TECHNICAL NOTE 07-01

A NEW VISUAL TECHNIQUE FOR DIAGNOSING COLD DAMAGE IN STEMS OF BAREROOT LOBLOLLY PINE SEEDLINGS

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ABSTRACT
Even with high quality loblolly pine (*Pinus taeda* L.) seedlings, good site preparation and planting, weather conditions can cause significant seedling mortality. During the planting season (November to March), cold weather events following unseasonable warm conditions have the greatest potential to impact seedling survival. Diagnosing the cause of seedling mortality can be difficult since many agents can be responsible and seedling death is often the result of a combination of factors. Cold damage, in particular, is very difficult to detect since the symptoms of damage may not occur until several months after the event. Typical symptoms of cold damage to loblolly pine seedling stems and roots include red to brown discolored wood and cambium. A new visual diagnostic method is now available to assist in the identification of cold damage in asymptomatic seedlings.

In winter 2003-04, loblolly pine seedlings planted near Eulonia, Georgia were damaged from a combination of unseasonably warm weather followed immediately by freezing conditions. Many seedlings died without showing any signs of freeze damage. Dissection of these dead seedlings revealed dark brown pith in the stem just above the ground-line. At the time of the assessment some trees were still dying. Dissection of these trees also revealed brown pith at the ground-line and green pith in the stem above and in the taproot below. One seedling in particular had a noticeable swelling above the brown pith from the accumulation of photosynthates that could not pass through the damaged stem. Brown pith is a symptom of cold damage in fruit bearing hardwoods and may also be an indicator of cold damage in loblolly pine.

INTRODUCTION
Diagnosing the cause of seedling damage and mortality is often difficult. Many times a combination of factors results in mortality since a seedling may survive the first stressful condition but is then weakened and predisposed to further attack and ultimately death by other agents. Further, seedling mortality at a planting site is often noticed several months after the seedlings have begun to die. As a consequence the actual cause of seedling mortality may be gone or masked by secondary processes such as decay. Like a detective at a crime scene, the investigator of a seedling survival problem must examine the planting site for clues and evaluate nursery cultural practices, seedling handling, planting records, and weather conditions before and after planting. If there are no symptoms of insect or pathogen attack as well as no evidence of improper nursery or planting procedures, then seedling mortality could be related to weather conditions.

Perhaps the most dangerous combination of weather conditions that can impact seedling survival involves a period of unseasonable warm weather followed immediately by a hard freeze. Alternating periods of warmth followed by freezing conditions have been demonstrated to cause freeze damage in a variety of plants from hardwoods to pines (Zalasky, 1976; Krasowski, et.al., 1994; South and Loewenstein, 1994; Ingram, et.al., 2001; McAvoy, 2004; South, 2004a,b). Warm winter air temperatures can quickly deaclimate plants initiating growth (Zalasky, 1976; Ingram, et.al. 2001). Conifers can begin to deaclimate in as little as two hours of unseasonably warm weather (Krasowski, et.al., 1993). If temperatures slowly drop after a warm period, plants will reaclimate to cold conditions (Ingram, et. al., 2001). With rapid temperature drops, deaclimated seedlings can be damaged and even killed.

Loblolly pine seedlings can be damaged from two types of freeze events. A radiational freeze can occur on calm, clear nights when heat radiates from the soil surface into the atmosphere. An advective freeze can occur during the passage of a cold front when temperatures drop quickly and are accompanied by high winds and low humidity. Seedlings can be damaged by either radiational or advective freezes when seedling tissue temperature falls below 28°F (Landis, 1989). The seedling stem just above the ground line is very susceptible to freeze damage (Landis, 1989). Freeze damage to loblolly pine seedlings has been determined in the past by exposing the cambium or cutting into the first year wood of stems or taproots. Freeze injuries in many other woody plants are characterized by red to brown discoloration of the cambium and wood (Zalasky, 1976; Rowan, 1984; Jackson, 1994).

The classic symptoms of cold damage in loblolly pine such as discoloration of the cambium or wood may not be present in all situations. During the planting season of 2003-04 cases of seedling mortality resulting from cold damage were reported at many locations in the South (South, 2004b). Loblolly pine planted near Eulonia, Georgia experienced high seedling mortality with no apparent cause. When cut, seedling stems of dead and dying seedlings did not display the classic browning of the wood or cambial tissue. However, more detailed dissection of the stem revealed a new diagnostic symptom that is associated with cold damage.

