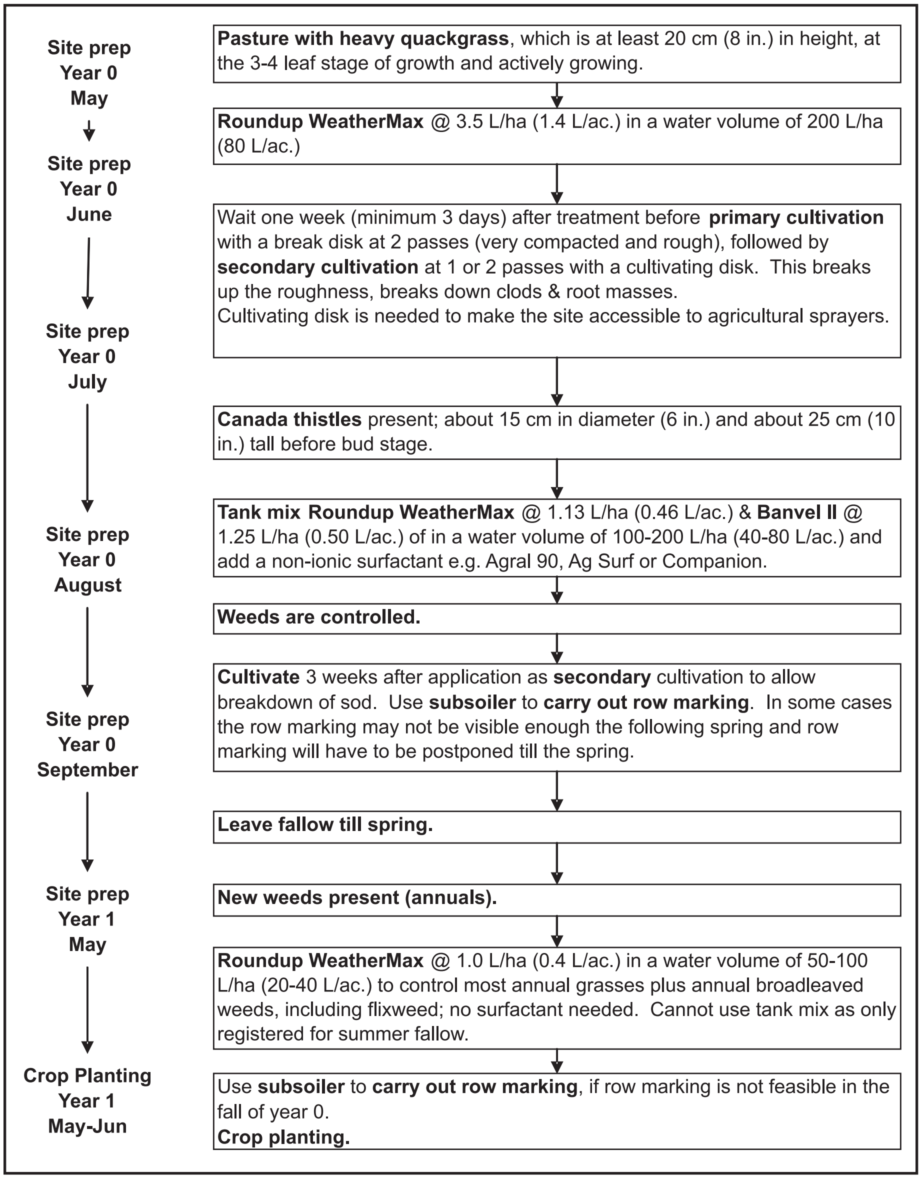
- **The first and second herbicide treatments in site preparation**

This pasture has a heavy quackgrass component. Quackgrass is a creeping perennial, which is difficult to control. It is at the 3-4 leaf stage of growth and actively growing. A glyphosate-based herbicide will kill and control the grass. In this example Roundup WeatherMax is used by itself to control the quackgrass. Please refer to the label for the application details (Appendix Q). Other glyphosate-based herbicides are also appropriate for use; a partial listing can be found in Appendix R.

Where a dandelion and Canada thistle problem exists in a pasture, the herbicide labels explain how to deal with that as well. In some cases the farmer may actually prefer to use a tank mix with one of the approved herbicides to provide extra control of some broadleaf perennial weeds in the pasture. Make sure to follow label instructions and note that tank mixes of glyphosate-based herbicides with other herbicides can only be used in a summerfallow application [see Module 5.5.2].

Although the labels recommend waiting one week (minimum 3 days) after treatment before primary cultivation, a longer waiting period is strongly recommended. In some cases waiting four to six weeks before primary cultivation is reported to provide superior control, although there may not be sufficient time to allow for such a long waiting period. If the stage of weed development allows it, spraying could be moved forward to allow for this additional waiting time.

Figure 5-2



A follow up treatment takes place well after the primary cultivation and could involve another tank mix to take care of new perennials that have developed since primary cultivation.

❖ Primary and secondary cultivation – entire field or tree rows only?

This scenario deals with primary and secondary cultivation of the entire site. Local conditions may preclude that approach, especially when soil erosion is of primary concern.

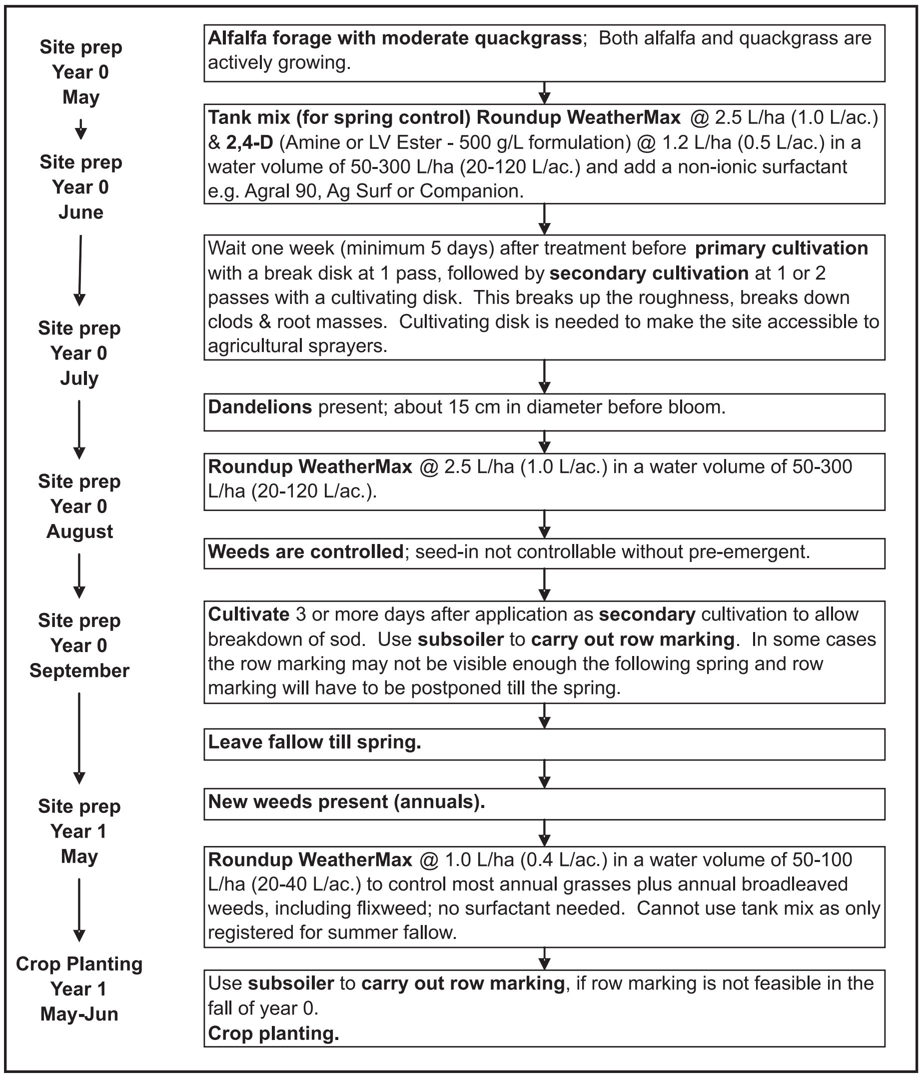
If that is the case, after spraying the entire field, primary cultivation is only targeted at the actual tree row locations. For instance, if the tree rows are located 3 m (10 ft.) apart, only till a 1 m (3 ft.) wide strip of the tree row location. A combination of a heavy-duty rotovator (approximately 1 m or 3 ft. wide), followed by a two-shank subsoiler (and possibly a harrow mounted behind it) will lead to good results. Row marking would have to take place to guide this work.

5.7.2 Forage conversion

Figure 5-3 is an example of the site preparation required to convert a forage field to an SRIC hybrid poplar crop. The sequence of events follows the planning and decision chart (Figure 5-1).

This scenario is essentially similar to the Pasture conversion [see Module 5.7.1].

Figure 5-3



This scenario also allows for variations regarding primary and secondary cultivation to accommodate local concerns and additional comments made in Pasture conversion [see Module 5.7.1] apply to this example equally as well.

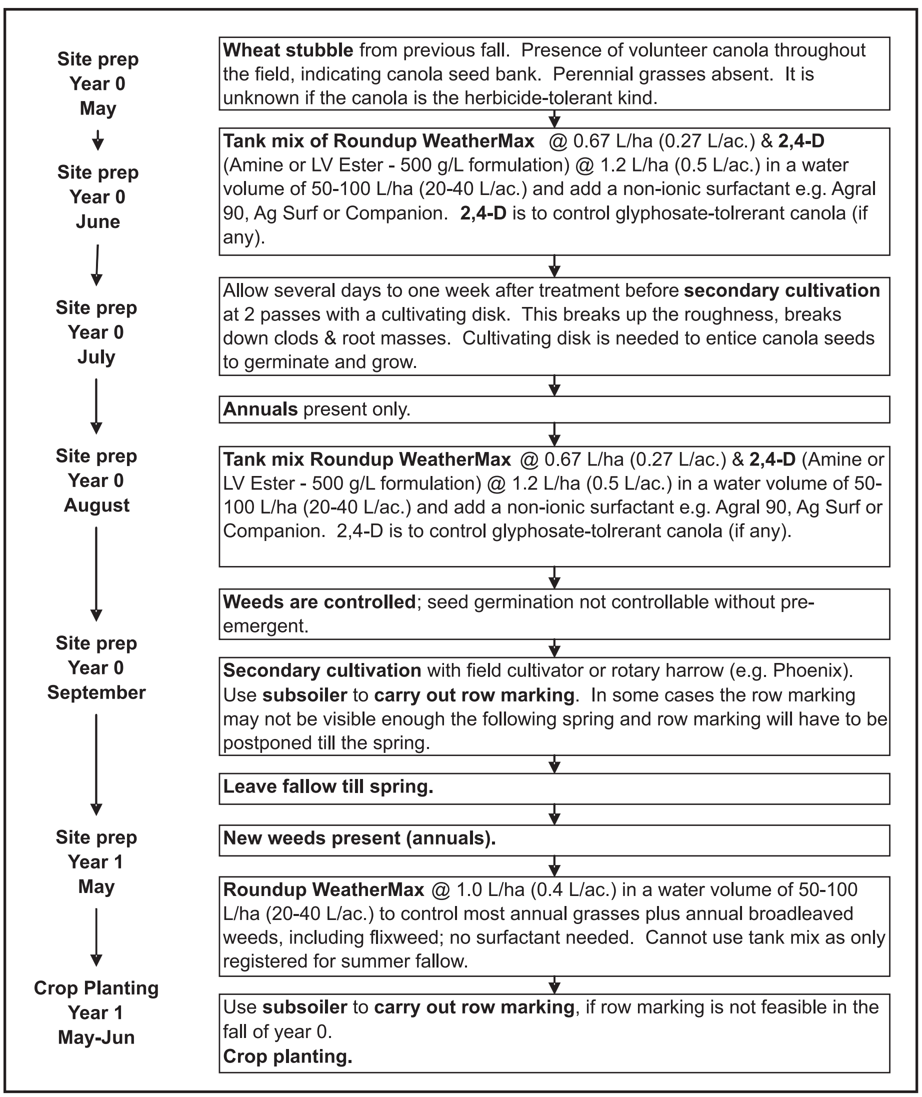
5.7.3 Crop conversion

Figure 5-4 is an example of the site preparation required to convert a more traditional crop to an SRIC hybrid poplar crop. The sequence of events follows the planning and decision chart (Figure 5-1).

For the conversion from a crop, the crop needs to be harvested first in the fall and the farmer can therefore not start the bulk of the work till the following spring. One serious challenge is how to deal with volunteer herbicide-tolerant species, such as canola.

One major difference between the crop scenario and the pasture and forage scenarios is primary cultivation is not needed, as there is no sod to deal with.

Figure 5-4



❖ The first and second herbicide treatments in site preparation

This crop field has a volunteer canola component. It is uncertain if this is an herbicide-tolerant variety. To maximize control, a tank mix is recommended. In this example Roundup WeatherMax is used in a tank mix with 2,4-D (Amine or Ester). Please refer to the label for the application details (Appendix Q). Other glyphosate-based herbicides are also appropriate for use; a partial listing can be found in Appendix R. Make sure to follow label instructions and note that tank mixes of glyphosate-based herbicides with other herbicides can only be used in a summerfallow application [see Module 5.5.2]. A follow up treatment takes place well after the secondary cultivation.

❖ Secondary cultivation – entire field or tree rows only?

This scenario deals with secondary cultivation of the entire site. Local conditions may preclude that approach, especially when soil erosion is of primary concern.

If that is the case, after spraying the entire field, secondary cultivation is only targeted at the actual tree row locations. For instance, if the tree rows are located 3 m (10 ft.) apart, only till a 1 m (3 ft.) wide strip of the tree row location. A combination of a two-shank subsoiler, followed by a field cultivator (approximately 1 m or 3 ft. wide) with a harrow mounted behind it will lead to good results. Row marking would have to take place to guide this work.

Suitable equipment for the second secondary cultivation around September in the crop conversion scenario includes the rotary harrow (Photo 5-4) and the field cultivator (Photo 5-5).

Phil Leduc (PAMI), SK.

Photo 5-4: Phoenix rotary harrow on a farm in Saskatchewan.

AAFC-PFRA Shelterbelt Centre

Photo 5-5: Cultivator with mounted harrows on a farm in Saskatchewan.

MODULE 6: CROP PLANTING

The crop planting phase includes all management activities before (including row marking), during or after (post-planting) the actual planting. The post-planting period could last from several days to several weeks and ends when the newly-planted crop breaks dormancy.

The very first activity of the crop planting phase should always be an assessment of weed growth.

a) Pre-plant activities:

- Pre-plant non-selective herbicide application in the spring of the planting year, possibly followed by cross marking only, in preparation of machine planting.

or

- Row marking in the summer or fall prior to the planting year, followed by a pre-plant non-selective herbicide application just prior to crop planting and followed several days to a week later by cross marking if required. This is in preparation of manual planting;

or

- Pre-plant non-selective herbicide application in the spring of the crop planting year, followed by cross marking and row marking. This is also in preparation of manual planting and occurs when row marking in the previous summer is not possible or practical;

b) Crop planting activities during May to mid-June:

- Machine planting

or

- Manual planting

c) Post-plant activities

- Any activities immediately following crop planting and possible herbicide applications prior to bud break of the crop in its first year.

Management activities in the crop planting phase depend on the planting method that will be used. Most planting of SRIC hybrid poplar crops for pulpwood and solid wood (such as veneer or saw logs) is still done using manual labour; machine planting of an SRIC crop has been infrequent.

6.1 Pre-plant Weed Control

The first order of business in the spring of the planting year is to assess the current weed species, their coverage and distribution and state of development. The details of this process are discussed in 'Vegetation history' [see Module 5.2], 'Weed control' [see Module 5.3] and 'Herbicides' [see Module 5.5.2].

6.1.1 Registered herbicides for pre-plant application

If weeds germinate or grow up from existing roots or stems before planting, there is an opportunity to apply a pre-plant non-selective herbicide. Weed control just prior to planting is the last opportunity to control newly germinated weeds and some of the more problematic creeping perennial weeds, such as quackgrass.

- **Glyphosate-based herbicides**

Herbicides registered for use in a pre-plant application are the glyphosate-based herbicides listed in Appendix R. Note that tank mixes of glyphosate-based herbicides with other herbicides are not permitted in a pre-plant application.

Appendix R lists three glyphosate-based herbicides that are also registered for use in aerial application which could be used if ground applications are not possible.

It is important to always follow the instructions on the product labels [see Module 5.5.2]. Access to product labels and MSDS sheets can be found in Appendix Q.

6.1.2 Other herbicides

Besides the glyphosate-based herbicides, other potentially suitable herbicides may also be available for use in summerfallow or chemical fallow during the site preparation phase. The 'Herbicide Selector' [Web-Alberta Herbicide Selector] or the PMRA label-search [Web-PMRA Labels] (choose 'Search Else') is a good starting point to check out the possibilities.

6.2 Row Marking

The decision what level of row marking and cross marking to use depends on the planting method used and the need for perfect spacing to enable cross cultivation or herbicide applications in two directions.

Row marking and cross marking options are discussed in the sections dealing with machine planting [see Module 6.4] and manual planting [see Module 6.5].

6.3 Choice of Planting Methods

6.3.1 Crop spacing and crop layout

The choice of planting method depends on the crop spacing [see Module 4.2] and layout [see Module 4.3]; these determine how crop maintenance, particularly weed control activities, is carried out. In most cases the minimum distance between tree rows must be 3 m (10 ft.) to accommodate the width of a tractor plus implement between the rows.

a) If perfect spacing is required between tree rows only and exact spacing within the row (in-row spacing) is not that critical, existing or modified mechanical planters [see Module 6.4] would be capable of doing the job quite well. This approach usually allows cultivation in one direction only;

b) If perfect crop spacing is required in two directions to enable cross cultivation, row marking and cross marking [see Module 6.5.1], followed by manual planting [see Module 6.5.2] is an effective method; however, there may be some options to still accomplish an acceptable level of precision [see Module 6.4.1] with a mechanical planter.

6.3.2 Weather and soil conditions

Weather and soil conditions have to be considered in the choice of planting methods. When it rains at the height of the planting season in May and June, or when the soils are very wet, tractor work may be impossible for some time and machine planting has to shut down. In contrast, manual planting is an all-weather operation and traction is not a problem; planting can continue on schedule and does not suffer from machine breakdowns or maintenance.

6.3.3 Availability of labour

It is of interest that industrial poplar planting in western Canada and the Pacific Northwest of the US is still done with manual labour, even on the drip-irrigated poplar farms in eastern Oregon and Washington States that have perfect year-round soil conditions, with minimal rainfall, for mechanized operations. The availability of a labour pool and the high planting productivities of the planters make manual planting very price competitive and there is no urgency in mechanizing the planting process. Many of the planters find employment in orchard and vegetable operations, where the labour season starts after the poplar planting is done. There are several planting contractors in western Canada who can offer good and competitive services. To plant manually or mechanically is an economic decision, but timing and logistics play a big role too.

6.4 Machine Planting

AAFC-PFRA Shelterbelt Centre

Photo 6-1: Single row planter for shelterbelt planting in Saskatchewan.

Note the herbicide tank and the rotovator set up for planting in a shelterbelt setting.

The arrow points to a planted tree.

AAFC-PFRA Shelterbelt Centre

Photo 6-2: Single row planter for planting in Saskatchewan.

In machine planting with a '1 or 2-row' mechanical planter (referred to in this section as a 'planter') there is no need for row marking as a separate activity, except when exact positioning is required for cross cultivation; in that case cross marking is required [see Module 6.4.1]. The tractor driver maintains the proper distance between tree rows by using a guiding or marking device that guides him on the return run. This device could be as simple as a dangling chain that tracks the previous row, or it could be a marker that scruffs up the soil or drops foam, marking a line where his front tire (or centre of the tractor etc.) should be when he returns. There are also sophisticated global positioning systems (GPS) on the market that control auto-steer tractors. The sophistication depends on the extent and logistics of the planting and on the budget of the farmer. GPS navigation systems that can pinpoint the exact location in the tree row to ensure cross cultivation can occur without unacceptable crop damage are not (yet) accurate and/or affordable enough.

There are three types of mechanical planters:

a) Floating on a tractor's three-point hitch. The entire planter can be lifted;

b) Semi-floating, with the front attached to the three-point hitch, but with its back end free-floating on wheels. The tractor cannot lift the entire planter, just the front end;

c) Trailer type, where the planter is just pulled by the tractor, but most of its weight is on the machine's wheels.

A good description and diagram can be found at a University of Missouri – Extension website [Web- Tree planter 1]. This site also addresses several operating issues that are helpful.

The mechanical planters are equipped with a knife or rolling coulter that cuts through the soil, followed by a planting shoe and a trencher, which acts like a furrow plow and opens up a planting trench. An operator sits behind this on the planter and inserts a plant right behind the trencher and holds it upright; two packing wheels follow and push and pack the soil back into the trench and around the planting stock. This system can handle bareroot stock, container stock (also called plug) or unrooted cuttings. For a description of the different stock types, please refer to 'Stock Type Selection [see Module 3.2]'.

The planter pictured in Photo 6-1 is a single furrow planter, capable of planting bareroot stock or cuttings, planted at a maximum depth of 25-30 cm (10-12 in.); it is used for shelterbelts and uses the method described above. This particular unit applies an herbicide, incorporates it in the soil with the rotovator mounted on the three-point hitch and plants the trees. Please note this planter setup is used in a shelterbelt setting, where the use of a soil-incorporated herbicide is permitted. A simpler setup that can be used in SRIC poplar planting is shown in Photo 6-2. This machine only plants the trees. Both planters have two operators who are placing the trees in the planting trench.

The Prairie Agricultural Machinery Institute (PAMI), located in Humboldt (SK), published a planting equipment guide [Web-PAMI planter] in 2003 with a listing of several mechanical planters, some of which were still in the prototype stage at that time. The report lists the capabilities of these planters and the stock types they are designed to plant; some can only handle unrooted cuttings and others only bareroot stock. None of the planters list container stock; however, if they can handle bareroot stock, they should be able to plant container stock. Many of the cutting planters are designed for planting at high densities, such as biomass crops or stoolbeds; these machines may not be suitable for planting an SRIC hybrid poplar crop.

The level of sophistication of mechanical planters varies. Cuttings lend themselves well to further mechanization due to the uniformity of the planting stock. Uniformity of bareroot stock varies, especially in the root systems.

6.4.1 Mechanical planters and cross marking

If the farmer decides to use a mechanical planter to establish the crop and also would like to cross cultivate after, there are some ways to accomplish that:

a) Ensure the non-selective herbicide treatment [see Module 6.1] is completed first. If cross marking is done before the herbicide treatment, the field will be too rough for regular agricultural sprayers and high flotation tracked tractors must be used for spraying at greater expense.

b) Then mark the field before planting with a cross marker at the required in-row spacing; i.e. mark perpendicular to the intended direction of the tree rows. This is called cross marking. To ensure comfort and safety of the person(s) on the mechanical planter that follows, the field cannot be roughed up too much using this method. For a marker the farmer could use a cultivator (Photo 6-3), with the shovels spaced at the required in-row spacing. Other methods might also work well. For instance, a spray boom with 2 or more (drop) nozzles, spaced at the required in-row spacing, can deliver a thin but visible band of paint; this will have to stick around for a few days at least. When using this paint spray method, it is important to eliminate or minimize sideways sway of the boom. A simple setup with a small tractor or ATV would be sufficient. One very simple solution is to use a pickup or flatbed truck with some form of marker mounted on the bumper (Photo 6-4);

c) Use the mechanical planter to plant the crop perpendicular to the cross marking, while the operator (or operators) on the planter places a tree at each of the intercepts with the cross marks. That may seem easy to do, but it requires constant concentration on the part of the operator(s).

Larry White, SK

Photo 6-3: Marker on a field in 2004 near Pleasantdale (SK). It shows the use of a cultivator to cross mark where the trees need to be planted.

Although the distance between the locations is only 2.4 m (8 ft.) in this picture, it shows the principle of marking with minimal soil impact.

Al Jurgens, SK

Photo 6-4: A very simple marker attached to the bumper of a flatdeck truck 'scratching' tree row locations on a field in 2004 near Maidstone (SK).

This field still requires the pre-plant herbicide application to control the newly emerging weeds.

❖ Square spacing

At a square spacing [see Module 4.2.1] of 3x3 m (10x10 ft.), planting trees at the exact location of the cross marks will be difficult with a mechanical planter; there is no margin for error. This precision is needed to accommodate the width of the equipment needed in cross cultivation or spraying, after the trees have been established. If the equipment to be used is based on the 3 m (10 ft.) width between tree rows, it must also fit between the trees in the row. It is unlikely that can happen without damage. Rectangular spacing [see Module 4.2.2] would then be a better option.

❖ Rectangular spacing

To minimize the chances of crop damage during cross cultivation or shielded spraying, a rectangular spacing is a better option than square spacing at 3x3 m (10x10 ft.). In the following example the assumption is that the spacing between the tree rows remains at 3 m (10 ft.). A cross marker (Photo 6-3) marks the field at a spacing of 3.2 m (10.5 ft.), which provides the operator on the planter with an extra allowance of 20 cm (8 in.). Every time the mechanical planter crosses the cross mark, the operator has a better chance to place the tree on the mark with an allowance of 10 cm (4 in.) on either side. If that allowance is still not sufficient, the allowance could be increased, but that will lower the number of trees planted per hectare.

By planting in this rectangular pattern, there will be 6 per cent fewer trees; instead of 1,100 spha (450 spac) at the 3x3 m (10x10 ft.) spacing, there are 1,042 spha (422 spac). That small decrease will more than likely be offset by savings in the crop maintenance phase.

For additional information, please see:

[Web-PAMI]

6.4.2 Mechanical planters and soil disturbance

The most effective way to control competing vegetation is to start the work in the summer before the next spring planting season [see Module 5.1]. A combination of summerfallow and cultivation is needed to get the site ready. This gives the soil time to settle down over the winter and early spring and provides an opportunity to carry out effective pre-plant weed control [see Module 6.1].

During the planting process in May and June, a mechanical planter opens up the soil with the trencher, plants the tree and subsequently pushes the soil back into the planting trench. The question is how much of the soil disturbance created by the mechanical planter results in a weed problem. Although current indications are that it is minimal, it is important to realize that there is a risk of new weed development in the tree rows following mechanical planting.

Note that SRIC poplar farmers do not have access to registered pre-emergent herbicides to suppress subsequent weed development.

6.5 Manual Planting

Manual planting offers the opportunity of 'all-weather' operations during times when machine planting is impossible. Postponing planting beyond the middle of June to wait for more favourable soil conditions is generally not recommended [see Module 6.7].

6.5.1 Row marking and cross marking

Manual planting requires row marking to ensure spacing between tree rows is at the required distance. Row marking is considered part of the crop planting phase. Ideally it would take place in the late summer of the year prior to planting. This allows the farmer an opportunity to more effectively control newly germinated and emerged weeds in a pre-plant herbicide application, as discussed previously [see Module 6.1]. However, at this time it is still uncertain whether or not row marks and cross marks established in the late summer will remain sufficiently visible by the following spring. There is not enough experience yet with this practice to make a general recommendation to complete row and cross marking in the (late) summer or early fall of the year prior to planting.

In machine planting, the mechanical planter pulls a knife or rolling coulter through the soil, followed by a trencher, which opens up a planting trench. The trench is deep enough to allow good placement of the roots. For manual planting the same is achieved by marking the tree rows with a subsoiler, which loosens the soil. An example of a '2-row' row marker, using subsoilers, can be seen in Photo 6-5.

This method loosens the soil in a trench, much like the mechanical planter, easing manual planting of cuttings, container or bareroot stock. This particular row marker uses a system of continuous mounding or hilling, using bedding disks mounted behind the subsoilers. Continuous mounding or hilling is not a recommended practice for the Prairie region for several reasons. If a dry period follows planting, the mounds will dry out too much. Mounds are also a serious obstacle for any equipment that has to drive across them (e.g. cross cultivation). This is especially a concern with agricultural spray equipment. Operator comfort and safety are also an issue.

When row marking and cross marking have to be completed just before planting in the spring, there is always the risk of poor weather or soil conditions leading to a delay in marking and subsequent planting. This causes a logistical problem, as the planters may have other contracts to complete.

If spring marking is the only possibility, the best order of business is to ensure the pre-plant non-selective herbicide treatment is completed first [see Module 6.1]. If the farmer decides to cross mark before the herbicide treatment, the field will be too rough for regular agricultural sprayers and high flotation tracked tractors must be used for spraying at greater expense. Cross mark first, followed by the row marking, preferably using subsoilers to ease planting. The result is very visible and easy for the planters to plant (Photo 6-6).

Cees van Oosten, B.C.

Photo 6-5: This '2-row' row marker was used in Whatcom County in Washington State. It clearly shows the two subsoiler shanks. Also visible is the marker in the bottom left corner that marks a line for the return trip.

Cees van Oosten, B.C.

Photo 6-6: A new farm being planted on a perfect square grid on one of AL-PAC's poplar farms near St. Paul in Alberta.

Trees are planted at the cross mark of the 2-way marking. This marking was completed just before planting and is very visible to the planters.

The tree rows run from the timber edge in the background to the bottom of the picture.


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Photo 6-7: Marking with a '4-row' row marker at one of AL-PAC's farms in Alberta. The tractor is a Cat Challenger (200 hp) with a GPS system hooked up to an auto-steer system. This allows the tractor to stay on course both ways. The 4 subsoilers mounted on the toolbar are at 3.0 m (10 ft.) spacing.

Row marking equipment varies in complexity from what was previously described in the section 'Mechanical planters and cross marking [see Module 6.4.1]' and 'Row marking and cross marking [see Module 6.5.1]'. At Alberta-Pacific Forest Industries Inc. (AL-PAC) in Alberta a '4-row' row marker (Photo 6-7) was developed and is currently in operation creating the perfect planting grid (Photo 6-6) for an orchard-style poplar crop. This marker is first used for cross marking, followed by row marking. The tractor is equipped with a GPS controlled auto-steer system.

6.5.2 Choice of planting crew

Who is to do the planting? If the job is small, for instance less than 1,000 trees, the planting could easily be done by a single person in an afternoon, or spread out over a couple of days. If the number exceeds 1,000 trees, machine planting would start to become more attractive, if a machine is available. But if soil or weather conditions are such that machine planting is out, the trees need to be planted manually, as the planting season cannot be extended too much. Planting too late into the season (e.g. beyond mid-June) can negatively impact survival and growth.

There are two options. The farmer could organize a local crew of planters himself possibly in cooperation with neighbours who are also planning to put in a poplar crop, or he could contract out the job to a planting contractor. The advantage of organizing a local crew is that the farmer probably knows most of the crew members; the disadvantage is that they do not have the experience or planting stamina of the professional tree planter. A professional tree planter can plant between 2,500 and 3,500 trees per day on a well prepared field. A crew of 6 planters can produce 15,000-21,000 trees, which covers about 15-21 hectares (37-52 ac.). The advantage is that the job gets done fast and right.

❖ Planting contractors

Professional planting contractors plant on a rate-per-tree basis. Hiring a planting contractor on a day rate is generally not recommended. Payment is subject to meeting quality standards, including stock handling in the field, the quality of actual planting and the spacing between the trees. If the contractor meets the quality standards [see Module 6.9.2], he gets full payment; if he does not, he either gets a price penalty, or in the case of very poor performance, he does not get paid at all. A good contractor has a supervisor who looks after the crew's affairs, including meeting the quality standards.

Reputable planting contractors are professional companies and carry full insurance and worker's compensation insurance of the province in which they operate. It is the responsibility of the farmer to check up on the reputation of the contractor before hiring him and to check with the provincial workers' compensation board to verify the contractor is 'in good standing'. To protect both the farmer and the contractor, there should be a written and signed contract spelling out prices, conditions and obligations.

Teams of tree planters are compatible in productivity, speed and quality. Most companies in western Canada employ young people, many of whom are college or university students. A majority of planters keeps returning to this work for several seasons, as they can earn good money. Some of the large planting contractors start their season on the west coast as early as January and complete planting by mid April. Crews then move to BC's interior and many start planting contracts in Alberta and some also in Saskatchewan. Most contractors keep planting throughout the summer for forest companies and some may return to the coast to finish the season in the late summer.

Although planting contractors have specialized in reforestation work on logged over forestland, some would actually welcome an opportunity to plant hybrid poplar on well prepared land. Most contractors are prepared to take care of all phases of planting, from picking up the stock at the local stock cooler to temporarily storing it in a tree cache in an adjacent woodlot or barn, to planting the crop. Extra services are negotiable and the cost will be in addition to planting price.

The farmer should insist that the crews have a designated supervisor who is responsible for the crew's work supervision and who carries out regular quality control on his planters. The supervisor must communicate often with the farmer to discuss quality and plan the next day's work. The farmer should also carry out independent checks to verify that what he is going to pay for is done well. If there happens to be a quality problem while the crew is still on site, corrective work can immediately take place to address the problem to everyone's satisfaction. Once the crew has left for another planting contract, it will be very tough to call them back to correct a problem. This will be discussed further in 'Planting Project Record Keeping' [see Module 6-9].

❖ Tools of the trade

The tools of the trade are quite simple: a special narrow tree planting spade is used for bareroot or container stock, and a dibble (Photo 6-8) can be used for container stock or unrooted cuttings.

The planters are outfitted with a set of planting bags (Photo 6-9), one on either side, that hold several hundred trees.

Photo 6-9: Trees are planted at the cross mark of the '2-way' row marking at one of AL-PAC's poplar farms near St. Paul (AB) in 2005. This professional planter plants dormant containerized (plug) stock. He dibbles a planting hole, takes out a tree and places it into the hole. The tree has to be planted 3-finger-width deeper than the top of the rootplug.

Photo 6-8: Tools of the trade - the 'dibble' for planting container stock or unrooted cuttings. With well prepared soil, the dibble's own weight helps create the right planting hole for the tree and the footstep is not needed to drive the dibble down into the soil. The footstep helps control the depth of the dibble hole.

The shape and size of these dibbles are close to the shape and size of the root plugs of the container stock.

To plant unrooted cuttings, a dibble with a smaller caliper should be used.

For information from the provincial Workers' Compensation Boards, check the following websites:
[WCB-Alberta]
[WCB-BC]
[WCB-Sask]
[WCB-Man]

The following websites contain information about tree planting contractors:
[Web-WSCA]
[Web-Planting contractors 1]
[Web-Planting contractors 2]

6.6 Planting Stock

The module 'Stock Procurement [see Module 3]' discusses considerations for stock type selection and contains a table summarizing stock standards [see Module 3.2.4]. Table 6-1 is a shortened version for planting stock. Note that BR is an acronym for bareroot stock, and PSB is the acronym for plug styroblock (a container-grown stock type). A description of the container types and sizes can be found in Appendix J.

Table 6-1

Unrooted stock		Top Caliper		Height	
		Target standard			
End use	Type	cm	inch	cm	inch
Planting stock	Cutting	1.0-2.0	3/8-3/4	20-30	8-12

Rooted Stock*		Top Caliper		Height	
		Target standard			
End use	Type	cm	inch	cm	inch
Planting stock	BR cutting **	0.7-1.0	1/4-3/8	varies	
Planting stock	PSB415D	0.5-0.7	3/16-1/4	varies	
Planting stock	PSB412A	0.5-0.7	3/16-1/4	varies	

* Caliper is measured at about 2.5 cm (1 in.) above the top of the starter cutting

** Interim Target Standard - Future target: 1.0-1.5 cm (3/8-5/8 in.)

The importance of meeting these standards becomes clear in the example presented in 'Soil temperature [see Module 6.7.1]'.

6.7 Planting Season

The best season to plant a new crop is in the spring when soils are re-charged with moisture and soil temperature is on the rise, which promotes root growth. Trees could be planted early, as soon as the risk of a serious frost has passed, but soil temperature is the important determining factor. Generally the optimum planting window is from mid May to mid June; planting beyond the latter part of June and into July is not recommended.

It is important to note that conditions vary considerably across the prairies from year to year and the planting window should be considered a guideline.

6.7.1 Soil temperature

A general rule of thumb is that when the soil temperature at 10 cm (4 in.) depth reaches 14°C (57.2°F), planting can start. At this soil temperature roots start to be initiated from unrooted cuttings. Temperatures from 18-22°C (64.4-71.6°F) are in the optimum range for root growth. This information is based on recent work done by the Shelterbelt Centre of the PFRA. Researchers found clonal differences in root initiation and root growth[19].

For bareroot and container stock these threshold temperatures are probably not as critical, but would still be optimal. It is recommended not to start planting bareroot and container stock types until the soil temperature reaches 10-12°C (50-53.6°F).

What happens when planting starts earlier? When the soils are still too cold, planting trees is like cold-storing them in the soil. Lack of sufficient soil temperature prevents roots from becoming active and the tree just sits there in a dormant state. Normally that would be quite acceptable, but there is a risk that the above-ground portion becomes very active after a few very nice and warm sunny days. The buds start to swell and may even start to flush when above-ground temperatures are favourable and the day length increases. When that happens, the roots must also become active to supply water to the plant, but they remain inactive due to the low soil temperature. The tree then starts to draw moisture from its stored reserves in the roots and/or stem. The result is that the tree dries out before the roots are able to take up water from the soil.

The plant stores reserves to draw on at the beginning of the growing season and the amount of stored food and water depends to a large degree on the dimension of the planting stock. Cuttings not meeting the minimum top caliper target standard of 1.0 cm (3/8 in.) (Table 6-1) should not be considered for planting a crop; they do not have sufficient food reserves to support the growth needed for a successful crop. For example, with a doubling of the top caliper, the volume of the cutting increases fourfold! That means it has 4x the food and water reserves of a cutting with half the caliper. That also holds true for bareroot and container stock. That is why it is so important to insist on meeting the stock standards.

The other risk of planting too early is that the tree roots or the cuttings sit in a fully saturated soil at low temperatures. If the stock is infected with a storage disease [see Module 9.1.4] or is in poor shape, it will continue to deteriorate. Trees may still flush, but there will be little growth and the stock will probably rot below ground and die.

19 Schroeder, W., Inouye, G. M. 2006 in Final project Report ADF project 200010048 - Hybrid Poplar Plantations for Farm Diversification in Saskatchewan (AAFC-PFRA Agroforestry Division).

6.7.2 Soil moisture

Sufficient soil moisture is required for successful establishment of the trees. This was already discussed in "Climate considerations and site suitability [see Module 1.1.4]', but warrants repeating here.

A report completed by the Shelterbelt Centre of the PFRA states: "areas with less than 375 mm (about 15 in.) annual precipitation or a moisture deficit of greater than -375 will have significantly restricted tree growth and are not suitable for large scale tree production unless supplemental moisture is available through irrigation or trees are able to access the water table. Availability of groundwater can mitigate the requirement for precipitation"[7]. This refers to total annual precipitation.

Another study done by Agriculture and Agri-Food Canada (AAFC) comes to a similar conclusion: "Areas with less than 300 mm (about 12 in.) of growing season precipitation, or 400 mm (about 16 in.) annual precipitation, or a moisture deficit of greater than -400 (mm) will have significantly restricted poplar growth and are not suitable for hybrid poplar production unless supplemental moisture is available through irrigation or trees are able to tap into the water table"[12].

If soil moisture levels are too low in the spring due to an insufficient snow pack and cannot be replenished through rainfall in time for planting, the farmer needs to make a tough decision whether or not to plant at all. If rain is forecast with some certainty, planting is on, but if a dry period is forecast, planting is off till sufficient moisture is on the way. Postponing planting beyond the latter part of June and into July is not advisable. Experiences with growth performance of stock planted this late are not good.

7 Schroeder, W., Silim, S., Fradette, J., Patterson, J., and de Gooijer, H. 2002. Detailed Site Analysis and Mapping of Agroforestry Potential in the Northern Agricultural Zone of Saskatchewan. Funded by the Saskatchewan Forest Centre - Forest Development Fund.

12 Vanin C., Burgon, M., Development of Suitability Maps for Hybrid Poplar Production in Alberta. Agriculture and Agri-Food Canada - P.F.R.A., Edmonton, AB. July 2003

6.8 Planting logistics

6.8.1 Transportation and delivery

Most nurseries can provide advice on or assist with the transportation and delivery of the stock; however, the price for the stock does not normally include this service. If the transport involves a large number of trees, a reefer van may be the answer to keep the stock cool. Check with local transport and trucking companies to see what services they can offer. A direct delivery is always best; it avoids the stock being routed through central truck yards where the transport is combined with other goods. Once this happens, the farmer loses control over the condition of the stock.

If a planting contractor is used to do the planting, he may be able to pick up the stock at the local stock cooler and bring it to the field, where it can be stored temporarily in a tree cache in an adjacent woodlot or in a barn. It is good practice to remove only as much stock from the cooler as can be planted in one day. If the storage cooler is located too far from the field to allow daily pickups, a proper interim storage near the planting site is needed. Some of the planting contractors have trucks with a properly insulated stock storage compartment, where trees can safely remain during the day.

When transporting stock in an open truck, the driver should consider covering the stock with a 'Silvicool' tarp to keep sunlight out and the cold in [see Module 6.8.2].

6.8.2 Storage on site

When stock arrives in large quantities, the farmer must ensure the delivery time and place are coordinated with the trucking company. The truck driver must have good instructions when and where to deliver the trees. Some firms might be able to provide the extra service to make sure the stock is stored properly; it is worth checking this out. A lack of coordination can result in stock being unloaded along a road somewhere without receiving the proper care of storage (Photo 6-10).

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Photo 6-10: Improperly stored stock at the end of May 2005 in the blazing sun near St. Paul (AB). The truck driver dropped off this stock without the owner being present. Found late in the day, this stock had to be moved to a cool and shady tree cache inside the adjacent woodlot.

Proper interim storage sites should be in the shade of an adjacent woodlot, or inside a barn with good ventilation. If no shady interim storage is available near the field, only bring out enough stock for a full day's work and stack it on the shady side of the truck or van. The stock should always be covered with a 'Silvicool' tarp, whether stored inside, in the shade or in full sunlight.

Silvicool tarps are specially made tarps to store planting stock and are standard equipment for planting contractors. The tarp has a reflective white side, which faces up. The inside of the tarp has silvery shiny coating to reflect back and keep in the cold. The silvery side should always be facing the trees; the white side should always face the sunny side. The tarp should be elevated to allow air circulation between the tarp and the boxes.

