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Estimating Time Since Death Using Plant Roots and Stems

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ABSTRACT: A number of methods have been used successfully in estimating time since death of long dead individuals, including physical decomposition of the corpse and clothing and the succession of insects. Using these sources, however, it is usually impossible to estimate accurately time since death for bodies which have been exposed more than a year. Roots and stems of perennial plants may be used as complementary sources of information. Stems and woody roots of perennial plants have annual growth rings which may be used to establish the minimum number of growing seasons since death. To be used, these plant parts must grow through the clothing, other personal effects, or bone or be affected indirectly by soil disturbance or body decomposition. Procedures for collecting, preserving, and examining these specimens and the limitations of the approach are presented.

KEYWORDS: pathology and biology, plants (botany), death, decomposition

Accurately estimating time since death is important. Time since death is one of the parameters needed by law enforcement agents in their investigation of a death and may be crucial in identifying remains. Nevertheless, it is often frustrating and difficult work.

While the estimation of time of death is accurate if death occurred within 24 to 48 h [*1*], the estimation becomes less reliable and more inexact with increasing time. For those dead more than a few days, only a few techniques have been used. Physical decomposition of the corpse [*2-5*][3], deterioration of the associated clothing [*5*], and insect succession [*2,6*][4] have been employed with success. These methods are not without their difficulties and limitations. The rate of decomposition varies with season, temperature, body size, body position, body condition, health state, insects and scavengers, altitude, slope, moisture, and coverings. To compound matters, there are regional, climatic, and topographic differences that make standards established in one region inapplicable to other regions. Perhaps the greatest limitation of these methods is that they can rarely be applied accurately to those individuals dead for more than one year.

Plant roots and stems are frequently found with exposed and shallowly buried bodies and

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may be useful in estimating time since death especially for those dead for several or more years. The association of roots with bodies found in forensic science contexts has been noted previously, and their potential for determining the relative [7] and absolute [8-11] time since death discussed.

Two authors [9-11] have considered the possibility of using the rate of root penetration as an estimator of absolute time since death, but their conclusions indicate caution should be exercised. The major problem with the application of root penetration is the assumption of a standard rate of root growth, which seems unlikely even for roots of the same plant, let alone roots of different individuals of the same species or roots of different species. One of these authors [11] concludes that it is rarely possible to estimate time since death from severed roots penetrating through bones which are delivered to the laboratory for analysis.

The usefulness of dendrochronology (the use of annual growth rings of wood) in estimating the absolute time since death has been noted elsewhere [8], but this source has been overlooked by many investigators in the United States. Also, there are specific collection methods and limitations to the approach which need to be stressed. The purpose of this paper is to show how severed roots of perennial plants and more systematically collected specimens can be used to establish the minimum time since death using annual growth rings.

Seasonal Rings

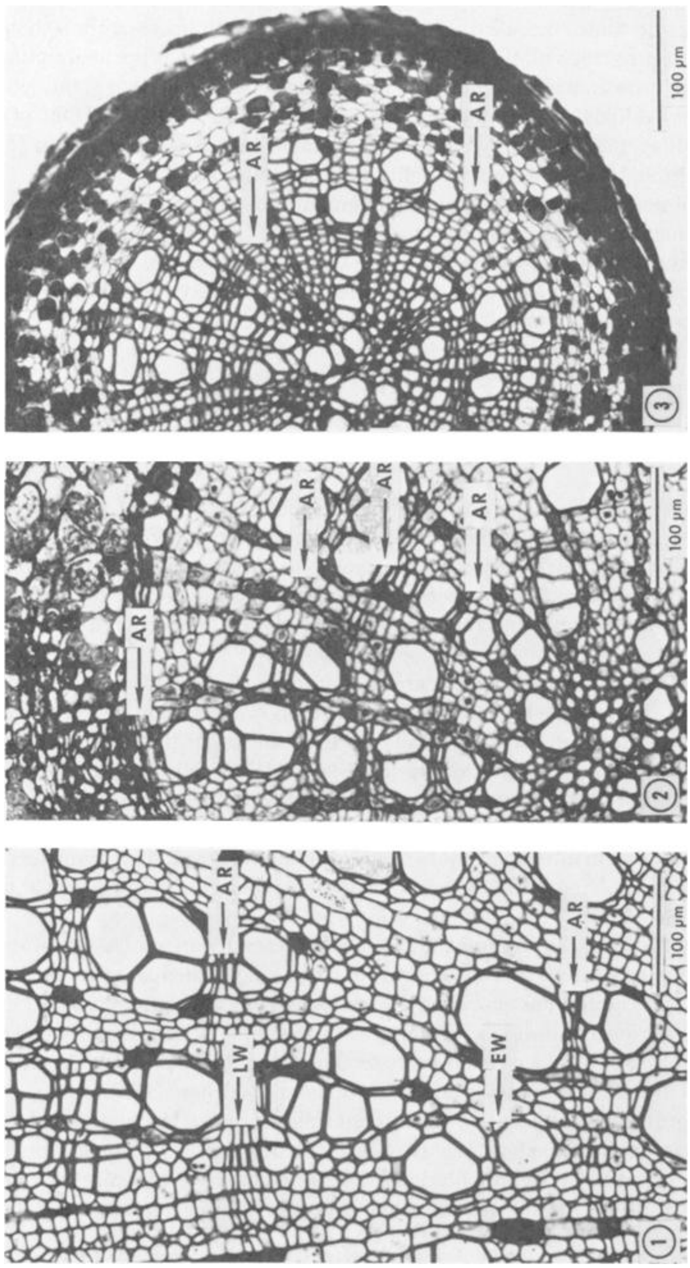
Using stems of perennial plants to estimate time is an obvious application because they exhibit annual rings of growth. When the stem of a perennial plant penetrates a skeleton, the stem can be cross-sectioned and the section examined for concentric rings which indicate periods of growth and dormacy. In our experience, though, roots are more commonly associated with these cases than stems, and roots of perennial plants, like stems, display annual growth rings.

