



Boron Deficiency in a Southern Pine Nursery

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ABSTRACT. Boron deficiency in seedling loblolly (*Pinus taeda* L.) and slash pine (*Pinus elliotti* Engelm.) in a northern Florida nursery was diagnosed by: (1) characteristic damage to shoot tips and buds, including necrosis of only part of the terminal; and (2) boron concentrations as low as only 1.9 ppm (dry weight) in affected tissues. Soil and soil-management features associated with deficiency include extremely low silt and clay contents, organic matter levels of 1 percent or less, lack of boron addition, and high calcium irrigation water leading to soil reactions above pH 6 by late summer. Consequences of deficiency were not limited to the nursery. Damaged seedlings that survived outplanting developed into bushy plants incapable of normal height growth in the first year or two.

The cause of a growth disturbance of slash and loblolly pine seedlings in an industrial forest nursery in northern Florida appears to be boron (B) deficiency. The initial diagnosis was based upon symptoms and low tissue content of B in holdover seedlings of the 1979 crop. At this time experimental treatment of the 1980 crop seemed valueless because of reported addition of B to all seedbeds. The observations reported here should facilitate the prevention and diagnosis of this deficiency in other nurseries.

SYMPTOMS AND BORON CONCENTRATION

Plants require a very low but continuous supply of boron for formation and expansion of new tissue (Stone 1968). Normally, this must come directly from the soil. Unlike many other nutrients, B contained in older foliage cannot be transferred to the points of greatest need, and hence there is no effective means of storing B for later use within the plant. Deficiency occurs whenever uptake rate fails to meet current needs, and it is only the shoot and root tips, buds and other young tissues that suffer. As a result, symptom development sometimes varies markedly from one seedling to the next, among seedbeds, or even in the same seedbed within successive years, depending on growth state and minor differences in root extent and soil characteristics.

In this nursery the first visible symptoms ap-

peared only in late September or October. The extent of damage to terminal shoots varied from necrosis of only the upper part of the terminal bud, which was apparent only upon sectioning (Figure 1, B), to death of the entire terminal bud cluster, to death of the entire shoot tip for distances of 1 to 5 cm. Shoots affected before elongation was complete had short and crowded primary needles. Although affected terminals failed to develop normal-size buds, this symptom alone often went unnoticed because of the wide range of bud maturity in late summer. Affected buds were often cemented or infiltrated with resin (Figure 1, D). Sectioning revealed various degrees of retarded development, "water-soaked" appearance, or necrosis of the buds, and adjacent vascular tissue and pith (Figure 1, B). All of these evidences concur with an earlier summary of B deficiency symptoms (Stone 1968) and the specific descriptions of deficiency in radiata pine (de Lanuza 1966, Stone and Will 1965). Seedlings affected by tip dieback or retardation relatively early in the fall developed numerous new buds and shoots just below the damaged tips, commonly from fasciated needles. These buds and, notably, the emerging shoots were in turn affected, either through death of the tips, internal necrosis, or arrested growth. Some seedlings appeared undamaged until very late in the season. For example, loblolly seedlings in one seedbed appeared completely healthy in early November, but showed internal breakdown of the terminal bud by February. Cessation of height growth, and the cold weather purpling of foliage reduce the likelihood of detecting such late damage, other than by sectioning or by comparisons of terminal bud size. The failure of seemingly healthy seedlings to begin normal height growth after outplanting has been a characteristic and puzzling consequence of this deficiency.

Boron concentration in seedling tissue was determined by the azomethine-H procedure (Sippola and Ervio 1977). Boron concentration in affected shoot tips (2 to 3 cm) averaged 1.9 ppm, with a range from 1.2 to 2.4 ppm. Concentrations in young replacement shoots arising below the damaged tips were similar. B concentrations in tips

from an adjacent, apparently unaffected, seedbed were not consistently higher, a fact later explained by appearance of symptoms in this bed also. There were no concentration differences between slash and loblolly pines. Concentrations in fascicled needles from below the shoot tips ranged from 1.8 to 4.2 ppm on damaged seedlings, and 3.5 to 4.2 ppm on apparently undamaged ones.

Such low tissue concentrations alone are indicative of deficiency. The value of 1.9 ppm is lower than any previously reported in B-deficient pine (Stone 1968). Presumably, it more nearly reflects the critical minimum at the actual site of injury, however, than do reported values for whole seedlings, or for foliage from below the point of dieback. Values of about 4 ppm in fascicle needles are low, although not unknown in conifers (Stone 1968). They demonstrate that available soil B was already low at the time these needles were formed, prior to the onset of shoot damage.