Silvicool tarps can be purchased in different sizes and weights. To find suppliers, just check the Internet and type in the word Silvicool and a host of suppliers will be listed. Many planting bags are made of the same material (Photo 6-9) for the same reason.

When the field is quite large and the planters or the planting machine runs out of stock before reaching the road again, it is good practice to build small tree caches in the field at regular intervals; this decreases down time and planting can continue without interruptions. These small tree caches should always be minimal in size, holding just enough stock to continue planting and should always be covered with Silvicool tarps. Suppliers sell them in smaller sizes for exactly this purpose.

Interim stock storage and how tree caches are maintained and managed are an integral part of the planting process.

6.8.3 Stock handling

Planting stock should always be handled gently; prevent throwing or handling the boxes with stock roughly. Boxed trees are living organisms in a stressed environment and do not need the additional abuse.

- **Frozen stock**

When stock has been frozen in freezer storage, the farmer should allow some time for the stock to be thawed. This is particularly important when planting container stock. Trees are bundled in 10's, 20's or 25's, depending on their size, and the root plugs will be frozen solidly together. Boxes should be stored under the tarp and if they are planned for planting within the next day or two, the boxes should be opened and the bundles placed upright (most will be stored on their side, due to their height). This acclimatizes the stock and gives it time to thaw the root plugs.

Frozen unrooted cuttings or bareroot stock will not require the same thawing time. When storing under the tarp, allow some space between the boxes for air circulation; this helps the thawing process.

- **Soaking stock**

Where possible, unrooted cuttings and bareroot stock could be placed in or dipped into water to prevent drying. When ordering the stock from the nursery, the farmer can request that cuttings be placed upright in a (double) plastic liner inside a box. If water is plentiful on site, it allows the planters to open the boxes and fill the liner with about 5 cm (2 in.) of water a day before planting to soak the stock; water should be clean. Before soaking the cuttings, ensure they are indeed stacked upright so only the bottom portion of the cuttings are soaked in water. It is not a good idea to soak the stock for more than a day or two at the most. When it is left in water for too long, the rising water temperature triggers the cuttings to start root growth. Once that has happened, the cuttings will be useless.

Soaking bareroot stock is much harder to do and is not practical. The stock is usually packaged sideways due to its size. Container stock should never be soaked, as this disintegrates the soil of the root plug and makes it impossible to plant.

The planters should be encouraged to put moist peatmoss in the bottom of their Silvicool planting bags when planting bareroot stock; this ensures roots remain damp, especially on warm and dry days. Using moist peatmoss with unrooted cuttings would not hurt either.

- **Miscellaneous practices**

It is recommended to leave stock in bundles in the planting bags; only untie or unwrap them just prior to planting. Plastic wrappers, ropes, elastic bands etc. should be kept for proper disposal when back at the truck.

Avoid putting stock back into storage.

All boxes should be flattened and recycled; quite often they can be returned to the nursery.

6.8.4 Crop planting

The mechanics and standards of good planting are similar for unrooted cuttings, bareroot and container stock. All stock types are plantable by planting machines or by manual planters. Although the following descriptions of crop planting are aimed mainly at manual planting, the standards of the end result – the planted tree – are the same for mechanical and manual planting. This includes planting the stock at the right location in the tree row and, if required, right on the intercept of the row mark and the cross mark.

❖ Unrooted cuttings

Cuttings are planted with one live bud above the soil surface, although there may be some exceptions where much longer cuttings are planted. Cuttings should have a target standard top caliper of 1.0-2.0 cm (3/8-3/4 in.) (Table 6-1) and have at least one live bud within approximately 2.5 cm (1.0 in.) of the top; a second live bud within 5.0 cm (2.0 in.) of the top would be optimal [see Module 3.2.1]. Cuttings should be free of any branches and show no sign of damage or disease.

When planting manually, the cutting could be pushed into the soil if the soil is loose, otherwise a dibble (Photo 6-8) can be used to prepare a planting hole. Air pockets should be eliminated by wedging the soil against the cutting with the dibble inserted about 7.5-10 cm (3-4 in.) from the cutting. When careful, the planter can also use the heel of his boot to push the dibble hole shut. Note that using the toe instead risks kicking into and damaging the stem; this method is discouraged in tree planting, although most planters continue do so. In machine planting the packing wheels perform that function. Do not pack the soil too tight around the cutting.

Ensure the cutting is straight and that it is planted 'right side up'! The nursery should have packaged all cuttings oriented the same way. The live bud should have its very tip pointed upwards. It would help tremendously if the nursery painted the tops of the cuttings [see Module 3.3.3]; that would also make the cuttings very visible after planting and helps in quality control.

❖ Bareroot stock

The stock should be planted slightly deeper than it grew in the nursery. The top of the roots should be well below the soil surface. An easy standard is to have the soil level just below the top of the old cutting and at the point where the new shoot emerges from the cutting (Photo 6-11). The buried stem of the original cutting will start to initiate additional roots above the existing ones.

When planting manually, a planting spade should be used. The 'slit' method of planting can be used with the roots trimmed back as shown in Photo 6-11. The planting spade is inserted into the soil to form a wedge-shaped (V-shaped) slit. The planter inserts the tree to the required depth, removed the spade and firms up the soil around the roots. This is done by inserting the spade 7.5-10 cm (3-4 in.) from the tree, pulling the spade back to firm soil around the roots and then pushing forward on the spade to seal the top of the V-shaped slit. The planter must ensure not to cut into the roots of the tree when doing this. When careful, the planter can

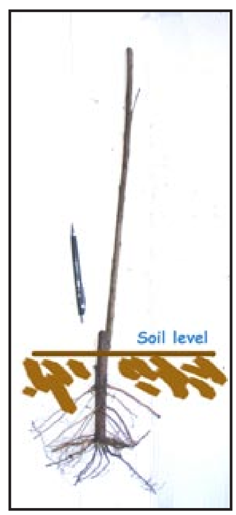

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Photo 6-11: The soil level should be just below the top of the old cutting and at the point where the new shoot emerges from the cutting.

New roots will form on the buried stem section above the current roots.

also use the heel of his boot to seal the top of the V-shaped slit. In machine planting the packing wheels perform that function. Do not pack the soil too tight around the roots. The tree must be planted in an upright position to avoid a crooked stem.

A frequent planting error with bareroot stock is the ‘J-root’ planting problem. The roots are stuffed into the soil without a properly prepared planting hole. As soon as the roots experience resistance in the soil, they bend sideways or even upwards. That is called a J-root error.

- **Container stock**

Planting instructions are similar to those for bareroot stock, with a few changes. Planting can be done with a dibble or with a narrow planting spade meant for container planting. This spade is usually much narrower than the spade used for bareroot planting.

The mechanics of planting are the same as for cuttings and bareroot stock, depending on the tool that is used. Planting should be at least 3-finger-width deeper than the top of the rootplug. This is the standard currently used by Alberta-Pacific Forest Industries Inc. (AL-PAC) in Alberta. The buried stem portion above the top of the rootplug will eventually initiate additional roots above the existing plug.

As with bareroot stock, ‘J-root’ planting errors occur. When the rootplug is stuffed into the soil without a properly prepared planting hole, the tip of the rootplug veers off to the side. The result is J-shaped rootplug.

6.8.5 Clonal deployment and marking crop locations

In ‘Deployment of Clones [see Module 2.3]’ it is recommended that if more than one clone is planted in a field, each clone should be planted in a distinct clonal block. This was also discussed in the ‘Crop Layout [see Module 4.3]’. Each clonal block should be of a shape and size that enables it to be managed as a distinct unit. Boundaries of each block should be permanently marked in the field with a set of stakes or posts and the location marked on a map with coordinates, distances or other measurements that make them easy to locate years after planting. The importance of proper mapping and marking of the clonal block boundaries cannot be overemphasized and is all too often a task that is ignored by the owner of the crop.

At the end of every day, the day’s planting should be clearly marked in the field for the next day’s start. Especially when planting unrooted cuttings, it will be hard to spot where cuttings were planted and where they still need to be planted. That is also the case with small bareroot and container stock; they will be hard to spot. A daily map should also be maintained showing what was planted. The supervisor, in close coordination with the farmer, should plan ahead where clonal block boundaries will be located. These should be clearly marked in the field on a temporary basis. Once the planting is completed and the boundaries are confirmed, the farmer needs to permanently mark and record them as discussed previously.

6.9 Planting Project Record Keeping

There are three records that need to be maintained for each planting project:

a) The planting map
b) The planting record by field
c) The planting quality assessment plot sheets

6.9.1 Planting map and planting record by field

Prior to starting the planting, the farmer provides the contract supervisor with copies of the planting map and planting record sheets (Appendix S). The map needs to be reasonably accurate, even if it only is a hand-drawn one. It needs to show road locations, field boundaries, intended clonal block boundaries and anything related to safety concerns. Before any planting takes place, the farmer and supervisor should review this map and the plan in the field to ensure there is a good understanding of the scope of the project.

The record keeping sheet contains the basic information of the plan, such as the area size, the number of trees and clone(s) to be planted, the in-row spacing standards and tolerances. The record is used by the supervisor to report daily production by field, block and clone. Additional blank sheets can be added for large planting projects. Progress is recorded on the map; colour coding would help distinguish between planting dates, clonal changes etc. It is good practice to review the records and maps with the supervisor on a daily basis if possible. There should be mutual agreement on how much stock was planted, how much is still to go, the clones that are planted etc. If a daily review is not practical, it could be done over the phone or in person every other day or so.

The planting record sheet also contains a summary of the planting and spacing quality determined by the payment plots [see Module 6.9.2] and calculates the final payment based on these (Appendix S). This gets done when the planting contract is completed.

Sizes, distances etc. can either be entered in metric, or in imperial measures; a few conversion values are included for this purpose on the planting record sheet.

6.9.2 Planting quality

The assumption is that row marking takes place every time an SRIC poplar crop gets planted. Planting standards are the same for machine and manual planting and were discussed in 'Crop planting [see Module 6.8.4]'. All planters and mechanical planter operators have their methods and habits of planting and these could be in conflict with the standards expected by the farmer. For that reason the farmer, who ultimately pays the bills, should check the planting early and often, especially at the beginning, paying attention to the actual planting quality and the plant locations.

The best approach is to insist on joint field inspections with the contractor supervisor right at the start of each planting contract. This is a good way to communicate planting standards and expectations, and to ensure both are on the same wavelength. A good contractor wants to do things right the first time, as re-work is always costly and hurts the contractor's and planter's reputations. After a good working relationship has developed between the farmer and the supervisor, discussion of quality issues will quickly lead to corrective action.

There are two types of quality assessment plots, both using the same system, but with different intensities and purpose.

a) Work quality plots
b) Payment plots

❖ Work quality plots

The supervisor of the contract crew carries out daily work quality plots and should have a very good idea how each individual planter is performing. Appendix T contains a format of a plot record that could be used to compile quality data of the daily work; the same format is used for the final payment plots. The only difference between these is the number and distribution of the plots. For the work quality plots the supervisor does as many plots for each planter or in each part of the field as he sees fit to ensure quality standards are met consistently throughout the field. The distribution and number of plots will vary from day to day and from planter to planter. It is a tool the supervisor has to use to get the job done right the first time.

The supervisor immediately discusses the findings of work quality plots with each of his planters. Plot taking is done often at the start of the contract for each of the planters. This ensures all planters become very familiar with the standards and expectation of the farmer right at the start of the project.

The farmer, who hires the contractor, would benefit from carrying out his own checks on a regular basis, much like the daily work quality plots, but at a much lower intensity. If he does find a problem or a concern, he can then discuss this with the supervisor. The supervisor is the right person to pass this information on to his crew. It is not a good idea for the farmer to assume this role, even if the supervisor is absent. Of course it is perfectly alright for the farmer to talk with the planters, but anything connected with the supervisor's responsibilities should be left to the supervisor.

The mere presence of the farmer in the field, checking the quality independently of the supervisor, sends a clear message to the crew and supervisor that the farmer is 'on top' of his crop and cares about the work quality.

❖ Payment plots

Close to the end of the project, the farmer needs to do a set of payment plots to calculate the final payment for the work. Appendix T contains a format that could be used to compile these plots and calculate planting quality. It is the same format used in the work quality plots.

The results of the payment plots should confirm what the farmer has already seen in the regular work quality plots done by the supervisor or by himself. If the work quality plots showed problems before, the contractor should have fixed them by now. The payment plots are really the final check to see that all the work has been done to the farmer's satisfaction and form the basis for the final payment.

A good approach is to carry out the final payment plots in the presence of the contract supervisor. This way any quality issues can be discussed and hopefully resolved. If corrective action is still required, it can be done while the planters are still on site. In most cases however the final payment plots should be a 'non-event'.

The only difference with the work quality plots is the number of plots required and the distribution of the plots.

6.9.3 Payment levels

The final payment level is determined by the planting quality and by the percentage of spacing errors (Table 6-2).

- **Planting quality percent**

The planting quality is the number of good trees divided by the number of trees planted; it is expressed as a percentage. The number of trees planted assumes that every planting spot has a tree planted in it. When the planting quality drops below 85 per cent, the contractor will not get paid. This rarely happens with good contractors, especially when the supervisor carries out the daily work quality plots [see Module 6.9.2]. When the quality level is 95-100 per cent, the payment level is 100 per cent. The details can be seen in Table 6-2.

Trees not recorded as good in the 'Good' column, will be assigned to one of five error columns of the planting quality assessment plot sheet in Appendix T.

The payment level is also influenced by the spacing quality.

- **Spacing quality**

The spacing quality reflects how well the trees are planted in their marked locations. Since all fields have row marking, each tree has to be planted right on the row mark. If it is planted to the side, it will be recorded as an error in the 'Not in tree row' column of the planting quality assessment plot sheet (Appendix T). There is no tolerance level for planting off the row mark.

A similar approach is taken with spacing in the row itself, called the in-row spacing. In the case where no cross marking is done there will be an allowance. Where cross marking has taken place, it indicates the crop is set up for cross cultivation and the in-row tolerance is zero per cent for manual planting and minimal for machine planting.

Faulty trees are recorded in the 'In-row spacing – Error' column of the planting quality assessment plot sheet in Appendix T. Where a small tolerance is indicated in the in-row spacing standards and a tree is missing the mark, the distance from the previous tree in the row to the sample tree is measured and recorded.

When the combined tree row and in-row spacing errors total 0-5 per cent, there is no further deduction from the payment level. If the spacing errors exceed a combined total of 5 per cent, there is a 5 per cent payment price penalty on top of the deduction for poor quality. The rationale is that poorly spaced trees are as good as 'condemned to death' by cultivation; these trees are lost and will not yield a crop.

Table 6-2

Planting Quality	Spacing error	Payment
95-100 per cent	0-5 per cent	100 per cent
85.0-94.9 per cent	0-5 per cent	Equal to the quality per cent
	More than 5 per cent	5 per cent price penalty
Less than 85 per cent	n/a	No payment

When spacing errors are within the 5 per cent tolerance level and are the only quality problems, the total quality per cent will be in 95-100 per cent range, resulting in full payment. The emphasis on spacing signifies its importance. Not only are trees lost to 'death by cultivation', the loss also represents a potential loss in yield and an immediate financial loss, as the farmer paid good money for these trees. This is a double loss and the 5 per cent price penalty on top of the quality percentage is fair.

6.9.4 Plot procedure

Although the following procedures apply to payment plots, the general principles also apply to the daily work quality plots. The only difference is that the distribution and number of plots are much more controlled for payment plots.

The precise methods of plot layout and the calculations to determine which trees to sample will be detailed in module 'Growth and Yield' [see Module 8]. The procedures described below are illustrated in 'Example - completed payment plots and planting record [see Module 6.9.5]'.

- **Number of sample trees per plot**

The target number of trees to be measured is 60, in 20 '3-tree' plots. This is sufficient to provide the accuracy required. The minimum number of trees to be sampled should be 45 in 15 '3-tree' plots.

The target number of 60 sample trees is independent of the field size. The key to accuracy is to ensure the samples are evenly distributed throughout the entire field. If the farmer finds very inconsistent quality throughout the field when sampling payment plots, it could be an indication that an insufficient number of work quality plots were done or that the planters did not respond to the feedback from the supervisor. If the planting and supervision, including the work quality plots, were done correctly, the outcome of the final payment plots should be known beforehand and should therefore be a 'non-event'.

❖ Number of sample trees in a plot

The number of sample trees in a plot is 3, the so called ‘3-tree’ plot. These are three consecutive trees in the sampled tree row, with a pre-determined location in the row (e.g. row 19 and the 113th to 115th tree in the row).

❖ Measuring spacing errors

As already described in ‘Payment levels [see Module 6.9.3]’, spacing errors include trees planted off the designated tree row, or exceeding tolerances for in-row spacing. Some of the in-row faulted trees need to have their spacing measured.

a) Off the tree row (manual planting only)
Planting off the tree row carries ‘zero’ tolerance and is an automatic ‘Not in tree row’ error.

b) Manual and machine planting – no cross marking
No cross cultivation is planned; however, trees need to be planted in-row within +/- 5 per cent of target.
If spacing exceeds tolerance, measure spacing distance from the previous tree.

c) Manual planting – cross marking
Cross cultivation is planned. Spacing in-row carries ‘zero’ tolerance and is an automatic ‘In-row spacing Error’.
No spacing distance is measured in ‘zero’ tolerance.

d) Machine planting – cross marking
Cross cultivation is planned. Spacing in-row carries +/- 10 cm (4 in.) tolerance.
If spacing exceeds tolerance, measure spacing distance from the previous tree.

Where spacing gets measured, it is always from the previous tree in the row. Using the example above, if the first sample tree in row 8 is the 113th tree and it is either too close or too far from the previous (112th) tree, measure the distance from the 112th tree, even through that tree is not in the plot. If it also looks like the 114th tree is too close or too far from the 113th tree, measure it and record the distance in the column ‘Spacing’, and so on.

❖ Plot layout

The plot layout is much more critical for the payment plots than for the work quality plots. To ensure a good and accurate sample, the sampling must cover all parts of the field. The layout procedure identifies the tree rows to be sampled, starting from the randomly selected first row. The sampling design has also calculated the number of trees between each sample. The first tree in the first randomly selected tree row is also randomly selected and ties in all the subsequent samples of the field.

All the farmer has to do is pick a random number from 1 to 10 to select the first row and pick another random number to select the first sample tree, walk down the selected tree row and measure the first tree with its next two subsequent neighbours in the row (e.g. row 8 and the 113th to 115th tree in the row) in plot #1. After the first plot, he counts off the number of trees from the first tree in each plot and starts the process again. When he finishes the row partway through the count, the count gets completed in the next sample row, where he samples the next three trees in the next plot and so on.

6.9.5 Example - completed payment plots and planting record

The following example is for a scenario of manual planting in a cross marked field.

Field 1 of Jones' farm is 10.2 ha (25.2 ac.) in size and is 201 m (660 ft.) wide by 507 m (1,663 ft.) long. The logical tree row layout is lengthwise with the greatest length of 507 m (1,663 ft.). At 3 m (10 ft.) spacing between tree rows, there are 66 plant rows. The outside tree rows have 3 m (10 ft.) wide headlands on the outside.

In this situation farmer Jones decides to sample only the minimum number of 45 trees in 15 '3-tree' plots. He determined the layout of the plot locations beforehand and selected rows 8, 19, 30, 41, 52 and 63. He calculated that there should be a plot every 68 trees. The layout procedures are described in more detail in the section dealing with quality plots and survival surveys [see Module 8.1].

Cross marking for manual planting means that there is zero tolerance for a mistake in planting location. The planter is either on the X mark or he is not, in which case the tree is faulted as an 'in-row spacing error' (Figure 6-1). Since all the area is cross marked, there is absolutely no reason to miss the X mark. The trees should always be right on the tree row as well. If the latter is not the case, the tree gets faulted in the 'Not in tree row' column. Farmer Jones finds three trees that were not planted on the intersect of the tree row and the cross mark and zero tolerance means three faulted trees. Since there is a zero tolerance, spacing distances do not need to be measured as described in the section 'Plot procedure [see Module 6.9.4]'.

Other errors he finds are a damaged tree in the very first plot and sample tree. It has kicking damage, indicating the planter used the toe of his boot to kick the planting hole shut. This error is recorded in the column 'Damage'. In the section 'Crop planting [see Module 6.8.4]' there was a mention of this: "When careful, the planter can also use the heel of his boot to push the dibble hole shut. Note that using the toe instead risks kicking into and damaging the stem; this method is discouraged in tree planting, although most planters continue do so." The other error he finds is a J-root. This is when a rooted tree is planted and the roots are just jammed into the planting hole. The roots turn sideways, hence the name J-root. This is a planting error and gets recorded in the 'Poor planting' column.

Figure 6-1

Planting Quality Assessment Plots
To be used for 'work quality plots' or 'payment plots'

Calculations on page 2

Farm name or #: Jones

Tree# refers to the location where a tree is or should have been planted.

Field Name:
Field #: 1
Contractor: T. Planter & Sons Ltd.
Start date: 23-May-05
End date: 2-Jun-05

	In-row spacing		Tolerance: No cross marking	Tolerance: Cross marking
Manual	3.00	m	+/- 5%	0%
		ft.		
Machine		m	+/- 5%	+/-10 cm
		ft.		+/- 4 in.

Row #	Plot #	Tree #	Good	In-row spacing: Error	In-row spacing: Spacing (m or ft.)	Not in tree row	Poor planting	Damage	Missing	Comment error
8	1	1						1		Kicked
		2	1							
8	3	7	1							
		8	1							
		9		1	*Note*					Tree out of line
19	4	10	1							
		11					1			J-root
		32	1							
		33								
52	11	34		1	*Note*					Tree out of line
		35		1	*Note*					Tree out of line
		43	1							
		44	1							
		45	1							
Total			40	3			1	1		

# of trees sampled:		A	45	Cannot exceed the highest tree #		
# of trees sampled that are good:		B	40			
# of trees with in-row spacing error:		C	3	=	6.7 %	Automatic 5% price penalty when >5%
# of trees not in the tree row:		D		=	%	
# of trees poorly planted:		E	1	**Total**	6.7 % **spacing errors**	
# of trees damaged:		F	1			
# of trees missing:		G				
Total errors	C+D+E+F+G=	H	5			
Planting quality:	(A-H)*100 / A		88.9 %			

Quality of 88.9% is in the 85.0-94.9 % range and gets payment of 88.9% and an adjustment to reflect 5% spacing error penalty. Resulting in 83.9% payment.

***Note**: For this example of manual planting with perfect cross marking, spacing is not measured. It's either on the mark or it is an automatic error.*

1 ha = 2.47 ac.
1 ac. = 0.4 ha
1 m = 3.28 ft.
1 ft. = 0.31 m

1 ha = 10,000 square meters, or a field 100x100 m
1 ac = 43560 sq. ft., or an area 66x660 ft.

The final result is that the contractor T. Planter and Sons Ltd. achieved only 88.9 per cent quality, which would normally result in an 88.9 per cent payment level Table 6-2. Due to the many spacing errors and the fact that the errors exceeded 5 per cent, the contractor gets an additional price penalty of 5 per cent, resulting in a total payment level of 83.9 per cent.

This is a heavy penalty to take and could have been avoided with better monitoring of the planters. In case of a disagreement between farmer Jones and the supervisor, another set of payment plots should be done, but this time sampling should cover at least 60 trees in 20 '3-tree' plots and the contractor should accompany Jones for the second sampling.

The standards used in the 'Planting Quality Assessment Plots Sheet', shown in Figure 6-1, are copied from the 'Planting Record by Field' card, shown in Figure 6-2.

Figure 6-2

Planting Record by Field

Farm name or #: Jones

Field Name:
Field #: 1
Size (ha): 10.2 *(1 ha = 2.47 ac.)*
Size (ac.): *(1 ac. = 0.4 ha)*

Planting contractor: T. Planter & Sons Ltd.
Start date: 23-May-05
Completion date: 2-Jun-05

Mapped: ☑
Planting type:
New planting ☑
Fillplanting ☐
Re-planting ☐
Planting method:
Machine planting: ☐
Manual planting: ☑
Marking:
Tree rows: ☑
Cross marked: ☑

Payment %: 83.9 includes the 5% price penalty
Paid: ☑

	Bid	Paid
Cost per tree:	18.3 ¢	15.4 ¢
Cost per ha:	$203.27	$170.60
Cost per ac.:	$	$
Total	$ 2,073	$ 1,740

Planting quality %: 88.9
Spacing error %: 6.7

Planting Quality	Spacing error	Payment
95-100%	0-5%	100%
85-94.9%	0-5%	Equal to quality %
	> 5%	**5% price penalty**
<85%	n/a	No payment

In-row spacing standards:

	In-row spacing	Tolerance: No cross marking	Tolerance: Cross marking	
Manual	3.0 m	+/- 5%	0%	*(1 m = 3.28 ft.)*
	ft.			
Machine	m	+/- 5%	+/-10 cm	*(1 ft. = 0.31 m)*
	ft.		+/- 4 in.	

Spacing error is 6.7%
1,108-(1,108*6.7%)=

					Net of Spacing error %
Spha standard:	1,111	spha	+/- 5%	**Spha actual-net:**	1,034
Spac standard:		spac		**Spac actual-net:**	

Planned Block #	Clone	Stock type	# trees	ha	spha	ac.	spac
1	A	BR	11,330	10.2	1,111		
Total			**11,330**				

Actual Block #	Clone	Stock type	# trees	ha	spha (gross)	ac.	spac (gross)
1	A	BR	4,540	4.1	1,108		
2	B	415 D	6,760	6.1	1,108		
Total			**11,300**				

The quality at 88.9 per cent on the 'Planting Quality Assessment Plots Sheet' (Figure 6-1) is above the 85 per cent minimum required. There are 40 good trees, 3 trees with in-row spacing errors and 2 trees with damage or poor planting errors. The total error is 5 trees. Out of the 45 trees measured, 40 are good; that is (40/45)*100=88.9 per cent quality (rounded to one decimal). The spacing errors add another price penalty of 5 per cent, resulting in a payment level of 83.9 per cent.

The payment is 83.9 per cent of the bid price of 18.3 ¢ per tree, as shown on the 'Planting Record by Field' sheet (Figure 6-2), resulting in a final payment of 15.4 ¢ per tree.

The record also shows that in the end 11,300 trees were planted on the 10.2 ha (25.2 ac.), versus a planned 11,330 trees. That indicates accuracy in mapping, as well as in-row and cross marking. If the numbers vary by more than 5 per cent, the farmer should take a look at the accuracy of his map, provided he found good quality with both row and cross marking. The standard for crop density was 1,111 spha (450 spac) and the resulting gross density is 11,300 trees divided by the area size, resulting in 1,108 spha (448 spac). That is well within the tolerance of 5 per cent.

The spacing errors totalled 6.7 per cent of the trees planted off the tree row and/or off the cross mark. Using cross cultivation to control weeds, these trees are in danger of being killed by the cultivation. The net density is 6.7 per cent lower at 1,034 spha (418 spac). That is substantially less than what was planned. The trees that will be lost to cross cultivation (6.7 per cent or almost 760 trees) not only represent a potential loss in yield, but they also represent trees for which the farmer paid money to the nursery. This represents a double loss and the 5 per cent price penalty on top of the quality percentage is fair.

6.10 Fillplanting

When using top of the line planting stock [see Module 3.2], 85-95 per cent survival should be the norm after the first growing season. This depends not only on stock quality, but also on site preparation and weed control. How much tree mortality the farmer is willing to accept depends on the distribution of the mortality and end use of the crop. This was discussed in detail in the section dealing with tree mortality [see Module 4.1.3] of 'Crop Density, Spacing and Layout [see Module 4]'. Table 6-3 shows the survival targets for the three crop types.

Table 6-3

Crop	Stems per hectare - spha	Stems per acre - spac	Survival target
Pulpwood and OSB	1,000-1,100	400-450	85-95 per cent
Saw log	500-800	200-325	>95 per cent
Peeler log	500-800	200-325	>95 per cent

To ensure the survival targets are met, it is good practice to carry out survival surveys in late August. The procedure for survival surveys is described in the section dealing with quality plots and survival surveys [see Module 8.1]. If required, fillplanting should take place the following spring during the regular planting period. Regardless of what stock type was planted originally, fillplanting with rooted stock is recommended. If no rooted stock is available of that particular clone, use good rooted stock of another acceptable clone. The fillplant date, clone identity and stock type should be noted on the map and on the planting record (Appendix S).

Module 'Growth and Yield [see Module 8]' deals with survival surveys [see Module 8.1] and presents a rationale to help decide whether or not to fillplant and/or re-plant the following season.

6.11 Re-planting

If a new crop shows heavy mortality, fillplanting may not be appropriate and a re-plant is needed the following spring. Whether or not to spray out and plow under the existing crop to prepare the site for new planting, depends on how extensive the mortality is and how it is distributed in the field. That will also be discussed in 'Growth and Yield [see Module 8]'.

MODULE 7: CROP MAINTENANCE AND IMPROVEMENT

The crop maintenance phase [see Module 7.1] starts once the newly-planted hybrid poplar crop has broken dormancy and is actively growing. The establishment period (consisting of several years) and the time till harvest are both considered part of the crop maintenance period. Cultural treatments integrate the use of pesticides (mostly herbicides) with mechanical treatments to optimize weed control and crop protection. The crop establishment period normally ends when the trees achieve canopy closure.

Crop improvement involves treatments other than weed control, including:

a) Fertilization treatments [see Module 7.2] to correct nutrient imbalances and/or improve crop growth;

b) Pruning treatments [see Module 7.3] to improve the shape and form of the trees during the establishment period and/or to create knot free wood and increase the value of the stem.

7.1 Weed Control

Some of the information in this section has already been covered in 'Herbicides – Site Preparation' [see Module 5.5], but applicable information warrants repeating in this section.

7.1.1 Why weed control?

As with any crop, survival and yield depend on the tree having access to sufficient water and nutrients. Poplars are also extremely shade intolerant and require full sunlight to grow. Weed control removes below-ground competition for water and nutrients and above-ground competition for sunlight.

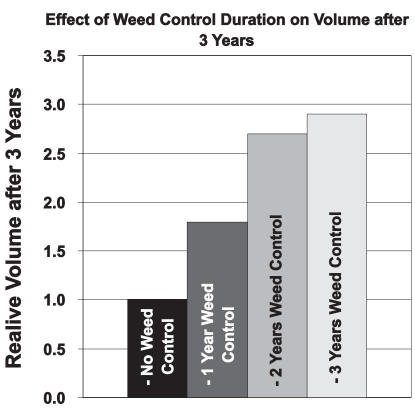
Another important reason to achieve good weed control is crop protection. Control of weeds, especially the creeping perennial grasses, removes habitat for damaging rodents, such as voles [Web- Voles1] and gophers (Richardson's Ground Squirrel) [Web-Gopher1]. These rodents can cause serious damage in a tree crop.

7.1.2 Weed control standard

Since the SRIC hybrid poplar crop density is low compared with traditional agricultural crops, the trees are not able to shade out the competing weeds for several years. Weed control ends when canopy closure is about to occur or has occurred. From a practical perspective, this is when tractor work has become impossible in the crop without the risk of damaging the tree branches or the tractor.

A practical target is 90% or better weed control during crop establishment. This is an acceptable level in agricultural crops and is appropriate for an SRIC hybrid poplar crop as well. Weed control impact on the poplar crop depends on reaching this weed free

Figure 7-1



target and shows a substantial benefit (Figure 7-1) in a trial on northern Vancouver Island. These trees were planted at a close spacing of 2 x 2 m (6.6 x 6.6 ft.).

Weed control for one year in the first year resulted after three growing seasons in 1.8x the volume of trees that had not been weeded, but survived and grew. Weed control for first two years grew 2.7x the volume after three growing seasons. In this trial the effect of three years weed control was not as dramatic, as trees had closed their canopy in the third growing season and started to shade out the weeds.

7.1.3 Weeds

Weeds are classified using definitions from 'Weeds of the Prairies'[15]:

a) Annual: A plant that germinates in the spring, sets seed in the same year and then dies.

b) Winter annual: A plant that germinates in the fall and survives the winter as a dormant rosette. It resumes growth in the spring, sets seed in early summer and then dies.

c) Biennial: A plant that germinates in the spring of the first year, producing a rosette that survives the winter in a dormant state. It resumes growth in the second year, flowers, sets seed and then dies.

d) Simple perennial: A plant that survives for three or more seasons. Each spring the plant re-grows from stored root and crown reserves. Seed production may occur in the first season and in each subsequent year. Spread of a simple perennial weed species is primarily by seed.

e) Creeping perennial: A plant that survives for three or more seasons and, in that way, is similar to a simple perennial. However, a creeping perennial has a specialized method of vegetative propagation (rhizomes, stolons and budding rootstocks) in addition to seed production.

The creeping perennials are the most difficult weeds to control. These include such species as quackgrass, field bindweed, Canada thistle, etc.

Anything that is not intended to be part of the crop can be considered a weed. For example, barley, wheat, oats and canola in a poplar crop are weeds and must be controlled.

Appendix P is a comprehensive list of weed species and herbicides registered for site preparation and poplar crop maintenance.

15 Bubar, C.J., McColl, S.J., and Hall, L.M., 2000 in Weeds of the Prairies

7.1.4 Herbicide-free weed control?

Some poplar farmers would like to grow an herbicide-free poplar crop. The chance of success in an herbicide-free approach to weed control will be low. Weeds do not stop growing and use of labour to keep up and control them is time consuming and expensive. This may work fine for a very small area, but when the farmer wants to get into growing several to many hectares of poplar, an integrated weed management approach is needed and herbicide use in site preparation is therefore strongly recommended.

To control weeds in the tree rows, mulches are effective, including plastic mulches. Use of woodchips, sawdust or straw can also be used effectively. There is a risk that small rodents, such as voles, use the plastic or the straw mulch as covered runways in which they are safe from raptors and can freely move from tree to tree.

- **Plastic mulch**

For weed control in the plantrows, plastic mulch is an option. The mulch has to be installed immediately after planting and before the trees have flushed, otherwise there is a risk of damage to the new foliage. For proper installation plantrows must be disked and cultivated the summer prior to planting to break up the soil and sod of the sprayed down vegetation. Just prior to applying the mulch the soil should be disked several times or rotovated to ensure the mulch applicator can properly install the plastic, using the loose soil to bury and thus hold the plastic down along the edges (Photo 7-1).

The Prairie Farm Rehabilitation Administration (PFRA) - Shelterbelt Centre website has a few publications on plastic mulch [Web-Plastic mulch]. The plastic controls most weeds in the tree rows. The vegetation in the area between the plantrows must be controlled though cultivation or mowing, if herbicides are not used; however, mowing tends to stimulate weed re-growth, which can negatively affect trees. The roots of young poplar trees quickly spread beyond the tree row into the area between the rows. Any vegetation present is below-ground competition for the trees.

When planning to grow an industrial supply of wood for a pulp and paper company, the use of plastic mulch as a weed control method may prove unacceptable to the customer. Contamination of pulpwood or chips with plastic spells trouble for pulp and paper manufacturing and the customer will refuse delivery of the wood or chips if there is the slightest risk of plastic entering the pulping process.

For additional information please see:

[Web-PFRA]

Cees van Oosten, BC

Photo 7-1: Plastic mulch in an R-2 hybrid poplar crop near Birch Hills (SK) in July 2005.

Site preparation: Summerfallow with Roundup (2x) in the summer and fall of 2003. Rows marked, subsoiled and then rototilled with 3-point hitch rotovator. Orchard grass was sown between the tree rows at freeze up.

Planted: Spring 2004 with clone Walker, stock type PSB415D; trees were small. Plastic mulch installed after planting, starting mid July 2004.

Larry White, SK

Photo 7-2: Clone 'Walker' planted in the spring of 2003 at a farm near Love (SK) – Photo taken in July 2003.

A 7.5-10 cm (3-4 in.) thick layer of wood chips and sawdust mulch resulted in excellent weed control.

Larry White, SK

Photo 7-3: The same clone after 2 full growing seasons in September 2004.

Several of the trees are 3 m (10 ft.) and over in height. Weed control still very good, but had to be augmented with backpack applications of a glyphosate-based herbicide. Some trees show a slight nitrogen deficiency (yellowish leaves), but all trees have benefited from excellent weed control.

❖ Wood chips or sawdust

Other forms of mulch are also effective; wood chips or sawdust for instance makes an acceptable mulch, but it needs to be applied in a thick layer (Photo 7-2) and on a weed-free soil to be effective. Transportation and application costs could be prohibitive if the source is not right next door. Wood chips and sawdust also place a high demand on the site for nitrogen and may limit nitrogen availability to the trees; however, the benefit of weed control outweighs that disadvantage (Photo 7-3).

7.1.5 Integrated weed management

A well thought out integrated weed management approach will lead to reduced cost, including a lower use of and cost for herbicides. The key is to 'do it right the first time' in the site preparation phase.

❖ Integrated weed management

The Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) define integrated weed management [Web-IWM] as follows: "Integrated Weed Management (IWM) uses all available weed control strategies in the best possible way to manage weed populations. Such strategies include cultural, chemical and mechanical methods of weed control."

OMAFRA further states: "All these practices are components and none of these control measures on their own can be expected to provide acceptable levels of weed control. Therefore, instead of relying on only one particular method of weed control, an IWM system uses a combination of methods to control weeds. By following the principles of an IWM system we can reduce the use of herbicides and at the same time provide optimum economic returns to the grower."

Cultural practices include clone selection and deployment [see Module 2], choice of stock type [see Module 3.2], selection of crop density, spacing and layout [see Module 4], and fertilization [see Module 7.2].

Chemical methods are used in the crop maintenance phase and include use of selective herbicides and non-selective herbicides [see Module 7.1.6].

Mechanical methods include cultivation to various depths, or mowing between rows when using plastic mulch or a cover crop (Photo 7-1). Mowing weeds can also be used to 'set them up' for a subsequent herbicide application [see Module 7.1.9].

To be effective all these methods have to work in harmony and methods used to control weeds will probably be different for random in-row spacing than for square, rectangular or diamond spacing [see Module 4.2]. The use of square, rectangular and diamond spacing allows the farmer an opportunity to cultivate in different directions. That option is not available for a crop with random in-row spacing.

7.1.6 Herbicides

There are only a few herbicides registered for use in poplar crop maintenance (Appendix Q-1). In most cases it would be best to enlist the help of licensed spray contractors, who are in a good position to provide the farmer with the advice and services required. There are several good references available to help the farmer choose; these are listed at the end of this section. Some of these also list crop protection companies and weed specialists.

The use of pesticides is subject to Provincial and Federal laws and regulations. Although every effort is made in this manual to ensure recommended practices fall within the laws and regulations, the farmer assumes the full risk and responsibilities under these laws and regulations.

The mentioning and listing of products do not imply endorsement, but are intended to provide the user of this manual with the broadest possible choices and comparisons.

❖ Product labels and MSDS

For complete information the user needs to review the respective product labels, where application rates, mixing and application instructions are listed, as well as safety instructions. For a more complete reference of registered herbicides in Canada, the Pest Management Regulatory Agency (PMRA) in Ottawa maintains a label-search [Web-PMRA Labels] website for easy access by product, active ingredient, PCP number, manufacturer etc. Other resources include the references listed at the end of this section and in Appendix Q-1, where websites for the chemical companies can be found with a lead to their herbicide labels and safety data sheets (MSDS). It lists products registered for use in a poplar crop during the crop maintenance phase.

❖ Metric and imperial units – cause for concern

Product labels in Canada list application rates in metric units, e.g. liters per hectare (L/ha), or kilograms per hectare (kg/ha). Many guides and Internet sites list rates in a confusing mix of metric and imperial units; rates are listed in liters per acre (L/ac.), or kilograms per acre (kg/ac.). This is a cause for concern, especially when application rates from the product labels, which are in L/ha, are misinterpreted as L/ac., and kg/ha as kg/ac. etc.

There are approximately 2.5 acres in each hectare and 0.4 hectare in each acre.

❖ Pre-emergent herbicides

Pre-emergent herbicides are applied to clean soil and prevent germination or early growth of weed seeds.

a) Dichlobenil (Casoron G-4)

The only registered pre-emergent herbicide for poplar is Casoron G-4 Granular herbicide with the active ingredient dichlobenil (Appendix Q-1). It is a soil-active herbicide that is taken up by the weed seedlings. It should be applied post-planting only, when the trees are established for at least six months and should be applied to weed free soil. The cost of product per hectare is prohibitive at the recommended rate of 110-174 kg/ha.

b) Other pre-emergent herbicides

There are no other pre-emergent herbicides registered for use in a poplar crop. Currently two initiatives are underway to obtain registration of several pre-emergent herbicides for use with and in a poplar crop. The possible registration of any one of these herbicides is not expected till 2007 at the earliest. Once registered for use, it is important to ensure the soil is completely bare of weeds when these herbicides are applied. The presence of actively growing annual or perennial weeds would render the use of some of these products ineffective and thus costly.

❖ Post-emergent herbicides (non-selective)

a) Glyphosate-based herbicides

There are several post-emergent non-selective glyphosate-based herbicides registered for use in a poplar crop for the control of weeds (Appendix Q-1). The main glyphosate-based herbicides used in agriculture are not registered for use in a poplar crop; however, they are for use in poplar in a shelterbelt setting and a current initiative is underway to obtain registration for use in poplar crop maintenance. Possible registration is not expected till 2007 at the earliest.

Since these herbicides are non-selective, they will kill or damage actively growing poplars when applied carelessly. They must be applied with a shielded sprayer when trees are small and still have green bark or green foliage near ground level. When the trees are older and have no more exposed live bark or green foliage at ground level, the herbicides can be applied in a directed spray.

Labelled rates for glyphosate-based herbicides with a formulation of 356 gr/L of acid equivalent, such as Vision Silviculture Herbicide (PCP# 19899) and Vantage Forestry Herbicide (PCP# 28884), are 3-6 L/ha of product in a directed or shielded spray. A rate of 2.5 L/ha of product was reported sufficient when using an Enviromist® shielded sprayer [see Module 7.1.8]; it pays to find out the lowest effective rate and the most effective application technology.

VisionMax Silviculture Herbicide (PCP# 27736) contains 540 gr/L of acid equivalent; its labelled rate is 2-4 L/ha of product. As with the previous herbicides, check what the lowest effective rate is.

b) Tank mixes with glyphosate-based herbicides

Unlike for site preparation in summerfallow [see Module 5.5.2], there are no tank mixes registered for use in crop maintenance with the labelled glyphosate-based herbicides.