Cold Damage Case Study at Eulonia, Georgia

Eulonia, Georgia is located approximately fifty miles southwest of Savannah. Loblolly pine seedlings from several family lines grown at a nearby nursery were lifted and planted in early December. Several days prior to lifting, all seedlings were treated with Pounce® 3.2 EC (2qts/100M seedlings) for regeneration weevil control. Hydroscopic root gel was applied to all seedling roots after lifting and the seedlings were then packaged in bags and stored in the nursery cooler (approximately 35°F) until shipping. Some seedlings were lifted on December 2nd and 3rd and hand-planted on December 4th and 5th. Other seedlings were lifted on December 8th and 10th and hand-planted on December 11th. Seedlings were shipped by refrigerated van from the nursery to the planting site. Best management practices were followed prior to and during planting. All seedlings were planted with the nursery root collar two to four inches below ground.

In May 2004, seedling survival was less than fifty percent. Inspection of dead and dying seedlings did not reveal any evidence of insect or pathogen attack and the classic cold damage symptoms such as brown cambial tissue and discolored wood were not present. However, another symptom was present which suggested the seedling mortality was probably caused by cold weather. In Figure 1a, the black stained surface of the wood and loose bark just above the ground-line indicates the stem was severely damaged. Additional dissection of the seedling stem in the damaged area revealed a previously unreported symptom of cold damage. Figure 1b shows the same dead seedling with dark brown pith in the damaged area of the stem. Further evidence of the relationship of discolored pith to stem damage just above the ground-line can be seen in two additional seedlings. In Figure 2, Seedling (a.) was dying at the time of survival assessment and has a section of brown pith located just above the ground-line with green pith above and below. Seedling b. has been dead for some time and has discolored pith throughout the stem, but the pith is a dark brown just above the ground-line indicating where the stem was first damaged.

a. b.

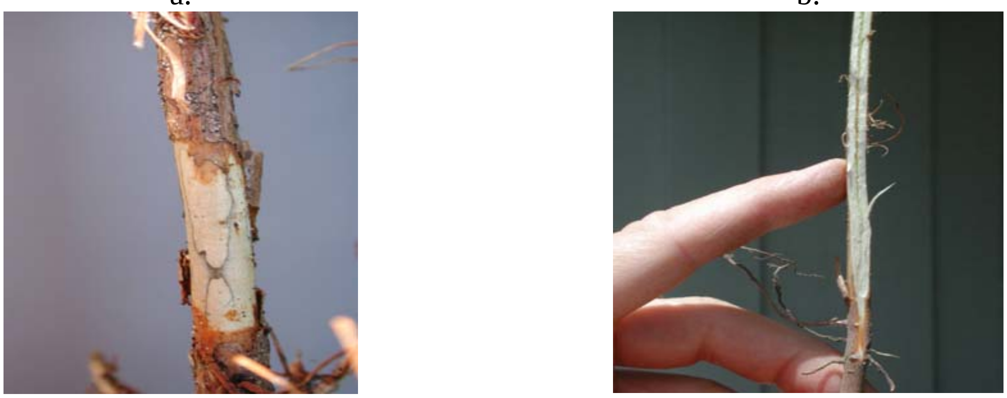

Figure 1. Photograph a. shows a seedling with black stains on the wood and loose bark just above the ground-line indicating stem damage. Photograph b. shows the same seedling with brown pith in the damaged stem under the loose bark.

a. b.

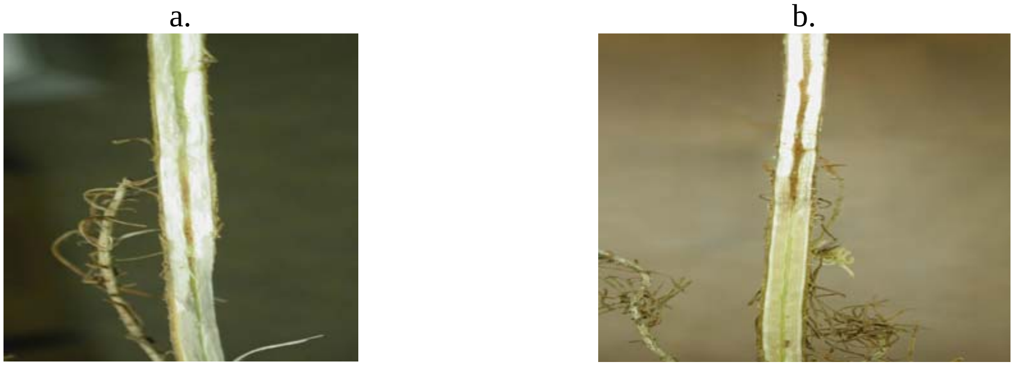

Figure 2. Seedling (a.) is in the process of dying with no external symptoms of insect or pathogen attack but has brown pith in a section of the stem immediately above the ground-line. Seedling (b.) is dead and has discolored pith throughout the stem but the pith is a darker brown just above the ground-line with green pith below. Note: visible branches were planted in the ground.