TREATMENT

Upon recurrence of symptoms in late October 1980, it was found that the spring application of B had been only 0.23 lbs/acre. In early November, seedbeds were sprayed with 0.5 percent B (as Solubor), with a total application of 0.5 lb/acre B. This treatment obviously could not reverse the damage to terminal shoots that had already occurred, and replacement growth was retarded by lower than normal temperatures in December and January. By February, however, vigorous lateral buds had developed around the damaged terminal or dead tips, (Figure 1, C) confirming B deficiency as the cause.

Height growth of the sprayed seedlings after outplanting has now been reported as normal, in contrast to that in previous years. Seedlings in a few holdover seedbeds flushed vigorously, with 5- to 8-inch shoots by mid-April 1981, in marked contrast to performance of similar beds in 1980. Nevertheless, occasional seedlings showed characteristic top kill, indicating renewed depletion of available B. Possibly most of the November spray application had been immobilized in the older foliage; in any event available B within the rooting zone was inadequate to sustain the surge of shoot growth in these dense beds.

ASSOCIATED FEATURES

Nurserymen reported that late-summer tip discoloration and dieback were first observed four or five years previously and could not be remedied by numerous modifications of fertilizer and cultural practices. This, together with retarded growth

of outplanted seedlings, prompted a search for possible pathogens. Some instances of nursery "tip dieback" or "tip blight" have been related to the action of known or suspected fungal pathogens, e.g., *Fusarium moniliforme* var. *subglutinans*—the pitch canker pathogen¹—*Phomopsis* sp.; *Diplodia* sp.; *Sphaeropsis*; etc. Failure to consistently isolate or detect any known pathogen(s) in our investigations, however, corroborates evidence of a nutritional cause. The possible role of B deficiency in predisposing seedlings to infection by parasitic or pathogenic microorganisms is unknown at this time.

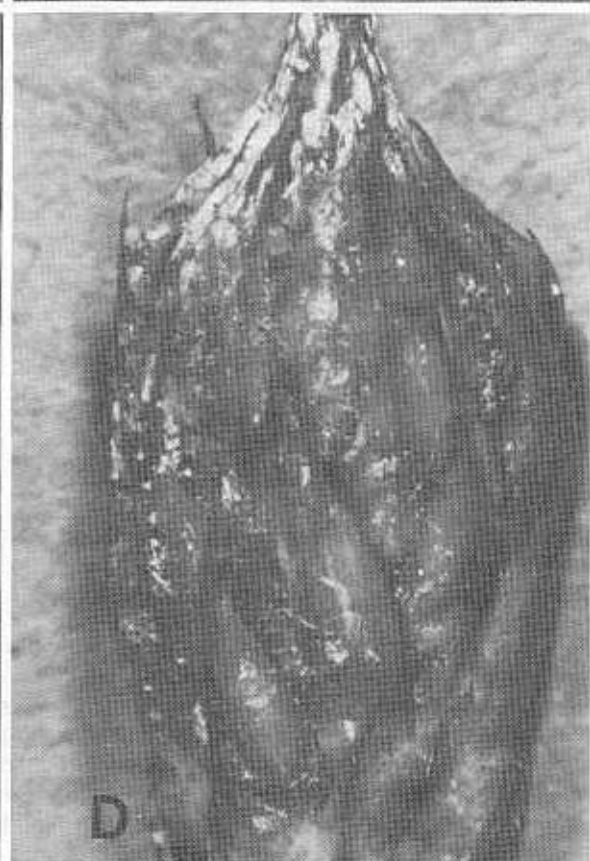
The nursery soil, Astatula sand, is a deep uncoated sand essentially devoid of nonquartz silt, clay, or weatherable minerals. Sawdust additions to the nursery soil had been discontinued about 10 years previously. Since that time organic matter maintenance has depended on an alternate-year rotation of cover crops and seedlings. Organic matter content (by loss on ignition) of surface 20 cm now averages about 1 percent, ranging from 0.5 to 1.5 percent in various compartments.

Fertility management has been based on non-leguminous cover crops, preplant application of NPK or PK fertilizer, and periodic top-dressings of nitrogen, and potassium or potassium-magnesium throughout the growing season. No micronutrients had been applied before 1980, except iron chelate sprays to correct nitrate-induced chlorosis. Irrigation water obtained from a deep well is high in calcium. In consequence, both extractable calcium and reaction of seedbed soil increase throughout the season, to >600 ppm and >pH 6, respectively. To counter the expected rise in pH, sulfur is added during soil preparation; in 1980 the rate was 300 lbs/acre S.

It is known that organic matter is the sole means of B retention in such a soil, and that B availability is greatest in acid soils. Hence, B availability in this nursery would have been maximal in spring, and would have decreased throughout the summer as cover crop residues decomposed and reaction of the surface soil rose from around pH 4.5 to 5.0 to above pH 6.0. In contrast, plant requirements increased late in the growing season, with the increasing volumes of cambial tissue, root tips, new shoots, and buds.