❖ Post-emergent herbicides (selective)

There are currently two post-emergent herbicides registered for use in a poplar crop.

a) Clopyralid

Lontrel 360, with the active ingredient clopyralid (Appendix Q-1), was approved for registration by the PMRA on the 4th of May 2006. This information can also be located by accessing the label-search [Web-PMRA Labels].

Lontrel 360 controls several broadleaf species such as Canada thistle, wild buckwheat and volunteer alfalfa. The herbicide can and does affect some hybrid poplar clones and the effect can differ substantially from clone to clone. Any impact will be temporary. The product label states this in the form of a warning:

"Poplar clones/hybrids vary in their tolerance to Lontrel 360 Herbicide. Injury observed includes leaf injury, leaf cupping (Photo 7-4), stem twisting, height reduction and diameter reduction. As not all clones/hybrids have been tested for tolerance to Lontrel 360 Herbicide, use of this product should be limited to a small area of each clone/hybrid to confirm tolerance prior to adoption as a general field practice."

By controlling these weeds, the impact can be quite dramatic (Photo 7-5). The maximum labelled rate of this herbicide is 0.83 L/ha of product, applied once per year. This rate worked fine for the poplars in Photo 7-5, where they show no ill effects, but may be too high for other poplar clones.

For instance, the rate of 0.42 L/ha was reported effective in one trial to control weeds without impacting the poplar clone. In a few other cases cupping of leaves and loss of stem turgor was reported at 0.56 L/ha and higher for some clones. It was also observed that young poplar stems started to grow horizontally for a while and lay flat on the ground. All these symptoms disappeared over time and normal growth resumed. To avoid these symptoms, it is strongly recommended to do some testing by clone before applying this herbicide at a larger scale.

Fabio Achinelli, Argentina

Photo 7-4: Clopyralid response in a poplar in Argentina in 2004.

Cupping in leaves of an eastern cottonwood. These symptoms occurred on 6 months old and one-year old poplars. Damage was temporary without a lasting impact on height growth.

There are clonal differences in the way poplars react to clopyralid and testing prior to applying on an operational scale is strongly recommended.

AAFC-PFRA Shelterbelt Centre

Photo 7-5: Trial with clopyralid at a PFRA trial site near Indian Head (SK).

Height growth increased dramatically after thistle control treatment with Lontrel.

The rate of 300 gr/ha of the active ingredient clopyralid is the equivalent of 0.83 L/ha of product, which is the maximum application rate per year.

b) Fluazifop-P-butyl

Venture L, with the active ingredient fluazifop-P-butyl (Appendix Q-1), controls annual and perennial grasses. This herbicide can be safely applied 'over-the-top' of actively growing poplars. It is only effective on grasses and does not affect broadleaved species, bluegrass species or sedges.

The maximum labelled rate is 2 L/ha of product; it can only be applied once a year. Although it does not kill quackgrass outright, it will provide season-long control. It is important to apply Venture L at the right developmental stage of the grass. This information can be found on the label (Appendix Q-1).

The label also lists lower application rates for several weed species.

For additional information please see:

[Web-SAF Crop Guide]
[Web-MB Crop Protection]
[Web-Blue Book]
[Web-Greenbook] – Note: The Canadian content may not always be accurate.
[Web-PMRA]

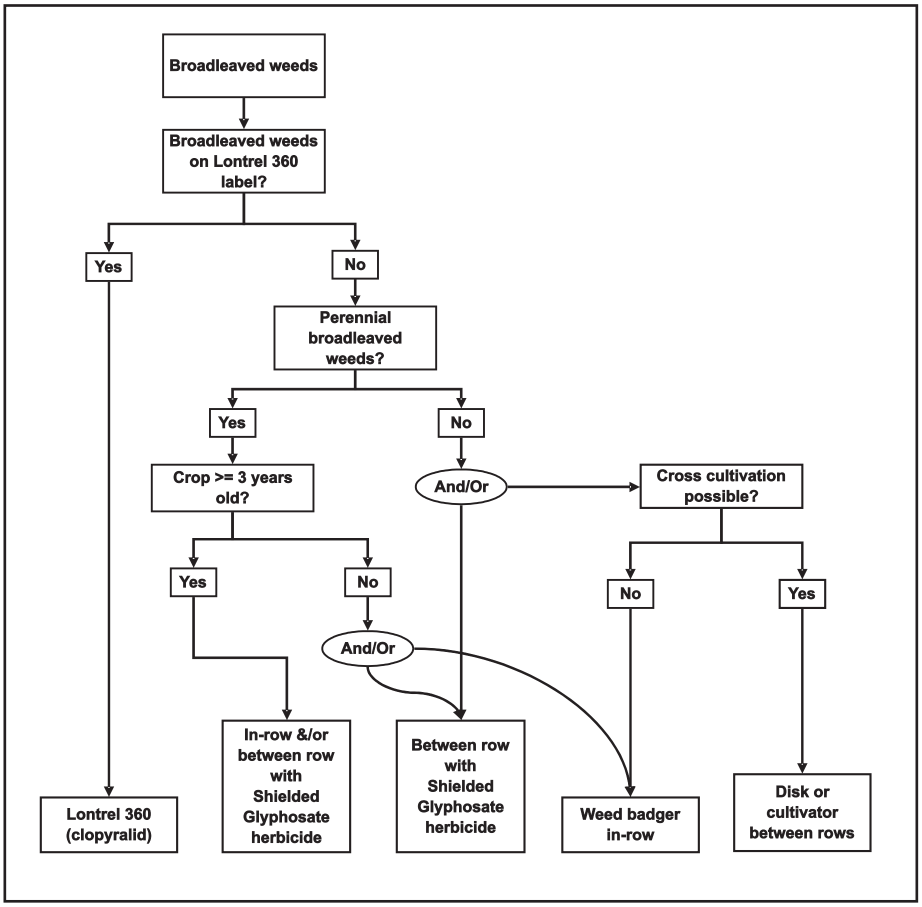
7.1.7 Weed control – choice of methods

The choice of weed control method(s) depends on the primary weed types (broadleaved or grassy weeds), the classification of the weeds (perennial, annual [see Module 7.1.3], the herbicide(s) used, age and layout of the crop.

❖ Broadleaved weeds

To control broadleaved weeds, there are two post-emergent herbicides available: Lontrel 360 (clopyralid) and various glyphosate-based herbicides (Appendix Q-1). Figure 7-2 is a decision flowchart to assist the farmer in choosing the weed control approach for broadleaved weeds.

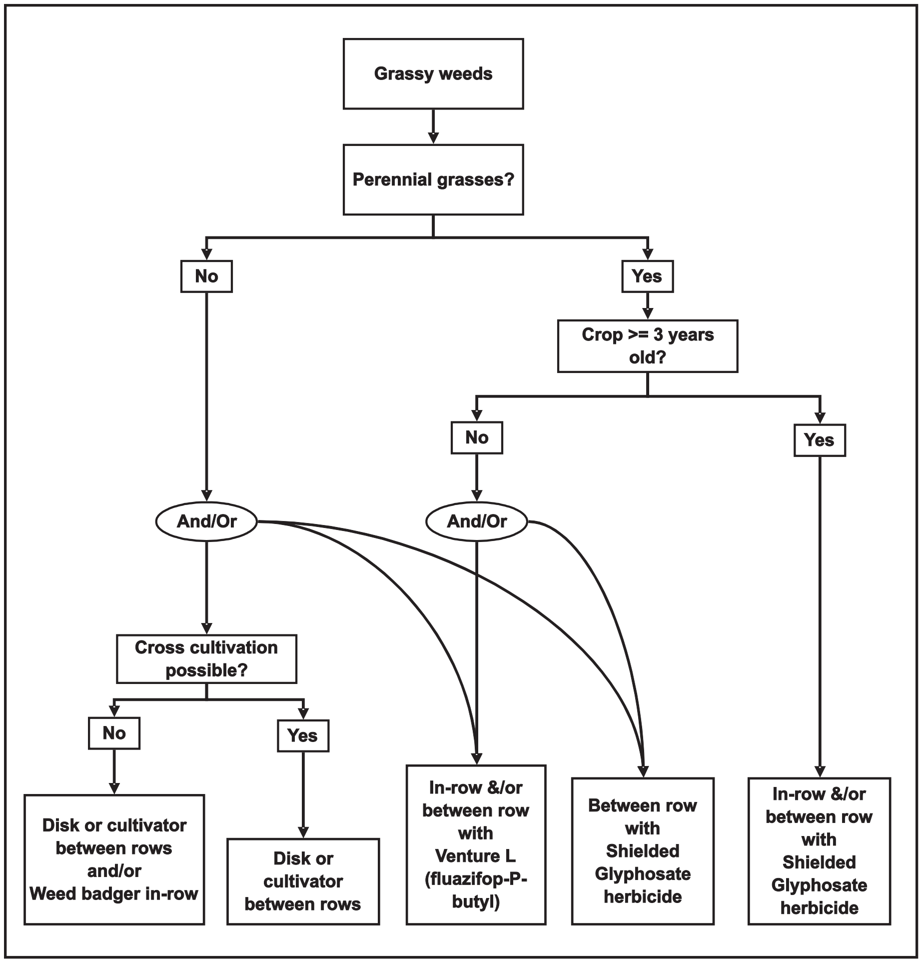
Figure 7-2



❖ Grassy weeds

For control of grassy weeds, there are also two post-emergent herbicides available: Venture L (fluazifop-P-butyl) and various glyphosate-based herbicides (Appendix Q-1). Figure 7-3 is the decision flowchart for grassy weeds.

Figure 7-3



In both situations the glyphosate-based herbicides must be applied in a shielded or directed spray to avoid damaging or killing the crop.

7.1.8 Herbicides – methods and equipment

❖ Post-emergent herbicides (non-selective) – glyphosate-based

The post-emergent (non-selective) glyphosate-based herbicides for use in a poplar crop (Appendix Q-1) can damage or kill the crop when the spray hits green bark or foliage. These herbicides should be applied with shielded sprayers only. The product labels also mention use of wick applicators to control where the herbicide gets applied. However, their use poses a substantial risk to young trees due to the high concentration of glyphosate used with these applicators and the likelihood of accidentally touching the tree bark or foliage. At these high concentrations the trees will succumb.

a) Timing of application – before the 1st week of August

The timing of application of glyphosate-based herbicides is important. These herbicides should not be applied after the first week of August. After this date the trees in the Prairie region become extremely susceptible to glyphosate-based herbicides, as the herbicide starts to translocate to the root systems where it inhibits critical growth processes, leading to severe damage or death.

Poplars can also be at risk from drift of glyphosate-based (and other) non-selective herbicides. The farmer should discuss the risk of spray drift with any neighbours planning to apply non-selective herbicides nearby.

b) In-row use

In-row use of glyphosate-based herbicides should not take place till the third year and should only be applied with shielded spray equipment.

c) Between row use

Between row use of glyphosate-based herbicides can take place from year one, but should also be applied with shielded spray equipment. When using the Enviromist® sprayer (Photo 7-9) with the rear-mounted 'Spraydome', between row use can continue beyond the 1st week of August.

❖ **Post-emergent herbicides (selective)**

The registered post-emergent (selective) herbicides for use in a poplar crop (Appendix Q-1) can be applied 'over-the-top' or in a directed application; however, caution is needed when applying Lontrel 360 (clopyralid) as discussed previously [see Module 7.1.6].

a) Timing of application

The success of Lontrel 360 (clopyralid) and Venture L (fluazifop-P-butyl) depends on the developmental stage of the targeted weeds. This information can be found on the product labels.

b) Fluazifop-P-butyl (Venture L) vs. glyphosate-based herbicides

In general, the effectiveness of fluazifop-P-butyl (Venture L) in controlling creeping perennial grasses such as quackgrass is not as good as that of glyphosate-based herbicides. The main advantage is that Venture L can be applied 'over-the-top' without any detrimental impact on the trees. When the trees are older and in-row shielded application of glyphosate-based herbicides becomes practical, their use will be more cost effective. This is reflected in Figure 7-3.

❖ Sprayers

a) Common shielded sprayers

There is a variety of shielded sprayers that can do the job in a shielded application. Most are assembled by farmers from existing spray equipment with an ingenious array of shields or skirts; these are simple and usually cheap to make (Photo 7-6 and Photo 7-7).

Labelled rates for glyphosate-based herbicides with a formulation of 356 gr/L of acid equivalent, such as Vision Silviculture Herbicide (PCP# 19899) and Vantage Forestry Herbicide (PCP# 28884), are 3-6 L/ha of product in a directed or shielded spray [see Module 7.1.6]. This gets delivered in 100-300 L/ha of water, according to the label.

Jake Eaton, OR

Photo 7-6: Shielded sprayer for use inside a poplar crop in Minnesota.

Cees van Oosten, B.C.

Photo 7-7: Shielded sprayer for use inside a poplar crop in Ontario. A real simple, cheap but effective shield for application of glyphosate-based herbicides.

Cees van Oosten, B.C.

Photo 7-8: The Enviromist® sprayer mounted on an ATV at the PFRA Shelterbelt Centre in Indian Head (SK).

This sprayer is equipped with the flexible apron on the side that 'wraps around' the stems of trees and protects them from being sprayed. The sprayer is mounted under the apron. The unit mounted behind the ATV is the 'Spraydome' (also dubbed the 'tub'), which covers the area between the tree rows.

b) Specialized shielded sprayers

Another more sophisticated shielded sprayer in use in several locations in North America and in the Prairie region is the Enviromist® (Photo 7-8), an Australian made sprayer [Web-Enviromist]. It uses a controlled droplet applicator (CDA), which is a rotary disc on which the herbicide is delivered creating droplets; it does not use pressure to produce these. This sprayer can deliver the herbicides more effectively and uses much less water.

A rate of 2.5 L/ha of product was reported as sufficient with the product delivered in a 9% solution (9 L of product in 100 L of spray solution) and thus uses only 28 L/ha of water. This is a real advantage and minimizes non-productive time. The other main advantages of this system are the lower herbicide use rate and the elimination of pressure to deliver the product, which minimize risk of drift.

The Enviromist® system was modified by a local contractor in Alberta, who has made several modifications to fit the work he is doing for Alberta-Pacific Forest Industries Inc. (Photo 7-9 and Photo 7-10) near Boyle (AB). The two 'Undavina' sprayheads mounted at the front of the tractor do the in-row spraying in three-year old and older poplar crops. The 'Spraydome', also referred to as the 'tub', is mounted on the 3-point hitch and is adjustable in width.

Cees van Oosten, B.C.

Photo 7-9: Enviromist® with the rear-mounted 'Spraydome' (dubbed the 'tub') with 2 spray nozzles is adjustable from a 1.5 m to 2.4 m width (5-8 ft). This sprayer works at Alberta-Pacific Forest Industries Inc. near Boyle (AB) and was modified by its owner to fit the job.

Cees van Oosten, B.C.

Photo 7-10: Two 'Undavina' sprayheads at the front for in-row spraying of 3-year old and older poplars. The width is hydraulically controlled. The 'Undavina' sprayers are designed for use in and around trees and other plantings and have a flexible apron that 'wraps around' and rolls around the stems. The contractor was working on an independent height control to enhance the protective features of the shielded sprayheads. Alberta-Pacific Forest Industries Inc. near Boyle (AB).

7.1.9 Mechanical weed control – methods and equipment

There are several implements that can be used for mechanical weed control. The effectiveness of each piece of equipment depends on the status of weed control and the spacing and layout of the crop.

- **Mowing**

a) Maintaining ground cover

Mowing is used when the farmer wants to maintain ground cover with the use of a cover crop between the tree rows (Photo 7-1). This is a viable option in cases where soils are at risk of erosion or when the farmer opts for zero till or wants to avoid use of herbicides. It is important to realize that the roots of the trees will spread out wide, even in the first growing season. They will quickly occupy the soil between the tree rows and any below ground competition from weeds or a cover crop will negatively impact the trees' performance. Mowing weeds or a cover crop does not eliminate this below ground competition and will impact tree growth negatively.

Cees van Oosten, B.C.

Photo 7-11: Newly established poplar farm near Pleasantdale (SK) requiring salvage.

Site prepared and planted in spring 2004 with 'Walker' and 'Northwest' at 2.4 x 2.4 m (8 x 8 ft.) square spacing, which is narrow; the planting stock was sub standard; many trees suffered dieback. Subsequent cultivation destroyed a fair number of trees due to the narrow spacing.

The remaining trees are healthy and are in need of immediate weed control; many of the weeds are perennial. Mowing first is recommended to 'set up' the weeds for a subsequent shielded spray with a glyphosate-based herbicide.

Cees van Oosten, B.C.

Photo 7-12: Poplar clonal planting near Birch Hills (SK) beyond salvage in early July 2005.

Site prepared and planted in the spring 2002, replanted spring 2003 and again replanted in the spring 2004.

Little or no effort was made to control the weeds. This crop is beyond salvage.

b) Crop salvage

Mowing is also a good method to 'set up weeds' for subsequent control with herbicides. It is the first step in salvaging a crop that has not been weeded. This can happen when soil conditions are too wet to allow equipment access and traction, or when the farmer simply missed the weed control window (Photo 7-11).

Since weeds quickly grow out of their most sensitive developmental state for effective control with herbicides, mowing can set them back in their development and make them more susceptible to herbicides. In some cases the crop is beyond salvage (Photo 7-12).

❖ Cultivation

Many poplar farmers in Canada and the US have been using a disk to maintain their poplar crops. Offset tandem disks, mounted on the three-point hitch of a small tractor, have been working very well, especially early in the growing season; they are capable of breaking up competing vegetation (Photo 7-13 and Photo 7-14).

Peter McAuliffe, B.C.

Photo 7-13: Offset tandem disk used with a small orchard tractor (about 80 hp) to break up the weed growth in a poplar crop near Snohomish (WA). This disk is about 2.4 m (8 ft.) wide.

Peter McAuliffe, B.C.

Photo 7-14: Offset tandem disk used with a small Landini orchard tractor (about 80 hp). This unit is very compact and the features of the orchard tractor make it very maneuverable.

It sets up the ground for subsequent cultivation with a disk, cultivator (Photo 7-15), harrow or rotovator. It makes use of shielded spraying between the tree rows easier as the soil is levelled by cultivation. The use of a disk, cultivator or harrow is fast and efficient. The disadvantage of cultivation is that it encourages new germination of weeds, especially when cultivating into a wet period. This is where timing and integration with chemical weed control become important.

❖ Weed Badger®

When cross cultivation is not possible, in-row weeds are difficult and expensive to control, especially since in-row shielded spraying with a glyphosate-based herbicide is not recommended in crops that are less than three years old. This is where the specialized equipment, such as the 'Weed Badger®', can be used (Photo 7-16 and Photo 7-17). This equipment is used in orchards, vineyards and berry farms where cross cultivation is not possible. The weeding head is a rotary tiller that moves in and out of the tree row and rips up any vegetation it encounters. To appreciate how this machine operates, a video can be viewed on the Weed Badger®'s website [Web-Weed Badger].

This rotary tiller can be equipped with a (mechanical) sensor that makes it retract the tiller when encountering a tree. In small trees this sensor does not work and the operator controls the tiller's movement.

Cees van Oosten, B.C.

Photo 7-15: The result of good maintenance using a cultivator in May 2005. This crop was laid out with random in-row spacing, which restricts it to one-way cultivation only.

This is an R-3 crop of 'Walker' at Alberta-Pacific Forest Industries Inc. near Boyle (AB).

Cees van Oosten, B.C.

Photo 7-16: The rotary tiller is mounted on the side of the tractor and moves in and out of the tree row. This machine is located at Alberta-Pacific Forest Industries Inc. near Boyle (AB).

Cees van Oosten, B.C.

Photo 7-17: The operator controls the movement of the rotating tiller. This machine is actually working an R-1 crop at one of Alberta-Pacific Forest Industries Inc.'s poplar farms near Boyle (AB). Due to the small tree size, the operator controls the movement of the rotary tiller.

❖ Impact of cultivation on roots

During cultivation there is a risk of root damage. Poplars quickly occupy all the soil with fine feeder roots located just below the soil surface. Cultivation will cut into these as well, but any negative impact will be more than offset by the benefits of weed control. Fine feeder roots have a high turnover rate and thus a short life. Cultivation damage of feeder roots is therefore negligible.

To prevent damage to the coarse roots, cultivation should be as shallow as possible. Continued (shallow) cultivation will 'train' the coarse roots to stay deeper. Severe damage can result in roots sending up many suckers that will be hard to control. Once cultivation is completely halted for an extended period, coarse roots will start to occupy the uppermost soil layers as well. To keep the option open of future cultivation or of soil incorporation of urea fertilizer in the third, fourth or fifth growing season [see Module 7.2.6], without the risk of excessive suckering of the roots, periodic cultivation should be maintained.

7.2 Fertilization

Fertilization of non-irrigated poplar is an uncommon practice in North America. The need for fertilization has always been considered minimal on good soils. On more marginal soils fertilization with nitrogen (N) is reported to have had good results[6]. Where fertilization does take place, it has mainly been with nitrogen fertilizers; the use of the other macronutrients phosphorus (P) and potassium (K) is rare. This is in contrast to poplar fertilization in Europe, where P and K are used in addition to N[21].

SRIC poplar crops are monoclonal and a positive fertilizer response for one clone may well be absent in another, requiring development of fertilization regimes by clone or group of compatible clones in the future. Results of fertilization and symptoms of deficiencies that are presented in this Module must therefore be viewed with this in mind. More research work is needed to establish nutrient requirements and limitations for hybrid poplars under Prairie conditions.

7.2.1 Fertilization to improve the crop

Fertilization is done to correct nutrient deficiencies and to improve crop establishment and crop yield.

❖ **Nutrient deficiency**

Often nutrient deficiencies negatively impact yield without showing clear symptoms. A poplar may look normal, but is not growing to potential. This may be the case with poplars that have been fertilized with N only for instance. The foliage responds and becomes dark green, but there is no significant growth increase to justify the expense. The lack of response may be the result of other critical nutrients becoming limiting without the tree showing that something is out of balance. This is referred to as 'hidden hunger'. The only way to determine the nutritional status of the tree is to analyze the foliage. With the exception of determining soil pH, there is no established diagnostic method yet to link soil fertility to poplar nutrient management, such as in traditional agricultural crops. To achieve this requires a substantial amount of research into methodology and plant responses to fertilizers. A complicating factor is that there will be differences among poplar clones in their responses to fertilizers.

Sometimes the causes of visual deficiency symptoms in poplar can be identified and dealt with. When identification is more complex, foliar analysis is needed, followed by a fertilizer recommendation. Being able to correct visual deficiencies is a luxury the poplar farmer has with a multi-year crop that the annual crop farmer does not, as it is often too late to correct the problem in an annual crop when a visual deficiency is noted. However, it is better to know beforehand what is limiting, rather than finding this out when the trees show symptoms, as visual symptoms point to a serious level of deficiency and reduced growth.

6 Dickmann, D.I., and Stuart, K.W. 1983. The culture of poplars in eastern North America. Michigan State University Press, East Lansing. 168 pp.

21 Blackmon, B.G. (Page 344) - "Response of Aigeiros poplars to soil amelioration". Proceedings - Symposium on Eastern Cottonwood and Related Species, 1976, Greenville, MS. Edited and compiled by Bart A. Thielges and Samuel B. Land, Jr. Published by Louisiana State University.

7.2.2 Deficiencies – symptoms

Recognizing deficiencies is difficult. It takes experience to know what to look for and to be able to identify the cause(s). Some symptoms that look like a deficiency could in fact be the result of a leaf disease, insect damage or even spray damage.

Appendix V provides a description of symptoms as were observed in a greenhouse study[27] of trees grown in various solutions that each lacked one of the nutrients. Some of the information is augmented with observations by practitioners in the field.

❖ pH and soil fertility

Soil pH is the scale used to measure the acidity or alkalinity of the soil by determining the concentration of hydrogen ions in solution. The acidity or alkalinity of soil is measured in pH units, at a scale of pH 0 to pH 14; the neutral value is pH 7.

Distilled water for instance has a pH of 7.0 (neutral) as it does not contain any positively or negatively charged ions; i.e. it is pure water, without dissolved salts. With an increase in hydrogen ions in the soil, the acidity increases and the pH value decreases. From pH 7 to pH 0 the soil becomes increasingly more acidic; from pH 7 to pH 14 the soil becomes increasingly more alkaline or basic.

Chemical reactions in the soil depend on the chemical properties, the most important of which affecting soil productivity is pH.

The optimum pH range for poplar is pH 5.0 - 7.5, which is slightly acidic to neutral [see Module 1.1]. Table 7-1 shows an interpretation of the acidity and alkalinity classes and also identifies the best range for most agricultural crops. There are differences among hybrid poplar clones in their sensitivity to a different pH level. In some cases this influences nutrient availability, to which various clones react differently.

Table 7-1

Soil pH						
5	5.5	6	6.5	7	7.5	8
Strongly Acid	Medium Acid	Slightly Acid	Neutral	Neutral	Mildly Alkaline	Moderately Alkaline
Optimum range for hybrid poplar						
			Best range - most crops			

There are 16 essential nutrients required for plant growth and reproduction. Three of these are carbon (C), hydrogen (H) and oxygen (O), which come from the atmosphere and from water. The remaining 13 nutrients come from soil or from fertilizers; of these, six are referred to as macronutrients, which include the main macronutrients used in fertilization: Nitrogen (N), phosphorus (P) and potassium (K). The remaining seven are referred to as micronutrients.

27 Hacskaylo, J. Finn, R.F., Vimmerstedt, J.P. Deficiency symptoms of some forest trees. Research Bulletin 1015. Ohio Agricultural Research and Development Center. January 1969.

Soil pH influences availability of several nutrients, particularly phosphorus (P) and micronutrients. A high pH can cause deficiencies in P, iron (Fe) and Copper (Cu). Soil biological processes are also influenced by pH.

Prior to planting a poplar crop the farmer should take soil samples to determine soil texture, pH and the main macronutrients [see Module 1.1.7].

❖ Nitrogen (N) deficiency

Nitrogen deficiency is probably the easiest to recognize. There is a reduction in leaf size and the colour turns pale yellowish-green. The terminal leaves, which are normally the largest leaves with a dark green colour, remain small with a pale green colour. Growth is stunted and the tree crown looks open.

N deficiency also shows up when young trees are subject to severe weed competition, especially from some of the perennial grasses, such as quackgrass.

❖ Phosphorus (P) deficiency

Bob van den Driessche, B.C.

Photo 7-18: Phosphorus deficiency in poplar tree with symptoms most evident in older foliage. Several of the lower leaves show dead (necrotic) patches. The top leaves look normal.

In a P deficiency only the older fully grown leaves are affected; the terminal foliage remains healthy looking. The P gets re-allocated in the tree to the actively growing leaves. This causes a P deficiency in the older leaves. In young poplar trees the interveinal tissue (tissue between the veins of the leaf) starts to discolour to a bronze (bronzing) or yellow tint and progresses to the tissue dying and turning black (called necrosis) (Photo 7-18).

It can be a progressive problem as the trees continue to grow. The severe symptoms may show in some clones but not in others. Symptoms can also show up following fertilization with N alone, when it results in P becoming limiting. The fact that there are clones that do not show these symptoms does not mean that P is not deficient. It is therefore advisable to obtain foliar samples for analysis in the summer prior to a planned fertilization [see Module 7.2.5] the following spring.

Fertilizing with P leads to a decrease in the uptake of Cu and zinc (Zn), which in turn can result in a poor response to P. This was shown in Euramerican hybrid poplars and subsequently also in the Interamerican hybrids[31].

❖ Potassium (K) deficiency

Potassium deficiencies are sometimes difficult to distinguish from magnesium (Mg) and manganese (Mn) symptoms. The immediate area of tissue around the veins is green and the interveinal tissue is yellow. Without a proper tissue analysis it is hard to identify the exact cause of the symptoms. Photo 7-19 shows a poplar with a serious K deficiency. This tree was planted in a farm field where hay crops were harvested several years in a row without fertilization. It took foliar samples to determine the exact cause. In this case the deficiency was eliminated by fertilizing with liquid dairy manure (Photo 7-20). Liquid dairy manure contains high amounts of K and offers an opportunity when a dairy farm is nearby [Web-Soil amendments]. Prior to applying any manure, it would be advisable to have a nutrient analysis done.

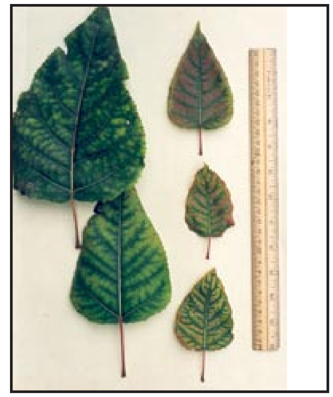
31 van den Driesssche, R. Influence of different levels of phosphorus, copper and zinc supply on growth and nutrition of a Populus trichocarpa x P. deltoides hybrid. Internal paper prepared for MB Paper Limited, Poplar Farms Division. 1997.

Cees van Oosten, B.C.

Photo 7-19: Potassium deficiency in an old hay field near Snohomish (WA). These R-1 trees showed serious deficiency symptoms. This tree was missed by the liquid manure application.

Cees van Oosten, B.C.

Photo 7-20: Potassium deficiency solved in an old hay field near Snohomish (WA). Trees continued to grow normally after the application of liquid dairy manure.



Bob van den Driessche, B.C.

Photo 7-21: Potassium and Manganese (Mn) deficiency after fertilizing with N and P (induced deficiency).

The large leaves on the left (L) are from a different clone than the small leaves on the right (R). The symptoms vary slightly, as a bronzing of interveinal tissue is visible in the one clone (R), but not the other (L).

Photo 7-21 shows K and Mn deficiencies in two different clones. Without foliar analysis the cause would have been impossible to identify visually.

❖ Iron (Fe) deficiency

Many soils in the Prairie region with a pH in excess of 8.0 may not be suitable for poplar crops. The high pH can lead to deficiencies as nutrients become insoluble and plants cannot readily extract them from the soil. A good example of this is iron (Fe) deficiency, caused by a high pH. Photo 7-22 and Photo 7-23 show the typical symptoms.

Cees van Oosten, B.C.

Photo 7-22: Clone WP69 (mother is Walker). The trees in the foreground show a high pH induced Fe deficiency. With a slight soil change (background), the trees look normal.

The location is the PFRA – Shelterbelt Centre near Indian Head (SK).

Cees van Oosten, B.C.

Photo 7-23: Clone unknown. The soil pH is 8.1, resulting in a Fe deficiency. A liquid ferrous sulfate solution, applied earlier in the growing season, could have saved this tree.

The location is the PFRA – Shelterbelt Centre near Indian Head (SK).

Although this condition can be alleviated for one growing season by a foliar application of a ferrous sulfate solution, maintaining this treatment for many years is costly and labour intensive and could probably only be justified in a nursery or stoolbed situation.

Bob van den Driessche, B.C.

Photo 7-24: Copper deficiency. Leaves are cupped and distorted. Some leaves show black necrotic tips. The top foliage looks normal; this tree has outgrown its Cu deficiency.

❖ Copper (Cu) deficiency

Copper deficiencies can be caused by a high pH. Symptoms are easy to recognize as it causes cupping and distortion of the leaves (Photo 7-24), necrotic leaf margins and tips, and reduced leaf size.

This is a common deficiency on more marginal soils. It strikes young trees; however, many trees tend to outgrow it. It has been reported[31] that there is significant interaction between P and Cu; there is little response to P in the absence of Cu, and vice versa. Fertilizing with P leads to a decrease in the uptake of Cu and Zn, which in turn can result in a poor response to P. More work is needed to determine if this interaction is of significance for the Prairie region.

7.2.3 Benefits of fertilization

❖ Mid to long term results

Most information on the benefits of fertilization is based on short term trials and typically on the response two to three years following application. Little is reported on the long term benefits of fertilizing poplars, such as an increased yield at the time of harvest. One French publication from 1947 reports increased tree heights and diameters after the 13th growing season from fertilizing with N, P and K in the second and third growing seasons[22].

A 2004 Canadian report on poplar growth response, following fertilization of trials on Vancouver Island in 1996 and 1997, concluded that there was a significant yield increase eight years following the first fertilization with N and P[23]. This was the age at which the poplars were scheduled for harvest. The addition of K did not result in any significant benefits. This report confirmed the findings of the 1998 analysis of the same trials, three year after fertilization[26].

In France, Euramerican hybrid poplars react favourably to fertilization with N and P, but negatively to K. In general the Interamerican group of hybrids does well with N, P and K[22].

A 1996 Canadian report also reported significant increases in growth of poplar in eastern Ontario four growing seasons after fertilizing at the start of the third growing season. Fertilization with N, P and K resulted in large growth increases[24] at age six. This was achieved on abandoned farmland with pH values between 7.8 and 8.2.

The good news is that favourable short term results of fertilizing with a balanced fertilizer mix will very likely result in increased yield at harvest. There are indications that poplars require additional nutrients besides N alone. It is less clear if these findings also apply to the very best soils, such as the rich black chernozemic soils that are common to the grasslands [see Module 1.1.3].

31 van den Driesssche, R. Influence of different levels of phosphorus, copper and zinc supply on growth and nutrition of a *Populus trichocarpa* x *P. deltoides* hybrid. Internal paper prepared for MB Paper Limited, Poplar Farms Division. 1997.

22 Soulères, G. 1992. Les milieux de la populiculture. Institut pour le Développement Forestier, Paris, France.

23 van Oosten, C., Zabek, L.M. March 2004. Response to Fertilization in SRIC Hybrid Poplar Plantations - Vancouver Island - Eight years after initial application. Forest 2020 / Greencover Plantation Demonstration Project, Project Delivery, Contribution Agreement 2003 – 2004.

26 Zabek, L.M. 2001. Nutrition and fertilization response: A case study using hybrid poplar. Ph.D. thesis. University of British Columbia.

24 Baldock, J.A., Burgess, D. 1996. Influence of fertilizer placement and form of nitrogen on growth of hybrid poplar at a site in Eastern Ontario. In. Proceedings of the Canadian Energy Plantation Workshop. Gananoque, ON 2-4 May 1995. J. Karau (eds). NRC, Ottawa, ON. Pp 67-71.

❖ More recent short term results

Based on the favourable results of fertilizing with both N and P in the third and fourth growing seasons on Vancouver Island, additional trials were undertaken to determine if fertilizer placement in the rooting zone at time of planting would be beneficial. The results showed significant growth improvements after the first year of placing a mix of mainly P with a little N near the rooting zone. The most promising and readily available fertilizer formulation was monoammonium phosphate (MAP) (See Appendix U for formulations). Additional N requirements can then be met just before canopy closure. The key conclusion was to concentrate and bury the P fertilizer in a band near or at the rooting zone, as P is quite insoluble and immobile in the soil.

Recent trials on old farmland in the boreal region of northwestern Quebec show similar positive results when fertilizing with both N and P[25] placed near the roots. Poplars planted on heavy clay soils were growing very slowly, resulting from poor initial root development due to the cold soils and heavy weed competition. Mechanical weed control to warm up the soil, and fertilizer placement in the rooting zone were considered important cultural techniques to promote faster establishment and growth. Although heavy clay soils are normally considered unsuitable [see Module 1.1.1, Table 1-1] for poplar, the results of this work show that good weed control and the use of N and P fertilizer can lead to favourable results in establishing poplars. Fertilizing with N alone had no impact; P alone resulted in a significant increase in diameter growth, and by adding N to the P fertilizer the diameter growth increased even more.

25 Guillemette, T., Desrochers, A. Fertilization and mechanical weed control of hybrid poplar plantations in the boreal forest, Québec. Université du Québec en Abitibi-Témiscamingue (UQAT). Presentation of MSc. research trials at the Poplar Council of Canada annual meeting in Vancouver, B.C., August 2004.

❖ Weed control

An important aspect in obtaining growth responses from fertilization is to ensure the standard of 90% or better weed control [see Module 7.1.2] can be met. Below-ground weed competition causes severe nutrient shortages and can lead to moisture deficits for the trees. Fertilization of a weedy crop primarily benefits the weeds, which are much better competitors than the poplars.

7.2.4 Foliar nutrient concentrations

Adequate levels of foliar nutrient concentrations in poplar are estimates based on several studies. These levels have been suggested as adequate to ensure fast growth. They vary by hybrid type[28] and also by clone. Nutrient concentration levels below which growth is less than 90% of maximum are called critical levels.

Table 7-2 provides a summary of published critical foliar nutrient concentrations and concentrations considered adequate for fast growth for a variety of poplars and hybrids[26]. The data were collected on trees aged from one to seven years. These values should be considered interim values. More work is required to improve them.

28 Hansen, E.A. A Guide for Determining When to Fertilize Hybrid Poplar Plantations. USDA, Forest Service, North Central Forest Experiment Station. Research paper NC-319. 1994.

26 Zabek, L.M. 2001. Nutrition and fertilization response: A case study using hybrid poplar. Ph.D. thesis. University of British Columbia.

Table 7-2

Nutrient	Critical foliar concentration (%)	
	Target	Range
N	3.00%	2.00% - 3.40%
P	0.33%	0.30% - 0.38%
K	1.50%	
Ca	0.63%	
Mg	0.15%	
S	0.50%	

The range of values seen for N is linked to the hybrid types. Hybrids with a European black poplar parent had critical values for N in excess of 3.0%, whereas hybrids with a black cottonwood or Japanese poplar parent had critical values for N ranging from 2.6-3.2%[28].

28 Hansen, E.A. A Guide for Determining When to Fertilize Hybrid Poplar Plantations. USDA, Forest Service, North Central Forest Experiment Station. Research paper NC-319. 1994.

7.2.5 Foliar sampling

When trees are growing well and generally meet growth expectations, there is no need to do any foliar sampling. If the farmer wants to know more about his crop and wants to find out if the trees suffer from 'hidden hunger' [see Module 7.2.1], he should consider sampling the foliage.

The foliar nutrient concentrations to be determined are for recently matured, full sun leaves. These are the newest, fully grown leaves of the tree and if there are growth issues as a result of deficiencies, these leaves should reflect that.

The time to collect is between the last week in July and the first week in August. The leaves to collect are the two to three fully expanded leaves from the top of the tree, usually four to five leaves from the top. For comparison reasons, it is important to keep the sampling position consistent among trees and years. For collecting, packaging, storing and transportation of foliar samples, see the example in Appendix W.

Several samples can be combined in a composite sample from several trees of the same clone in the same field. It is best to contact the lab before sampling to discuss a sampling plan and to determine which nutrients to check for. The values in Table 7-2 can be used for critical values.

7.2.6 Fertilization recommendations

The farmer should recognize that any of the following fertilization recommendations are based on experiences and procedures developed in other regions. Current local experiments with fertilizers have not yet yielded sufficient information to recommend a general fertilization practice, and the description of these recommendations must be viewed with that in mind.

Fertilization with N alone, without the addition of P and possibly K, has not yielded satisfactory results. If the foliar nutrient concentrations are close to the levels in

Table 7-2 there is no need to consider fertilization. The inherent problem is that we cannot collect good indicative foliar samples till the trees are at least two to three years old, while ‘hidden hunger’ continues to slow establishment and growth.

❖ Phosphate fertilizer (P) - banding at time of planting

When fertilization takes place at time of planting, deep placement or deep banding (i.e. buried) in or near the rooting zone of the trees is more successful and efficient than broadcasting. This has been shown in trials in B.C. For instance, in earlier trials triple super phosphate (0, 46, 0) was broadcast at 100 kg of P per hectare, which is 230 kg of P_2O_5 per hectare (multiply by 2.3) or 500 kg of fertilizer per hectare. Based on approximately 1100 spha (450 spac), this is 90 grams of P per tree, which resulted in a positive growth response.

In subsequent trials with deep placement in BC, rates of about 25 grams per tree of P proved successful. Similar results were obtained in Quebec trials. That is close to one quarter of the 90 grams per tree rate used when broadcasting 100 kg of P per hectare. Since phosphate fertilizer is highly insoluble and largely immobile in the soil, it is an advantage to place this fertilizer close to the tree roots and out of reach of the weeds. The use of monoammonium phosphate (11, 52, 0) proved very successful with little or no risk of tree roots getting damaged. The fertilizer was banded at the very bottom of the planting trench with a modified row marker (Photo 7-25).


Al Bertschi, AB

Photo 7-25: This row marker/fertilizer dispenser was developed on Vancouver Island. During row marking it deposits a continuous band of monoammonium phosphate at the bottom of the planting trench. Planting stock is planted right on top of the fertilizer.

This photo was taken at one of Alberta-Pacific Forest Industries Inc. near Boyle (AB), where it was tested for row marking.

The small amount of N in the monoammonium phosphate stimulates growth for the first two growing seasons. While not as effective as deep placement in terms of growth response and amount of fertilizer used, banding is easy to mechanize. It uses more fertilizer than deep placement, but less than broadcast.

The required (estimated) application rate of monoammonium phosphate (11, 52, 0) is 220-340 kg of fertilizer per hectare, which supplies between 50 and 75 kg of P per hectare.

❖ Urea fertilizer (N)

Additional N will likely benefit poplars when they are three to five years old and start to approach canopy closure. Foliar sampling should take place in the last week of July and first week of August [see Module 7.2.5] of the second growing season to determine any current or potential deficiencies. The effect of the small amount of N provided through the monoammonium phosphate (11, 52, 0) at time of planting will have worn off by then. If the macronutrient levels are still at or near those in Table 7-2 and no fertilization is planned, the foliar sampling should be repeated in the third and/or fourth growing season (using an extended pruning tool) to determine additional N needs.

The recommended amount of N is 150-200 kg of N per hectare, based on operational fertilizer experience. Urea (46, 0, 0) is a good fertilizer to use and at this rate it requires 325-430 kg of urea fertilizer per hectare.

The recommended application time is at the start of the third (or fourth, fifth) growing season. Urea fertilizer that is applied in warm weather will volatilize and it should be worked into the soil. It is best to apply the urea in a band between the tree rows (e.g. 1 m or 3 ft. wide) and disk it in right away. If a good rain fall follows the urea application, disking in the fertilizer is not needed.