Without any symptoms of insect or pathogen attack and no evidence of improper seedling lifting, handling, or planting, the only other possible cause of the stem damage just above the ground-line as indicated by brown pith is the weather. An examination of temperature records from the Savannah, Georgia International Airport indicate a period of abnormally warm conditions in January 2004 followed by a rapid temperature drop. In early January, the weather was almost "summer-like" with day air temperatures approaching 80^{o}F and evening temperatures near 60^{o}F (Table 1). After four days of very warm weather, the evening temperature quickly dropped to 25^{o}F. In addition, windy and dry conditions existed during this period with wind gusts above 20mph and very low rainfall. The very warm temperatures, particularly at night, may have caused the seedlings to deaclimated to some extent making them more susceptible to the following freeze.

Table 1. High temperature (^{o}F), low temperature (^{o}F), average wind speed (mph), maximum wind gust (mph), and total precipitation (inches) from January 1st to January 10th, 2004 as observed at the Savannah International Airport, Savannah, Georgia.

Date	High Temperature	Low Temperature	Average Wind Speed	Maximum Gust Speed	Rain
1 / 1	69	31	0	-	0.00
1 / 2	69	36	0	-	0.00
1 / 3	78	47	1	-	0.00
1 / 4	80	60	5	-	0.00
1 / 5	81	62	6	23	0.00
1 / 6	67	41	11	24	0.00
1 / 7	49	27	12	15	0.00
1 / 8	57	25	3	-	0.10
1 / 9	47	41	5	13	0.43
1 / 10	47	32	13	22	0.00

During the May survival assessment one seedling was observed to be wilting with a prominent stem swelling. Once again there were no symptoms of insect or pathogen attack. Dissection of this seedling also revealed brown pith just above the ground-line. In Figure 3a, the seedling stem is swollen above a constricted area. The constricted area was located just above the ground-line. Dissection of the stem reveals brown pith in the constricted area and green pith above and below (Figure 3b). In the absence of other possible causes, it appears the weather event in January was sufficient to damage the stem above the ground-line but not result in immediate seedling mortality. Evidently the xylem tissue of the stem was undamaged by the cold weather and the seedling roots were able to supply water to the seedling top until the return of spring weather. During this time, photosynthates were unable to pass through the stem at the ground-line due to damaged phloem tissue. This resulted in an accumulation of photosynthates and the stem swelling.

a. b.

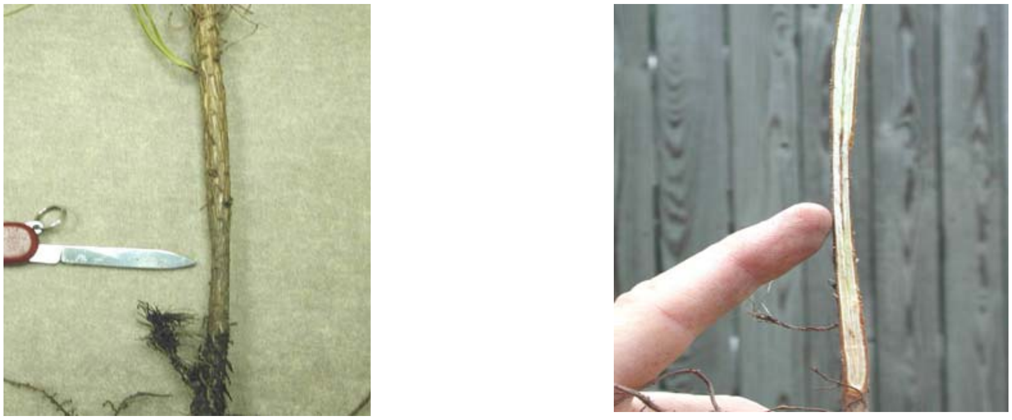

Figure 3. A seedling in the process of dying in June, 2004 has a noticeable swelling above a constriction in the stem (a.). Dissection of the stem through the constriction (b.) revealed brown pith indicating cold damage in the constricted area. Note: Branches below the constricted area were below ground.

DISCUSSION

Nursery cultural practices are designed to produce the highest quality bareroot loblolly pine seedlings fully conditioned or acclimated for winter and transplanting stress. These seedlings are expected to survive and then rapidly grow the following spring. Typically, loblolly pine first year seedling survival is good to excellent at most planting locations. Unfortunately, survival failures do occur. Poor seedling survival can result from many causal agents including the weather.

