Identifying the root collar on forest tree seedlings

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This paper offers practical guidelines on how to identify the root collar of species commonly grown in Ontario forest tree nurseries. These guidelines would also be applicable to naturally-regenerated seedlings. Difficulties associated with locating the root collar on transplanted stock are also addressed. Colour differences on the stem are not reliable for locating the root collar; stem colouration can vary according to surface soil level and planting depth. The paper distinguishes among three parameters: apparent root collar (ARC), root collar, and ground-line diameter.

Key words: caliper, cotyledon, hypocotyl

Cet article présente des directives pratiques sur la manière d'identifier le collet racinaire des espèces couramment produites dans les pépinières forestières de l'Ontario. Ces directives peuvent être aussi appliquées aux semis issus de la régénération naturelle. Les difficultés associées à la localisation du collet racinaire des semis transplantés sont également abordés. La différence de couleur sur la tige ne constitue pas un moyen fiable de localisation du collet racinaire; la coloration peut varier en fonction du niveau du sol de surface et de la profondeur de plantation. Cet article établit la distinction entre trois paramètres; le collet racinaire apparent (CRA), le collet racinaire, et le diamètre au niveau du sol.

Mots clés: compas forestier, cotylédon, hypocotyle

Introduction

Morphological attributes are frequently used to characterize seedlings in the nursery and after field planting (Chavasse 1980; Jalkanen *et al.* 1992; Muse and Hatchell 1992). Features that are commonly measured or assessed include stem length, stem diameter, mass of roots and shoots, appearance of buds and foliage, number of first-order lateral roots, root fibre, root deformity, and stem form. Seedling size, primarily described by stem length and diameter, is used to cull and grade seedlings in Ontario (Mullin and Christl 1981, 1982; Reese and Sadreika 1979; von Althen 1969). Of these morphological characteristics, stem diameter has frequently been cited as the morphological measure most strongly related to seedling performance after planting (Mexal and Landis 1990; Mullin and Christl 1981, 1982; Mullin and Svaton 1972; Thompson 1985).

The root collar is commonly used as the location for measuring stem diameter and the reference base for measuring the stem height of forest tree seedlings. But, where exactly is the root collar? There is no common opinion or approach on how to identify its location. For example, at various Ontario nurseries the root collar is often identified by the colour difference on the stem. The relative position of the colour difference may be highly variable between adjacent trees, because it is affected by shifts in the surface soil and planting depth. In other instances, the first lateral root is used to identify the position of the root collar, but this can be affected by treatment as new lateral roots can form above the root collar or at various positions on the plant (Esau 1977). Another practice is to identify the root collar at or near the soil surface (Sutton and Tinus 1983). Two potential problems with this approach are that i) the soil surface does not have a consistent relationship with the position of the seedling, and ii) the seedlings may be planted with their root collars at different positions relative to the soil surface. Using

different approaches to locate the root collar can create confusion when researchers, nursery and field staff try to exchange information on seedling morphology and treatment effects.

The objective of this paper is to propose practical guidelines for identifying the root collar, thereby ensuring that data collected by different individuals at different locations are consistent and comparable. The recommendations are applicable to both naturally- and artificially-regenerated seedlings less than five-years old.

Key Factors to Consider

Terminology (see also Appendix 1)