For additional information please see:

[Web-AB Fertilizer]
[Web- Nutrition-1]
[Web-AB pH and Nutrients]
[Web-SK Fertilizer]

7.3 Pruning

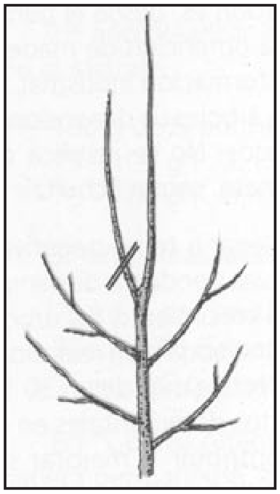


Figure 7-4: This tree is developing multiple leaders. The shaping and singling treatment removes one of the leaders to ensure this tree grows into a single stem.

Source:
3 Cultivo del Alamo [Populus spp.] Parte 2. Corporación Nacional Forestal, Chile. 1998

Pruning is the removal of branches, forks, multiple tops etc. This treatment is carried out for the following reasons:

a) To improve the shape and form of the tree during the establishment phase at ages one through three years. This is referred to as 'shaping and singling';

b) To create knot-free wood for the production of clear lumber or veneer. This treatment takes place in two to four lifts during the rotation when the tree diameter and tree height reach a certain size.

7.3.1 Shaping and singling

Normally poplars grow into a single stem with a single terminal leader, which exerts dominance over the branches. Should that leader be damaged or removed for some reason, one or more of the upper-most branches will take over the role as terminal leader, frequently resulting in multiple stems. In some cases one of these becomes dominant and suppresses the other; however, in other cases both leaders compete for dominance, causing potential quality problems later on. Shaping and singling corrects this problem and ensures that only one terminal leader remains, which will grow into a single stem (Figure 7-4).

Cees van Oosten, BC

Photo 7-26: This tree was never singled to one leader. Both leaders competed for dominance, which resulted in a failure following a wind event. Note the black surface area of the split; this is the result of decay.

(Vancouver Island).

Failure to remove this extra leader not only leads to a possibility of multiple stems, but also to splitting of the stem as a result of wind or snow pressure (Photo 7-26).

Many young trees also develop excessively heavy branches on the lower stem, which spread out over the ground, so called 'sweeper' branches, which frequently interfere with cultivation or spraying operations. They require removal in the first and/or second growing seasons. These sweeper branches will be hard to remove due to size later if left on the trees for too many years. It is best to remove them while they still have a small diameter.

Other branches that can be removed at this stage are the excessively heavy branches that may develop higher up the stem that will present a problem when pruning starts.

Shaping and singling should be carried out in late spring or early summer to ensure pruning wounds heal quickly and to avoid or reduce epicormic branching.

7.3.2 Pruning

Private landowners need to realize the maximum net value from their land. To accomplish this with an SRIC hybrid poplar crop, the maximum amount of merchantable wood needs to be grown in the shortest possible time to produce the highest net value per hectare. The amount of high value merchantable wood that can be grown depends not only on the crop density [see Module 4.1.2], but also on the creation of clear lumber and veneer grades through pruning.

Pruning is a standard practice in many countries where poplars are grown at low crop densities of 156-200 spha (63-81 spac). These densities are not recommended for the Prairie region. If the farmer is interested in producing lumber and veneer grades, the recommendation is to plant the crop at a maximum of 816 spha (330 spac), with a spacing of 3.5 x 3.5 m (11.5 x 11.5 ft.), or its equivalent in rectangular spacing [see Module 4.2.2]. This is a conservative crop density that allows the farmer some flexibility to produce not only saw log grades, but also wood for the OSB or pulp and paper industry. If the decision is made not to follow through on pruning, there are sufficient trees per hectare (acre) to produce a mix of lower grade saw logs, OSB logs and pulpwood, rather than just OSB and pulpwood grades.

If the farmer wants to produce larger log sizes and is prepared to follow through on pruning, the crop density could decrease to 625 spha (250 spac), with a spacing of 4 x 4 m (13.1 x 13.1 ft.), or its equivalent in rectangular spacing; intermediate crop densities would also be appropriate. A lower crop density results in a lower total volume; however, the proportion of merchantable wood increases and so does the value.

These recommendations are based on a recent review of hybrid poplar crop densities for the Prairie Provinces[30], which also concluded that pruning appears to be a good investment for crop densities of 897 spha (363 spac) and lower.

- **Pruning height**

The pruning height is determined by the lengths of saw log and veneer log grades.

Saw log and veneer log lengths

Saw logs and veneer logs are generally produced in imperial log lengths in North America, unless grades are developed for off-shore markets, such as Asia. Table 7-3 shows typical log lengths, including trim.

30 van Oosten, C. 200501 - Crop Density for Hybrid Poplar. Project 200501 - Saskatchewan Forest Centre, March 2006.

Table 7-3

Saw log lengths		
	Length, including 15 cm or 6 in. trim	
Sort	Metric (m)	Imperial (ft.)
8 ft. log	2.6	8.5
10 ft. log	3.2	10.5
12 ft. log	3.8	12.5
14 ft. log	4.4	14.5
16 ft. log	5.0	16.5

Veneer log lengths - Multiples of 4 ft. plus trim.
Most logs are produced in an 8 ft. log sort plus trim.

The pruning heights should therefore cover a combination of log lengths plus trim. Most logs will probably be in the 8-12 ft. log sort, which also accommodates the veneer log lengths. A plan to produce a 12 and 10 ft. log sort would require a minimum pruning height to 7 m (23 ft.). To compensate for a rough stump (this is where the sweeper branches were), it is advisable to add 0.3 m (1 ft.) for a total pruning height of 7.3 m (24 ft.). This decision can be made at a later date and will be influenced by the growth of the tree. Not all trees will yield a 12 and 10 ft. log sort; some will only produce two 8 ft. log sorts. It is a decision that needs to be made tree by tree during the 2nd and/or 3rd lift.

❖ Tree height and pruning

The objective of pruning is to create the maximum amount of clear, knot-free wood in a tree. The groundwork for pruning and quality improvements has been laid during shaping and singling [see Module 7.3.1], when sweeper branches lower down on the stem and excessively heavy branches higher up the stem were removed. The age at which to start pruning depends on the diameter and height of the tree. This will likely be around four to six years of age in the Prairie region.

a) Diameter

Pruning should start when the diameter at breast height (DBH) reaches 10 cm (4 in.) dob;

b) Height - 1st Lift

Pruning starts when the trees are approaching approximately 6 m (19 ft.) in height. As a rule of thumb, the 1st lift should not exceed 40% of that total tree height; in this case 2.4 m (8 ft.). This is a convenient height and pruning can be done with a variety of hand tools (Figure 7-5). At this point, excessively heavy branches that develop above this height should also be removed. Standards for pruning can be viewed in Appendix X.

Figure 7-5: Pruning tools for shaping and singling and for the 1st pruning lift.

Source:
3 Cultivo del Alamo [Populus spp.] Parte 2. Corporación Nacional Forestal, Chile. 1998

A candidate for pruning should have a straight and well-formed stem without any signs of diseases or scarring. If a tree is straight to a minimum height of 3 m (9.8 ft.), but shows bending or forking thereafter, consider pruning this tree to an 8 ft. log sort plus trim only.

c) Height - 2nd Lift

The 2nd lift requires pruning tools on an extension that can prune to a height of approximately 5 m (16 ft.). Total pruning height (1st and 2nd lifts) should not exceed 40% of total tree height. In some cases pruning to a greater height is possible depending on total tree height. It may be possible to prune to 5.2 or 5.8 m (17-19 ft.) to produce either two 8 ft. log sorts or an 8 and 10 ft. log sort.

A pole pruning saw is used when working this height (Photo 7-27). The pruner lifts the saw to its maximum height for that year (e.g. 5 meters or 16 ft.) and then moves the saw down the stem while cutting the branches. This way the weight of the saw can be supported by the still uncut branches below. Labour productivity for each lift will be about the same.

d) Height - 3rd Lift

A 3rd lift is required to produce any other combination of log sorts, such as two 10 ft. sorts, or a 12 and 10 ft. log sort. In that case another pruning system may be required, although experienced pruners can use a pole pruning saw up to 8 m (26 ft.).

Several poplar farmers in South America and Europe have built platforms, supported by a tractor on which one or two workers stand and prune to a height of 8 m (26 ft.) (Photo 7-28).

Cees van Oosten, B.C.

Photo 7-27: When pruning height is too high for hand tools, a pole pruning saw is used. Experienced pruners can prune to a height of 8 m (26 ft.).

Location: Company and El Alamo Agriculture and Forest Company in Chile.

Pruning in two lifts to 7 m (23 ft.) to produce two 3.2 m knot-free logs plus trim.

Cees van Oosten, B.C.

Photo 7-28: 'Mechanical' pruning with use of hydraulic lifts. Each bucket has controls to maneuver up and down and also partway around the tree. The tractor driver just controls the tractor speed. There are two such buckets mounted on the tractor.

Location: Company and El Alamo Agriculture and Forest Company in Chile.

❖ Time of the year for pruning

Pruning should take place in the late spring or early summer. This ensures the pruning wounds heal over fast and epicormic branching is reduced. Pruning in the dormant season is not recommended, as this induces epicormic branching due to high light levels in the early spring and the potential for disease. Pruning wounds also do not heal well and the open wounds become entry points for various diseases, such as Cytospora canker [see Module 9.1.3], which is a secondary fungal disease (Photo 7-29).

Cees van Oosten, B.C.

Photo 7-29: A pruned 'Walker' poplar at the Meadow Lake (SK) density trial.

Trees were pruned during the dormant season at the start of R-5 to recover branch cuttings for new planting stock. Pruning during the dormant season does not allow the wounds to heal properly and risks infection through the branch scars, especially lower down on the stem. This pruning wound was probably infected with Cytospora canker, caused by the fungus *Cytospora chrysosperma*.

The cut surface of the pruned branch is still visible.

For additional information please see:

[Web-Pruning PFRA]
[Web-Poplar pruning]
[Web-Poplar pruning 2]

MODULE 8: GROWTH AND YIELD

This module contains useful information on how to measure diameters at breast height (DBH), tree heights, determine tree volumes, plan and lay out surveys and inventories. This will be followed by a brief review of volume tables and yields.

8.1 Surveys and inventories

There are several surveys and inventories needed over the life of a crop. Surveys generally refer to the gathering of data and can be a simple walk-through or a more detailed sampling of crop performance, for which various measurements are taken, such as planting quality surveys [see Module 6.9] or survival surveys. The intensity of the survey depends on the accuracy of information the farmer wants to collect. With experience, many poplar farmers rely on a walk through crop assessment to know what is happening and only take occasional measurements. This Module will deal with the more detailed survey methods. Inventories refer to the measurement of trees to calculate tree volumes and this requires measurements of DBH and heights.

Any formal survey or inventory includes the following steps:

a) Determination of 'type', the survey or inventory unit;
b) The sampling plan - method of sampling;
c) Plot layout and sampling intensity
d) Sampling procedures
e) Compilation of the data
f) Interpretation of the results

8.1.1 'Types' – mapping of survey or inventory units

A good map forms the basis for the sampling plan. Normally a logical survey or inventory unit, which is called a 'type' equals the block or field. Sometimes it covers several blocks or even fields where crop conditions are similar (e.g. same survival rate, same growth rate etc.). Before the survey or inventory work starts, the farmer should have walked his fields a few times to determine where the crop conditions are fairly homogeneous. If that is the case, he can combine them in 'a type' for sampling purposes. If there are trouble spots and they amount to more than just a few trees, they should be identified on the ground and delineated on the map for special attention. A rule of thumb for size of these trouble spots is when they exceed 0.5 ha (1.2 ac.). If there are several of these, they can be combined into a second type with a separate sampling plan.

The reason for the 'typing' is to improve the sampling results. If two very different types are combined, sampling results will be unreliable and will not reflect the real conditions.

8.1.2 The sampling plan

The target number of trees to be sampled in a type should be approximately 60. This can either be done as 60 individual trees, spread evenly over the type, or in 20 '3-tree' plots [see Module 6.9.4]. The method of sampling in '3-tree' plots is recommended. At no point should the number of trees to be sampled drop below 45 (preferably in 15 '3-tree' plots), otherwise the sampling accuracy is suspect.

The target number of 60 sample trees is independent of the field size. The key to accuracy is to ensure the samples are evenly distributed throughout the entire type. This sampling plan works for planting quality assessment, which is done by field or block [see Module 6.9.4], survival surveys and inventories.

The sampling procedures described cover the '3-tree' plot system. A '3-tree' plot consists of three consecutive trees in the sampled tree row, with a pre-determined location in the row (e.g. row 19 and the 113th to 115th tree in the row).

8.1.3 Plot layout and sampling intensity

To ensure a good and accurate sample, the sampling must cover all parts of the type. The plot layout procedure identifies the tree rows to be sampled, starting from a randomly selected first row. The sampling design will also calculate the number of trees between '3-tree' plots. The first tree in the first randomly selected tree row is also randomly selected and ties in all the subsequent plots. The procedures described apply to all surveys and inventories, including the planting quality survey [see Module 6.9.4].

The steps to determine the sampling layout and intensity are listed in Table 8-1, which includes a numerical example in the two right-hand columns. Table 8-2 is a companion table to determine tree row selection for sampling that is used in Table 8-1.

Table 8-1

Step	**Steps to determine the sampling layout and intensity**	**Example**	
		Metric	**Imperial**
1	Determine the size of field, block or type (ha or ac.).	16.2	40.0
2	Determine the width (average) of field, block or type (m or ft.).	330	1,083
3	Determine the tree row spacing (m or ft.).	3	9.8
4	Calculate the average # of tree rows. Divide the width (Step 2) by the row spacing (Step 3), and subtract 1.	109	109
5	Use the Table 8-2 to determine which rows to sample.	8	8
6	Crop density planted (spha or spac).	1,111	450
7	Calculate the # of trees planted. Multiply the spha or spac (Step 6) by the hectares or acres (Step 1).	18,000	18,000
8	The target # of '3-tree' plots is 20 (60 trees).	20	20
9	Calculate the sampling intensity (One '3-tree' plot every so many trees). Divide trees planted (Step 7) by target # of '3-tree' plots (Step 8).	900	900
10	Calculate the # of trees between plots. Divide the above number of trees (Step 9) by the selected number of Table 8-2 (Step 5).	113	113

Table 8-2

Sampling layout and intensity		
# of tree rows		Sample every x^{th} row
From	To	
50	74	4^{th}
75	99	6^{th}
100	124	8^{th}
125	149	10^{th}
150	174	12^{th}
175	199	14^{th}
200	224	16^{th}
etc.		

The first row to sample is selected by random choice and should be between 1 and 4 for a sample every 4^{th} row, 1 and 6 for a sample every 6^{th} row, 1 and 8 for every 8^{th} row and 1 and 10 for any sampling intensity thereafter. The procedure to select the first tree in the first sample row is by a random number between 1 and 10.

8.1.4 Sampling procedures

Walk down the selected tree row and measure the first tree with its next two neighbours in the row; for example, plot #1 will be in row 8 and includes the 113^{th} to 115^{th} trees in the row. After the first plot is done, the farmer counts 113 trees past the first measured tree in this example and starts the measuring process all over again. When he finishes the row partway through the count, it gets completed in the next sample row, where he samples the next plot and so on.

❖ Planting quality

The planting quality measuring system was discussed previously in the 'Crop Planting' [see Module 6.9]. It uses the ploy layout procedures described above. Sampling for planting quality is restricted to each block.

❖ Survival survey

The main reasons behind survival surveys are to determine how the crop is doing after the fist growing season and to find outz if any replanting is required in case of a crop failure, or if any fillplanting is needed the following spring.

For survival surveys, the tree heights are recorded. When trees are missing or dead, the height and DBH fields are left blank. See Appendix Y for detailed instructions and Table 8-3 for an example, using the data from Table 8-1.

Table 8-3: Example of a survival survey

Table 8-3

Farm Name:	*Jones*		**Type #:**	A	**Trees Planted:**	18,000	
Farm Number:			**Field #:**	1&2	**# Plots:**	20	**P**
			Block#:		**Trees/Plot:**	3	
	Ha	**Ac.**			**Sample every:**	8	th Row
Total Area:	16.2	40.0			**Sample every:**	113	th Tree - **T**
Spha/spac pltd:	1,111	450.0			**Start with:**	7	th Tree in 1st Row

ROW #	PLOT #	TREE #	HT (m)	DBH (cm)	Volume m^3	Count dead or missing	Clone	Comments
3	1	1	0.95			12		12 dead in row 1
		2						
		3	1.05					
	2-19	4-57	VARIOUS			248		248 dead in 12 rows
107	20	58				10		10 dead in row 107
		59	0.90					
		60	1.30					
Total			61.80			270		
			C	D	E	F		

# of trees sampled:	**A**	60	Cannot exceed the highest tree #	
# of trees alive:	**B**	52		
% Survival:	**S%**	87	%	=(**A**/**B**) x 100
Average Height (HT):		1.19	m	**=C/B**
Average Diameter (DBH):			cm	**=D/B**
Average Volume per tree:			m^3	**=E/B** (inside bark/outside bark)
Spha survived:			/ha	**=spha planted** (top of form) x **S%**
Average Volume per Hectare:			m^3 per Ha	(inside bark/outside bark)
Extra - % Dead or Missing:		12	%	**=(F/(P x T)) x 100**
Occupancy %:		100	%	**=(# of Plots with 1 or more trees/P) x 100**

The form in Appendix Y and its example in Table 8-3 require tallying the dead and missing trees in each row that is sampled. This can be done at the same time. To help in this count, a mechanical counter is very useful; they are reasonably priced and are a good investment. Results are recorded in the ‘Count’ column. In the example row 3, the first row to sample, has 12 dead or missing trees, including the tree that was dead or missing in plot 1. This extra count of dead or missing trees provides additional information on tree mortality. When the typing for the farm is done correctly, the percentage mortality obtained through the count should be fairly close to that obtained through the plots. In this example the count recorded a mortality of 12%, while the plots recorded a survival rate of 87% and thus a 13% mortality rate. When the farmer encounters mortality in the row, he can observe if any mortality continues in adjacent rows or not. This is a good way of spotting and then mapping patches of dead or dying trees.

When the survival survey is done during the late winter or early spring, the trees are dormant and recognizing mortality takes a bit of experience. It is a good idea to carry out a survival survey in late summer or early fall of the first year, while leaves are still on the trees, and again during the following late winter or early spring. That way results can be compared and can identify if there was significant additional winter mortality. This information is needed to make decisions on fillplanting or re-planting [see Module 8.1.5]. Heights should be measured in 5 cm (2 in.) intervals for this first year’s survey; always round off to the lower value. The two surveys use the random start approaches described above; there is no need to measure the exact same trees.

It is a good idea to follow up with a third survival survey a few years after planting, for instance at age three or four. As trees will probably be 2-3 m (6.5-10 ft.) tall by then, a simple height pole would help in the process. A one or one-and-a-half inch PVC pipe is handy to use. Heights can be marked with a waterproof felt pen. This is a quick and easy method of measuring. Height measurements should be done in 10 cm (4 in.) intervals at this stage. It is easy to add a pole extension with a 'male/female' threaded coupler in case more height is needed.

❖ Inventory sampling

Inventory sampling is done to determine the volume of the crop. It follows exactly the same procedures as for survival surveys, except that tree DBH is also measured in order to calculate volumes. When trees are missing or dead, the height and DBH fields are left blank. See Appendix Y for detailed instructions.

Heights can either be measured or estimated. With some experience the farmer can measure the heights of one of the three trees in each plot and estimate the other two neighbouring trees, using the measured tree as a reference. Estimating 100% of the heights, without any height measurement, is not recommended. DBH should always be measured and never estimated; it is measured at a height of 1.30 m (4.3 ft.).

❖ DBH and height measurements

In Appendix Z, the user can find useful tips how to measure DBH and height.

The illustrations show some unusual situations and solutions when encountering trees that make measuring the DBH at 1.3 m (4.3 ft.) difficult. For DBH measurements the farmer can either use a caliper (see Appendix Z) or a DBH tape. The advantage of a caliper is that it is fast and convenient; the disadvantage is that it will be inaccurate in trees that are not perfectly round, unless two measurements are made perpendicular to each other. The DBH tape is slower, but more accurate. If a caliper is used, it should be used in a consistent manner for all the trees.

For height measurements when trees are from 0-3 m (0-10 ft.), the simple home made PVC height pole works best. When heights are 3-8 m (10-26 ft.), the fiberglass telescopic pole is a good tool; some even have tape readout. When using telescopic height poles, it is sometimes necessary to work with two people: one person to operate the pole and another to spot the height and to record. For greater heights, a clinometer is required (sometimes referred to as a hypsometer). These tools measure the angles to the tree top and bottom, from which heights can be calculated when the distance to the tree is known. This is explained very well in Appendix Z. Equipment to measure heights varies from the simple to use tool, such as the 'Suunto' clinometer, to the more pricey electronic tools that use lasers, sound etc.

Forestry equipment firms sell height poles and other survey equipment, including the 'Suunto' clinometer or other similar tools. To find suppliers, check the Internet and type in: 'forestry survey equipment'.

For additional information please see:
[Web-Forestry Equipment]

8.1.5 Mortality and fillplanting or re-planting

No fillplanting is required when mortality is evenly distributed throughout the crop and the survival rate meets the targets in Table 8-4. The extra count of dead or missing trees in the 'Count' column (Table 8-3) provides additional information on tree mortality and will help the farmer make a decision in case of serious tree mortality.

Table 8-4: Survival standards

Crop	Stems per hectare – spha	Stems per acre – spac	Survival target
Pulpwood and OSB	1,000-1,100	400-450	85-95%
Saw log	625-816	250-330	>95%
Peeler log	625-816	250-330	>95%

With the low crop densities for the production of saw logs and peeler logs, a higher survival rate is required than for pulpwood or OSB production.

❖ Distribution of survival or occupancy percentage

When survival rates drop below those listed in Table 8-4, the distribution of survival (or that of mortality) needs to be considered. This is referred to as 'occupancy'. Occupancy is defined as the number of survival survey plots ('3-tree' plots) that have one or more live trees in them and this is expressed as a percentage. The survival survey can theoretically have 20 '3-tree' plots, where each plot only has only one live tree. That is a 100% occupancy, indicating good distribution of live trees; however, only 20 of 60 trees planted survived, indicating a survival ratio of 1/3 or 33.3%. Although surviving trees are well distributed, the number of trees is too low for a profitable crop and fillplanting or re-planting is required.

❖ Distribution of mortality in pulpwood and OSB crops

When the survival rate is at 85% for a pulpwood or OSB crop, the crop is acceptable. The 20 '3-tree' plots would have 85% of 60 trees = 51 live trees. The maximum acceptable number of plots without any tree is three (17 plots at 3 trees = 51 trees). This is an occupancy rate of 85%, which indicates good distribution at the survival rate of 85%. This pulpwood crop is fine.

❖ Distribution of mortality in saw log and peeler log crops

A survival rate greater than 95% for a saw log or peeler log crop is required. The 20 '3-tree' plots would have 95% of 60 trees = 57 trees in them. The maximum number of plots without any tree is one (19 plots at 3 trees = 57 trees). This is an occupancy rate of 95%, which indicates good distribution at the survival rate of 95%. This crop is also fine.

❖ Survival % and occupancy %

When survival drops below 85% for a pulpwood crop and 95% for a saw log or peeler log crop, a decision needs to be made what action to take. The values in Table 8-5 are guidelines that can be used to make a decision to fillplant or re-plant.

Table 8-5: Fillplant or re-plant standards

Crop	Survival %		Occupancy %	
Pulpwood and OSB	<80%	and	<90%	Fill- or re-plant
Saw log	<90%	and	<95%	Fill- or re-plant
Peeler log	<90%	and	<95%	Fill- or re-plant

8.2 Volume tables and yields

8.2.1 Volume tables

Once DBH and heights are measured and recorded on the 'Survey and Inventory Form (Appendix Y), volume tables can be used to determine the tree volume. There is a choice volume tables; two provide volumes outside bark (Appendix O) and Appendix O-1) and one provides the inside bark volume (Appendix O-2).

Appendix O was developed by the Fast Growing Forests Technology Development Unit that was located in Brockville (On.) for hybrid poplar that was considered suitable for operational use; Appendix O-1 and Appendix O-2 were developed for Quebec by the Canadian Forestry Service (1986). These volume tables can be used for hybrid poplar grown in the Prairie Provinces until local volume tables can be developed.

In most cases the user would want to determine volume inside bark and will need to use the volume table in Appendix O-2.

8.2.2 Yields

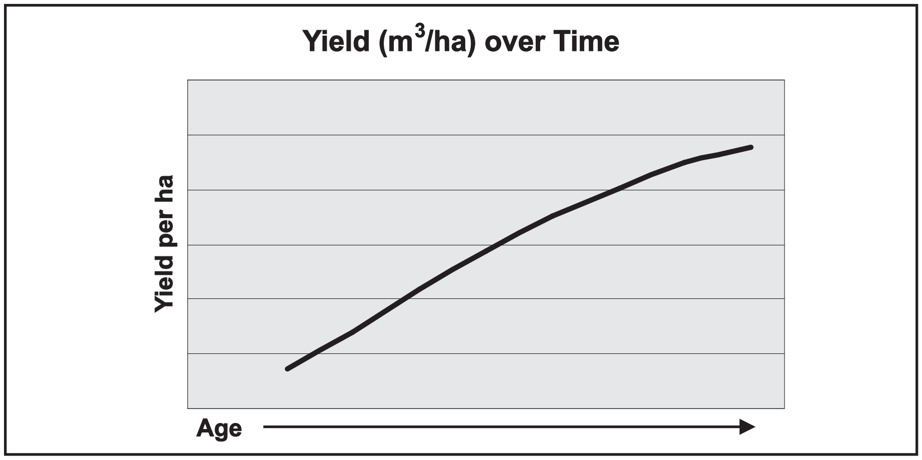
The information presented next should be viewed as a general description of hybrid poplar yield over time. The figures presented below are representative of how poplars grow and illustrate what happens over time.

A few new terms are introduced that are commonly used when discussing tree yields.

- **Yield**

Yield is the amount of volume grown per hectare during a rotation. The volume is expressed in cubic meters per hectare (m^3/ha). Figure 8-1 is a typical yield curve for hybrid poplar. It climbs slowly and then levels off.

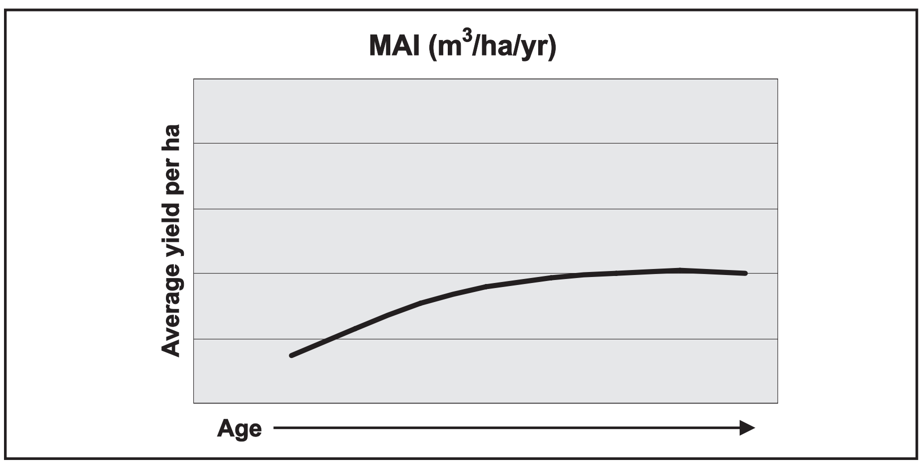
Figure 8-1



❖ Mean annual increment (MAI)

Mean annual increment or MAI is the yield divided by the years of the rotation. It is expressed as cubic meters per hectare per year (m^3/ha/yr). It is the average annual yield of the crop. For instance, if the total yield at the end of 20 years is 240 m^3/ha, the MAI is 240 m^3/ha, divided by 20 years = 12 m^3/ha/yr. That means the crop is growing an average per hectare of 12 m^3 per year over its 20 year rotation (Figure 8-2).

Figure 8-2

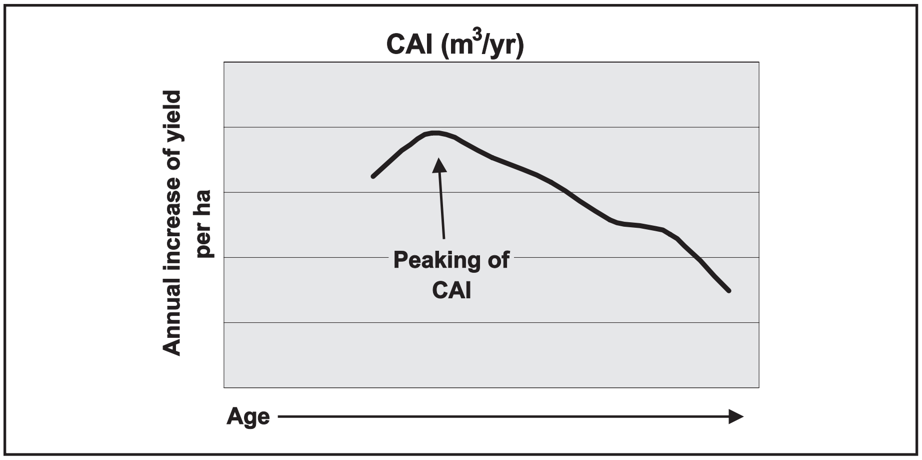


After a steady climb, the MAI curve levels off and starts a gradual decline towards the end of the rotation.

❖ Current annual increment (CAI)

CAI stands for current annual increment. It is the year-over-year increase of the volume per hectare and is expressed as m^3 per hectare, or m^3/ha. Year-over-year growth quickly accelerates and peaks early in the rotation (Figure 8-3) and then rapidly declines.

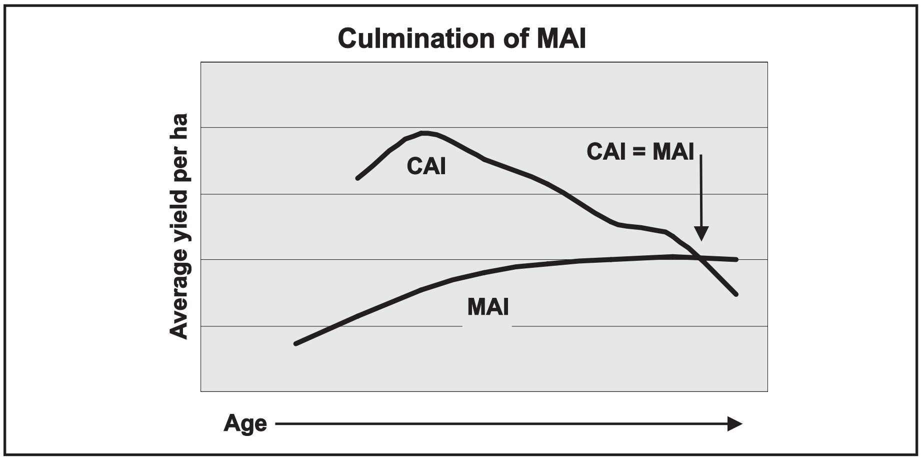
Figure 8-3



❖ Culmination of mean annual increment

Culmination of mean annual increment is where MAI and CAI are the same; i.e. when the year-over-year volume increase equals the average volume per hectare per year at that age. It is when the MAI is at its highest (Figure 8-4).

Figure 8-4



When culmination of MAI occurs, the farmer has the highest average yield of the rotation. Theoretically this is the point at which to harvest the crop; however, from a financial point of view this may not be when harvesting should take place [see Module 10]. The MAI curve past the point of culmination, when CAI = MAI, shows a very gradual decline. This gradual decline means that the farmer will not lose a significant amount of volume growth per hectare per year when he decides to leave the trees standing for a few more years. This is good news, as it allows the land owner some flexibility to schedule the harvest and possibly time it when prices are more favourable.

MODULE 9: DISEASES AND INSECTS

Prior to being released for operational use, hybrid poplar clones are screened for susceptibility to diseases and insect pests. Only clones showing sufficient resistance or tolerance to damaging organisms are released. Despite this procedure, it has been the experience that these organisms will in time develop the capability of overcoming a hybrid poplar's resistance or tolerance and become a problem. To manage this risk it is important to follow good clonal deployment guidelines [see Module 2.3].

Preventing problems is a better strategy than trying to combat them. To fight disease and insect problems with pesticides is at best a temporary measure; it does not make sense for a multi-year crop like SRIC hybrid poplar to rely on pesticides alone. A good clonal deployment method, and increased selection and breeding of new hybrid poplar clones on an ongoing basis will have to be the cornerstone of prevention.

There is general consensus among experienced poplar farmers and poplar experts that solving poplar disease problems is of a higher priority than solving insect problems for the Prairie region. With expected climate change farmers can expect new diseases and insect pests to show up with an expanding SRIC hybrid poplar crop base.

This module provides an overview of the main disease and insect pests affecting hybrid poplar and identifies several Websites where additional information can be found. In the event that unfamiliar diseases and insects show up, the Northern Forestry Centre -Canadian Forest Service in Edmonton can offer assistance identifying them. The contact is:

Greg Pohl
Insect and Disease Diagnostic Officer
Ph: 780 435 7211
Natural Resources Canada
Canadian Forest Service
Northern Forestry Centre
5320 – 122nd Street
Edmonton AB T6H 3S5

9.1 Diseases

As in many tree species and traditional agricultural crops, poplars suffer from a variety of diseases. The most serious diseases are those c aused by fungi and include stem cankers, leaf rusts, leaf blights and leaf spots. Of these the most important diseases are Septoria stem cankers, caused by *Septoria musiva* and leaf rust, caused by various *Melampsora* species[19].

A very worthwhile handbook on poplar diseases[34] can either be ordered in handbook form [Web-Poplar Diseases BC] or downloaded as a series of PDF documents [Web-Poplar Diseases BC-1] from the Canadian Forest Service – Pacific Forestry Centre Website. This handbook contains extensive descriptions and pictures.

19 Schroeder, W., Inouye, G. M. 2006 in Final project Report ADF project 200010048 - Hybrid Poplar Plantations for Farm Diversification in Saskatchewan (AAFC-PFRA Agroforestry Division).

34 Callan, B.E.. Diseases of Populus in British Columbia: A Diagnostic Manual. 1998. Natural Resources Canada, Canadian Forest Service, Pacific Forestry Centre, Victoria, BC. 157 p. (includes: colour illustrations).

9.1.1 Septoria leaf spot and stem canker

Septoria stem canker is the most serious poplar disease in North America. This disease is caused by the fungus *Septoria musiva*, also referred to as *Mycosphaerella populorum* [Web-Septoria-1]. It causes both Septoria leaf spots and Septoria stem cankers [Web-Septoria-2]. Although leaf spot is considered a serious leaf disease, the stem canker is the more problematic one.

Septoria stem cankers often result in stem breakage, leading to multiple tops, which in turn are susceptible to ongoing infection. In some cases the tree will never be able to outgrow the canker and repeated breakage leads to a tree that cannot be used for anything. The R-3 hybrid poplar in Photo 9-1 shows the start of a Septoria canker problem on its stem. The R-6 tree in Photo 9-2 has an advanced stem canker.

Cees van Oosten, B.C.

Photo 9-1: Clone NE207 in a New York State industrial poplar clonal trial for biomass purposes. This *Septoria musiva* stem canker is in its early development; it will seriously degrade this stem through increased risk of stem breakage.

Cees van Oosten, B.C.

Photo 9-2: Clone NE17 in an Ontario R-6 crop with *Septoria musiva* causing this stem canker. This canker is in an advanced state, seriously damaging the stem; this stem will break.

Septoria stem cankers have been present in the Prairie Provinces for some time and the disease was probably introduced with poplar stock imported from Quebec[33]. It has been causing stem damage in several trials in Saskatchewan and Alberta in susceptible clones. The symptoms are hard to distinguish from similar-looking Cytospora cankers, caused by *Cytospora chrysosperma* [see Module 9.1.3].

High crop densities of 800-1,000 spha (325-400 spac) or higher are considered conducive to the spread of this disease. It is reasonable to assume that decreasing crop densities will be effective in lowering the incidence of this and several other diseases and may be a sensible preventative strategy for susceptible clones.

This disease is not restricted to North America, it is also present in many parts of Argentina, where poplars are planted at much lower crop densities. The disease has been around as long as people have been planting hybrid poplars there as well, even tough poplars are not native to the southern hemisphere. The disease was probably imported from eastern North America. Many farmers there seem able to live with the disease (Photo 9-3) and are still able to extract good value from these trees.

33 Newcombe, G. 1996. The specificity of fungal pathogens of *Populus*. *In* Biology of Populus and its implications for management and conservation. Part I, Chapter 10. *Edited* by R.F. Stettler, H.D. Bradshaw, Jr., P.E. Heilman, and T.M. Hinckley. NRC Research Press, National Research Council of Canada, Ottawa, ON K1A 0R6, Canada. Pp. 223-246.

Jake Eaton, Oregon.

Photo 9-3: Old Septoria canker damage caused multiple tops in these irrigated hybrid poplars near Mendoza, western Argentina.

Crop densities range from 400-600 spha (160-240 spac) in this area. The trees are used for lumber production.

Curiously enough, the disease is absent west of the Rocky Mountains, despite the fact that much planting stock from Quebec and Ontario was imported to that region as well. The best defense against this disease is through selection and breeding of hybrid poplar clones from diverse parentage and probably by planting at reduced crop densities when using susceptible clones (Table 9-1).

Table 9-1

Clone	Disease Rating	Suitable for SRIC	Rating Codes
Brooks 6	2	X	1 = resistant, 2 = moderately susceptible, 3 = highly susceptible, for Septoria (*Septoria musiva*) stem canker and Melampsora (various *Melampsora* species) leaf rust diseases[19].
Hill	2	X	
Katepwa	2	X	
Northwest	2	X	
Walker	2	X	
WP-69	1	X	

19 Schroeder, W., Inouye, G. M. 2006 in Final project Report ADF project 200010048 - Hybrid Poplar Plantations for Farm Diversification in Saskatchewan (AAFC-PFRA Agroforestry Division).

There are a few fungicides registered in Canada to treat Septoria leaf spot on poplar and several more to treat Septoria leaf spot on other crops species. The labels do not identify which species of leaf spot this is. A good starting point to find out more is through the label-search [Web-PMRA Labels] website for easy access by product, active ingredient, PCP (Pest Control Product) number, manufacturer etc., or the more advanced search, where the user can type in the disease (e.g. type in the word Septoria and then search the label for 'poplar'). This website is maintained by the Pest Management Regulatory Agency (PMRA) in Ottawa. This information will point to the manufacturer or registrant, where the up to date product label can be accessed.

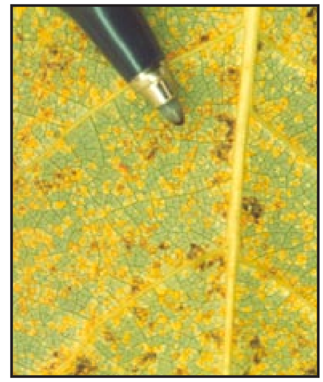
9.1.2 Melampsora leaf rust

Melampsora leaf rust is the most serious foliar disease in North America, including the Prairie region. There are several Melampsora species that cause this rust, with *Melampsora medusae* being the most prominent one in hybrid poplar in the Prairie region. This rust requires two tree species, called co-hosts, to complete its life cycle. Co-hosts include larch (tamarack) and various conifer species; the other co-host is the poplar. The rust spores are windblown from the conifer co-hosts to the poplars and infect them. The rust then overwinters on the fallen poplar leaves and in the early spring is windblown to the larch and conifer co-hosts, after which the cycle starts again.

The Melampsora rusts [Web-Melampsora] are easy to recognize (Photo 9-4, Photo 9-5), but it is much harder to distinguish between the various species of Melampsora rust. Rust infection starts mid summer and becomes progressively worse during the late summer and early fall. In some cases it can defoliate the tree (Photo 9-6) in the early fall.

Cees van Oosten, B.C.

Photo 9-4: Melampsora rust shows up as orange pustules on the underside of a leaf. This leaf is heavily infected.



Cees van Oosten, B.C.

Photo 9-5: The leaf is heavily infected with a Melampsora rust species. It is activating a defense mechanism by creating necrotic (dead) patches, which effectively cordons off the rust. When the infection becomes overwhelming, as in this case, the tree will completely defoliate in the early fall.

Cees van Oosten, BC

Photo 9-6: Melampsora rust can defoliate trees during a serious infection. On the right is a poplar that is resistant to this rust species.

This picture was taken in a natural black cottonwood stand on northern Vancouver Island in September 1991. The rust was *Melampsora occidentalis*, which is native to the west coast. All trees survived this rare epidemic.

This disease can cause major growth losses, especially when it starts to infect the trees in the early summer, followed by defoliation in August. The tree will be severely weakened going into the winter and may not survive the following growing season.

Close proximity to the larch and conifer co-hosts can result in an early infection date. When the disease infects poplars in a stoolbed, it weakens the stools and affects the health of the planting stock for next season [see Module-9.1.4].

There is great variation in susceptibility to this rust between various hybrid poplar clones. As with the Septoria leaf spot and stem canker, the best defense against this disease is through selection and breeding of hybrid poplar clones from diverse parentage and probably by planting at reduced crop densities when using susceptible clones (Table 9-1). The reduction of crop density is a strategy used by European poplar farmers to minimize the impact of leaf rust, caused by several other Melampsora rust species. It is one of the main reasons poplars are planted at very low densities (156-200 spha or 63-80 spac).

Oddly enough, there are no registered fungicides in Canada for the treatment of poplar Melampsora leaf rust.

9.1.3 Cytospora canker

Cytospora cankers are caused by the fungus *Cytospora chrysosperm*a, also known as *Valsa sordida*. These cankers do not occur on healthy and vigorous poplar stems, but need a stressed or damaged stem to invade. The fungus is considered a secondary pathogen that can nevertheless cause serious stem damage. It is considered a weak parasite that infects stems of stressed or wounded poplars. This disease often occurs at a young age and affects the lower stem of one or two year old poplars. Patches on the bark get a 'sunken' appearance and die. When many of these occur together, they girdle the tree, resulting in death. It is easily recognized in the spring and early summer. Tops are dying and new shoots are coming up from ground level. There is nothing that can be done at this stage, except maybe to cut off the damaged stem and prune back several of the new shoots (if more than one) to a single leader. This is referred to as 'shaping and singling' [see Module 7.3.1]. The cause of this is stress or damage during the winter and could be the direct result of the trees not getting into full dormancy before winter sets in. Some clones are more susceptible to this secondary disease than others.