Seasonal rings in woody stems and roots are produced by changes in growth conditions which affect cell size. The boundary between growth rings is evident when there is an abrupt change in cell size from the last cells of late fall growth to the larger first cells at the beginning of the next growing season in early spring. Early wood (EW) cells are commonly larger in their radial dimension than the late wood (LW) cells, while the periclinal dimension is relatively unchanged (Fig. 1). Growth rates of roots and stems vary between individuals of the same species, resulting in differing annual ring widths and root and stem diameters. This feature is shown in Figs. 1, 2, and 3 in basswood (*Tilia* sp.) roots which have grown at differing rates.

There are three difficulties that complicate the accurate identification of seasonal rings in roots and stems. False rings are extra rings formed during a single calendar year. Incomplete rings are rings that lack additional new wood on some segments of the stem or root. Eccentric rings are rings that form following irregular growth around the circumference and result in oval or other distortions from a circular cross section. All of these phenomena make age estimation difficult and have been described in more detail elsewhere [12,13].

There are some problems with identifying seasonal rings in roots. The boundary between one year's growth and the succeeding year may be difficult to detect in some roots. Ring definition depends, in part, on the orientation of the root: namely, growing horizontally, obliquely, or vertically to the ground surface. Root exposure to light can also influence ring growth.

Because of these limitations, it may be impossible to determine the age of a root or stem. However, when true growth rings can be identified, a minimum age of the plant part can be established. It may be necessary to consult a plant anatomist in cases where ambiguity is suspected. Plant anatomists can be found in botany and forestry departments of most large universities.

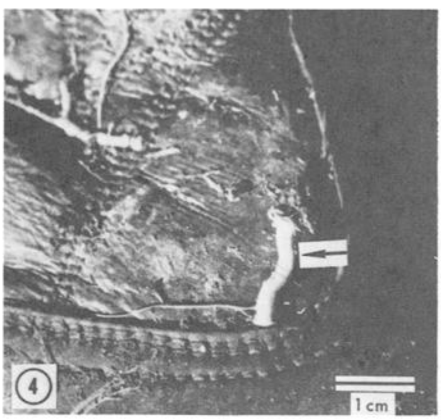


FIGS. 1 to 3—Tilia *(basswood) roots. Three roots showing difference in cell size between early wood* (EW) *and late wood* (LW). *The boundary between two years' growth is the annual ring* (AR). *Note great variation in width of annual rings and diameter of roots among individual plants of the same species. These microtone sections were made from fixed and embedded specimens.*

Context

The association of the plant with the human remains is crucial in accurately estimating time since death. The association may be either direct or indirect. When the plant grows into or through the human remains or personal effects (Fig. 4), the association is direct, but care must be exercised in analyzing appropriate specimens. Roots and stems that lie on, under, or even above the remains may have preceded the individual's death and thus inaccurately indicate a time greater than the actual one. This warning is especially pertinent to graves where roots may have been replaced over the body during burial and surface "burials" which may have been covered with living plants to obscure the remains. An exception to the penetration rule is when a body is "shrouded" or matted in roots in a manner which could have happened only through growth of the plant, not through disturbance or artificial placement. In addition to direct association, indirectly associated specimens may be used to estimate time since death.

When a plant's growth is affected by modifications caused by the human remains or its deposition, indirect estimation of time since death may be possible. The churned soil of a grave or the decomposition of a body may increase subsequent growth of plants which grew at the site before the event by increasing the available minerals and moisture. Comparison between disturbed and undisturbed plants of the same species is necessary to determine the year of change and minimum time since death. The relationship of the plants to the grave