Root collar is a forestry term which generally does not appear in botanical texts. Esau (1977) refers to a *transition region*: "A region in the plant axis where root and shoot are united and which shows primary structural characteristics transitional between those of stem and root." The Empire Forestry Association (1953) definition for root collar is similar, being described as "...the transition zone between the stem and root, sometimes recognizable in trees and seedlings by the presence of a slight swelling." Although the root collar may be easily recognizable in some species, Burdett (1979) cautioned that "... in other species such as Douglas-fir (*Pseudotsuga menziesii* (Mirb) Franco) and white spruce (*Picea glauca*) (Moench) Voss) the position of the stem-root junction is not so clearly evident. In such cases the lowermost branch or needle could be used as a reference point." Sutton and Tinus (1983) summarized various definitions of 'root collar' as: "1) loosely, the point along the main stem-root axis at which the primary vascular anatomy changes from that of a stem to that of a root. The transition point between stem and root (Panshin and de Zeeuw 1980); 2) the groundline level on the main axis; 3) the position on the main stem at an arbitrary distance, usually two to three cm, below the cotyledonary node; 4) the point on the seedling's stem midway between the soil surface and the cotyledon scar (Chavasse 1977)." Day *et al.* (1987) suggested measuring root collar diameter in the lower five mm of the hypocotyl. Mexal and Landis (1990) reported that root collar diameter is measured at the ground line and that some nurseries standardize the location by measuring root collar diameter at the cotyledon scar or one cm above

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the first lateral root. Considering these definitions, there does not appear to be consensus on the location of the root collar.

The root collar occurs somewhere along the *hypocotyl*, i.e. below the cotyledonary node and above the uppermost roots (see Fig 1A,B). As Sutton and Tinus (1983) pointed out, the lower part of the hypocotyl is root-like and the upper part of the hypocotyl is stem-like in anatomy. Even if one were to study the internal anatomical structure of the hypocotyl, it would be difficult to locate the root collar as a distinct point on the stem separating the root from the shoot. What hope then do we have of locating the root collar on the outside of the seedling? At best, only an *apparent root collar* (ARC) can be identified. The root collar then becomes a zone on the stem, chosen not arbitrarily, but on the basis of an understanding of seedling development and morphology. These morphological characteristics depend on seed germination; specifically, whether the cotyledons are raised above the soil (in epigeal species) or remain below the soil (in hypogeal species).

Epigeal Germination

The location of the root collar differs by species. For seeds of species exhibiting *epigeal germination* (Fig. 1A,B), the elongation of the hypocotyl raises the cotyledons above the soil (Schopmeyer 1974). This is the case for most conifers and some hardwoods grown in Ontario (see Appendix 2).

For most Ontario conifers, including white pine (*Pinus strobus* L.), red pine (*Pinus resinosa* Ait.), jack pine (*Pinus banksiana* Lamb.), black spruce (*Picea mariana* (Mill.) B.S.P.), and white spruce (*Picea glauca* (Moench) Voss), the hypocotyl has virtually no taper and can be readily seen as the stem below the cotyledons. There is usually a distinct swelling or bump at

the cotyledonary node (Fig. 1A, 2A,C,E) which separates the hypocotyl (below) from the epicotyl (above). Such a swelling is commonly absent on eastern white cedar (*Thuja occidentalis* L.) and therefore the lowermost branch can be taken as the reference point to identify the *apparent root collar* (ARC) instead of the cotyledonary node.

In some hardwoods, such as white ash (*Fraxinus americana* L.), a ring of dormant buds may be the only clue to the location of the cotyledonary node (Fig. 1B, 3A). The hypocotyl may also exhibit a pronounced degree of taper, which makes the location of the ARC more difficult.

For untransplanted seedlings of epigeal conifers, we recommend locating the ARC 0.5 cm below the cotyledonary node if present, or 0.5 cm below the lowermost branch in the case of eastern white cedar. For untransplanted seedlings of epigeal hardwoods, we recommend locating the ARC 0.5 cm below the cotyledonary node if visible, or 0.5 cm below the lowermost ring of dormant buds.

Hypogeal Germination

For seeds exhibiting *hypogeal germination* (Fig. 1C), the cotyledons and hypocotyl remain below ground while the epicotyl elongates (Schopmeyer 1974). In hypogeal species, such as black walnut (*Juglans nigra* L.), northern red oak (*Quercus rubra* L.), and silver maple (*Acer saccharinum* L.) the true root collar is below the soil surface and inaccessible. Locating an ARC on hypogeal species is further complicated by the high degree of taper of the stem just above the soil surface.