The Cytospora stem cankers develop on young branches and stems and may resemble Septoria cankers [Web-Cytospora-1]. To distinguish between them takes experience and in some cases it is better to collect samples and send them to a lab to be analyzed. The cankers can occur anywhere on the stem and are frequently associated with stem and top breakage. When the tree regains its vigour, these cankers are outgrown by the tree; however, the wounds will be visible for some time.

Of particular concern are the Cytospora cankers that can result from pruning trees [see Module 7.3.2]. Pruning should take place in the late spring or early summer. This ensures the pruning wounds heal over fast and epicormic branching is reduced. Pruning in the dormant season is not recommended, as wounds do not heal and become easy entry points for various diseases, such as Cytospora canker, which is a secondary fungal disease (Photo 9-6).

Cytospora chrysosperma is also one of the so-called 'blackstem' diseases in poplar [see Module 9.1.4].

Cees van Oosten, BC

Photo 9-6: A pruned 'Walker' poplar at the Meadow Lake (SK) density trial.

Trees were pruned during the dormant season at the start of R-5 to recover branch cuttings for new planting stock. Pruning during the dormant season does not allow the wounds to heal properly and risks infection through the branch scars, especially lower down on the stem. This pruning wound was probably infected with Cytospora canker, caused by the fungus *Cytospora chrysosperma*.

The cut surface of the pruned branch is still visible.

9.1.4 Blackstem disease

Blackstem disease of poplar is caused by the secondary fungi *Cytospora chrysosperma* [see Module 9.1.3] and *Phomopsis oblonga*. These diseases can occur separately or together. Disease symptoms are very similar. Both diseases can also cause cankers like the Cytospora canker described earlier [see Module 9.1.3], but blackstem disease refers to the disease that occurs on unrooted and rooted dormant planting stock (e.g. cuttings) and in stoolbeds. The disease is mostly noticed after planting and is associated with damaged or stressed planting stock that has been in cold storage. It is therefore also commonly named 'storage' disease.

❖ Stoolbed conditions

Stress caused by shading in the stoolbed prior to harvest of whips is frequently the cause of 'storage' disease. In a dense stoolbed, some of the whips get suppressed and are shaded by neighbours. The stem of the suppressed whip has a light green to a yellow-green colour and a smaller caliper than its neighbours. Cuttings processed from these suppressed whips are predisposed to blackstem disease, which quickly infects the weakened stem.

This problem can be avoided by removing suppressed whips before or at harvesting time, i.e. before processing and packaging. If this is not done, it is unlikely that people processing the whips can recognize them as unfit.

When a serious leaf disease has affected the stoolbed the growing season before harvest, the stools will be in poor physiological state going into the winter. The harvested whips are stressed, but do not show the symptoms until stock processed from them is planted. Leaf diseases in stoolbeds can be avoided by planting resistant clones or by applying fungicides. In some cases the stools that were affected by a serious leaf disease the growing season before, either fail to re-sprout or are delayed in re-sprouting following the whip harvest. By the time this is discovered, it will be too late to recall the planting stock.

❖ Symptoms

The bark of the cuttings or newly planted stock turns a faint orange colour, after which it turns black (dead). Sometimes the cutting or tree fails to flush or the new shoot wilts and dies. The black surface of the stem or cutting has a 'sunken' appearance and is sharply delineated from the healthy part of the bark, which is still olive green. The bark surface shows pimple-like spots, which are the fruiting bodies of the fungus. Sometimes these black bark patches occur lower down on the stems or cuttings, but often they are located near the tip of the cutting. In some cases affected trees can outgrow the disease, but often the tree is already dying or dead.

There are no effective treatments for these blackstem diseases, as the diseases are caused by secondary fungi infecting an already weakened plant. The best strategy is to ensure the planting stock is in good physiological condition in the nursery and stoolbeds.

9.1.5 Venturia leaf blight or shepherd's crook

A common disease in young poplar is Venturia leaf blight or shepherd's crook, caused by the fungus *Venturia populina*. Humid conditions in the spring are very conducive to this disease. Spores are windborne and infect the trees. Raindrops can also splash the disease on to the foliage and stems and twigs from previously infected parts of the tree. The young shoots and leaves get infected, turn black and may die. The infected leaves get irregular necrotic patches that make them look crumpled. The necrotic patches on leaves and stems or twigs are sometimes partly covered by a moss-green velvety layer.

The bark of terminal leaders and the tips of branches gets infected, which frequently leads to tops or branch tips drooping like a 'shepherd's cook' [Web-Venturia-1], hence the name of the disease (Photo 9-7). When the entire tree is infected and the branches and leaders keep breaking, the tree will remain bush-like and could eventually die (Photo 9-8).

Cees van Oosten, BC

Photo 9-7: The leader of this R-1 tree is infected with Venturia disease, causing a wound on the stem which results in the stem bending over and eventually dying.

Cees van Oosten, BC

Photo 9-8: This tree kept getting infected by Venturia disease throughout the season. All the leaders and branches are infected and have broken, with some displaying the typical 'shepherd's crook'.

As with other diseases, the best defense against this serious problem is through selection and breeding of hybrid poplar clones from diverse parentage. This disease took on epidemic proportions in extensive hybrid poplar crops in northwestern Oregon and on northern Vancouver Island, causing major damage in the Oregon production clones. The disease is currently under control with the introduction of new hybrid clones that were screened for their resistance and tolerance. It has proven a fairly easy disease to overcome with a good selection and breeding program.

Although there are several fungicides registered in Canada for Venturia (scab) in apple and pear, none are registered for poplar.

The extent of cankering varies from clone to clone. Most cankers heal very well (Photo 9-9), others less so, resulting in risk of top breakage (Photo 9-10). These wounds can become entry points for secondary fungi, such as the blackstem diseases *Cytospora chrysosperma* [see Module 9.1.3] and *Phomopsis oblonga* [see Module 9.1.4], which can cause more serious cankers in the young stems.

Cees van Oosten, BC

Photo 9-9: This terminal leader has recovered well from a serious Venturia disease that caused extensive wounding of the stem.

Cees van Oosten, BC

Photo 9-10: This wound from the Venturia disease was severe, but it healed reasonably well, although there is still a risk of wind breakage.

9.1.6 Marssonina leaf spot

Marssonina leaf spot is caused by the fungus *Marssonina brunnea* and probably also by *Marssonina populi. Marssonina brunnea* also affects trembling aspen; *Marssonina populi* is specific to the eastern cottonwood, balsam poplar and black cottonwood [see Module I.4.1]. It is a serious leaf disease and can be a problem in nurseries and stoolbeds. The leaf spots are very small, angular in shape and dark in colour [Web-Marssonina-2]. When the leaf spots converge, they can form large necrotic (dead) blotches on the leaves. A distinguishing feature is that the disease also causes lesions on the leaf stems (petioles) and young stems [Web-Marssonina-1]; these are lens-shaped with a white centre.

The best defense against this potentially serious problem is through selection and breeding of hybrid poplar clones from diverse parentage.

There are several fungicides registered in Canada for the prevention and treatment of this disease, which is indicative of its seriousness in the nursery and stoolbed business. A good starting point to find out more is through the label-search [Web-PMRA Labels] website for easy access by product, active ingredient, PCP (Pest Control Product) number, manufacturer etc., or the more advanced search, where the user can type in the disease (e.g. type in the word Marssonina and then search the label for 'poplar'). This website is maintained by the Pest Management Regulatory Agency (PMRA) in Ottawa. This information will point to the manufacturer or registrant, where the up to date product label can be accessed.

For additional information please see:

[Web-Diseases BC]
[Web-PMRA]

9.2 Insects

Poplars are subject to a variety of insect problems. As with diseases, poplars are hosts to a very large number of potentially damaging insects. The most serious ones are the defoliators, shoot feeders and stem borers[35].

9.2.1 Defoliators

- **Cottonwood leaf beetle - CLB**

The cottonwood leaf beetle - CLB (*Chrysomella scripta*) is a major defoliating insect that occurs throughout southern Canada, including Saskatchewan[19]. It is a native insect and can have more than one generation per year; however, this is dependent on the climate. As the climate is forecast to warm, it can be expected that the CLB will have more than one generation, thereby increasing its damage. More information needs to be gathered about the impact this insect may have in the Prairie region.

The key to long term management of this pest is through an ongoing selection and breeding program. There do not appear to be any insecticides registered in Canada to prevent and treat this insect pest.

For additional information please see:

[Web- CLB-1]
[Web- CLB-2]
[Web-CLB-3]

- **Forest tent caterpillar - FTC**

The forest tent caterpillar - FTC (*Malacosoma disstria*) is a defoliating insect that primarily affects trembling aspen. Balsam poplar is also reported to be susceptible to this insect. The impact of this insect on SRIC hybrid poplar crops is unknown; however, due to the abundance of trembling aspen near SRIC hybrid poplar crops, this insect needs to be watched carefully.

There is a biological insecticide registered in Canada to fight this insect. It is based on the species *Bacillus thuringiensis* (sub-species *kurstaki*) and it is most effective against young caterpillars; it does not control adult moths. There is one other insecticide that lists this insect on its label; however, it is only registered for shelterbelt use. A good starting point to find out more is through the label-search [Web-PMRA Labels] website for easy access by product, active ingredient, PCP (Pest Control Product) number, manufacturer etc. This website is maintained by the Pest Management Regulatory Agency (PMRA) in Ottawa. This information will point to the manufacturer or registrant, where the up to date product label can be accessed.

For additional information please see:

[Web-FTC-1]
[Web-FTC-2]
[Web-FTC-3]

35 Mattson, W.J., Hart, E.A., and Volney, W.J.A. 2001 Insects pests of Populus: coping with the inevitable. In Poplar Culture in North America. Part A, Chapter 5. Edited by D.I. Dickmann, J.G. Isebrands, J.E. Eckenwalder, J. Richardson. NRC Research Press, National Research Council of Canada, Ottawa, ON K1A 0R6, Canada. Pp. 219-248.

19 Schroeder, W., Inouye, G. M. 2006 in Final project Report ADF project 200010048 - Hybrid Poplar Plantations for Farm Diversification in Saskatchewan (AAFC-PFRA Agroforestry Division).

9.2.2 Shoot feeders

❖ Spotted poplar aphid - SPA

The spotted poplar aphid - SPA – (*Aphis maculatae*) is a sucking insect which can be a serious pest in young poplars. They feed on elongating shoots and expanding leaves of poplars. Due their high numbers and the many generations during the summer, the potential impact on young poplar trees can be very significant, especially in stoolbeds. The aphids have many natural enemies, such as lady bugs, parasitic wasps etc.). The use of broad spectrum insecticides should therefore be avoided. This pest needs to be closely monitored to determine its impact in the Prairie region.

The PMRA label search [Web- PMRA Labels] turned up one aphicide (pesticide that kills or control aphids) that has poplar on its label, but this is for ornamental poplars only. This website is maintained by the Pest Management Regulatory Agency (PMRA) in Ottawa.

There are probably differences of susceptibility among various clones and a good long term strategy is to select and breed resistant clones if this becomes a priority.

9.2.3 Stem borers

❖ Poplar borer

The poplar borer (*Saperda calcarata*) is a large beetle and a potentially serious pest. It is native to North America. It bores into the stems of young poplar trees with a diameter of around 10 cm (4 in.). The larvae burrow into the wood to make galleries, which weaken the stem. When they finally emerge as adults, they start feeding on the foliage.

Look for spots on the bark that exude sap and sap mixed with insect frass, which looks like narrow wood shavings. A stem weakened by this insect attracts diseases, such as blackstem disease (see Module 9.1.4]. The larvae are legless grubs with creamy-white bodies and brown heads; they can be up to 5 cm long (2 in.). It is reported that this insect occurs more in open crops than in dense ones. Damage to the wood is serious.

One insecticide is registered in Canada for wood borers and can be used on poplar and willow. This is for a bark treatment only. A good starting point to find out more is through the label-search [Web-PMRA Labels] website for easy access by product, active ingredient, PCP (Pest Control Product) number, manufacturer etc. This website is maintained by the Pest Management Regulatory Agency (PMRA) in Ottawa. This information will point to the manufacturer or registrant, where the up to date product label can be accessed.

For additional information please see:

[Web-Poplar borer-1]
[Web-Poplar borer-2]

❖ Poplar-willow borer - PWB

The poplar-willow borer - PWB - (*Cryptorhynchus lapathi*) is a weevil and is a damaging pest, not native to North America. It was introduced into North America from Europe. The borer occurs all across Canada. It attacks poplars, willows and alders, but not aspen. Although the species is reported to prefer two year old stems with a diameter greater than 2.5 cm (1 in.), the borers can also attack trees that are of merchantable size. This has been reported in eastern Oregon and coastal British Columbia with certain poplar clones (Photo 9-11).

Host trees are riddled with small holes and irregular bark splits from which white to yellowish, stringy and clumpy frass is exuded with tree sap. Wood shavings and boring dust accumulates at the base of the trees. The larvae are white, legless and grub-like and about 1.3 cm (0.5 in.) long.

There are indications that this pest prefers certain clones over others. Hybrid poplar clones with black cottonwood or eastern cottonwood parentage are preferred over those with European black poplar or Japanese poplar parentage [see Module I.4.1]. This bodes well for the potential to breed future hybrid clones that are resistant or less palatable. Damage to the wood can be considerable and in some cases the trees can die from a serious attack.

The same insecticide mentioned for poplar borers could be used for poplar-willow borer. It is registered in Canada for wood borers on both poplar and willow. It is a bark treatment only. A good starting point to find out more is through the label-search [Web-PMRA Labels] website for easy access by product, active ingredient, PCP (Pest Control Product) number, manufacturer etc. This website is maintained by the Pest Management Regulatory Agency (PMRA) in Ottawa. This information will point to the manufacturer or registrant, where the up to date product label can be accessed.

For additional information please see:

[Web-PWB-1]
[Web-PWB-2]
[Web-PWB-3]

Photo 9-11: Serious poplar-willow borer damage in an R-10 crop in the eastern Fraser Valley in British Columbia in July 2005.

This crop was planted at 3.0 x 2.8 m (10 x 9 ft.) or 1200 spha (484 spac). The farm was inadvertently planted to a mix of three clones, one of which was heavily infected with the poplar-willow borer.

MODULE 10: ECONOMIC ANALYSIS

The difference between an annual farm crop, such as canola, and a multi-year crop of hybrid poplar is that revenues for a multi-year crop are not generated in the same year that the (main) costs are incurred to establish the crop. The element of time has to be incorporated in the cash flow (the stream of costs and revenues). A dollar spent today has to be earned back by some income in the future. If a person has the option to invest his money in a savings account, that dollar will grow to a certain amount of money in the future, depending on the interest rate. To illustrate: $100 invested today at 4% interest (compounded) will be worth $148.02 in 10 years. If he decides instead to invest his money in a 10-year crop and spends $100 per hectare on the crop today, he will have to generate $148.02 at the time of the harvest in year 10 to have the same return on his money as if he had invested it at 4% with the bank.

For multi-year crops the future income from the crop needs to cover (at least) the costs of crop establishment. The complicating factor is that crop establishment starts today, but there will be crop maintenance activities taking place later in the crop cycle. How can the multiple costs be compared to the future revenue? The discounted cash flow (DCF) method is used to accomplish this.

10.1 Discounted cash flow method – DCF

The DCF calculates the present values (PV) of future costs and revenues, which is called the cash flow. All costs and revenues are discounted to the present, using an interest rate, called the discount rate.

How much is the anticipated crop worth today, based on what it will be in the future? The predicted cash flow (costs and revenues) is discounted to produce a PV. When the PV of all costs is subtracted from the PV of all revenues, the result is the net present value or NPV.

10.1.1 Time scale

In the DCF method all expenditures and/or revenues are assumed to occur at the end of the year in which they are incurred and/or received.

- **Year 0 – the present**

The present is referred to as 'year 0'. This is normally the year site preparation takes place, e.g. the summerfallow, followed by row marking [see Module 6.2]. Since year 0 is the present, $100 spent in year 0 has a present value (PV) of $100. The money spent is assumed to have been spent at the end of year 0, i.e. just before the first year of the new crop.

- **Year 1**

In 'year 1' planting takes place and the assumption is that the money is spent at the end of the year. The PV of $200 in year 1 spent on planting for instance, is the amount it is worth now, the present. Appendix AA shows PV's for up to 30 years at discount rates from 2 -10%. At a 4% discount rate, $1 dollar in year 1 has a PV of

$0.962 and the PV of $200 would be $200 x 0.962 = $192.40. If a 6% discount rate is used, the PV would be $200 x 0.943; at 8% it would be $200 x 0.926 etc. The higher the discount rate is, the lower the PV will be.

- **Year 2, 3, 4 etc.**

The same principles apply to the following years. If the farmer spends $50 on weed control in 'year 2', the PV at a 4% discount rate would be $50 x 0.925 = $46.25 (see Appendix AA).

10.1.2 Future costs and revenues

To complete the DCF analysis, the farmer needs to enter all future costs and revenues. Since the future cannot be predicted, no one knows what the costs will be several years from now, and even worse, no one can say anything about the price of wood 20 to 30 years from now.

To avoid the guess work, current cost and price information should be used. If the price of wood per m^3 delivered to the customer is $60 now, that is the price to use for the wood in 20 or 30 years. If several years from now the prices have changed, a new DCF analysis can be done with the new values.

The DCF method will not provide an absolute answer, but it enables a comparison of various alternatives for the land. The farmer may consider growing an SRIC hybrid poplar crop for a 20 year crop cycle, but he wants to compare that investment to the one of successive crops of canola, wheat, barley or forage (in a sensible crop mix). He can schedule all the costs, revenues for each of the 20 years, calculate the PV for each and then compare the NPV of the annual crops scenario to the NPV of the SRIC hybrid poplar crop. It is a method of ranking investment choices to determine which option provides the best possible return.

10.1.3 DCF form

To make the calculations as easy as possible, a DCF form can be used that is described in Appendix AB. The farmer can use this form or a format of his own choosing. The key to doing the calculations is to keep it organized and systematic.

Using the DCF form in Appendix AB, the following steps are needed:

1. Costs per hectare or acre are entered in the appropriate column and appropriate treatment for the year the cost is incurred. For instance, site preparation is normally entered in 'year 0'; however, if there are site preparation activities that take place just prior to planting, a portion of the costs can be entered under 'year 1'. The farmer can add years to the empty year fields if he anticipates future crop maintenance treatments, such as pruning for saw log or veneer logs. Eligible costs could be for activities to generate alternate revenue, for instance intercropping or fencing to keep cattle in etc.;

2. The harvest year needs to be identified;

3. Harvest and transport costs are in $/m^3. These need to be converted to $/ha (or $/ac), by multiplying the anticipated volume per hectare (ac.) with the $/m^3 harvest and transportation cost. These costs are entered under the 'Harvest Year' on the 'Harvest and transport' lines.

4. The total costs are added up by year and entered on the 'Total Costs' line.

5. Next enter the expected revenues by year on the appropriate revenues line (include revenues from other products or services). The harvest revenue is entered in the 'Harvest Year' column. Add the revenues by year on the 'Total Revenues' line;

6. Enter the discount rate that is going to be used;

7. Enter the corresponding values of the PV values from Appendix AA on the PV line;

8. Multiply the value for each year on the 'Total Costs' line by the PV value on the 'PV' line for that year and enter it for that year on the 'Present Value (PV) of costs' line; Do the same for the 'Total Revenues' line and enter on the 'Present Value (PV) of revenues' line;

9. Total the values on the 'Present Value (PV) of costs' line in the 'Total' field; do the same for 'Present Value (PV) of revenues' line;

10. Subtract the total from the 'Total' field of the 'Present Value (PV) of costs' line from the 'Total' field of the 'Present Value (PV) of revenues' line;

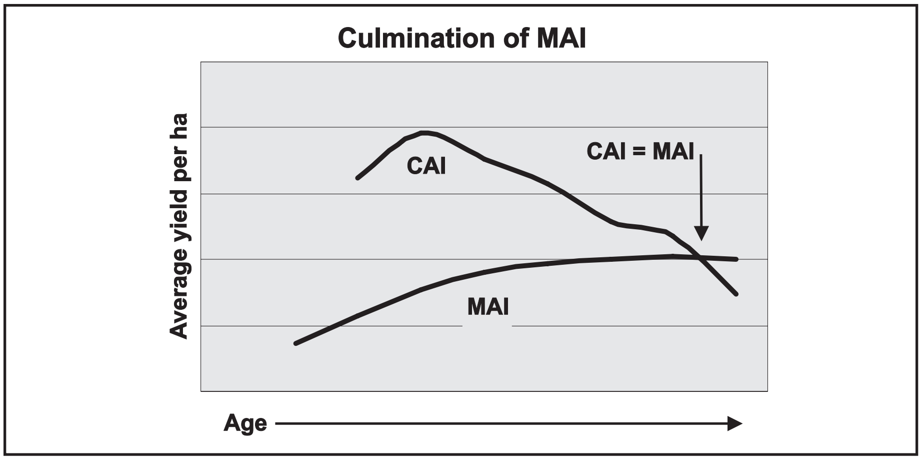
11. The resulting value is the NPV of the planned crop.

It is important to ensure the correct values from Appendix AA are used.

10.2 Culmination of mean annual increment

Culmination of mean annual increment [see Module 8.2.2] is where mean annual increment (MAI) and current annual increment (CAI) are the same. This is when the year-over-year volume increase per hectare, the CAI, equals the average volume per hectare per year, the MAI, at that age. It is when the MAI is at its highest (Figure 10-1) and, from a productivity standpoint, should be the time to harvest.

Figure 10-1



From a financial standpoint it is often more advantageous to harvest earlier, even though the total volume may be less. The longer the crop cycle is, the lower the PV will be. This is very sensitive to the discount rate. For instance, at the lower discount rate of 2%, the PV of one dollar of revenue in 'year 25' will be $0.610 (Appendix AA). With a discount rate of 8%, the PV of one dollar of revenue in 'year 25' will only be $0.146. This may still be OK, as long as the total PV of the revenue is high enough to cover the PV of all the costs incurred during the crop cycle (including the harvest and transport costs). This is the main reasons why farmers should try to maximize net value from their land, rather than total volume. To accomplish this with an SRIC hybrid poplar crop, the maximum amount of merchantable wood needs to be grown in the shortest possible time to produce the highest net value per hectare.

For additional information please see:

[Web-DCF calculator]; this is an interactive DCF calculator.

GLOSSARY OF TERMS

AAFC Agriculture and Agri-Food Canada.

See: Web-AAFC

Afforestation Afforestation: The establishment of a tree crop on an area from which it has always or very long been absent.

Source: Web-NRCAN

See: Reforestation

Agroforestry Agriculture in which there is integrated management of trees or shrubs along with conventional crops or livestock.

Ah Horizon Ah Horizon is the uppermost soil layer characterized by the following two features:

(1) A layer in which well decomposed organic matter is mixed with mineral particles.

(2) A zone of translocation from which eluviation has removed finer particles and soluble substances.

Source: Web- Soils glossary

See: Eluviation

See: Soil horizon

Annual (weed) A plant that germinates in the spring, sets seed in the same year and then dies.

A winter annual is a plant that germinates in the fall, survives the winter, resumes growth in the spring, sets seed in early summer and then dies.

See: Winter annual

Aspen Aspen is the common name for *Populus* species, such as *Populus tremuloides, P. grandidentata and P. tremula* (not native to North America) in the Populus section – formerly Leuce – (Aspens and white poplars). Hybrid aspen usually refers to the artificial interspecific hybrids of *P. tremuloides* and *P. tremula* or *P. davidiana* (Chinese or Korean poplar – which is considered a variety of *P. tremula*).

See: Interspecific hybrids

Bareroot stock Hybrid poplar plant grown in an outdoor nursery bed. The stock is usually started from an unrooted, dormant cutting, planted in the nursery bed. Cuttings form roots along the underground portion of the cutting. The resulting plant (shoot and root) is called bareroot or simply BR.

Biennial (weed) A plant that germinates in the spring of the first year, producing a rosette that survives the winter in a dormant state. It resumes growth in the second year, flowers, sets seed and then dies.

See: Winter annual

Biomass crop	A biomass crop using poplar or willow trees can be used for various purposes. The most common uses are to produce chips of wood, bark, branches, and leaves, and utilize them as a feed stock for power generation or the manufacture of chemical fuels, such as ethanol. Sometimes biomass crops can also be used to utilize municipal effluents or biosolids resulting from sewage treatment plants. See: Crop cycle
Block	Block is a sub-unit of a field. A block is planted to a single clone (monoclonal block). See: Field See: Monoclonal
BR	Bareroot stock See: Bareroot
Breeding	The process of developing plants or animals through sexual propagation. See: Hybridization
CAI	CAI stands for current annual increment. It is the year-over-year increase of the volume per hectare and is expressed as m^3 per hectare, or m^3/ha. See: MAI
Caliper	Caliper is the same as diameter; it is used a lot in planting stock standards. The diameters of small trees and unrooted cuttings are referred to as calipers. Calipers are measured using a 'caliper'.
Canopy	The uppermost layers of foliage in a forest. In this case the poplar crop. See: Canopy closure
Canopy closure	Canopy closure or crown closure is a stage in the development of a tree crop, where individual tree crowns start to touch each other, thereby shading the ground. This is also called crown closure. The timing of canopy closure depends of the distances between the trees, the age of the trees, the architecture of the individual tree crowns and the ability of the trees to compete with its neighbours. The farther apart the trees are, the later canopy closure occurs. In some extreme distances, canopy closure may not happen at all. See: Canopy

CEC

Cation exchange capacity is the capacity of a soil to exchange cations with the soil solution. Cations are atoms, molecules or compounds that carry a positive charge. CEC is often used as a measure of potential soil fertility.

Source: Modified from Web- Soils glossary

CFS

Canadian Forest Service, in particular the Northern Forestry Centre of the Canadian Forest Service in Edmonton, Alberta.

See: Web-CFS

Clonal crop

A hybrid poplar crop (usually) consisting of just one clone.

See: Monoclonal crop.

Clone

An individual or group of individuals reproduced asexually from a single organism, and therefore genetically identical to the parent. The word clone has a Greek origin and means "twig".

In poplar, an individual that originated from one 'mother' plant (not necessarily a female plant) by vegetative (asexual) reproduction, either naturally or by artificial propagation is sometimes also referred to as a ramet. Ramets taken from the same plant all belong to the same clone. Trees in the same clone carry identical DNA.

Genetically identical poplars are called a 'clone'. For instance the clone 'Walker' is a well-known hybrid poplar used for farm shelterbelts and is now also used to establish SRIC hybrid poplar crops in the Prairie region.

Source: Web-AFGRC

See: DNA

See: SRIC

Container

A container is a small pot filled with potting soil in which a seed is sown or a cutting or small plant is planted. When the plant is ready for outplanting, it is extracted from the pot and stored or planted in the field. For poplar the container is most often a stryrofoam block with a number of cavities filled with potting soil in which small dormant cuttings are planted. This is also referred to simply as styroblock. The plants can be extracted when rooted and are subsequently planted as a crop. The planting stock type is referred to as PSB, plug or container stock.

Container stock

Container-grown stock type.

See: Container

Coppicing

Coppicing is a method of managing woody crops, by which young tree stems are cut down to a low level. When this is done in the winter, many new shoots re-sprout and grow up.

See: Stool

Creeping perennial (weed)
A plant that survives for three or more seasons and, in that way, is similar to a simple perennial. However, a creeping perennial has a specialized method of vegetative propagation (rhizomes, stolons, budding rootstocks) in addition to seed production.

See: Simple perennial

Crop cycle
Crop cycle, also called rotation, is the length of time between crop planting and the final harvest. In the case of an SRIC hybrid poplar crop, this cycle varies with the crop type.

a) For biomass crops the crop cycle could vary anywhere from four to seven years; in some countries the cycle can actually be annual.

b) For a pulpwood crop the expected crop cycle or rotation would last from 15 to 25 years.

c) For a solid wood crop, such as saw- or peeler logs, the rotation varies from 20 to 30 years.

See: SRIC

See: Biomass crop

Crop maintenance phase
The crop maintenance phase starts once the newly-planted crop has broken dormancy and is actively growing. The establishment period (consisting of several years) and the time till harvest would be considered the crop maintenance period. Cultural treatments integrate the use of pesticides (mostly herbicides) with mechanical treatments to optimize weed control and crop protection.

Crop planting phase
The crop planting phase includes all management activities before (including row marking), during or after (post-planting) the actual planting. The post-planting period could last from several days to several weeks and ends when the newly-planted crop breaks dormancy.

Cross marking
The lay out of the tree rows is called row marking. To ensure a layout that allows for cultivation in two directions, cross marking takes place perpendicular to the direction of the row marking.

See: Row marking

Crossbreeding
The processes of breeding individuals or populations that possess different genetic makeups.

See: Hybridization

Crown lift When trees grow taller in a dense crop, the live branches on the lower part of the stems cannot be sustained due to lack of light. This process is referred to as crown lift. It is a naturally occurring process and varies from clone to clone.

This expression is also used to indicate the pruning of a tree to a certain height, called crown lift.

Cultivar Abbreviation for cultivated variety. A cultivar is a horticultural variety that is produced by selective breeding, rather than by natural selection, and continues only in cultivation (not found in the wild).

See: Variety

Cultivation Tillage or manipulation of the soil, done primarily to eliminate weeds that compete with crops for water and nutrients. Cultivation may be used in crusted soils to increase soil aeration and infiltration of water; it may also be used to move soil to or away from plants as desired. Cultivation among crop plants is best kept at a minimum; excessive cultivation can be harmful as it may cause root pruning and loss of soil water due to increased evaporation.

Source: Web- The Columbia Encyclopedia, Sixth Edition

Cultivator Agricultural implement that has blades or shovels that work up the soil without turning it over; it is pulled between rows of plants to kill the weeds.

See: Harrow

See: Cultivation

Cutting Unrooted stem or root section originating from a plant and used for vegetative (asexual) propagation. Cuttings are usually dormant when used.

Cuttings can either be planted to form the crop when they meet certain minimum size requirements, or be used as propagation material for bareroot nursery beds, stoolbeds or container-grown stock.

d/h ratio Diameter over height ratio of a standing tree. This is the diameter at breast height (DBH) in cm divided by the tree height in m (DBH/Height). For pulpwood crops the d/h ratio is typically 0.90 (0.85-1.00), depending on the age and development of the crop. The ratio should be higher for saw- or peeler log crops.

See: DBH

DCF Discounted cash flow. The discounted cash flow (DCF) method calculates the present values of costs and future revenues.
See: PV
See: NPV

DBH	Diameter at breast height. The height is at 1.30 m (4.3 ft.) and is at a convenient level for a person to measure the diameter of the trees. Tree volume calculations are based on this diameter. The measurements always include the bark. See: dib See: dob
dib	Diameters used for log specifications always exclude the bark; that is called 'diameter inside bark' or dib. See: dob
Dictionary	See: Web-Dictionary
Dioecious	A tree species having female and male sex organs on different plants. Poplars are dioecious. Source: Web-AFGRC
DNA	The material inside the nucleus of cells that carries genetic information. The scientific name for DNA is deoxyribonucleic acid. It is a large, double-stranded, molecule in the form of a helix that contains genetic instructions for growth, development, and replication. In poplar, trees of the same clone have the same DNA. The test for DNA is frequently called fingerprinting See: Clone See: Fingerprinting
dob	When the measurement of diameters includes the bark, it is called 'diameter outside bark' or dob. See: DBH See: dib
Eluviation	Eluviation is movement of humus, chemical substances, and mineral particles from the upper layers of a soil to lower layers by the downward movement of water through the soil profile. Source: Web- Soils glossary See: Illuviation
Epicormic branches	Epicormic branches develop from adventitious buds, which are latent or dormant buds located in the bark. In poplar these buds become active in response to increased light availability and subsequently grow into a branch, the epicormic branch. The sudden increase in light can be caused by pruning and thinning.

Euramerican hybrids Euramerican poplars are interspecific hybrids originating from crossbreeding North American female parents of Eastern cottonwood with European male parents of European black poplar.

See: [glos-Interspecific hybrids]
See: [glos-Crossbreeding]

Field A distinct management unit of a farm. A field can be managed as a stand-alone unit and is distinct from other fields by virtue of the boundaries (ditches, roads, windbreaks etc.). A farm can consist of one or more distinct fields.

See: Block

Field capacity The water remaining in a soil after the complete draining of the soil's gravitational water.

Source: Web- Soils glossary

Fillplanting The practice of fill-in planting of an existing poplar crop to replace dead or missing trees. This can be an effective treatment when replacing contiguous patches of dead or missing trees in a crop. It is usually done with dormant stock during the spring planting season.

Fingerprinting Fingerprinting in poplar is the DNA testing to verify the identity of a clone.

See: Clone

See: DNA

Fungus Spore producing organisms that feed on organic matter. Fungi (or funguses) include moulds, yeast and mushrooms. Many disease organisms in plants are fungi.

Gleysol Gleysol Soil is a soil order (type) of the Canadian System of Soil Classification. This soil type is found in habitats that are frequently flooded or permanently waterlogged. Its soil horizons show the chemical signs of oxidation and reduction. This process is referred to as gleying or gleyed.

Source: Web-Soils glossary

GMO Genetically modified organism or GMO is an organism that, through human intervention in a laboratory, has had its genome, or genetic code, deliberately altered through the insertion of a specific identified sequence of genetic coding material (generally DNA) that has been either manufactured or physically excised from the genome of another organism. Genetic modification may be used to alter any of a wide range of traits, including insect and disease resistance, herbicide tolerance, tissue composition and growth rate.

Source: Web-AFGRC

GPS	GPS is the acronym for Global Positioning System. It is a network of well-spaced satellites orbiting the Earth enabling people with receivers to pinpoint their exact location. This system is controlled by the US military, but is accessible to civilian uses, such as navigation, precision agriculture etc.
Growing degree days	The number of degrees that the average temperature is above a baseline value. Every degree that the average temperature is above a baseline value becomes a growing degree day. Used by farmers to predict the date that a crop will reach maturity.
Harrow	Agricultural implement with steel teeth or spikes; it breaks up clumps and smoothes out the soil. See: Cultivator See: Cultivation
Heterosis	Heterosis or hybrid vigour is the tendency of the hybrid to show qualities (e.g. growth rate) that are superior to those of either parent or parent species. This is the case with many hybrid poplars that not only exhibit superior growth, but frequently also superior resistance to pests and diseases. See: Hybrid vigour
Hotplanting	The practice of planting actively growing and rooted planting stock.
Hybrid aspen	Aspen plant (or group of plants) created by crossbreeding two closely related species of aspen.
Hybrid poplar	Poplar plant (or group of plants) created by crossbreeding two parents from closely related species of poplar (interspecific hybrids), or by crossbreeding two parents with a different genetic makeup within a species of poplar (intraspecific hybrids). A hybrid is designated by the ‘times’ (x) symbol. For instance, a hybrid between the balsam poplar (*Populus balsamifera*) and the eastern cottonwood (*Populus deltoides*) is written as *Populus balsamifera* x *P. deltoide*s; the abbreviation for this hybrid poplar cross is BxD or BD. The female parent is always listed first. See: Interspecific hybrids See: Intraspecific hybrids

Hybrid vigour

Hybrid vigour or heterosis is the tendency of the hybrid to show qualities (e.g. growth rate) that are superior to those of either parent or parent species. This is the case with many hybrid poplars that not only exhibit superior growth, but frequently also superior resistance to pests and diseases.

See: Heterosis

Hybridization

The processes of crossbreeding individuals or populations that possess different genetic makeups.

Source: Web-AFGRC

Illuviation

Deposition of humus, chemical substances, and fine mineral particles in the lower layers of a soil from upper layers because of the downward movement of water through the soil profile.

Source: Web- Soils glossary

See: Eluviation

Interamerican hybrids

Interamerican poplars are interspecific hybrids originating from crossbreeding North American female parents of Eastern cottonwood with North American parents of black cottonwood, or the reverse.

See: Interspecific hybrids
See: Crossbreeding

Intersectional hybrids

Interspecific hybrids created between species from different sections. For instance between the eastern cottonwood (*Populus deltoides*) of the Aigeiros section and the balsam poplar (*Populus balsamifera*) of the Tacamahaca section.

See: Interspecific hybrids

Interspecific hybrids

Hybrids created between different species, e.g. between black cottonwood (*Populus trichocarpa*) and eastern cottonwood (*Populus deltoides*), designated as *Populus trichocarpa* (♀) x *P. deltoides* (♂), or simply TxD or TD; ♀ is the symbol for female and ♂ is the symbol for male.

Inter-tree competition

Competition between individual trees for growing space, water and nutrients.

Intraspecific hybrids

Crosses created between trees from the same species with a different genetic makeup, e.g. between two eastern cottonwoods (*Populus deltoides*) trees, designated as *Populus deltoides* (♀) x *P. deltoides* (♂), or simply DxD or DD.

♀ is the symbol for female and ♂ is the symbol for male.

Ion

An ion is an atom, molecule or compound that carries either a positive (cation) or negative (anion) electrical charge.

Source: Web- Soils glossary

See: CEC

Lift (pruning)

Lift refers to pruning of trees. The first pruning ‘lifts' the live crown to a height of 2-2.4 m (6.5-8 ft.); the second pruning lift is to e.g. 4 m (13 ft.) etc.

LVL

Laminated veneer lumber (LVL) is a layered composite of wood veneers and adhesive. Once it is fabricated into billets of various thicknesses and widths, it can be cut at the factory into stock for headers and beams, flanges for prefabricated wood I-joists, or for other specific uses. Veneer thicknesses range from 2.5mm (0.10”) to 4.8mm (3/16”) and common species are Douglas fir, larch, southern yellow pine and poplar.

Source: Web-LVL

Macronutrients

Sixteen nutrient elements are essential for the growth and reproduction of plants. Thirteen of these essential elements, which may be supplied by the soil or supplemented by fertilizers, are generally divided into two groups. The macronutrients are nitrogen (N), phosphorus (P), potassium (K), sulfur (S), calcium (Ca), and magnesium (Mg). The second group of essential elements is called micronutrients because those elements are required in small (micro) amounts by plants. They include manganese (Mn), iron (Fe), boron (B), zinc (Zn), copper (Cu), molybdenum (Mo), and chlorine (Cl). Although these elements are frequently referred to as minor or trace elements, the term “micronutrient” is preferred.

Source: Web- Nutrition-1

MAI

MAI stands for mean annual increment. It is the yield divided by the years in the rotation and is expressed as m^3 per hectare per year, or m^3/ha/yr.

See: Rotation
See: CAI

Micronutrients The second group of essential elements is called micronutrients because those elements are required in small (micro) amounts by plants. They include manganese (Mn), iron (Fe), boron (B), zinc (Zn), copper (Cu), molybdenum (Mo), and chlorine (Cl). Although these elements are frequently referred to as minor or trace elements, the term "micronutrient" is preferred.

Source: Web- Nutrition-1

See: Macronutrients

Moisture deficit Precipitation surplus/deficit. Precipitation less potential evapotranspiration. This is expressed in a negative number and in mm.

Monoclonal crop A hybrid poplar crop consisting of a single clone.

See: Clonal crop

See: Polyclonal crop

See: Clone

Monoculture The cultivation of a single crop to the exclusion of others, or an area where such a practice prevails (The Canadian Oxford Dictionary 1998)

In hybrid poplar a monoculture is a crop consisting of only one clone. It is actually a monoclonal crop.

In traditional forest management monoculture indicates a stand or stands of trees of a single species, for instance a spruce stand. The spruce trees in this stand would all be genetically different from each other, but it is the only species present.

See: Monoclonal crop

See: Polyculture

MSDS Material Safety Data Sheet, for instance for herbicides.

Non-selective herbicide A non-selective herbicide is effective against a wide ranging number of plant species, including crop species. The label instructs the user to use shielded or directed methods of application to protect the crop species.

See: Selective herbicide

NPV NPV is the net present value. It is the residual value after subtracting the present value of the costs from the present value of the revenues.

See: DCF
See: PV

Occupancy	Occupancy is defined as the number of survival survey plots that have one or more live trees in them. This is expressed as a percentage and is a measure of the distribution of survival in a crop.
OSB	OSB and waferboard are panel products made of aspen or poplar (as well as southern yellow pine in the US) strands or wafers bonded together under heat and pressure using a waterproof phenolic resin adhesive or equivalent waterproof binder. Oriented strandboard and waferboard are plywood substitutes. Source: Web-OSB
OWD	Acronym for over-wintered dormant. This term is generally used for plug stock that was grown in the nursery the year before it is planted. The stock is lifted from the styroblocks, packaged and stored in a cooler or freezer till needed.
Perennial (weed)	A plant that survives for three or more seasons. See: Simple perennial See: Creeping perennial
PFRA	Prairie Farm Rehabilitation Administration (PFRA) – Shelterbelt Centre in Indian Head, Saskatchewan. See: Web-PFRA
pH	pH is the scale used to measure the alkalinity or acidity of a substance through the determination of the concentration of hydrogen ions in solution. A pH of 7.0 is neutral. Values below 7.0, to a minimum of 0.0, indicate increasing acidity. Values above 7.0, to a maximum of 14.0, indicate increasing alkalinity Source: Web- Soils glossary
Phytoremediation	Phytoremediation is the use of plants to clean up and/or to remediate sites by removing contaminants from soil and water.
Plug	A container-grown stock type. See: Container
PMRA	Pest Management Regulatory Agency of Health Canada See: Web-PMRA

Polyclonal crop	A polyclonal crop consists of more than a single clone in a field. The clones are not planted in distinct units that can be managed as a stand-alone crop. Polyclonal crops consist of truly mixed clones; for example every other tree is a different clone, or every second row is a different clone etc. See: Field See: Clone See: Monoclonal crop
Polyculture	The deliberate mixing of species in a crop. In hybrid poplar a polyculture is a crop consisting of more than one clone. It is actually a polyclonal crop. See: Polyclonal crop
Poplar	Poplars are fast growing tree species that are members of the willow (*Salicaceae*) family. The poplars belong to the genus *Populus*, including its many hybrids. The trembling or quaking aspen species (*Populus tremuloides*), which is native to the Prairie Region, also belongs to this genus. Poplar is frequently used as the common name for all the non-aspen species, such as balsam poplar (*Populus balsamifera*), black cottonwood (*P. trichocarpa*) - both native to North America, Japanese poplar (*P. maximowiczii*) and Laurel poplar (*P. laurifolia*) in the Tacamahaca section (Balsam poplars), and eastern cottonwood (*P. deltoides*) - native to North America, and European black poplar (*P. nigra*) in the Aigeiros section (Cottonwoods and black poplar). Hybrid poplar thus refers to the natural or artificial interspecific, intraspecific and/or intersectional hybrids. See: Interspecific hybrids See: Intraspecific hybrids See: Intersectional hybrids
Populus	The genus *Populus* – the poplars and aspens.
Post-emergent herbicides	Post-emergent herbicides are applied on weeds after they have emerged.
Pre-emergent herbicides	Pre-emergent herbicides are applied to clean soil and prevent germination or early growth of (mostly annual) weed seeds.
Proleptic branches	Branches that grow from the last year's buds c.f. sylleptic branches. See: Sylleptic branches

Pruning	Pruning is the removal of mostly lower branches of a tree. It is carried out to improve the shape of a tree when it is still small. It also includes removal of excess terminal leaders. This is called shaping or singling. Pruning of taller trees is done to create knot free wood and increase the value of the stem. See: Shaping or singling
PSB	Plug styroblock; a container-grown stock type. See: Container
PV	Present value. The present value is the discounted value of a future cost or revenue. See: DCF See: NPV
R-9 (or R-1, R-2 … R-15 etc.)	R-9 stands for rising 9. See: Rising
Rectangularity	Rectangularity is the ratio between the long and short sides of a rectangle. For example, a 4x3 m (10x13 ft.) rectangle has a rectangularity of 4:3; so does a 8x6 m (20x26 ft.) rectangle.
Reforestation	Reforestation: The reestablishment of trees on denuded forest land by natural or artificial means, such as planting and seeding. Source: Web-NRCAN Glos See: Afforestation
Riparian	The word ‘ripa’ means shore or bank in Latin. Riparian habitat is the land immediately bordering a watercourse or water body.
Rising (e.g. rising 9 or R-9)	Poplar farmers frequently refer to the age of a poplar crop with the word ‘rising, followed by the number of years the crop has been growing. For instance, when the crop is growing in its ninth growing season it is called an R-9 (R9) or rising 9 crop. The crop is not eight years old anymore and is not yet nine years old, hence the R-9 designation.
Rotation	Crop cycle. See: Crop cycle
Row marking	The lay out of the tree rows is called row marking. It ensures perfect spacing is maintained between tree rows. See: Cross marking
Salinity	Soil salinity is a measure of the total amount of soluble salt in soil. Source: Web-Salinity-1

Salix — The genus *Salix* – the willows.