Weather records indicate the Eulonia, Georgia site experienced very warm day and night temperatures in January which were quickly followed by very cold, windy, and dry conditions. Newly planted loblolly pine seedlings are generally more susceptible to cold damage than seedlings in the nursery bed due to the open nature of the planting site. With good site preparation, planted pine seedlings are often the tallest objects around and are fully exposed to weather conditions. The warm January weather may have predisposed the seedlings to cold damage. The quick return of freezing conditions immediately following the warm weather resulted in damage to the seedling stems just above the ground-line and those trees not immediately killed died when warm spring weather returned.

The location of the brown discolored pith just above the ground-line, the documented weather conditions, the absence of other insect or disease agents and proper seedling handling from the nursery through planting strongly suggests the pith was damaged by cold weather. Brown pith was also found in the stem constriction of a seedling which survived until May. The cold damaged the phloem just under the bark but was not sufficient to damage the underlying xylem. As a result water was transpired to the foliage but photosynthates could not be translocated to the roots and accumulated above the damaged area causing noticeable stem swelling. Without any evidence of other causal agents, the only possible factor which could have damaged the seedling stem was the cold weather.

Brown pith in the stem just above the ground-line in dead and dying loblolly pine seedlings has not been previously reported in the literature as a symptom of cold damage. Browning of the pith is an indicator of cold damage in stems and buds of fruit trees (Filiti and Neri, 1989; Ingram, et.al., 2001). Cold damage symptoms in Caragana seedlings (*Caragana aborescans* Lamb.) include grayish-brown discoloration of periderm, cortex, and phloem tissues (Zalasky, 1976). The brown color associated with cold damaged tissue usually develops from the oxidation of polyphenols (Linden, 2002). Wood discoloration (primarily the oxidation of phenolic compounds) is associated with both pathogen and abiotic, such as cold damage, induced wounds (Smith, 2002; Eyles, et.al., 2003). In the absence of symptoms of other damaging agents, brown pith just above the ground line in dead or dying trees is a good diagnostic symptom of cold damage. Cutting the seedling stem to reveal the pith just above the ground-line is a new diagnostic method land managers can use to help explain the cause of seedling mortality.

REFERENCES

Dierauf, T. and H.L. Olinger. 1977. January 1977 cold damage to Loblolly seedlings at New Kent Nursery. Virginia Division of Forestry, Occasional Rpt. 51, 4p.

Eyles, A., N.W. Davies, C. Mohammed, t. Mitsungaga and R. Mihara. 2003. Eucalyptus wound wood extractives show antimicrobial and antioxidant activity (A case study with *E. globulus* and *E.* nitens). 8th International Congress of Plant Physiology, February 2003, New Zealand. Poster Session.

Filiti, N. and D. Neri. 1989. Cold damage in fruit bud tissues of pear. Acta Hort. 256: 133-136

Ingram, D.L., T. Yeager, and R.L. Hummel. 2001. Cold protection for nursery crops. Florida Cooperative Extension Serv., Environmental Horticultural Department, Institute of Food and Agricultural Sciences, University of Florida, BUL201, 12p.

Jackson, L.K. 1994. Cold damage symptoms on Citrus. Florida Cooperative Extension Serv., Department of Horticultural Sciences, Institute of Food and Agricultural Sciences, University of Florida, Fact Sheet HS-120, 4p.

Krasowski, M.J., L.J. Herring, and T. Letchford. 1993. Winter freezing injury and frost acclimation in planted coniferous seedlings: A literature review and case study from northeastern British Columbia. FRDA II; Canada - British Columbia Partnership Agreement on Forest Resource Development. 36p.

Landis, T.D. 1989. Environmental and mechanical damage. In: Forest Nursery Pests. USDA, Forest Service, Agriculture Handbook No. 680. pp. 155-158

Linden, L. 2002. Measuring cold hardiness in woody plants. Academic Dissertation. Department of Applied Biology, University of Helsinki, Helsinki, Norway, 86p.

McAvoy, G. 2004. Hendry County Horticulture News: Cold weather can threaten landscape plantings. Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences. University of Florida.

Smith, K. 2002. This is a wound. Plant Physiologist, Northeastern Forest Experiment Station.

South, D.B. 2004a. Freeze damage: Pointing the finger in a different direction. Presentation at the Auburn University Forest Nursery Management Cooperative Contact Meeting. Charleston, South Carolina. July 12, 2004

South, D.B. 2004b. Freeze damage. In: Southern Forest Nursery Management Cooperative Newsletter. Spring 2004. pp. 6-7

South, D.B. and N.J. Loewenstein. 1994. Effects of Viterra root dips and benomyl on root growth potential and survival of longleaf pine seedlings. Southern J. Appl. For. 18: 19-23

Zalasky, H. 1976. Structural changes in tissues of Caragana seedlings after frost damage. Can. J. Plant Sci. 56: 941-945