On excavated seedlings, a pronounced crook may be present on the stem just below the soil surface (Fig. 3C). Such a crook can develop when the epicotyl elongates around the buried

Figure 1. A, a 3-year-old white pine (*Pinus strobus* L.) seedling, showing the location of the epicotyl, cotyledonary node, hypocotyl, and soil level; B, a 1-year-old white ash (*Fraxinus americana* L.) seedling, showing the location of the epicotyl, cotyledonary node marked by a ring of dormant buds, hypocotyl, and soil level; and C, a 1-year-old black walnut (*Juglans nigra* L.) seedling, showing the location of the epicotyl, the scar at or just beneath the soil surface, and soil level.

Figure 2. Conifers: A & B, 1-year-old jack pine (*Pinus banksiana* Lamb.); C & D, 3+0 white pine (*Pinus strobus* L.); and E & F, 3+0 white spruce (*Picea glauca* (Moench) Voss). The arrow points to the swelling at the junction between the hypocotyl and the epicotyl at the cotyledonary node. This figure also shows the colour difference before (A, C & E) and after (B, D & F) scraping the bark. Note: there is no conspicuous colour difference in these conifers before scraping.

seed coat and cotyledons. At or just below the soil surface the stem may develop a distinct line or scar, often accompanied by a swelling or bump (Fig. 3C, E).

For untransplanted seedlings of hypogeal hardwoods, we recommend that the ARC be located 2 cm above the scar at the soil surface if present, or 2 cm above the soil surface. This location will usually avoid the most highly tapered region on the stem and is consistent with the current practice of measuring the stem diameter 1.3 to 2.5 cm (0.5 to 1 inch) above the soil surface on hardwood seedlings (M. Rose, St. Williams Nursery, per. com.).

Transplants and Deeply Planted Seedlings

The root collar is often difficult to locate on transplants and seedlings that have been deeply planted at the nursery or on field sites. These trees often undergo a radical change in morphology: a close examination of three-year-old black spruce greenhouse transplants reveals that the original root collar is often located far below a major lateral root and well below the surface of the soil (Fig. 4A,B). Often, needle remnants or branch stubs may be the only clue to its location (Fig. 4C). In such cases, the original root collar would be an impractical point to use for mea-

Figure 3. Hardwoods: A & B, 1+0 white ash (*Fraxinus americana* L.); C & D, 1+0 silver maple (*Acer saccharinum* L.); and E & F, 1+0 black walnut (*Juglans nigra* L.). For white ash (A & B) the arrow points to the swelling at the junction between the hypocotyl and the epicotyl at the cotyledonary node. For silver maple (C & D) and black walnut (E & F) the arrow points to the line or scar at the surface of the soil. This figure also shows the colour difference before (A, C & E) and after (B, D & F) scraping the bark. Note: there is no conspicuous colour difference in these hardwoods before scraping. No colour difference was detected in black walnut even after scraping.

suring stem diameter, stem length, or stem height.

For deeply planted seedlings or transplants with buried root collars, we recommend that stem diameter be measured 2 cm above the soil surface. The term *ground-line diameter* should be used to indicate that stem diameter was measured on deeply planted or transplanted seedlings and that this measurement was not taken at the apparent root collar. Measurements should be taken at least 2 weeks after planting to permit soil around newly planted trees to settle.

Colour Difference

A difference in stem colour, from green to off-white, has often been used to identify the location of the root collar. Green colouration indicates the presence of chlorophyll, the production of which is stimulated by exposure of the stem to light. However, colour difference may not be a reliable indicator of the location of the root collar. For example, if the root collar is buried (as might occur in transplanted seedlings) or if the soil level around the seedling shifts to cover more of the stem, the

4A

4B

4C

Figure 4. 3-year-old black spruce (*Picea mariana* (Mill.) B.S.P.) greenhouse transplants. Arrows labelled "a" point to the position of the root collar before transplanting. Arrows labelled "b" point to contradictory evidence which makes it difficult to consistently locate the apparent root collar using criteria such as "below lowermost branch" or "above uppermost root". For example, arrows labelled "b" point to a root off of lowermost branch (A); an old branch buried below primary lateral roots (B); and a root and branch initiated from the same point on the stem (C).

soil would block the sunlight and likely prevent the formation of chlorophyll. The location of the colour difference would therefore be misleading, as it could be considerably higher on the stem than the actual root collar (Fig. 2B,D,F) and its position on the stem could vary considerably between adjacent individuals. Perhaps the strongest argument against using the colour difference to locate the root collar is that often the colour difference is not distinct unless the stem bark is scraped away (Fig. 2D,F, 3B). Scraping is time-consuming and damaging.