Selective herbicide — A selective herbicide is only effective against certain species. Some selective herbicides can have a minor (usually temporary) impact on crop species.

See: Non-selective herbicide

Set — Whip. Can also be a rooted whip or set, which is referred to in Quebec as a steckling.

See: Whip

See: Steckling

SFC — Saskatchewan Forest Centre in Prince Albert, Saskatchewan.

See: Web-SFC

Shaping or singling — Shaping or singling is a pruning treatment to improve the shape of a small tree by removing excess terminal leaders, forks, excessively large branches and 'sweeper' branches that interfere with crop maintenance.

See: Pruning

Shielded sprayer — A shielded sprayer is used in the application of non-selective herbicides that can damage or kill the crop; it avoids herbicide drift. It delivers a spray from one or more spray nozzles that is completely shielded from the influence of wind. The spray droplets cannot travel beyond the shield and are directed towards the vegetation the shield is covering.

Simple perennial (weed) — A plant that survives for three or more seasons. Each spring the plant re-grows from stored root and crown reserves. Seed production may occur in the first season and in each subsequent year. Spread of a simple perennial weed species is primarily by seed.

See: Creeping perennial

Single bud cutting — A short cutting with just a single live bud near the top, which will form a shoot when planted. Single bud cuttings are used to start a new nursery crop in containers and are an efficient way to make maximum use of scarce cutting material. The cuttings are typically 2.5 cm (1 in.) long and have a single live bud near the top.

See: Cutting

Site preparation phase — Site preparation phase consists of a combination of mechanical and chemical methods to prepare the land for the short-rotation-intensive-culture (SRIC) poplar crop. Site preparation can take place from one to two years to just before the actual planting of the crop.

Soil horizon — A layer within a soil showing unique characteristics. Four major horizons are normally found in a soil profile: LFH, A, B and C. The LFH layer, which is on top of the soil, is present in forested soils. This layer is absent in cultivated soils.

See: Ah horizon

Soil texture — Soil texture of a soil refers to the size distribution of the mineral particles composing the soil. Particles are normally grouped into three main classes: sand, silt, and clay.

Source: Web-Introduction to Soils

spac — Stems per acre or trees per acre. An acre is approximately 0.4 hectares.

See: spha

spha — Stems per hectare or trees per hectare. A hectare is approximately 2.5 acres.

See: spac

SRIC — Acronym for short-rotation-intensive-culture. The SRIC hybrid poplar crop, or simply SRIC hybrid poplar, SRIC poplar etc. denotes hybrid poplar grown as an agronomic crop on farmland on a short crop cycle or rotation, using intensive cultural practices. It is a multi-year farm crop. The length of the crop cycle or rotation depends on the end product the farmer intends to grow and will vary depending on the location; i.e. the cycle will be shorter under more favourable growing conditions.

See: Hybrid Poplar
See: Crop cycle

Starter stock — Usually dormant mini cuttings, 2.5 cm to 7.5 cm (1.0 to 3.0 in.) in length, that are stuck in plant containers filled with a suitable soil mix to produce a so-called ‘plug’. They can also be planted in outdoor nursery beds to produce a bareroot plant, or new stools in a stoolbed.

Starter stock used for container grown stock can also consist of single bud cuttings.

See: Single bud cutting

Steckling — The name of a rooted whip in Quebec.

See: Whip

See: Set

Stool — An individual plant in a stoolbed that gets repeatedly cut back in the winter to produce additional shoots the following growing season. This is called coppicing.

See: Stoolbed

See: Coppicing

Stoolbed Nursery beds planted with closely spaced rooted or unrooted dormant cuttings to produce shoots that are harvested as one- or two-year old cuttings or whips. The shoots are processed to produce new cutting material for additional stoolbeds to be used in container stock or bareroot stock production, or for outplanting as cuttings or whips to produce a new crop. The individual plants are called 'stools'. Stoolbeds are sometimes also referred to as panel beds.

See: Stool

Styroblock A Styroblock is a container system to produce planting stock. For poplar the container is most often a stryrofoam block with a number of cavities filled with potting soil in which small dormant cuttings are planted.

See: Container

Subsoiling The breaking of compact subsoils, without inverting them, with a special knifelike instrument (chisel), which is pulled through the soil usually at depths of 30 to 60 cm (12 to 24 in.) and spacings of 60 to 150 cm (2 to 5 ft.). Also called chiseling.

Source: Web-CanSis

Sylleptic branches Branches that grow from the current year's buds c.f. proleptic branches.

See: Proleptic branches

Turgor Rigidity of cells due to the absorption of water.

Type Type is an area identified on a farm field or over several fields, where crop conditions are similar (e.g. same survival rate, same growth rate etc.). If the crop is considered homogeneous, the field or fields can be considered one 'type'. This also applies to blocks, which are are sub-units of a field. If crop conditions are similar over several blocks, they can be combined into one 'type'. A 'type' is used as a survey or inventory unit with uniform crop conditions.

The process of delineating types is called 'typing'.

See: Field
See: Block

1 Dickmann, D.I. 2001. An overview of the genus Populus. In Poplar Culture in North America. Part A, Chapter 1. Edited by D.I. Dickmann, J.G. Isebrands, J.E. Eckenwalder, J. Richardson. NRC Research Press, National Research Council of Canada, Ottawa, ON K1A 0R6, Canada. Pp. 1-42.

Variety[1]

- A subspecies; an individual or group (usually fertile) within the species to which it belongs, but differing from the species type in some qualities. A good example is the black cottonwood, *Populus trichocarpa*, which has a subspecies named *P. trichocarpa hastata* 'Henry', which has thick narrow leaves and smooth long fruits.
- A cultivar

A variety is usually commercially propagated.

See: Cultivar

Whip

Unrooted stem or shoot originating from a plant and used for vegetative propagation. The size is usually between 1.5 and 2.0 m (5.0-6.5 ft.). A set is a rooted whip. In Europe and South America whips or sets can be 5.0-6.0 m tall (16-20 ft.) tall!

A whip is also the shoot coming from a stool in a stoolbed.

See: Set

See: Steckling

See: Stool

See: Stoolbed

Willow

Trees in the genus *Salix*, including its many hybrids

Winter annual (weed)

A plant that germinates in the fall and survives the winter as a dormant rosette. It resumes growth in the spring, sets seed in early summer and then dies.

See: Annual

See: Biennial

APPENDICES

19 Schroeder, W., Inouye, G. M. 2006 in Final project Report ADF project 200010048 - Hybrid Poplar Plantations for Farm Diversification in Saskatchewan (AAFC-PFRA Agroforestry Division).

Appendix A-1: Characteristics of poplar clones[19]

Clone	Tree Characteristics			Hardiness	Disease	Recommended Use				
	Growth	Form	Sex			SRIC	Shelterbelt	Riparian	Phytoremediation	Unsuitable
Assiniboine	2	1	Male	3	1		X	X	X	
Berolinensis	2	2	Male	2	2					X
Brooks 6	2	1	Male	1	2	X	X	X	X	
CanAm	2	2	Female	3	1		X	X	X	
DN-182	1	1	Male	4	1					X
DN-34	1	2	Male	4	1					X
Griffin	2	1	Male	2	3					X
Hawktree	2	2	Male	2	1		X	X	X	
Hill	2	2	Female	2	2	X	X	X	X	
Katepwa	1	1	Male	2	2	X	X	X	X	
Manitou	2	3	Male	1	3					X
NM-6	1	1	Male	4	1					X
Northwest	2	3	Male	2	2	X	X	X	X	
Prairie Sky	1	1	Male	3	1					X
Russian	2	2	Male	1	3					X
Tristis SBC	2	3	Male	1	1		X	X	X	
Walker	1	1	Female	3	2	X	X	X	X	
WP-69	1	2	Male	1	1	X	X	X	X	

Growth Rate (height)			Form		Hardiness Ratings		Disease Rating	
1	Fast	>1.0 m (3.3 ft.) per year	1	Straight/narrow crown	1	Not vulnerable	1	Resistant
2	Moderate	0.8-1.0 m (2.6-3.3 ft.) per year	2	Moderately wide crown	2	Slightly vulnerable	2	Susceptible
			3	Wide spreading crown	3	Moderately vulnerable	3	Highly susceptible
					4	Very vulnerable		

Appendix A-2: Clone names, origin and alternative names[19]

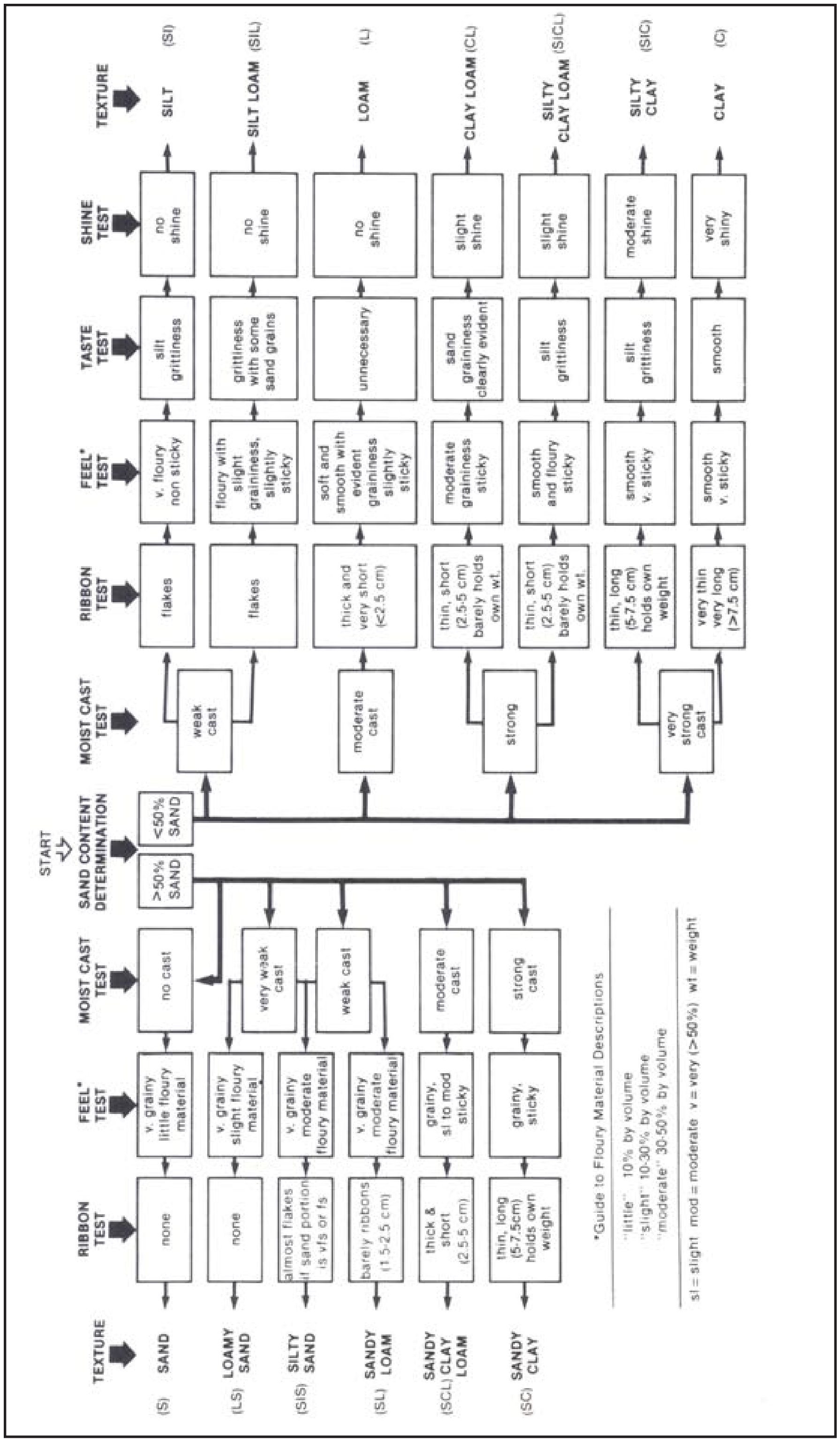
Clone names, origin and alternative names

Clone	Origin	Alternate Names	Unsuitable
Assiniboine	Open-pollinated Walker seedling	OPW-130L-86	
Berolinensis	*Populus laurifolia* x *P. nigra*	Berlin	X
Brooks 6	*Populus deltoides* x *P. xpetrowskyana*	Green Giant	
CanAm	Open-pollinated Walker seedling		
DN-182	*Populus deltoides* x *P. nigra*	Raverdeau	X
DN-34	*Populus deltoides* x *P. nigra*	Imperial, Eugenei	X
Griffin	*Populus deltoides* x *P. xpetrowskyana*	Brooks 1	X
Hawktree	Open-pollinated Walker seedling		
Hill	*Populus deltoides* x *P. xpetrowskyana*	FNS 44-55	
Katepwa	Open-pollinated Walker seedling	OPW-180H-86	
Manitou	Open-pollinated Walker seedling	OPW-34L-86	X
NM-6	*Populus nigra* x *P. maximowiczii*	Max-5	X
Northwest	*Populus balsamifera* x *P. deltoides*		
Prairie Sky	*Populus deltoides* x *P. nigra* 'Italica'		X
Russian	*Populus laurifolia* x *P. nigra*	petrowskyana	X
Tristis SBC	*Populus tristis* (Tacamahaca species)		
Walker	*Populus deltoides* x *P. xpetrowskyana*	FNS 44-52	
WP-69	*Populus x* 'Walker' x *P. xpetrowskyana*		

19 Schroeder, W., Inouye, G. M. 2006 in Final project Report ADF project 200010048 - Hybrid Poplar Plantations for Farm Diversification in Saskatchewan (AAFC-PFRA Agroforestry Division).

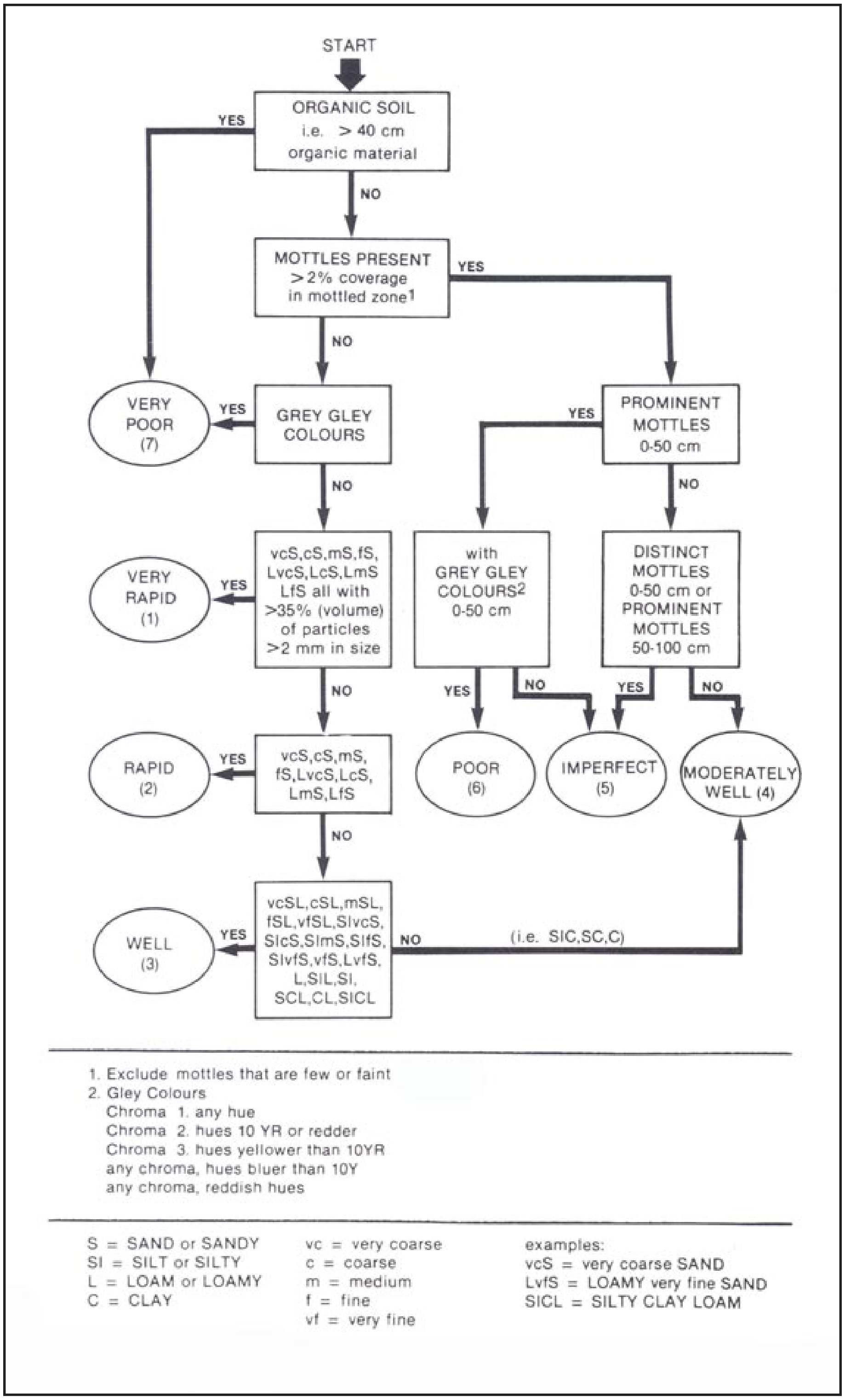
Appendix B: Finger assessment of soil texture

Source: Ontario Institute of Pedology. 1985 Field Manual for Describing Soils, 3rd Edition. Published by Ontario Institute of Pedology, Guelph, 42.pp.

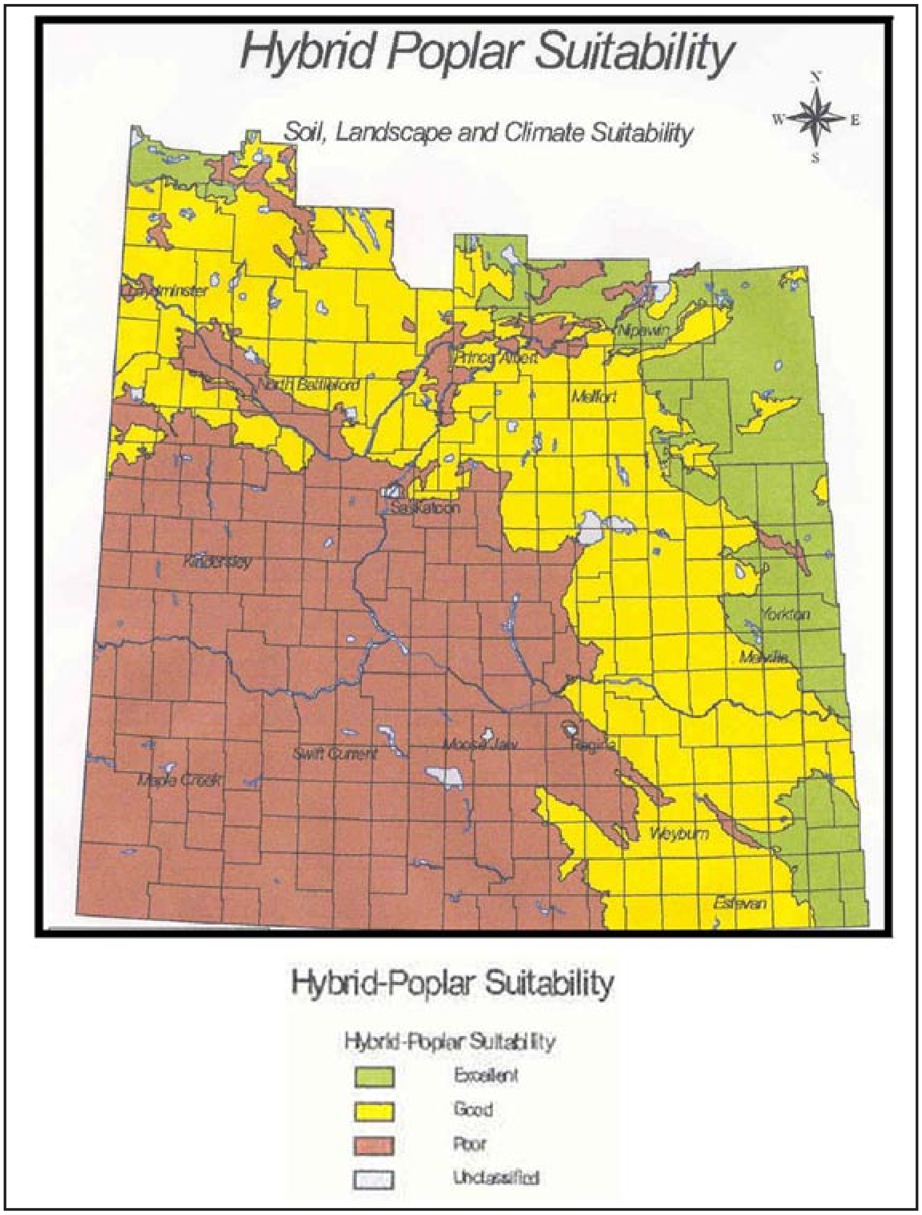


Appendix C: Soil drainage

Source: Ontario Institute of Pedology. 1985 Field Manual for Describing Soils, 3rd Edition. Published by Ontario Institute of Pedology, Guelph, 42.pp.

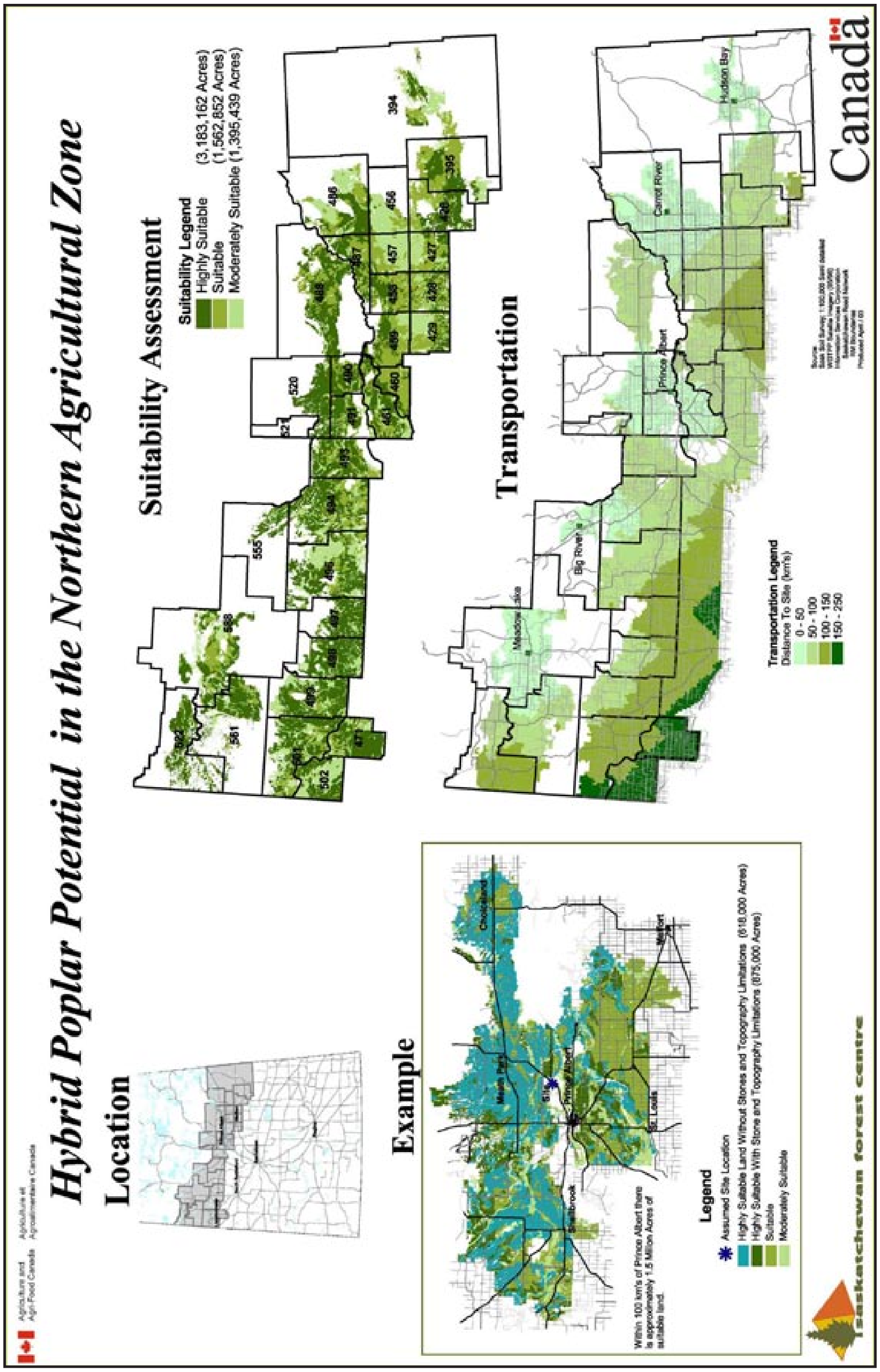


Appendix D: Hybrid Poplar suitability map for Saskatchewan



Appendix E-1: Hybrid Poplar suitability - northern agricultural zone Saskatchewan

For the legend, see Appendix E-2



Appendix E-2: Legend for Hybrid Poplar suitability - northern agricultural zone Saskatchewan for the map in Appendix E-1

Agriculture and Agri-Food Canada   Agriculture et Agroalimentaire Canada

Hybrid Poplar Suitability Assessment

Hybrid poplar suitability maps for 32 Saskatchewan rural municipalities are provided. A three class hierarchical system is used to describe suitability (Table 1) on agricultural land. An additional class of Land Use Limitation was added that applied to areas such as forest, brush, lakes or urban areas where hybrid poplar afforestation would not apply. Although generally applicable to hybrid poplar, these maps were based on data for the hybrid *P.* x Walker.

Table 1: Land suitability Assessment for Walker poplar plantations on agricultural land

Class	Designation	Definition
	Highly Suitable	Land having negligible limitations affecting productivity, management or degradation risks.
	Suitable	Land having slight to moderate limitations affecting productivity, management or degradation risks.
	Marginally Suitable	Land having severe limitations affecting productivity or land having moderate productivity but with severe, management limitations or degradation risks.
	Land Use Limitations	Lands classified as currently in forest, brush, lakes, rivers or urban.

The criteria supplied for hybrid poplar suitability required the evaluation of soil and landscape factors including depth to water table, soil texture, salinity, slope percentage and length, and flooding. The criteria were applied to the 1:100,000 semi-detailed soil database for the province of Saskatchewan. Additional information was obtained from the National Soil Databases for Canada.

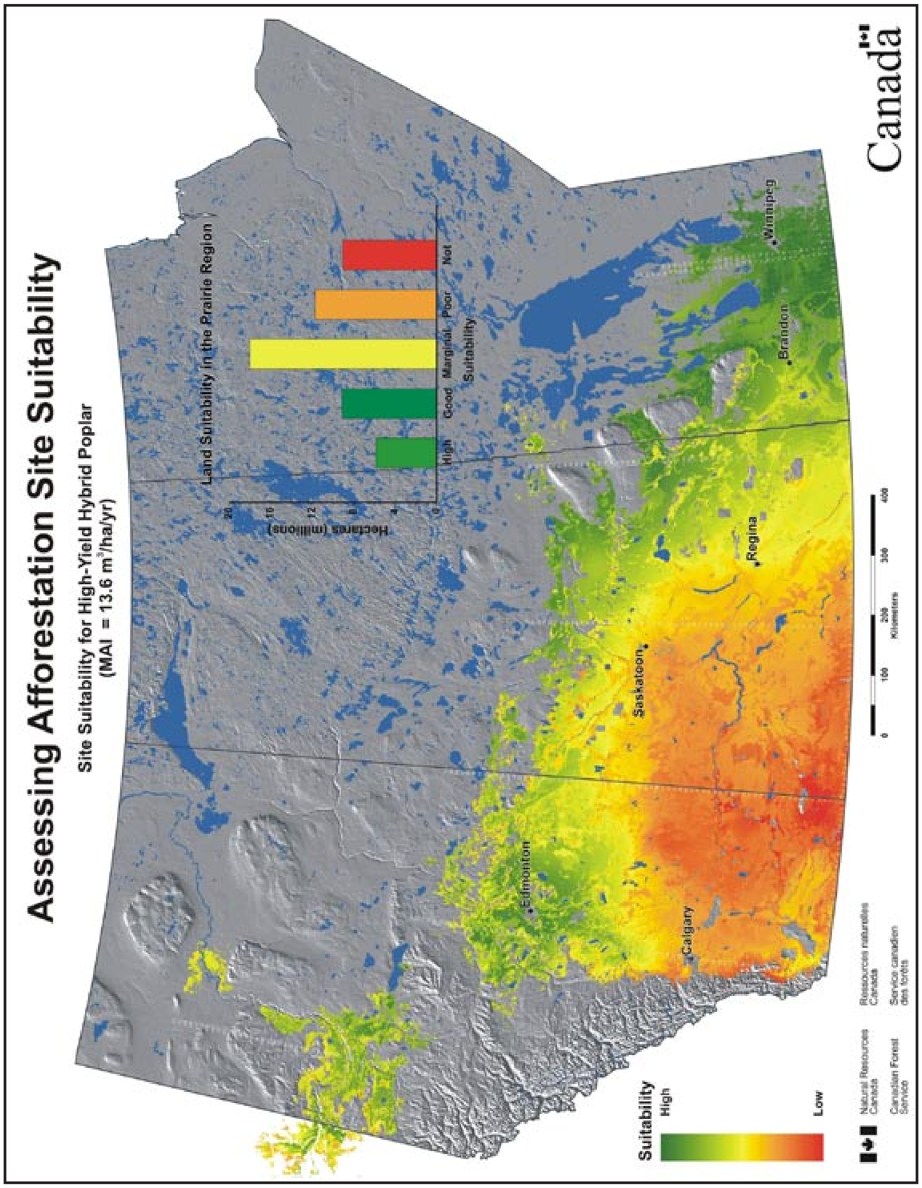
The assessment does not consider hazards such as fire, pests or disease. It does, however, indirectly take in to account establishment costs by indicating attributes that affect site preparation, management and land degradation hazards. In planning for tree planting, as with any crop, it is important to consider not only soil and climate but also market, social and economic factors before making any decisions. The classifications of land suitability outlined in the maps should be regarded as a basic framework upon which more detailed assessment can be based. Suitability maps were developed for the following rural municipalities in the province of Saskatchewan:

RM No.	RM Name	RM No.	RM Name	RM No.	RM Name
394	Hudson Bay	461	Prince Albert	497	Medstead
395	Porcupine Plain	471	Eldon	498	Parkdale
426	Bjorkdale	486	Moose Range	499	Mervin
427	Tisdale	487	Nipawin	501	Frenchman Butte
428	Star City	488	Torch River	502	Britannia
429	Flett Springs	490	Garden River	520/521	Paddockwood / Lakeland
456	Arborfield	491	Buckland	555	Big River
457	Connaught	493	Shellbrook	561	Loon Lake
458	Willow Creek	494	Canwood	588	Meadow Lake
459	Kinistino	496	Spiritwood	622	Beaver River
460	Birch Hills				

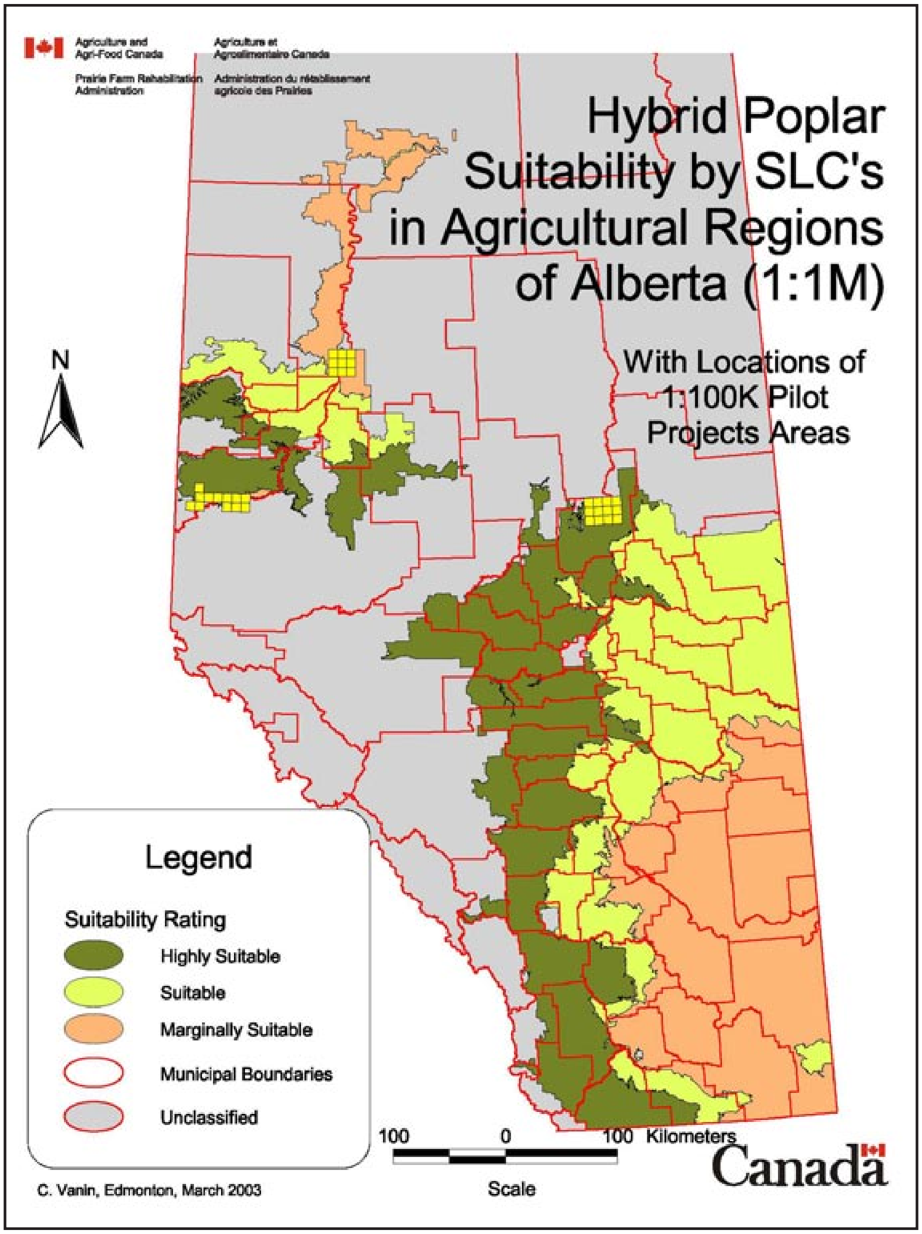
saskatchewan forest centre

Canada

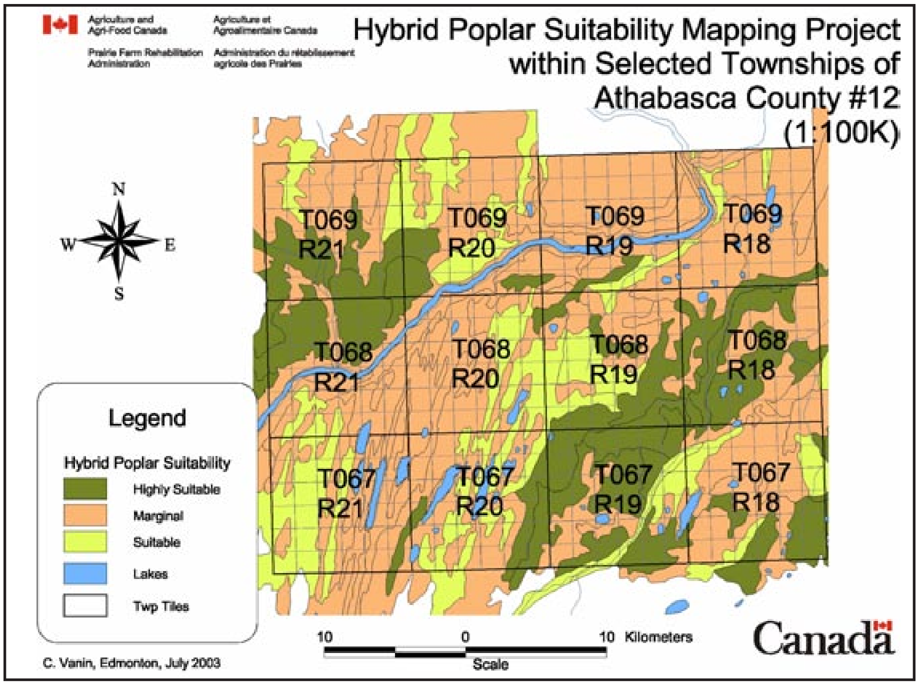
Appendix F: Afforestation Land Suitability in the Prairie Region



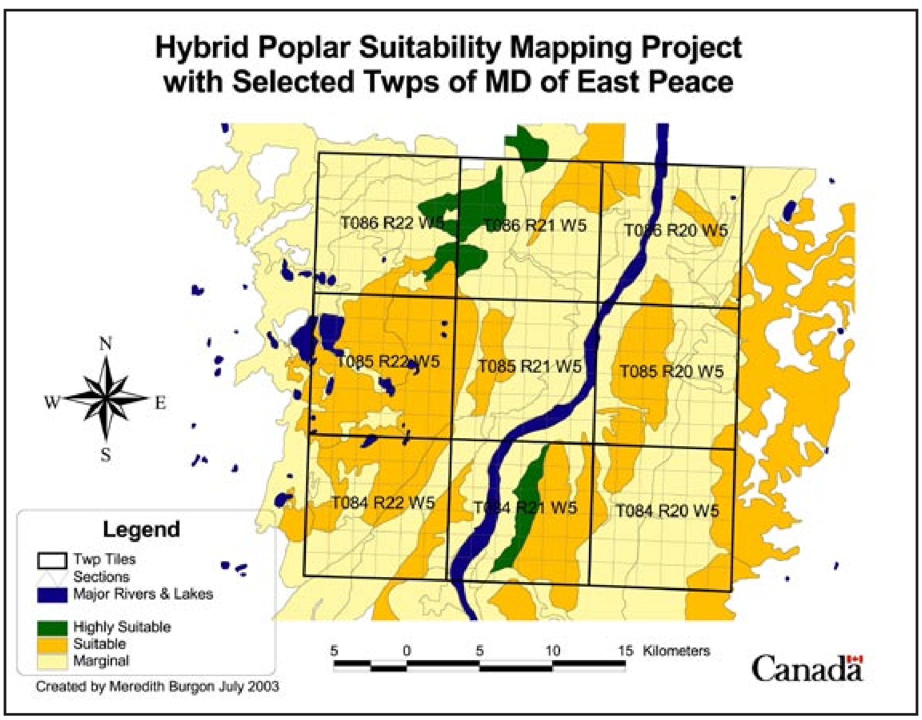
Appendix G: Hybrid Poplar suitability map for Alberta



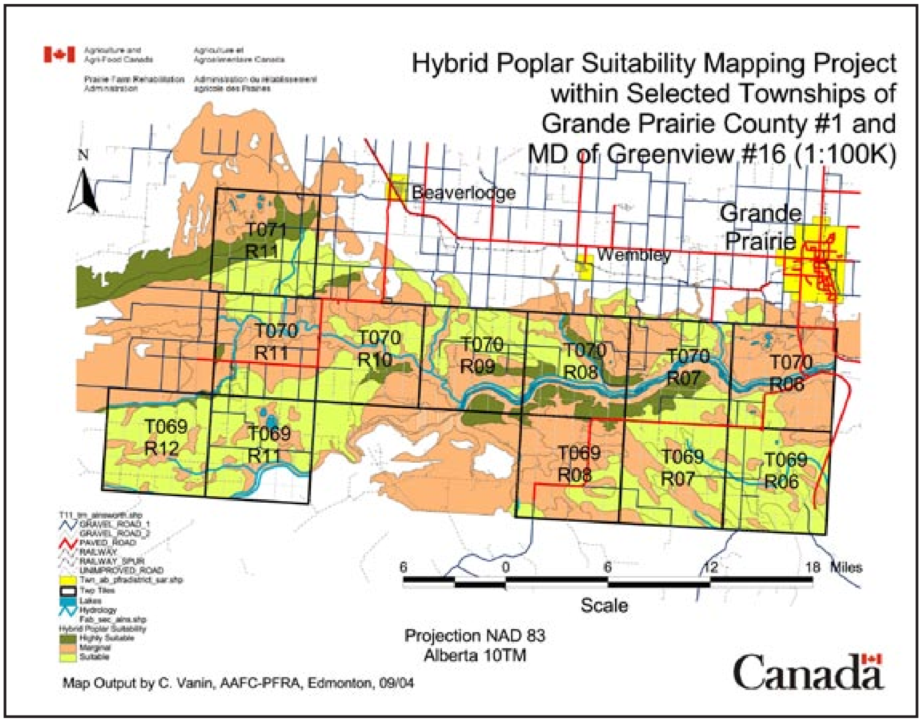
Appendix G-1: Hybrid Poplar suitability map for Alberta – Athabasca County #12



Appendix G-2:Hybrid Poplar suitability map for Alberta – Peace River



Appendix G-3: Hybrid Poplar suitability map for Alberta – Grande Prairie



Appendix H: Soil Sampling Guidelines Page 1 of 2

Enviro-Test Laboratories

Calgary – Saskatoon – Winnipeg

Soil Sampling Guidelines

August 2000

Time of Sampling

Take samples prior to fertilizer or manure application.