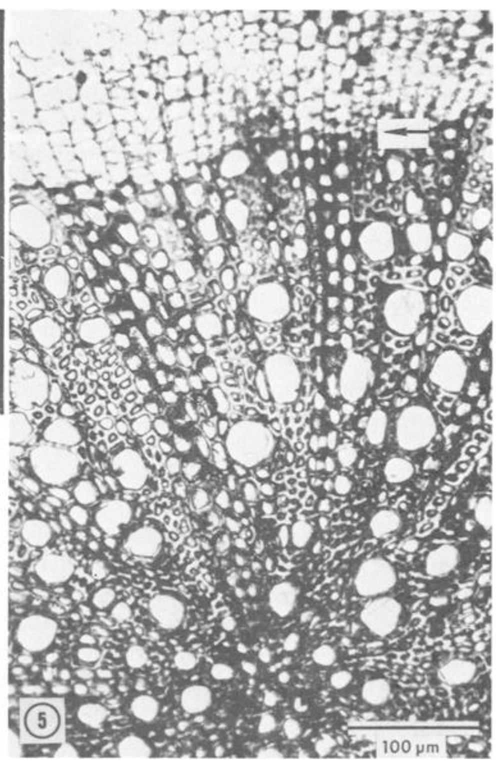


FIG. 4—*Root of unknown species penetrating into boot seam of forensic science case UT85-4.*

FIG. 5—*Freehand cross section of same root shown in Fig. 4. Arrow indicates outer limits of wood. Because no annual rings are evident within the wood, the root appears to be in its first year of growth.*

and human remains is particularly crucial in this approach. An example of this method will clarify the application.

Denne [*8*] reports recovering an elder tree root from the edge of a shallow grave. The root had branches penetrating into the grave. Sectioning the root showed a marked increase in the vessel size from the older rings to the younger rings. The change occurred between two years' growth, suggesting the grave was dug between late summer one year and spring of the next. Although Denne used vessel size, we believe that this method may be expanded by inspecting the annual ring widths for the first season of increased growth. Adjacent samples from the same species must be used for comparison.

Methods and Materials

Collection

When an appropriate specimen is discovered, steps should be taken to insure its recovery, preservation, and later, its precise identification. Identification is facilitated by as complete a collection of plant parts as possible. Some plants can be identified from a single leaf or other fragments by a plant taxonomist, but this is difficult. Identification from roots alone is very difficult if not impossible even for a plant anatomist. Plant parts can be pressed and dried for later identification by placing stems with attached leaves, flowers, or fruits between 10 to 15 layers of newspapers. The newspaper should then be sandwiched between cardboard and placed under pressure. Drying may be hastened by moderate heat (about 100°F [37.7°C]) for a few days. For best age determination root and stem specimens should be kept moist, thus retaining the cellular detail necessary in determining time since death. Ideally, the specimens should be placed in a liquid preservative at the time of collection. The best preservative for this purpose is formalin-acetic-alcohol (5-mL formalin, 5-mL acetic acid, 90-mL 50% ethyl alcohol), or if unavailable, full strength rubbing alcohol (70% isopropyl alcohol or 50 to 70% ethyl alcohol) may be substituted. Site photographs documenting the relation of roots and association of the stems to the remains often prove useful and should be required.

Plant parts which are not systematically collected in the field, but are included with material submitted for laboratory analysis, may be useful in estimating time since death. We have found that plant specimens submitted in plastic body bags retain moisture and plant samples can be recovered. These specimens should be kept moist and cool and examined within a few days before deterioration occurs. Even plants that have dried may be useful, but they have to be rehydrated before fixing, sectioning, and age estimation can be performed. The major difficulty with plant specimens not systematically collected in the field is that any peculiarities in growth may be impossible to explain.

Microscopic Analysis

Age determination of the root or stem can be made from freehand cross sections cut with a razor blade and mounted unstained in water or 50% ethanol (Fig. 5). If the root proves too difficult to section freehand or if sufficient detail is not visible, it may be necessary to process, dehydrate, embed, section, and stain the root. This process is time-consuming, but it will reveal more detail (Figs. 1, 2, 3). The preparations of plant tissues are broadly similar to those used by pathologists for histological animal preparations using a microtome. Procedures can be found in standard plant microtechnique texts [*14-16*].

Conclusions

Perennial plant roots and stems that penetrate the body, clothing, or personal effects of long dead bodies or "shroud" the body as well as plants demonstrating growth changes associated with the remains may be used to estimate time since death. This approach is particularly useful for bodies exposed above ground or shallowly buried for more than one year. This method complements the techniques currently in use by lengthening the period for which time since death can be estimated.

It must be stressed that the number of rings indicates the minimum time since death. It is entirely possible that the stems and roots did not invade the body, clothing, or grave the first season they were present or even the first year. Instead they may have penetrated the body years after it was deposited. As a consequence of this limitation, only minimum time since death can be established from the growth rings, not actual time.

In many plants, unfortunately, the distinction between annual growth rings may be difficult to establish. Some portions of plants may have incomplete rings with little or no growth on segments of the circumference. In addition, there may be false rings as a result of dry and wet cycles within a year and eccentric rings as a result of unusual growing conditions, orientation, or mechanical pressure.

This paper has emphasized perennial plants, but *annual* plants should be mentioned. When the root or stem of an annual plant is associated directly with a skeleton, its presence establishes that the remains were exposed sometime during a growing season. Because annual plants die after one season's growth and these tissues usually decay quickly, these parts at best may be present for only a few seasons. Lacking annual growth rings, the association of annual plants can be used only to indicate exposure of the body during the most recent growing season.

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