We recommend that colour difference not be used to locate the root collar on forest tree seedlings.

Recommendations: Identifying the Root Collar

Identifying the *apparent root collar* (ARC) ensures that there is consistency in the location and in the terminology used to describe where stem diameter is being measured on a young tree. It is not our intention to propose strict rules for locating the root collar, but rather suggest guidelines according to the species and the planting situation.

The following recommendations are applicable to both naturally- and artificially-regenerated seedlings. A summary of these guidelines, for nursery and field use, is given (Table 1).

1. For untransplanted seedlings of epigeal species with a distinct cotyledonary node, locate the *apparent root collar* (ARC) on the hypocotyl, 0.5 cm below the cotyledonary node, or 0.5 cm below the lowermost ring of dormant buds.
2. For untransplanted seedlings of epigeal species without a distinct cotyledonary node, such as eastern white cedar, locate the *apparent root collar* (ARC) 0.5 cm beneath the lowermost branch.
3. For untransplanted seedlings of hypogeal species, locate the *apparent root collar* (ARC) 2 cm above the scar at the soil surface if visible, or 2 cm above the soil surface.
4. Sometimes it is not possible to locate the apparent root collar as we have suggested, or it may be impractical to use the apparent root collar for diameter measurements. This is true when measuring deeply planted seedlings or transplants in the nursery or on field sites. In such instances, diameter measurements should be taken 2 cm above the soil surface for conifers and hardwoods. Such measurements should be identified as the *ground-line diameter*, not as apparent root collar.

The authors have not examined all native Ontario species before offering these recommendations. Rather, the recommendations are based on an examination of a sample of trees from the most common species, stock types and age classes produced by the private and provincial nurseries. Accordingly, we caution readers to evaluate the recommendations by trying to use them while closely examining their species, stock types, and age classes.

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Table 1. Summary of recommendations for identifying the apparent root collar or the ground-line diameter on forest tree seedlings. Only species examined by the authors are listed. Species are listed alphabetically by their common names

Species	Where to locate the apparent root collar (ARC)
Ashes Green ash White ash	Untransplanted seedlings of epigeal species with a distinct cotyledonary node
Dogwoods Red Osier dogwood	Hardwoods
Larches European larch Japanese larch Tamarack	0.5 cm below the cotyledonary node or 0.5 cm below the lowermost ring of dormant buds
Maples Sugar maple	
Pines Eastern white pine Jack pine Red pine	Untransplanted seedlings of epigeal species with a distinct cotyledonary node Conifers
Spruces Black spruce Norway spruce White spruce	0.5 cm below the cotyledonary node
Arbor-vitae Eastern white cedar	Untransplanted seedlings of epigeal species without a distinct cotyledonary node 0.5 cm below the lowermost branch
Maples Silver maple	Untransplanted seedlings of hypogeal species
Oaks Northern Red oak White oak	2 cm above scar at soil surface or 2 cm above soil surface
Walnuts Black walnut	
Other situations	Where to locate the ground-line diameter
Transplants	2 cm above soil surface
Deeply planted trees	
Unable to locate ARC	Such measurements should be identified as ground-line diameter
Impractical to use ARC	

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Appendix 1. Selected glossary of terms

apparent root collar. (ARC) ¹A location on the stem where the root collar diameter should be measured. It is located using reference points based on the morphological and germination characteristics for a given species.

cotyledonary node. That part of the stem at which ... [the cotyledons] ... are attached (Esau 1977).

cotyledons. First leaves developed in the embryo of a seed. They may contain stored food for the initial growth of the seedling as in the dicotyledonous genus *Quercus* or they may become functional leaves after germination as in the polycotyledonous genus *Pinus* (Schopmeyer 1974).

epicotyl. Portion of the axis of a plant embryo or seedling stem above the cotyledons (Schopmeyer 1974).