Fall Sampling: You can sample anytime after harvest if you follow a few nutrient-cycling concepts.

The main concern about sampling "too early" is the soil won't have mineralized some of the organic matter and/or crop residue into N, but for this to occur you need both heat and moisture. If the soil remains dry after harvest, cooling of the soil will not significantly change the soil N level. Moisture is required to mineralize N, temperature affects the speed at which this happens.

Here's what to do if you have NOT grown pulses or legumes and have NOT applied manure . . .

- If the soil has been moist for a couple of weeks during/following harvest, go ahead and sample, as most of the mineralization will have occurred.
- If the soil has been dry then you get a good rain, you might want to wait a couple of weeks for the immobilization to catch up to the mineralization (sampling too soon following rain can show a false high level of N), then sample. If you know your soil well, you don't have to wait the couple of weeks . . . just remember N levels will jump after a rain if the soil was dry beforehand, then N levels will fall as immobilization catches up to mineralization. The warmer it is, the faster this whole process will occur.
- If the soil has been dry, sample anytime (little mineralization will have occurred) but reduce the N recommendation. The amount depends on the native fertility of the soil and organic matter is a fair indicator of a soil's N-supplying power. Reduce the actual-N application rate by about 5 lb/ac for 2 to 3% organic matter soils, 10 lb/ac for 4 to 5% and 15 lb/ac for 6 to 7% organic matter. About 50% of both soil N and fertilizer N are crop available, so there's no calculation necessary.

If you have pulses or legumes in the rotation or manure has been applied . . .

- You have to be more careful. Even a few years after a legume has been grown or manure applied you can get a burst of N mineralization if the environmental conditions are just right. If the soil has been moist for 2 to 3 weeks, you can sample. But if its been dry you have to consider you'll have somewhere between 20 and 40 lb/ac or more N come available a couple of weeks after it does rain. If its dry, you can take samples in the Fall and then re-sample a couple of fields in the Spring to measure the change in soil N. Most of the N fertilizer can be Fall applied but, if more is needed, the seedbox blend can be topped up in Spring.

Spring Sampling: Generally, you can take the sample as soon as it is possible to do so without probe plugging or frost layer problems.

Sampling Depth

The 0-12"+12-24" or 0-6"+6-24" sampling depths are still the best, but dry soil conditions, stones, time, sampling equipment, etc. often make the taking of an accurate 2-depth sample to 24" difficult. Note, these are preferred when trying to figure out a problem field.

Most samples taken are 0-12" or 0-6". The 0-12" is a little better for the mobile nutrients (N, S and Cl) if you don't have a good 'feel' for the field.

A 0-6" sample must be taken if organic matter and/or pH are to be used for determining herbicide application or residue carryover.

Other sampling depth combinations are 0-6"+6-12", and a 0-6"+6-12"+12-24" (commonly used on saline or irrigated fields to monitor salt levels).

Whatever the depth(s) of sampling, make sure they are accurate.

Appendix H: Soil Sampling Guidelines Page 2 of 2

Definition of a "Field"

Any portion of land farmed as a single unit is suitable for sampling provided it has a recent history of similar management. Fallow and stubble fields, fields sown to different crops and manured and non-manured areas should be sampled separately. If one sample is being taken from a field with a rolling landscape, all the sample cores should be taken from the mid-slope position. Upper slopes and lower slopes should be treated as if they were separate fields. Fields larger than 160 acres should be split into smaller parcels.

Taking the Sample

Take a minimum of 15 cores throughout the field, even if the field is only 10 acres. If the previous summer was dry, take 22 cores. A proper soil sampling probe or auger must be used to provide an accurate sample.

Random Sampling: Travel over (the mid-slope portion of) the field in a random zigzag pattern collecting cores. Avoid atypical areas such as eroded knolls, depressions, saline areas, fence lines, old roadways and yards, water channels, manure piles and field edges.

In fields where knolls or depressions represent significant acreage, these areas should be sampled as separate "fields".

Benchmark Sampling: Select an area ¼ to 1 acre in size that is representative of the field and take all 15 to 22 sample cores from that area.

Point Benchmark Sampling: Select an area that is representative of the field using GPS and take all 15 to 22 sample cores within in a 2 to 5 metre radius.

Handling the Samples & Paperwork

If the entire sample will not fit in the sample bag, collect the soil for each depth in a separate clean plastic container. Once the 15 to 22 cores have been taken, break up the clods and mix the sample thoroughly and fill the appropriate bag(s).

Fill out the Information Sheet (see attachment), take the appropriate colour stickers from the back page and place on the bags (no other information has to be placed on the bags), send the top copy with the samples and keep the bottom copy for your records.

Place the sample in a cooler or container out of direct sunlight while other fields are sampled. Samples should be kept cool but NOT frozen, until they can be put on a courier or bus express the next day. Freezing induces rapid mineralization of the soil nitrate once the sample thaws.

Samples do NOT have to be dried prior to shipment provided they will be delivered to the lab within 48 hours. To dry samples, spread the soil on plastic or paper in an area at room temperature. Placing a fan nearby to improve air flow will speed drying.

Sampling Supplies

Soil sampling supplies such as sample bags and information sheets are provided at no cost.

Call 1-800-667-7645 for assistance . . .

Sample Information & Supplies:

Alberta:	Agricultural Services
Saskatchewan:	Data Entry for sample information
	Shipping/Receiving for supplies
Manitoba:	Agricultural Services

Agronomic Assistance:

Alberta:	Brandon Green
Saskatchewan:	Troy McInnis
Manitoba:	Paul Routledge

Our addresses:

Alberta:	Enviro-Test Laboratories 1313 – 44th Avenue N.E. Calgary, AB T2E 6L5
Saskatchewan:	Enviro-Test Laboratories 124 Veterinary Road Saskatoon, SK S7N 5E3
Manitoba:	Enviro-Test Laboratories 745 Logan Ave. Winnipeg, MB R3E 3L5

Appendix I: Nursery Listing

(* Clone not recommended for the Prairie region)

Nursery	Address	Stock Types	Clones
Coast to Coast Reforestation Inc. (C2C) [Web-C2Ctrees]	C2C - Head Office #200, Albrumac Business Centre 8657 - 51 Ave Edmonton, AB T6E 6A8 Contact: Larry Lafleur Phone : (780) 472 - 8676 Fax : (780) 472 - 0460	Stoolbed Cuttings Container Bareroot	Customer supplied
Gaudet Christmas Trees [Web-Gaudet]	266-14th Street West Prince Albert, SK S6V 3L3 Phone: (306) 922-1052 Fax: (306) 922-8733	Stoolbed Cuttings Bareroot	Griffin; Hill; Katepwa Northwest; Walker
Pacific Regeneration Technology (PRT) [Web-PRT]	PO Box 1921 Hwy 2 North Prince Albert, SK S6V 6J9 Contact: Grant Harrison - Manager Phone: (306) 953-4700 Fax: (306) 953-4709 To order: Glenn Goodwill, Customer Support Representative Cell: (780) 831-5725	Stoolbed Cuttings Container Bareroot	Green Giant; Hill; Katepwa; Walker DN34*; DN182* Customer supplied
Parkland Agroforestry Inc. [Web-PAF]	Box 517 Melfort, SK S0E 1A0 Contact: Bill Sullivan Phone: (306) 874-2080 Fax: (306) 874-2080	Stoolbed Cuttings Container Bareroot	Assiniboine; Hill Katepwa; Walker WP69
Poplar Choice	Box 184 Quill Lake, SK. S0A 3E0 Contact: Greg Govan Phone: (306) 383-2869	Stoolbed Cuttings	(Cottonwood); Assiniboine; Green Giant; Hill; Katepwa; Northwest; Walker
Rose Hill Simmental Farm	Box 56 Weldon, SK S0J 3A0 Contact: Elwood Wenig Phone: (306) 864-3231 Note: Also offers 'Custom Field Services'	Stoolbed Cuttings Cuttings Bareroot	Walker
Scott Paper Limited (SPL)	1625-5th Avenue New Westminster, BC V3M 1Z7 Contact: Dan Carson Ph: (604) 520-9284 Fax: (604) 520-9200	Stoolbed Cuttings	Walker (small amount)
Threshold Agroforestry Corporation [Web-Threshold]	Threshold Agroforestry Corporation 41 Wilkinson Crescent Portage la Prairie, MB R1N 1A5 Contact: Tam McEwen Phone: (204) 857-9111 Fax: (204) 239-1277	Stoolbed Cuttings Bareroot	Green Giant; Hill; Northwest; NM6*; DN17*; DN2*; DN34*; DN182*
Woodmere Nursery - AB Division [Web-Woodmere]	P.O. Box 498 Fairview, AB T0H 1L0 Contact: Jeff Hoyem Phone: (780) 835-5292 Fax: (780) 835-5459	Container	Customer supplied
Tree Bay [Web-TreeBay]	Web-based market place for planting stock. Saskatchewan Forest Centre [Website-SFC]	Varies	Varies

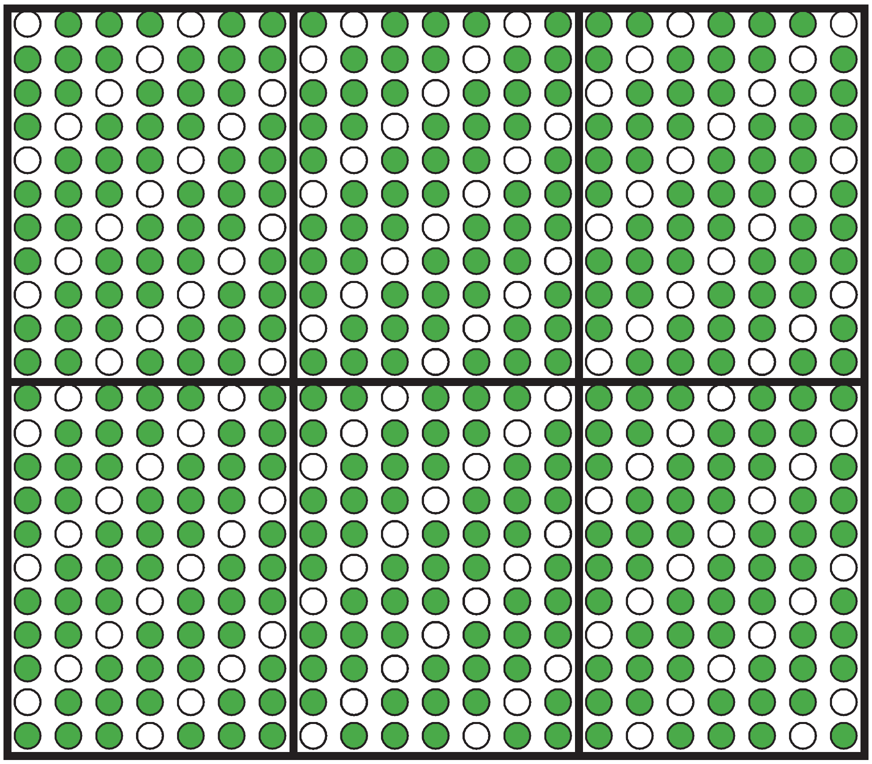
* Not recommended for the Prairie region

Appendix J: Styroblock container types and sizes

Styroblock container types and sizes

Container	Metric Name	Styro	Depth		Diameter Top		Volume		Plant Density	
			mm	in.	mm	in.	ml or cm³	in.³	#/m²	#/ft.²
211A	240/40 ml	2	114	4.5	27	1.1	39	2.4	1130	105
313A	198/60 ml		133	5.3	28	1.1	52	3.2	936	87
310B	160/60 ml		105	4.1	30	1.2	60	3.7	764	71
313B	160/65 ml	4	127	5.0	30	1.2	65	4.0	764	71
315B	160/90 ml	5	152	6.0	30	1.2	90	5.5	764	71
323A	160/120 ml	7	228	9.0	30	1.2	160	9.8	764	71
410A	112/80 ml		105	4.1	36	1.4	80	4.9	527	49
415B	112/105 ml	6	149	5.9	35	1.4	93	5.7	527	49
412A	77/125 ml		117	4.6	42	1.7	126	7.7	366	34
415D	77/170 ml	10	152	6.0	43	1.7	172	10.5	366	34
512A	60/220 ml		119	4.7	52	2.1	220	13.4	280	26
515A	60/250 ml		152	6.0	51	2	250	15.3	280	26
615A	45/340 ml	20	152	6.0	60	2.4	336	20.5	215	20

Appendix K: PSB 415D Styroblock with empty cavities



Example of a PSB415D (or 412A) styroblock, where every 4th cavity is left empty. By using the diagonal pattern in this example, these blocks average close to 58 trees (green) per block vs. the regular 77 cavities.

The diagonal pattern ensures that every tree benefits the most from the extra room that is created to lessen the above-ground competition. The response will be an improved caliper for the 58 trees.

Appendix L: Metric conversion table – Crop density and spacing

Note that all conversions are rounded off.

Crop density – Stems per hectare to stems per acre (and reverse)

spha	spac	spac	spha
500	200	200	490
600	240	250	610
700	280	300	740
800	320	350	860
900	360	400	980
1000	400	450	1110
1100	440	500	1230
1200	480	550	1350

Meters to feet (and reverse)

m	ft.	ft.	m
1.5	4.9	5.0	1.5
1.8	5.7	6.0	1.8
2.0	6.5	7.0	2.1
2.3	7.3	8.0	2.4
2.5	8.2	9.0	2.7
2.8	9.0	10.0	3.0
3.0	9.8	11.0	3.3
3.3	10.6	12.0	3.6
3.5	11.4	13.0	3.9
3.8	12.3	14.0	4.2
4.0	13.1	15.0	4.5
4.3	13.9	16.0	4.8
4.5	14.7	17.0	5.1
4.8	15.5		
5.0	16.4		

Appendix M: Spacing to density conversion

Spacing to density – Stems per hectare (spha)

	Spacing – m														
Spacing – m	**1.5**	**1.8**	**2.0**	**2.3**	**2.5**	**2.8**	**3.0**	**3.3**	**3.5**	**3.8**	**4.0**	**4.3**	**4.5**	**4.8**	**5.0**
1.5	4440	3800	3330	2960	2660	2420	2220	2050	1900	1770	1660	1560	1480	1400	1330
1.8	3800	3260	2850	2530	2280	2070	1900	1750	1630	1520	1420	1340	1260	1200	1140
2.0	3330	2850	2500	2220	2000	1810	1660	1530	1420	1330	1250	1170	1110	1050	1000
2.3	2960	2530	2220	1970	1770	1610	1480	1360	1260	1180	1110	1040	980	930	880
2.5	2660	2280	2000	1770	1600	1450	1330	1230	1140	1060	1000	940	880	840	800
2.8	2420	2070	1810	1610	1450	1320	1210	1110	1030	960	900	850	800	760	720
3.0	2220	1900	1660	1480	1330	1210	1110	1020	950	880	830	780	740	700	660
3.3	2050	1750	1530	1360	1230	1110	1020	940	870	820	760	720	680	640	610
3.5	1900	1630	1420	1260	1140	1030	950	870	810	760	710	670	630	600	570
3.8	1770	1520	1330	1180	1060	960	880	820	760	710	660	620	590	560	530
4.0	1660	1420	1250	1110	1000	900	830	760	710	660	620	580	550	520	500
4.3	1560	1340	1170	1040	940	850	780	720	670	620	580	550	520	490	470
4.5	1480	1260	1110	980	880	800	740	680	630	590	550	520	490	460	440
4.8	1400	1200	1050	930	840	760	700	640	600	560	520	490	460	440	420
5.0	1330	1140	1000	880	800	720	660	610	570	530	500	470	440	420	400

Spacing to density – Stems per acre (spac)

	Spacing – ft.												
Spacing – ft	**5.0**	**6.0**	**7.0**	**8.0**	**9.0**	**10.0**	**11.0**	**12.0**	**13.0**	**14.0**	**15.0**	**16.0**	**17.0**
5.0	1740	1450	1240	1080	960	870	790	720	670	620	580	540	510
6.0	1450	1210	1030	900	800	720	660	600	550	510	480	450	420
7.0	1240	1030	880	770	690	620	560	510	470	440	410	380	360
8.0	1080	900	770	680	600	540	490	450	410	380	360	340	320
9.0	960	800	690	600	530	480	440	400	370	340	320	300	280
10.0	870	720	620	540	480	430	390	360	330	310	290	270	250
11.0	790	660	560	490	440	390	360	330	300	280	260	240	230
12.0	720	600	510	450	400	360	330	300	270	250	240	220	210
13.0	670	550	470	410	370	330	300	270	250	230	220	200	190
14.0	620	510	440	380	340	310	280	250	230	220	200	190	180
15.0	580	480	410	360	320	290	260	240	220	200	190	180	170
16.0	540	450	380	340	300	270	240	220	200	190	180	170	160
17.0	510	420	360	320	280	250	230	210	190	180	170	160	150

Appendix N: Diameter over Height Ratios – d/h

The d/h ratio is the Diameter at Breast Height (DBH) in cm divided by the Height in m.

Diameter over Height Ratios - d/h

	Diameter at Breast Height (DBH) - cm									
Height - m	10	12	14	16	18	20	22	24	26	28
8	1.25									
9	1.11	1.33								
10	1.00	1.20	1.40							
11	0.91	1.09	1.27							
12	0.83	1.00	1.17	1.33						
13	0.77	0.92	1.08	1.23	1.38					
14	0.71	0.86	1.00	1.14	1.29					
15		0.80	0.93	1.07	1.20	1.33				
16		0.75	0.88	1.00	1.13	1.25	1.38			
17		0.71	0.82	0.94	1.06	1.18	1.29			
18			0.78	0.89	1.00	1.11	1.22	1.33		
19			0.74	0.84	0.95	1.05	1.16	1.26	1.37	
20			0.70	0.80	0.90	1.00	1.10	1.20	1.30	1.40
21			0.67	0.76	0.86	0.95	1.05	1.14	1.24	1.33
22				0.73	0.82	0.91	1.00	1.09	1.18	1.27
23				0.70	0.78	0.87	0.96	1.04	1.13	1.22
24				0.67	0.75	0.83	0.92	1.00	1.08	1.17
25					0.72	0.80	0.88	0.96	1.04	1.12

Note: Trees with a d/h ratio in excess of 1.30 indicate that crop density may be too low.

Trees with a d/h ratio below 0.70 do exist in crops with a crop density that is too high. A d/h ratio of 0.70 is already an indication that the crop is getting too dense.

Appendix O: Production Hybrid Poplar Stem Volume Table (outside bark)[2]

Note: The volume table on page 99 of the Ontario manual is incorrect (Notice of correction memo sent out in 1992). The table below was compiled using the Production Stem Volume Equation:

Stem Volume (m^3=(EXP(-2.884601+1.604938*LN(DBH in cm)+1.203873*LN(HT in m))*1.013914/1000

Production Hybrid Poplar Stem Volume Table - m^3 per tree - stem volume (outside bark)														
Height - m		8	9	10	11	12	13	14	15	16	17	18	19	20
Diameter at Breast Height (DBH) - cm	10	0.0279	0.0321	0.0365	0.0409	0.0454	0.0500	0.0547						
	11		0.0374	0.0425	0.0477	0.0529	0.0583	0.0637						
	12		0.0431	0.0489	0.0548	0.0609	0.0670	0.0733	0.0796	0.0861	0.0926			
	13		0.0490	0.0556	0.0623	0.0692	0.0762	0.0833	0.0906	0.0979	0.1053			
	14			0.0626	0.0702	0.0780	0.0859	0.0939	0.1020	0.1102	0.1186	0.1270	0.1356	0.1442
	15			0.0699	0.0784	0.0871	0.0959	0.1049	0.1139	0.1231	0.1325	0.1419	0.1514	0.1611
	16					0.0966	0.1064	0.1163	0.1264	0.1366	0.1469	0.1574	0.1680	0.1787
	17					0.1065	0.1172	0.1282	0.1393	0.1505	0.1619	0.1735	0.1851	0.1969
	18						0.1285	0.1405	0.1527	0.1650	0.1775	0.1901	0.2029	0.2158
	19						0.1402	0.1532	0.1665	0.1800	0.1936	0.2074	0.2213	0.2354
	20								0.1808	0.1954	0.2102	0.2252	0.2403	0.2556
	21								0.1955	0.2113	0.2273	0.2435	0.2599	0.2764
	22									0.2277	0.2449	0.2624	0.2800	0.2979
	23									0.2445	0.2630	0.2818	0.3007	0.3199
	24											0.3017	0.3220	0.3425
	25											0.3221	0.3438	0.3657
	26												0.3661	0.3895
	27												0.3890	0.4138
	28													0.4386

The data range does not exceed 20 m in height and 28 cm in DBH.

2 Boysen, B., Strobl, S. (Editors), 1991. A Grower's guide to Hybrid Poplar. Ontario Ministry of Natural Resources. (Out of print).

Appendix O-1: Hybrid Poplar Stem Volume Table (outside bark)

These volume tables are valid for crop densities of 400-1000 spha (Popovich, 1986); samples based on 555 spha[29].

Fields highlighted are based on the best data; non-highlighted fields are less reliable.

29 Popovich, S. Hybrid poplar - The first form factor and volume tables for Quebec. Information Report LAU-X-71E, Laurentian Foretsry Service - Canadian Forestry Service, 1986

Hybrid Poplar Stem Volume Table - m^3 per tree - stem volume (outside bark)

Diameter at Breast Height (DBH) - cm	Height - m												
	8	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
10	0.0300	0.0334	0.0367	0.0399	0.0431	0.0463							
11	0.0349	0.0388	0.0426	0.0464	0.0500	0.0536							
12	0.0403	0.0448	0.0492	0.0535	0.0577	0.0618	0.0658						
13	0.0463	0.0515	0.0566	0.0615	0.0663	0.0710	0.0755						
14	0.0528	0.0588	0.0646	0.0703	0.0758	0.0811	0.0862						
15		0.0667	0.0734	0.0798	0.0860	0.0921	0.0980						
16			0.0828	0.0901	0.0972	0.1040	0.1107	0.1171	0.1233				
17			0.0930	0.1012	0.1092	0.1169	0.1244	0.1316	0.1386	0.1453	0.1518	0.1581	0.1640
18				0.1131	0.1220	0.1307	0.1391	0.1472	0.1551	0.1627	0.1700	0.1770	0.1837
19				0.1257	0.1357	0.1454	0.1548	0.1639	0.1727	0.1812	0.1894	0.1973	0.2048
20				0.1391	0.1503	0.1611	0.1716	0.1817	0.1915	0.2010	0.2101	0.2189	0.2274
21					0.1657	0.1777	0.1893	0.2006	0.2115	0.2220	0.2322	0.2420	0.2514
22					0.1819	0.1952	0.2080	0.2205	0.2326	0.2442	0.2555	0.2664	0.2769
23					0.1990	0.2136	0.2278	0.2415	0.2548	0.2677	0.2802	0.2922	0.3038
24					0.2170	0.2330	0.2485	0.2636	0.2782	0.2924	0.3061	0.3194	0.3322
25						0.2533	0.2703	0.2868	0.3028	0.3183	0.3334	0.3480	0.3621
26						0.2745	0.2930	0.3110	0.3285	0.3455	0.3620	0.3779	0.3934
27						0.2966	0.3167	0.3363	0.3554	0.3739	0.3918	0.4092	0.4261
28						0.3197	0.3415	0.3627	0.3834	0.4035	0.4230	0.4419	0.4603

Appendix O-2: Hybrid Poplar Stem Volume Table (inside bark)

These volume tables are valid for crop densities of 400-1000 spha (Popovich, 1986);

Samples are based on 555 spha and report volumes outside bark.

29 Popovich, S. Hybrid poplar - The first form factor and volume tables for Quebec. Information Report LAU-X-71E, Laurentian Foretsry Service - Canadian Forestry Service, 1986

$$\left\{ 0.41791 - \frac{0.51408}{\text{Height}} - \frac{0.1293 \text{ X Height}}{\text{DBH}} + \frac{0.94392 \text{ X Height}}{(\text{DBH})^2} + \frac{55.5001}{(\text{DBH})^2 \text{ X Height}} \right\} \text{ X Basal Area X Height}$$

Fields highlighted are based on the best data; non-highlighted fields are based on fewer data points.

Hybrid Poplar Stem Volume Table - m³ per tree - stem volume (inside bark)

	Height - m												
Diameter at Breast Height (DBH) - cm	8	9	10	11	12	13	14	15	16	17	18	19	20
10	0.0248	0.0276	0.0304	0.0331	0.0358	0.0384							
11	0.0288	0.0322	0.0354	0.0386	0.0417	0.0448							
12	0.0333	0.0372	0.0410	0.0448	0.0484	0.0519							
13	0.0382	0.0428	0.0472	0.0515	0.0558	0.0599	0.0638						
14	0.0436	0.0488	0.0540	0.0590	0.0638	0.0686	0.0732						
15		0.0554	0.0613	0.0670	0.0726	0.0781	0.0833						
16			0.0692	0.0758	0.0821	0.0883	0.0943	0.1002	0.1058				
17			0.0777	0.0851	0.0923	0.0994	0.1062	0.1128	0.1192				
18				0.0951	0.1032	0.1112	0.1189	0.1263	0.1336	0.1407	0.1475	0.1541	
19				0.1057	0.1149	0.1237	0.1324	0.1408	0.1490	0.1569	0.1646	0.1720	
20				0.1170	0.1272	0.1371	0.1467	0.1561	0.1653	0.1741	0.1827	0.1911	
21					0.1402	0.1512	0.1619	0.1724	0.1825	0.1924	0.2020	0.2113	
22					0.1540	0.1661	0.1780	0.1895	0.2008	0.2117	0.2224	0.2328	
23					0.1684	0.1818	0.1948	0.2076	0.2200	0.2321	0.2439	0.2553	
24					0.1836	0.1982	0.2125	0.2265	0.2402	0.2535	0.2665	0.2791	
25						0.2154	0.2311	0.2464	0.2613	0.2759	0.2901	0.3040	
26						0.2334	0.2505	0.2672	0.2835	0.2994	0.3149	0.3301	
27						0.2522	0.2707	0.2888	0.3066	0.3239	0.3408	0.3573	
28						0.2717	0.2918	0.3114	0.3306	0.3494	0.3678	0.3857	

Appendix P: Weeds by Herbicide

(1)	Roundup Original	Tank mix with 2,4-D in summerfallow
(RR)	Roundup Original	Not effective on glyphosate-resistant Canola
(2)	Casoron G-4	Controlled with the higher rates and late fall applications.
(3)	Lontrel 360	Suppression only. Higher rate for control.
(4)	Lontrel 360	Perennial sow thistle - top suppression only
(X)	Lontrel 360	Narrow-leaved hawksbeard is not on the label
(5)	Venture L	Quackgrass - top suppression only @ 1.0 L/ha
Note 1	Not in Prairie region	
Weed ID	Use only scientific names in search	[Web-USDA Weeds]

Family Name	Common Name	Scientific Name	Multiple common names - See scientific names	Weed type					Herbicides				
				Annual (A)	Winter Annual (WA)	Biennial B)	(Simple) Perennial (SP/P)	Creeping Perennial (CP)	Roundup Original (PCP 13644)	Vision Silviculture (PCP# 19899)	Casoron G-4	Lontrel 360	Venture L
Amaranth	red root pigweed	Amaranthus retroflexus		A					X		X		
Amaranth	slim amaranth	Amaranthus hybridus	Amaranthus hybridus	A					X				
Amaranth	smooth pigweed	Amaranthus hybridus	Amaranthus hybridus	A					X				
Borage	bluebur	Lappula squarrosa		A	WA				X(1)				
Buckwheat	curled dock	Rumex crispus	Rumex crispus				P		X	X			
Buckwheat	curly dock	Rumex crispus	Rumex crispus				P		X	X			
Buckwheat	field dock	Rumex pseudonatronatus					SP						
Buckwheat	green smartweed	Polygonum scabrum	Polygonum scabrum	A					X				
Buckwheat	Japanese knotweed	Polygonum cuspidatum					P		X	X			
Buckwheat	lady's thumb	Polygonum persicaria		A					X				
Buckwheat	pale smartweed	Polygonum lapathifoliurn	Polygonum lapathifoliurn	A							X		
Buckwheat	Pennsylvania smartweed	Polygonum pensylvanicum		A					X				
Buckwheat	prostrate knotweed	Polygonum aviculare		A			P				X		
Buckwheat	red sorrel	Rumex acetosella	Rumex acetosella				P				X(2)	X(3)	

Appendix P: Weeds by Herbicide **(Continued)**

(1)	Roundup Original	Tank mix with 2,4-D in summerfallow
(RR)	Roundup Original	Not effective on glyphosate-resistant Canola
(2)	Casoron G-4	Controlled with the higher rates and late fall applications.
(3)	Lontrel 360	Suppression only. Higher rate for control.
(4)	Lontrel 360	Perennial sow thistle - top suppression only
(X)	Lontrel 360	Narrow-leaved hawksbeard is not on the label
(5)	Venture L	Quackgrass - top suppression only @ 1.0 L/ha
Note 1	Not in Prairie region	
Weed ID	Use only scientific names in search	[Web-USDA Weeds]

Family Name	Common Name	Scientific Name	Multiple common names - See scientific names	Weed type					Herbicides				
				Annual (A)	Winter Annual (WA)	Biennial B)	(Simple) Perennial (SP/P)	Creeping Perennial (CP)	Roundup Original (PCP 13644)	Vision Silviculture (PCP# 19899)	Casoron G-4	Lontrel 360	Venture L
Buckwheat	sheep sorrel	Rumex acetosella	Rumex acetosella				P				X(2)	X(3)	
Buckwheat	smartweed	Polygonum lapathifoliurn	Polygonum lapathifoliurn	A							X		
Buckwheat	smartweed (green-flowered)	Polygonum scabrum	Polygonum scabrum	A					X				
Buckwheat	wild buckwheat	Polygonum convolvulus		A					X		X(2)	X	
Cashew	poison ivy spp.	Toxicodendron rydbergii (a.k.a. Rhus radicans)	Toxicodendron rydbergii				P		X	X			
Cashew	western poison ivy	Toxicodendron rydbergii (a.k.a. Rhus radicans)	Toxicodendron rydbergii				P		X	X			
Cattails	cattail (common)	Typha latifolia					P		X	X			
Dogbane	hemp dogbane	Apocynum cannabinum					P		X	X			
Fern	bracken fern	Pteridium aquilinum						CP			X		
Figwort	flax (volunteer)	Linaria spp					P		X				
Figwort	toadflax (yellow)	Linaria vulgaris						CP	X	X			

Appendix P: Weeds by Herbicide (Continued)

(1)	Roundup Original	Tank mix with 2,4-D in summerfallow
(RR)	Roundup Original	Not effective on glyphosate-resistant Canola
(2)	Casoron G-4	Controlled with the higher rates and late fall applications.
(3)	Lontrel 360	Suppression only. Higher rate for control.
(4)	Lontrel 360	Perennial sow thistle - top suppression only
(X)	Lontrel 360	Narrow-leaved hawksbeard is not on the label
(5)	Venture L	Quackgrass - top suppression only @ 1.0 L/ha
Note 1	Not in Prairie region	
Weed ID	Use only scientific names in search	[Web-USDA Weeds]

Family Name	Common Name	Scientific Name	Multiple common names - See scientific names	Weed type					Herbicides				
				Annual (A)	Winter Annual (WA)	Biennial B)	(Simple) Perennial (SP/P)	Creeping Perennial (CP)	Roundup Original (PCP 13644)	Vision Silviculture (PCP# 19899)	Casoron G-4	Lontrel 360	Venture L
Geranium	stork's bill (redstem)	Erodium cicutarium		A	WA	B			X				
Goosefoot	kochia	Kochia scoparia		A					X		X		
Goosefoot	lamb's-quarters	Chenopodium album		A					X		X		
Goosefoot	Russian thistle	Salsola pestifer (Salsola kali spp.)		A					X				
Grass	barley	Hordeum vulgare		A					X				
Grass	barley (volunteer)	Hordeum spp.		A					X				X
Grass	barnyard grass	Echinochloa crusgalli		A					X				X
Grass	blue grass (annual)	Poa annua		A					X		X		
Grass	blue grass (Canada)	Poa compressa					P		X	X			
Grass	blue grass (Kentucky)	Poa pratensis					P		X	X			
Grass	broomcorn millet	Panicum miliaceum	Panicum miliaceum	A					X				X
Grass	corn (volunteer)	Zea Mays		A					X				
Grass	crab grass (large)	Digitaria sanguinalis	Digitaria sanguinalis	A					X		X		X

Appendix P: Weeds by Herbicide **(Continued)**

(1)	Roundup Original	Tank mix with 2,4-D in summerfallow
(RR)	Roundup Original	Not effective on glyphosate-resistant Canola
(2)	Casoron G-4	Controlled with the higher rates and late fall applications.
(3)	Lontrel 360	Suppression only. Higher rate for control.
(4)	Lontrel 360	Perennial sow thistle - top suppression only
(X)	Lontrel 360	Narrow-leaved hawksbeard is not on the label
(5)	Venture L	Quackgrass - top suppression only @ 1.0 L/ha
Note 1	Not in Prairie region	
Weed ID	Use only scientific names in search	[Web-USDA Weeds]

Family Name	Common Name	Scientific Name	Multiple common names - See scientific names	Weed type					Herbicides				
				Annual (A)	Winter Annual (WA)	Biennial B)	(Simple) Perennial (SP/P)	Creeping Perennial (CP)	Roundup Original (PCP 13644)	Vision Silviculture (PCP# 19899)	Casoron G-4	Lontrel 360	Venture L
Grass	crab grass (smooth)	Digitaria ischaemum		A					X		X		X
Grass	downy brome	Bromus tectorum		A	WA				X				
Grass	fall panicum	Panicum dichotomiflorum		A					X				X
Grass	foxtail	Setaria spp.		A							X		
Grass	foxtail barley	Hordeum jubatum					SP		X	X			
Grass	giant foxtail	Setaria faberi	Setaria faberi	A					X				X
Grass	green bristlegrass	Setaria viridis	Setaria viridis	A					X				X
Grass	green foxtail	Setaria viridis	Setaria viridis	A					X				X
Grass	hairy crabgrass	Digitaria sanguinalis	Digitaria sanguinalis	A					X		X		X
Grass	Japanese bristlegrass - Note 1	Setaria faberi	Setaria faberi	A					X				X
Grass	Johnsongrass	Sorghum halepense						CP					X
Grass	pearl millet	Pennisetum glaucum (a.k.a. Panicum americanum)		A			P						
Grass	Persian darnel	Lolium persicum	Lolium persicum	A					X				X

Appendix P: Weeds by Herbicide **(Continued)**

(1)	Roundup Original	Tank mix with 2,4-D in summerfallow
(RR)	Roundup Original	Not effective on glyphosate-resistant Canola
(2)	Casoron G-4	Controlled with the higher rates and late fall applications.
(3)	Lontrel 360	Suppression only. Higher rate for control.
(4)	Lontrel 360	Perennial sow thistle - top suppression only
(X)	Lontrel 360	Narrow-leaved hawksbeard is not on the label
(5)	Venture L	Quackgrass - top suppression only @ 1.0 L/ha
Note 1	Not in Prairie region	
Weed ID	Use only scientific names in search	[Web-USDA Weeds]

Family Name	Common Name	Scientific Name	Multiple common names - See scientific names	Weed type					Herbicides				
				Annual (A)	Winter Annual (WA)	Biennial B)	(Simple) Perennial (SP/P)	Creeping Perennial (CP)	Roundup Original (PCP 13644)	Vision Silviculture (PCP# 19899)	Casoron G-4	Lontrel 360	Venture L
Grass	Persian ryegrass	Lolium persicum	Lolium persicum	A					X				X
Grass	proso millet	Panicum miliaceum	Panicum miliaceum	A					X				X
Grass	quackgrass	Agropyron repens (a.k.a. Elytrigia repens)						CP	X	X	X(2)		X(5)
Grass	smooth brome grass	Bromus inermis					P		X	X			
Grass	wheat (volunteer)	Triticum aestivum		A					X				X
Grass	wild millet/ green foxtail	Setaria viridis	Setaria viridis	A					X				X
Grass	wild oats	Avena fatua		A					X				X
Grass	wild proso millet	Panicum miliaceum	Panicum miliaceum	A					X				X
Grass	wirestem muhly	Muhlenbergia frondosa					P		X				X
Grass	witchgrass	Panicum capillare		A									X
Grass	yellow foxtail	Setaria pumila (a.k.a. Setaria glauca)		A					X				X
Horsetail	field horsetail	Equisetum arvense	Equisetum arvense					CP			X		

Appendix P: Weeds by Herbicide (Continued)

(1)	Roundup Original	Tank mix with 2,4-D in summerfallow
(RR)	Roundup Original	Not effective on glyphosate-resistant Canola
(2)	Casoron G-4	Controlled with the higher rates and late fall applications.
(3)	Lontrel 360	Suppression only. Higher rate for control.
(4)	Lontrel 360	Perennial sow thistle - top suppression only
(X)	Lontrel 360	Narrow-leaved hawksbeard is not on the label
(5)	Venture L	Quackgrass - top suppression only @ 1.0 L/ha
Note 1	Not in Prairie region	
Weed ID	Use only scientific names in search	[Web-USDA Weeds]

Family Name	Common Name	Scientific Name	Multiple common names - See scientific names	Weed type					Herbicides				
				Annual (A)	Winter Annual (WA)	Biennial B)	(Simple) Perennial (SP/P)	Creeping Perennial (CP)	Roundup Original (PCP 13644)	Vision Silviculture (PCP# 19899)	Casoron G-4	Lontrel 360	Venture L
Horsetail	horsetail	Equisetum arvense	Equisetum arvense					CP			X		
Loosestrife	purple loosestrife	Lythrum salicaria					SP		X	X	X		
Madder	cleavers	Galium aparine		A	WA				X				
Mallow	roundleaved mallow	Malva rotundifolia (pusilla)		A		B			X				
Mallow	velvetleaf	Abutilon theophrasti		A					X				
Milkweed	milkweed (common)	Asclepias syriaca					P		X	X			
Mint	hempnettle	Galeopsis tetrahit		A					X				
Morningglory	field bindweed	Convolvulus arvensis						CP	X	X	X(2)		
Morningglory	field dodder	Cuscuta spp.	Cuscuta spp.	A					X				
Morningglory	parasitic dodder	Cuscuta spp.	Cuscuta spp.	A					X				
Mustard	bittercress (hairy) - Note 1	Cardamine hirsuta		A	WA						X		
Mustard	canola (volunteer)	Brassica napus		A					X (RR)				
Mustard	charlock mustard	Sinapsis arvensis (a.k.a. Brassica kaber)	Sinapsis arvensis	A					X				
Mustard	flixweed	Descurania sophia		A	WA	B			X				

Appendix P: Weeds by Herbicide (Continued)

(1)	Roundup Original	Tank mix with 2,4-D in summerfallow
(RR)	Roundup Original	Not effective on glyphosate-resistant Canola
(2)	Casoron G-4	Controlled with the higher rates and late fall applications.
(3)	Lontrel 360	Suppression only. Higher rate for control.
(4)	Lontrel 360	Perennial sow thistle - top suppression only
(X)	Lontrel 360	Narrow-leaved hawksbeard is not on the label
(5)	Venture L	Quackgrass - top suppression only @ 1.0 L/ha
Note 1	Not in Prairie region	
Weed ID	Use only scientific names in search	[Web-USDA Weeds]

Family Name	Common Name	Scientific Name	Multiple common names - See scientific names	Weed type					Herbicides				
				Annual (A)	Winter Annual (WA)	Biennial B)	(Simple) Perennial (SP/P)	Creeping Perennial (CP)	Roundup Original (PCP 13644)	Vision Silviculture (PCP# 19899)	Casoron G-4	Lontrel 360	Venture L
Mustard	hoary cress	Cardaria draba					P		X	X			
Mustard	shepherd's purse	Capsella bursa-pastoris		A	WA				X		X		
Mustard	stinkweed	Thlaspi arvense		A	WA				X				
Mustard	various	various spp.		A	WA						X		
Mustard	wild mustard	Sinapsis arvensis (a.k.a. Brassica kaber)	Sinapsis arvensis	A					X				
Nightshade	cupped nightshade	Solanum sarrachoides	Solanum sarrachoides	A									
Nightshade	cutleaf nightshade	Solanum triflorum	Solanum triflorum	A					X				
Nightshade	eastern black flowering nightshade	Solanum ptycanthum	Solanum ptycanthum	A					X				
Nightshade	hairy nightshade	Solanum sarrachoides	Solanum sarrachoides	A									
Nightshade	potatoweed	Solanum sarrachoides	Solanum sarrachoides	A									
Nightshade	West Indian nightshade	Solanum ptycanthum	Solanum ptycanthum	A					X				
Nightshade	wild tomato	Solanum triflorum	Solanum triflorum	A					X				
Pea	alfalfa	Medicago sativa					SP		X	X		X	
Pea	alsike clover	Trifolium hybridum		A			P					X	

Appendix P: Weeds by Herbicide (Continued)

(1)	Roundup Original	Tank mix with 2,4-D in summerfallow
(RR)	Roundup Original	Not effective on glyphosate-resistant Canola
(2)	Casoron G-4	Controlled with the higher rates and late fall applications.
(3)	Lontrel 360	Suppression only. Higher rate for control.
(4)	Lontrel 360	Perennial sow thistle - top suppression only
(X)	Lontrel 360	Narrow-leaved hawksbeard is not on the label
(5)	Venture L	Quackgrass - top suppression only @ 1.0 L/ha
Note 1	Not in Prairie region	
Weed ID	Use only scientific names in search	[Web-USDA Weeds]

Family Name	Common Name	Scientific Name	Multiple common names - See scientific names	Weed type					Herbicides				
				Annual (A)	Winter Annual (WA)	Biennial B)	(Simple) Perennial (SP/P)	Creeping Perennial (CP)	Roundup Original (PCP 13644)	Vision Silviculture (PCP# 19899)	Casoron G-4	Lontrel 360	Venture L
Pea	American vetch	Vicia americana					P						
Pea	bird vetch	Vicia cracca	Vicia cracca				P					X	
Pea	garden vetch	Vicia sativa (var. angustifolia)	Vicia sativa		WA				X				
Pea	narrow-leaved vetch	Vicia sativa (var. angustifolia)	Vicia sativa		WA				X				
Pea	red clover	Trifolium pratense		A			P					X	
Pea	tufted vetch	Vicia cracca	Vicia cracca				P					X	
Pea	vetch	Vicia spp.		A		B	P				X(2)	X	
Pea	white clover	Trifolium repens					SP					X	
Pink	common chickweed	Stellaria media		A	WA				X		X		
Pink	corn spurry	Spergula arvensis		A					X				
Pink	cow cockle	Saponaria vaccaria		A					X				
Pink	night flowering catchfly	Silene noctiflora		A	WA				X				
Plantain	broadleaf plantain	Plantago major	Plantago major	A			SP		X(1)		X		
Plantain	plantain	Plantago major	Plantago major				SP		X(1)		X		
Purslane	common purslane	Portulaca oleracea	Portulaca oleracea	A							X		
Purslane	purslane	Portulaca oleracea	Portulaca oleracea	A							X		

Appendix P: Weeds by Herbicide (Continued)

(1)	Roundup Original	Tank mix with 2,4-D in summerfallow
(RR)	Roundup Original	Not effective on glyphosate-resistant Canola
(2)	Casoron G-4	Controlled with the higher rates and late fall applications.
(3)	Lontrel 360	Suppression only. Higher rate for control.
(4)	Lontrel 360	Perennial sow thistle - top suppression only
(X)	Lontrel 360	Narrow-leaved hawksbeard is not on the label
(5)	Venture L	Quackgrass - top suppression only @ 1.0 L/ha
Note 1	Not in Prairie region	
Weed ID	Use only scientific names in search	[Web-USDA Weeds]

Family Name	Common Name	Scientific Name	Multiple common names - See scientific names	Weed type					Herbicides				
				Annual (A)	Winter Annual (WA)	Biennial B)	(Simple) Perennial (SP/P)	Creeping Perennial (CP)	Roundup Original (PCP 13644)	Vision Silviculture (PCP# 19899)	Casoron G-4	Lontrel 360	Venture L
Rush	grasses (Juncus species)	Juncus spp					P				X		
Sedge	Chamisso's cottongrass	Eriophorum chamissonis	Eriophorum chamissonis				P		X	X			
Sedge	cottontop	Eriophorum chamissonis	Eriophorum chamissonis				P		X	X			
Sedge	grasses (Sedge species)	Cyperus spp.					P				X		
Sedge	yellow nutsedge	Cyperus esculentus						CP	X	X	X(2)		
Spurge	leafy spurge	Euphorbia esula						CP			X		
Spurge	thyme-leaved spurge	Euphorbia serpyllifolia		A					X(1)				
Sunflower	absinth(e)	Artemisia absinthium	Artemisia absinthium				SP		X	X	X(2)		
Sunflower	annual ragweed	Ambrosia artemisiifolia		A					X			X	
Sunflower	artemisia	Artemisia absinthium	Artemisia absinthium				SP		X	X	X(2)		
Sunflower	blue aster (smooth) - Note 1	Aster laevis (Aster spp.)					P				X		

Appendix P: Weeds by Herbicide (Continued)

(1)	Roundup Original	Tank mix with 2,4-D in summerfallow
(RR)	Roundup Original	Not effective on glyphosate-resistant Canola
(2)	Casoron G-4	Controlled with the higher rates and late fall applications.
(3)	Lontrel 360	Suppression only. Higher rate for control.
(4)	Lontrel 360	Perennial sow thistle - top suppression only
(X)	Lontrel 360	Narrow-leaved hawksbeard is not on the label
(5)	Venture L	Quackgrass - top suppression only @ 1.0 L/ha
Note 1	Not in Prairie region	
Weed ID	Use only scientific names in search	[Web-USDA Weeds]

Family Name	Common Name	Scientific Name	Multiple common names - See scientific names	Weed type					Herbicides				
				Annual (A)	Winter Annual (WA)	Biennial B)	(Simple) Perennial (SP/P)	Creeping Perenial (CP)	Roundup Original (PCP 13644)	Vision Silviculture (PCP# 19899)	Casoron G-4	Lontrel 360	Venture L
Sunflower	Canada fleabane	Conyza canadensis (a.k.a. Erigeron canadensis)	Conyza canadensis	A	WA				X				
Sunflower	Canada thistle	Cirsium arvense						CP	X	X	X(2)	X	
Sunflower	Canadian horseweed	Conyza canadensis (a.k.a. Erigeron canadensis)	Conyza canadensis	A	WA				X				
Sunflower	cocklebur	Xanthium strumarium		A					X				
Sunflower	common groundsel	Senecio vulgaris		A	WA						X	X	
Sunflower	common ragweed	Ambrosia artemisiifolia		A					X			X	
Sunflower	dandelion	Taraxacum officinale					SP		X	X	X(2)		
Sunflower	fleabane	Conyza canadensis (a.k.a. Erigeron canadensis)	Conyza canadensis	A	WA				X				
Sunflower	horseweed	Conyza canadensis (a.k.a. Erigeron canadensis)	Conyza canadensis	A	WA				X				
Sunflower	narrow-leaved hawksbeard	Crepis tectorum		A	WA				X			(X)	
Sunflower	ox-eye daisy	Chrysanthemum leucanthemum						CP				X(3)	

Appendix P: Weeds by Herbicide (Continued)

(1)	Roundup Original	Tank mix with 2,4-D in summerfallow
(RR)	Roundup Original	Not effective on glyphosate-resistant Canola
(2)	Casoron G-4	Controlled with the higher rates and late fall applications.
(3)	Lontrel 360	Suppression only. Higher rate for control.
(4)	Lontrel 360	Perennial sow thistle - top suppression only
(X)	Lontrel 360	Narrow-leaved hawksbeard is not on the label
(5)	Venture L	Quackgrass - top suppression only @ 1.0 L/ha
Note 1	Not in Prairie region	
Weed ID	Use only scientific names in search	[Web-USDA Weeds]

Family Name	Common Name	Scientific Name	Multiple common names - See scientific names	Weed type					Herbicides				
				Annual (A)	Winter Annual (WA)	Biennial B)	(Simple) Perennial (SP/P)	Creeping Perennial (CP)	Roundup Original (PCP 13644)	Vision Silviculture (PCP# 19899)	Casoron G-4	Lontrel 360	Venture L
Sunflower	perennial sow thistle	Sonchus arvensis	Sonchus arvensis					CP	X			X(4)	X
Sunflower	prickly lettuce	Lactuca scariola (serriola)		A	WA				X				
Sunflower	scentless chamomile	Matricaria maritima		A	WA	B	SP					X	
Sunflower	sow thistle	Sonchus spp.									X		
Sunflower	sow thistle (annual)	Sonchus oleraceus		A	WA				X				
Sunflower	sow thistle (annual-spiny)	Sonchus asper	Sonchus asper	A	WA								
Sunflower	sow thistle (perennial)	Sonchus arvensis	Sonchus arvensis					CP	X			X(4)	X
Sunflower	spiny annual sow thistle	Sonchus asper	Sonchus asper	A	WA								
Sunflower	wormwood	Artemisia absinthium	Artemisia absinthium				SP		X	X	X(2)		

Appendix Q: Herbicide labels and safety data sheets (MSDS)

Regarding the glyphosate-based herbicides, this is not a complete listing of all available glyphosate-based herbicides for site preparation.

PCP#	Product Name	Active Ingredient	Company Labels	Company MSDS	Misc. info
23545	LONTREL 360 HERBICIDE	clopyralid	http://www.dowagro.com/ca/prod/lontrel.htm	http://www.dowagro.com/ca/prod/lontrel.htm	
12533	CASORON G-4 GRANULAR HERBICIDE	dichlobenil	http://www.uap.ca/products/products.htm	http://www.uap.ca/products/products.htm	Marketed through UAP Canada
21209	VENTURE L POSTEMERGENCE HERBICIDE	fluazifop-P-butyl	http://www.syngenta.ca/en/labels/index.asp?nav=lbl	http://www.syngenta.ca/en/labels/index.asp?nav=msds	
27090	IPCO FACTOR® LIQUID HERBICIDE	glyphosate	http://www.ipco.ca/content.asp?content_id=27	http://www.ipco.ca/content.asp?content_id=27	Click on product: Factor® Glyphosate
26429	MAVERICK HERBICIDE SOLUTION	glyphosate	http://www.dowagro.com/ca/labels/index.htm	http://www.dowagro.com/ca/labels/index.htm	
25866	NUFARM CREDIT LIQUID HERBICIDE	glyphosate	http://www.nufarm.ca/	http://www.nufarm.ca/	Click on product: Credit®
27457	ROUNDUP ORIGINAL 360 LIQUID HERBICIDE	glyphosate	http://www.monsanto.ca/products/labelsmsds/index.shtml	http://www.monsanto.ca/products/labelsmsds/index.shtml	
13644	ROUNDUP ORIGINAL LIQUID HERBICIDE	glyphosate	http://www.monsanto.ca/products/labelsmsds/index.shtml	http://www.monsanto.ca/products/labelsmsds/index.shtml	
27487	ROUNDUP WEATHERMAX WITH TRANSORB 2 TECHNOLOGY LIQUID HERBICIDE	glyphosate	http://www.monsanto.ca/products/labelsmsds/index.shtml	http://www.monsanto.ca/products/labelsmsds/index.shtml	
26884	VANTAGE FORESTRY HERBICIDE SOLUTION	glyphosate	http://www.dowagro.com/ca/prod/vantage-forestry.htm	http://www.dowagro.com/ca/prod/vantage-forestry.htm	
26172	VANTAGE HERBICIDE SOLUTION	glyphosate	http://www.dowagro.com/ca/labels/index.htm	http://www.dowagro.com/ca/labels/index.htm	
26171	VANTAGE PLUS HERBICIDE SOLUTION	glyphosate	http://www.dowagro.com/ca/labels/index.htm	http://www.dowagro.com/ca/labels/index.htm	
27736	VISION MAX SILVICULTURE HERBICIDE	glyphosate	http://www.monsanto.ca/products/labelsmsds/index.shtml	http://www.monsanto.ca/products/labelsmsds/index.shtml	
19899	VISION SILVICULTURE HERBICIDE B MONSANTO	glyphosate	http://www.monsanto.ca/products/labelsmsds/index.shtml	http://www.monsanto.ca/products/labelsmsds/index.shtml	

Appendix Q-1: Herbicide labels and safety data sheets (MSDS) – Crop Maintenance

Regarding the glyphosate-based herbicides, this is not a complete listing of all available glyphosate-based herbicides for crop maintenance. Glyphosate-based herbicides not specifically labelled for use in poplar are not useable in a poplar crop.

PCP#	Product Name	Active Ingredient	Company Labels	Company MSDS	Misc. info
23545	LONTREL 360 HERBICIDE	clopyralid	http://www.dowagro.com/ca/prod/lontrel.htm	http://www.dowagro.com/ca/prod/lontrel.htm	
12533	CASORON G-4 GRANULAR HERBICIDE	dichlobenil	http://www.uap.ca/products/products.htm	http://www.uap.ca/products/products.htm	Marketed through UAP Canada
21209	VENTURE L POSTEMERGENCE HERBICIDE	fluazifop-P-butyl	http://www.syngenta.ca/en/labels/index.asp?nav=lbl	http://www.syngenta.ca/en/labels/index.asp?nav=msds	
26884	VANTAGE FORESTRY HERBICIDE SOLUTION	glyphosate	http://www.dowagro.com/ca/prod/vantage-forestry.htm	http://www.dowagro.com/ca/prod/vantage-forestry.htm	
27736	VISION MAX SILVICULTURE HERBICIDE	glyphosate	http://www.monsanto.ca/products/labelsmsds/index.shtml	http://www.monsanto.ca/products/labelsmsds/index.shtml	
19899	VISION SILVICULTURE HERBICIDE B MONSANTO	glyphosate	http://www.monsanto.ca/products/labelsmsds/index.shtml	http://www.monsanto.ca/products/labelsmsds/index.shtml	

Appendix R: Glyphosate-based herbicides for site preparation

This is not a complete listing of all available glyphosate-based herbicides.

				Pre-plant	Site Prep		
PCP#	Product Name	Registrant's name	SRIC Poplar Crop	All crops	Summerfallow	Aerial	Tankmix Summer fallow
27090	Ipco Factor® Liquid Herbicide	Interprovincial Cooperative Limited		✓	✓		Banvel®; Pardner®; 2,4-D
26429	Maverick Herbicide Solution	Dow Agrosciences Canada Inc.		✓	✓		Banvel®; Pardner®; 2,4-D
25866	Nufarm Credit Liquid Herbicide	Nufarm Agriculture Inc.		✓	✓		Banvel®; Pardner®; 2,4-D
27457	Roundup Original 360 Liquid Herbicide	Monsanto Canada Inc.		✓	✓		Banvel®; Pardner®; 2,4-D
13644	Roundup Original Liquid Herbicide	Monsanto Canada Inc.		✓	✓		Banvel®; Pardner®; 2,4-D
27487	Roundup Weathermax With Transorb 2 Technology Liquid Herbicide	Monsanto Canada Inc.		✓	✓		Banvel® II; Pardner®; 2,4-D
26884	Vantage Forestry Herbicide Solution	Dow Agrosciences Canada Inc.	✓			✓	
26172	Vantage Herbicide Solution	Dow Agrosciences Canada Inc.		✓	✓		Banvel®; Pardner®; 2,4-D
26171	Vantage Plus Herbicide Solution	Dow Agrosciences Canada Inc.		✓	✓		Banvel®; Pardner®; 2,4-D
27736	Vision Max Silviculture Herbicide	Monsanto Canada Inc.	✓			✓	
19899	Vision Silviculture Herbicide B Monsanto	Monsanto Canada Inc.	✓			✓	

Appendix S: Planting Record by Field

Planting Record by Field

Farm name or #:	____________	**Mapped:**	☐
		Planting type:	
		New planting	☐
Field Name:	____________	Fillplanting	☐
Field #:	____________	Re-planting	☐
Size (ha):	______ *(1 ha = 2.47 ac.)*	**Planting method:**	
Size (ac.):	______ *(1 ac. = 0.4 ha)*	Machine planting:	☐
		Manual planting:	☐
Planting contractor:	____________	**Marking:**	
Start date:	______	Tree rows:	☐
Completion date:	______	Cross marked:	☐

Payment %: ______ **Planting quality %:** ______

Spacing error %: ______

Paid: ☐

	Bid	Paid
Cost per tree:	¢	¢
Cost per ha:	$	$
Cost per ac.:	$	$
Total:	$	$

Planting Quality	Spacing error	Payment
95-100%	0-5%	100%
85-94.9%	0-5%	Equal to quality %
	> 5%	**5% price penalty**
<85%	n/a	No payment

In-row spacing standards:

	In-row spacing	Tolerance: No cross marking	Tolerance: Cross marking	
Manual	m	+/- 5%	0%	*(1 m = 3.28 ft.)*
	ft.			
Machine	m	+/- 5%	+/-10 cm	*(1 ft. = 0.31 m)*
	ft.		+/- 4 in.	

					Net of Spacing error %
Spha standard:		spha	+/- 5%	**Spha actual-net:**	
Spac standard:		spac		**Spac actual-net:**	

Planned Block #	Clone	Stock type	# trees	ha	spha	ac.	spac
Total							

Actual Block #	**Clone**	**Stock type**	**# trees**	**ha**	**spha (gross)**	**ac.**	**spac (gross)**
Total							

Comments: --

Appendix T Page 1 of 2: Planting Quality Assessment Plots

Planting Quality Assessment Plots
To be used for 'work quality plots' or 'payment plots'

Calculations on page 2

Farm name or #: ________________

Field Name: ______________________
Field #: ______________
Contractor: ______________________
Start date: ______________
End date: ______________

	In-row spacing		**Tolerance**	
			No cross marking	Cross marking
Manual		m	+/- 5%	0%
		ft.		
Machine		m	+/- 5%	+/-10 cm
		ft.		+/- 4 in.

				In-row spacing						
Row #	Plot #	Tree #	Good	Error	Spacing (m or ft.)	Not in tree row	Poor planting	Damage	Missing	Comment error

Appendix T Page 2 of 2: Planting Quality Assessment Plots

				In-row spacing						
Row #	Plot #	Tree #	Good	Error	Spacing (m or ft.)	Not in tree row	Poor planting	Damage	Missing	Comment error
Total										

# of trees sampled:	**A**		Cannot exceed the highest tree #		
# of trees sampled that are good:	**B**				
# of trees with in-row spacing error:	C		=		%
# of trees not in the tree row:	D		=		%
# of trees poorly planted:	E		**Total**		% **spacing errors**
# of trees damaged:	F				
# of trees missing:	G				

Appendix U: Fertilizer Formulations

Modified from [Web-Fertilizers]

	(%)				
Material	**N**	**P_2O_5**	**K_2O**	**MgO**	**S**
Ammonium Nitrate	35.0	-	-	-	-
Ammonium Sulphate	21.0	-	-	-	24.0
Calcium Nitrate	15.5	-	-	-	-
Diammonium Phosphate	18.0	46.0	-	-	-
Monoammonium phosphate	11.0	52.0	-	-	-
Muriate of Potash	-	-	60.0	-	-
Potassium Nitrate	13.5	-	44.0	-	-
SKMG or SULPOMAG	-	-	22.0	18.0	22.0
Sulphate of Potash	-	-	50.0	-	18.0
Single Super Phosphate	-	22.0	-	-	14.0
Triple Super Phosphate	-	46.0	-	-	-
Urea	46.0	-	-	-	-

Formulations of P_2O_5, K_2O and MgO converted to elemental values of P, K and Mg respectively.

		(%)		
Elemental values		**P**	**K**	**Mg**
Diammonium Phosphate		20.0		
Monoammonium phosphate		22.6		
Muriate of Potash			50.0	
Potassium Nitrate			36.7	
SKMG or SULPOMAG			18.3	10.8
Sulphate of Potash			41.7	
Single Super Phosphate		9.6		
Triple Super Phosphate		20.0		

27 Hacskaylo, J. Finn, R.F., Vimmerstedt, J.P. Deficiency symptoms of some forest trees. Research Bulletin 1015. Ohio Agricultural Research and Development Center. January 1969.

Appendix V: Deficiency symptoms of macro- and micro nutrients[27]

Deficiency symptoms of macro- and micro nutrients as observed in a greenhouse study of trees grown on solutions that lacked one of the nutrients. Some of the information is augmented with observations by practitioners in the field.

Macronutrients		**Description**
Nitrogen	N	Reduction in leaf size Pale yellowish-green colour
Phosphorus	P	Leaf size unaffected Bronzing of interveinal leaf tissue, starting with lower foliage (P is mobile) In more serious state, tissue necrosis (blackening and dying) of lower foliage Uppermost foliage still looks relatively healthy
Potassium	K	Leaf size slightly smaller The veins are green; interveinal tissue turns yellow In more serious state, tissue necrosis (blackening and dying) of leaf margins in lower foliage
Calcium	Ca	Terminal bud and uppermost leaves are disintegrating Terminal leaves are small, yellow and will die
Magnesium	Mg	The veins are green; interveinal tissue turns yellow (difficult to distinguish from K deficiency)
Sulphur	S	Pale green interveinal tissue Tissue near the veins darker green Leaf sizes are markedly reduced

Micronutrients		**Description**
Iron	Fe	Yellow-green to almost white leaves (looks bleached). This is a common problem in the Prairie region on high pH soils Veins darker green Reduced leaf size Symptoms develop first in terminal leaves (Fe is relatively immobile)
Manganese	Mn	Little effect on leaf size Leaves may have a wrinkled look (difficult to distinguish from K deficiency)
Zinc	Zn	Deficiency symptoms may be varied
Boron	B	Rosetting of terminal leaves (resembles damage caused by a thrips species)
Copper	Cu	Leaves mottled green to yellow-green Leaves are smaller and are cupped and/or distorted Some necrosis could occur along margins Blackening of the leaf tips Trees tend to outgrow this
Molybdenum	Mo	Unclear
Chlorine	Cl	Yellowing, followed by necrosis

Appendix W: Example of foliar sampling guidelines

Enviro-Test Laboratories
Plant Sampling Guidelines

Plant analysis indicates the nutritional status of the plant. It is used to check for hidden hunger in a good-looking crop as-well-as nutrient deficiencies in a poor crop.

Nutrient deficiency can occur in the plant due to...
- that nutrient being low in the soil
- another nutrient being high in the soil
- another nutrient being low in the soil
- environmental conditions
- herbicide residue or disease

Plant analysis is not a replacement for soil sampling, but an agronomic tool that enhances the soil test.

When to take the plant sample
- *When the crop looks poor:* if the poor crop is in patches, 2 plant samples and 2 soil samples are usually taken - 1 plant sample and 1 soil sample from the 'good' areas and 1 plant and 1 soil from the 'poor' areas. If the crop is generally poor looking, 1 plant sample (and a soil sample if one wasn't taken earlier).
- *When checking for hidden hunger early, so corrections can be made:* often from tillering to leaf sheath lengthening in cereals, rosette in oilseeds, and vegetative stages of pulses and forages.
- *When checking for hidden hunger late, to evaluate the fertility program:* often from flag leaf to head fully emerged in cereals, from late flowering to pods formed/filling in oilseeds and pulses, and during late flowering of forages.
- *High value crops:* corn and sugar beets are often sampled 3 to 4 times and potatoes every week or 2 during the growing season to ensure optimal nutrient supply.

The attached Plant Sampling Staging-Guide shows that samples can be taken during most growth stages, especially for cereals.

Number and part of plant to sample

The attached Plant Sampling Staging-Guide shows the number and part of plant to sample depending on the growth stage.

Where to take the sample

- Random sampling: stay out of low and high areas or take separate samples from these areas.
- Benchmark sampling
- Transect sampling: plants are taken every so many feet along a straight line crossing the field or area of the field.

How to take the sample

- When the plant is not under heat stress (in the morning is often best).
- Avoid plants affected by disease, pesticide, insects, hail, wind, frost and recent fertilizer application.
- Cleanliness is important: avoid contact with fertilizer, salt, grease, soil, etc.
- Cut the plants with a clean, rust-free knife or scissors and put in the Enviro-Test plant envelope.
- Keep the sample cool (do NOT freeze) and courier, bus or deliver to the lab.
- Enviro-Test supplies Envelopes, Information Sheets, and courier waybills free-of-charge.

For assistance, call 1-800-667-7645

	Supplies	Agronomy
Alberta:	Amanda Tran	Brandon Green
Saskatchewan:	Richard Seaward	Troy McInnis
Manitoba:	Blaine Boughen	Paul Routledge

Appendix X: How to prune correctly

Source: Boysen, B., Strobl, S. (Editors), 1991. A Grower's Guide to Hybrid Poplar. Ontario Ministry of Natural Resources. (Out of print).

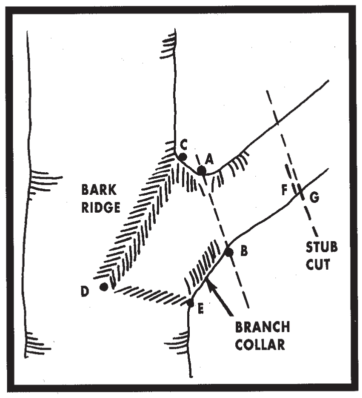


FIGURE 8.2 **MAKING A PROPER CUT** *(Adapted from Shigo 1989, p. 29)*

There are three important rules to remember when you are pruning
- **Do not leave stubs**
- **Do not make flush cuts**
- **Do not paint wounds.**

HOW TO PRUNE CORRECTLY

(Refer to Figure 8.2 at left)

1. Find the branch bark ridge and the branch collar, E to B.
2. Make a small cut at F, then cut through the whole branch at G (called a stub cut).
3. Find points A and B where the branch joins the branch collar. Cut with care from A to B, or from B to A.
   If the position of B is not readily found, picture a line from A to E. Point D is the beginning of the branch bark ridge. The angle EAD is approximately the same as angle EAB.

Proper pruning of a living branch is a cut as close as possible to the branch collar (but not flush with the stem). If the cut is not made at this point there will be a break in the woundwood around the perimeter of the cut and the wound will not heal fully. There is no set angle for a proper cut – the cuts illustrated in Figure 8.3 are all proper cuts.

FOR FURTHER READING

Shigo, A.L. 1989. Tree pruning – a worldwide photo guide. Shigo and Trees Associates. 186 pages.

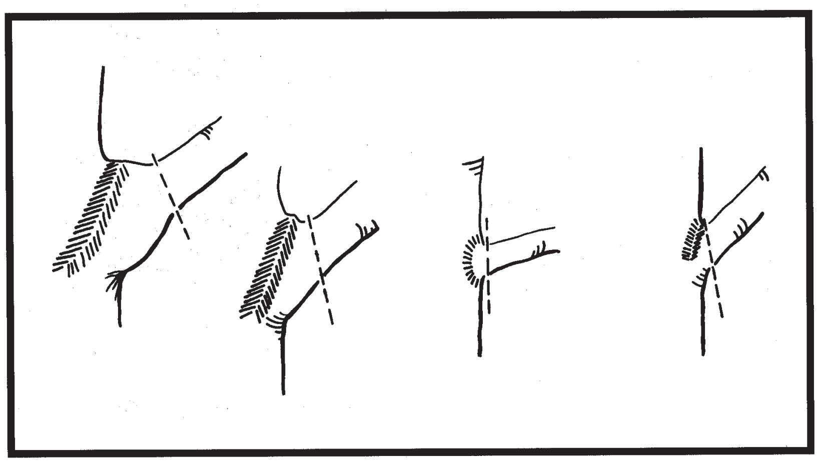


FIGURE 8.3 **PROPER CUTS** *(Adapted from Shigo 1989, p. 29)*

Appendix Y: Survey and Inventory Form (Page 1 of 2)

Farm Survey & Inventory Form			**Date:**			**SURVIVAL**	**or**
Farm Name:			**Type #:**		**Trees Planted:**		
Farm Number:			**Field #:**		**# Plots:**		**P**
			Block#:		**Trees/Plot:**		
	Ha	**Ac.**			**Sample every:**		th Row
Total Area:					**Sample every:**		th Tree - **T**
Spha/spac pltd:					**Start with:**		th Tree in 1^{st} Row

INVENTORY

ROW #	PLOT #	TREE #	HT (m)	DBH (cm)	Volume m^3	Count dead or missing	Clone	Comments
	1	1						
		2						
		3						
	2	4						
		5						
		6						
	3	7						
		8						
		9						
	4	10						
		11						
		12						
	5	13						
		14						
		15						
	6	16						
		17						
		18						
	7	19						
		20						
		21						
	8	22						
		23						
		24						
	9	25						
		26						
		27						
	10	28						
		29						
		30						
	11	31						
		32						
		33						
	12	34						
		35						
		36						
	13	37						
		38						
		39						
	14	40						
		41						
		42						

Appendix Y: Survey and Inventory Form (Page 2 of 2)

Farm Survey & Inventory Form **Date:** ______ | **SURVIVAL** or **INVENTORY**

Farm Name:		**Type #:**	
Farm Number:		**Field #:**	
		Block#:	

Trees Planted:			
# Plots:		**P**	
Trees/Plot:			
Sample every:		th Row	
Sample every:		th Tree - **T**	
Start with:		th Tree in 1st Row	

	Ha	Ac.
Total Area:		
Spha/spac pltd:		

ROW #	PLOT #	TREE #	HT (m)	DBH (cm)	Volume m^3	Count dead or missing	Clone	Comments
	15	43						
		44						
		45						
	16	46						
		47						
		48						
	17	49						
		50						
		51						
	18	52						
		53						
		54						
	19	55						
		56						
		57						
	20	58						
		59						
		60						
Total								
			C	D	E	F		

For **Survival Survey**, only **fill in** height (**HT**) field; leave **empty** when **dead** or **missing**.
For **Inventory**, **fill in** height (**HT**) **and** diameter (**DBH**); leave **empty** when tree is **dead** or **missing**.
In column 'Count - dead or missing' tally all trees between and in plots that are dead or missing.
In column 'Volume' enter values from Volume Tables (Appendices O or O-1 or O-2).

# of trees sampled:	**A**		Cannot exceed the highest tree #		
# of trees alive:	**B**				
% Survival:	**S%**		%	=(**A/B**) x 100	
Average Height (HT):			m	=**C/B**	
Average Diameter (DBH):			cm	=**D/B**	
Average Volume per tree:			m^3	=**E/B**	(inside bark/outside bark)
Spha survived:			/ha	=**spha planted** (top of form) x **S%**	
Average Volume per Hectare:			m^3 per Ha		(inside bark/outside bark)
Extra - % Dead or Missing:			%	=**(F/(P x T)) x 100**	
Occupancy %:			%	=**(# of Plots with 1 or more trees/P) x 100**	

1 ha	=	2.47 ac.
1 ac.	=	0.4 ha
1 m	=	3.28 ft.
1 ft.	=	0.31 m

1 ha = 10,000 square meters, or a field 100x100 m
1 ac = 43560 sq. ft., or an area 66x660 ft.

Appendix Z: How to measure DBH and height (Page 1 of 3)

Source: Boysen, B., Strobl, S. (Editors), 1991. A Grower's Guide to Hybrid Poplar. Ontario Ministry of Natural Resources. (Out of print).

APPENDIX 10.1 HOW TO MEASURE DBH AND HEIGHT

DBH, diameter of a tree at breast height, is measured at 1.3 metres (4.5 feet) above the ground. It is usually measured to the nearest 0.5 or 1.0 centimetres. In summary tables these measurements can be grouped into 2 centimetre diameter classes to show distribution of tree size (eg. the 4 cm DBH class includes trees with a DBH of 3.1 to 5.0 cm). DBH can be measured using a diameter tape or a set of callipers. There are a number of situations where diameter will be measured at other than breast height – see Figure 1.

Wrap the diameter tape snugly around the tree at breast height. The tape should not sag or be wrapped at an angle – it should be held at the same level all around the tree. The reading from the tape is the diameter of the tree. If a regular tape measure is used, the reading must be divided by 3.14 (π or pi).

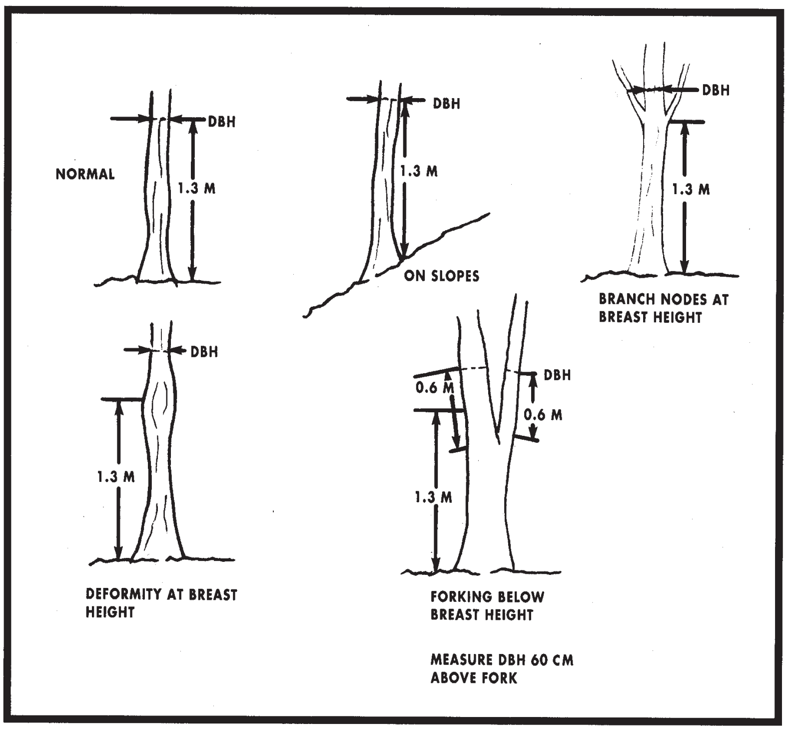


FIGURE 1 DBH MEASUREMENT

Appendix Z: How to measure DBH and height (Page 2 of 3)

GROWTH AND YIELD OF HYBRID POPLAR

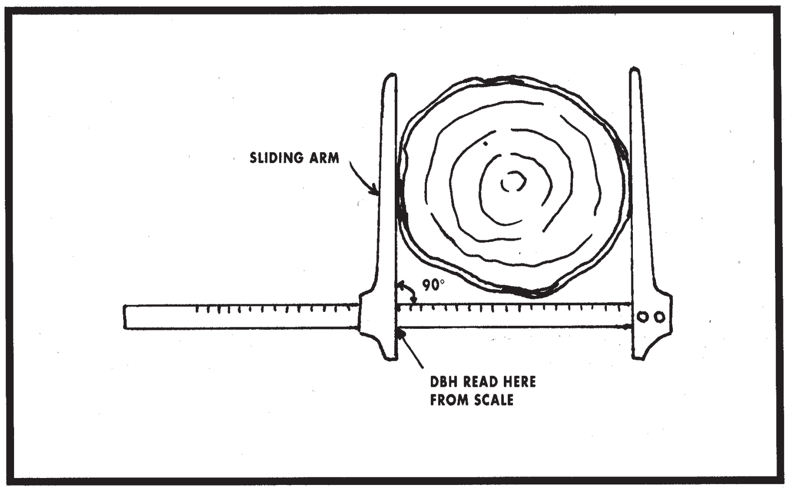


FIGURE 2 **USE OF CALLIPERS TO MEASURE DBH OF TREE – X-SECTIONAL VIEW**

A set of callipers consists of a graduated scale with two arms perpendicular to the scale; one arm fixed at the end of the scale, the other arm moving to fit around a tree. Hold the sliding arm at right angles to the scale when the two arms are pressed around a tree (See Figure 2). Read the measurement where the inside of the second arm crosses the scale.

HOW TO MEASURE HEIGHT

The total height of the tree is measured from the base of the tree to the tip of the crown using a height pole or an instrument called a hypsometer. A height pole works well for trees less than 12 metres. For taller trees a hypsometer should be used (eg. Suunto, Abney level or Haga altimeter). Heights are usually measured to the following levels of precision:

< 3 m	– to the nearest 0.01 metre
3-6 m	– to the nearest 0.10 metre
6-10 m	– to the nearest 0.25 metre
10-13 m	– to the nearest 0.50 metre
> 13 m	– to the nearest 1.00 metre

Appendix Z: How to measure DBH and height (Page 3 of 3)

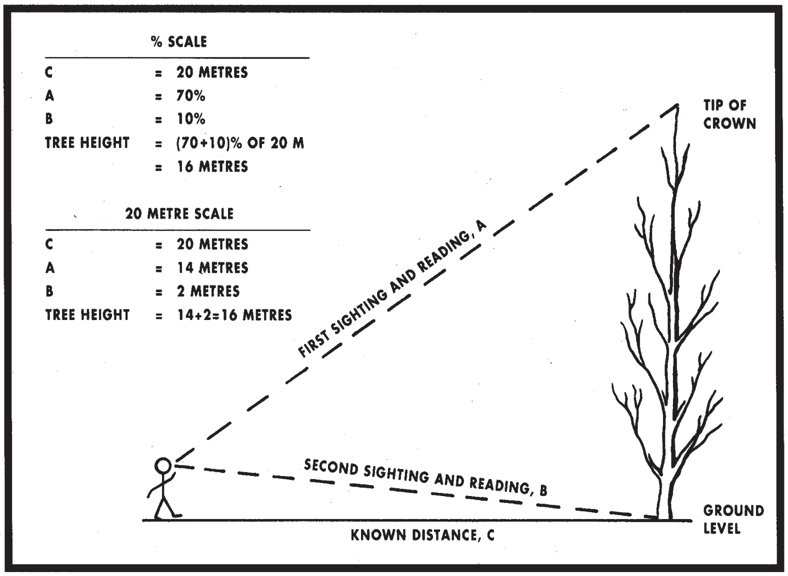


FIGURE 3 USE OF SUUNTO HYPSOMETER TO MEASURE HEIGHT

HEIGHT POLE

Fixed length height poles can be easily made of wood or aluminum and the graduations measured and marked on for easy visibility from a distance. Telescopic height poles are also available. Both require one person to hold the pole against the tree and a second person to stand a distance away. The second person reads the height from the fixed height pole where it meets the tip of the crown. With a telescopic pole, the person holding it reads the height off a meter on the pole when the second person tells him that the pole is even with the top of the tree.

HYPSOMETER

Hypsometers, small hand-held instruments based on principles of trigonometry, are used to measure the height of a tree indirectly. Using, for example a Suunto (a commonly used hypsometer) stand a known distance away from the tree where both the top and the bottom of the tree are visible. Sight on the top of the tree and take a reading from the per cent scale. Then sight on the bottom of the tree and take a second reading (See Figure 3). Add the second reading, if on the negative scale, to the first reading, or if on the positive scale, subtract it from the first reading. The result is a per cent that is multiplied by the distance you are away from the tree, to give the height of the tree.

Appendix AA: Discounting table with present values (PV)

The tables below can be used in financial analysis to calculate PV, using various discount rates. For instance:

Today's PV of one dollar earned next year:

- At a 2% discount rate, one dollar in year 1 is worth today (present) 98.0¢.
- At a 10% discount rate, one dollar in year 1 is worth today (present) 90.9¢.

Today's PV of one dollar earned 20 years from today:

- At a 2% discount rate, one dollar in year 20 is worth today (present) 67.3¢.
- At a 10% discount rate, one dollar in year 20 is worth today (present) 14.9¢.

This table contains rounded off PV values.

	Year										
	0	1	2	3	4	5	6	7	8	9	10
2%	1.000	0.980	0.961	0.942	0.924	0.906	0.888	0.871	0.853	0.837	0.820
3%	1.000	0.971	0.943	0.915	0.888	0.863	0.837	0.813	0.789	0.766	0.744
4%	1.000	0.962	0.925	0.889	0.855	0.822	0.790	0.760	0.731	0.703	0.676
5%	1.000	0.952	0.907	0.864	0.823	0.784	0.746	0.711	0.677	0.645	0.614
6%	1.000	0.943	0.890	0.840	0.792	0.747	0.705	0.665	0.627	0.592	0.558
7%	1.000	0.935	0.873	0.816	0.763	0.713	0.666	0.623	0.582	0.544	0.508
8%	1.000	0.926	0.857	0.794	0.735	0.681	0.630	0.583	0.540	0.500	0.463
9%	1.000	0.917	0.842	0.772	0.708	0.650	0.596	0.547	0.502	0.460	0.422
10%	1.000	0.909	0.826	0.751	0.683	0.621	0.564	0.513	0.467	0.424	0.386

	Year									
	11	12	13	14	15	16	17	18	19	20
2%	0.804	0.788	0.773	0.758	0.743	0.728	0.714	0.700	0.686	0.673
3%	0.722	0.701	0.681	0.661	0.642	0.623	0.605	0.587	0.570	0.554
4%	0.650	0.625	0.601	0.577	0.555	0.534	0.513	0.494	0.475	0.456
5%	0.585	0.557	0.530	0.505	0.481	0.458	0.436	0.416	0.396	0.377
6%	0.527	0.497	0.469	0.442	0.417	0.394	0.371	0.350	0.331	0.312
7%	0.475	0.444	0.415	0.388	0.362	0.339	0.317	0.296	0.277	0.258
8%	0.429	0.397	0.368	0.340	0.315	0.292	0.270	0.250	0.232	0.215
9%	0.388	0.356	0.326	0.299	0.275	0.252	0.231	0.212	0.194	0.178
10%	0.350	0.319	0.290	0.263	0.239	0.218	0.198	0.180	0.164	0.149

	Year									
	21	22	23	24	25	26	27	28	29	30
2%	0.660	0.647	0.634	0.622	0.610	0.598	0.586	0.574	0.563	0.552
3%	0.538	0.522	0.507	0.492	0.478	0.464	0.450	0.437	0.424	0.412
4%	0.439	0.422	0.406	0.390	0.375	0.361	0.347	0.333	0.321	0.308
5%	0.359	0.342	0.326	0.310	0.295	0.281	0.268	0.255	0.243	0.231
6%	0.294	0.278	0.262	0.247	0.233	0.220	0.207	0.196	0.185	0.174
7%	0.242	0.226	0.211	0.197	0.184	0.172	0.161	0.150	0.141	0.131
8%	0.199	0.184	0.170	0.158	0.146	0.135	0.125	0.116	0.107	0.099
9%	0.164	0.150	0.138	0.126	0.116	0.106	0.098	0.090	0.082	0.075
10%	0.135	0.123	0.112	0.102	0.092	0.084	0.076	0.069	0.063	0.057

Appendix AB: DCF Form

DCF Analysis

			Year									Harvest Year
Main phases	Details		0	1	2	3	4					
Site Preparation costs												
Crop Planting costs												
Crop Maintenance costs												
Harvest & transport												
	Harvest ($\$/m^3 \times m^3/ha$)											
	Transport ($\$/m^3 \times m^3/ha$)											
Total Costs												
Revenues	Poplar											
	Other											
Total Revenues												
Discount rate	%											
PV (Appendix AA)												
		Total										
Present Value (PV) of costs - \$/ha												
Present Value (PV) of revenues - \$/ha												
Net Present Value (NPV) - \$/ha			Subtract PV costs from PV revenues									