Stem portion of the plumule in seedlings (Sutton and Tinus 1983).

epigeal. Type of seed germination in which the cotyledons are forced above the ground by the elongation of the hypocotyl (Schopmeyer 1974).

hypocotyl. Part of the axis of a plant embryo or seedling stem between the cotyledons and the radicle (Schopmeyer 1974). Sometimes considered to divide the root from the stem (Sutton and Tinus 1983).

hypogeal. Type of seed germination in which the cotyledons remain below ground while the epicotyl elongates ... (Schopmeyer 1974).

root collar. Loosely, the point along the main stem-root axis at which the primary vascular anatomy changes from that of a stem to that of a root. Transition point between stem and root (Sutton and Tinus 1983).

The transition zone between the stem and root, sometimes recognizable in trees and seedlings by the presence of a slight swelling (The Empire Forestry Association 1953).

ground-line diameter. ¹Term used when stem diameter of young trees is measured at a point other than the apparent root collar.

stem height. ¹Vertical or perpendicular height of the stem from the base of the topmost bud to some reference point, usually the root collar or the soil surface.

stem length. ¹Linear distance along the stem from the base of

the topmost bud to some reference point, usually the root collar.

transition region. A region in the plant axis where root and shoot are united and which shows primary structural characteristics transitional between those of stem and root. Best exhibited in seedlings (Esau 1977).

Appendix 2.

Epigeal species: cotyledons raised above the ground (Burns and Honkala 1990A,B)

Conifers

<i>Abies</i>	firs
<i>Juniperus</i>	junipers
<i>Larix</i>	larches, tamarack
<i>Picea</i>	spruces
<i>Pinus</i>	pinos
<i>Taxus</i>	yews
<i>Thuja</i>	arborvitae
<i>Tsuga</i>	hemlocks

Hardwoods

<i>Acer</i>	maples (most)
<i>Alnus</i>	alder
<i>Amelanchier</i>	serviceberry
<i>Betula</i>	birches
<i>Carpinus</i>	hornbeam
<i>Catalpa</i>	catalpa
<i>Cornus</i>	dogwood
<i>Fagus</i>	beech
<i>Fraxinus</i>	ashes
<i>Gleditsia</i>	honey-locust
<i>Liriodendron</i>	yellow poplar
<i>Malus</i>	apples
<i>Morus</i>	mulberry
<i>Ostrya</i>	eastern hornbeam
<i>Platanus</i>	sycamore
<i>Populus</i>	poplars, aspen
<i>Prunus virginiana</i>	choke cherry
<i>Rhamnus</i>	buckthorn
<i>Rhus</i>	sumac
<i>Ribes</i>	currant, gooseberry
<i>Robinia</i>	locust
<i>Salix</i>	willows
<i>Sambucus</i>	elder
<i>Sorbus</i>	mountain-ash
<i>Tilia</i>	basswood, linden
<i>Ulmus</i>	elms
<i>Viburnum</i>	viburnums, nannyberry

Hypogeal species: cotyledons remain below the ground (Burns and Honkala 1990B)

Hardwoods

<i>Acer saccharinum</i>	silver maple
<i>Aesculus</i>	buckeye, horse chestnut
<i>Carya</i>	hickory
<i>Corylus</i>	hazel, filbert
<i>Juglans</i>	walnut, butternut
<i>Prunus</i>	cherries, peaches, plums (most)
<i>Prunus serotina</i>	black cherry
<i>Quercus</i>	oaks
<i>Sassafras</i>	sassafras

¹Definitions proposed by the authors.