The total quantity of B actually removed by pine seedlings is astonishingly small. If one assumes seedling production to be 5 tons per acre (dry weight) with B content of 20 ppm (both liberal estimates), then total B uptake would be only 0.2 lbs/acre. Actual uptake by the seedlings studied may have been less than a quarter of this amount and certainly less than the .23 lb/acre applied in 1980. Much larger amounts must be present in the

¹ G. M. Blakeslee, personal communication.



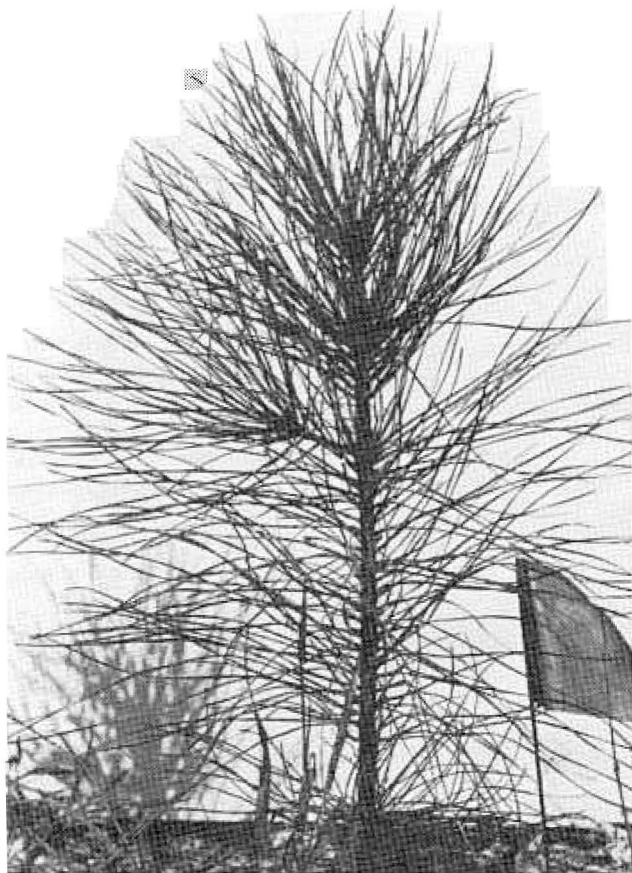


Figure 2. Contrasting development of normal (left) and B-deficient slash pine seedlings one year after outplanting. In the latter, the multiple shoots produced during recovery from tip damage result in a bushy plant that has not yet reestablished a central leader.

soil to allow adequate uptake, however, and as already mentioned, the supply of B must be continuous. High Ca/B ratios in the soil, such as prevailed in late summer, reduce B absorption, and high tissue concentrations of potassium, nitrogen, and calcium appear to increase B needs (Stone 1968).

BEHAVIOR OF OUTPLANTED SEEDLINGS

The general effects of boron deficiency on growth after planting have been observed in a several-year sequence of provenance trials with seedlings grown in this nursery. Furthermore,

during the past two years, seedlings from selected beds have been outplanted in comparative trials with those from other nurseries. Observations from both areas lead to the following interpretations: Initial survival of deficient and near-deficient seedlings has not been clearly less than that of unaffected seedlings, although there has been no definitive test of this. Seedlings that survive long enough to establish new roots will no longer be boron deficient because, so far as known, uptake from field soils is adequate. Nevertheless, the shoot and bud damage suffered in the nursery determine early-growth patterns. Height growth is retarded until new leaders develop from fascicle buds or small shoots, which means at least one year's delay in establishment. Recovery from such beds results

Figure 1. Apical buds of normal and B-deficient slash pine. A: Normal seedlings, February. B: Longitudinal section of damaged shoot. The terminal bud has aborted; the lateral buds and pith are intact but discolored. C: Recovery by vigorous lateral buds after application of B spray to tip-damaged seedling. Arrow indicates the dead immature terminal bud. D: Arrested immature terminal bud of B-deficient seedling one year after outplanting. The bud developed in the nursery and has remained undeveloped but still green. The white resin coating is characteristic.

in short bushy plants until a single leader eventually dominates. In the comparative outplanting trials, seedlings from this nursery were easily recognized in later remeasurements because of their bushy form (Figure 2).

CONCLUSION

Boron deficiency should be a nonproblem in nurseries, because it is easily avoided by use of soil additions or foliar sprays. Including appropriate amounts of B in the preplant fertilizer application is a useful precaution. It appears desirable to supplement this with at least one late-summer addition wherever soils are low in organic matter or above pH 6 in reaction. Inasmuch as excess B is highly toxic, however, especially in acid sandy soils, additions should be small. Application rates should follow recommendations for the soil textural class, and records of cumulative application should be maintained. As is true for many other nutrients, increasing soil organic matter facilitates maintenance of adequate B supplies, and widens the tolerable range between deficiency and excess.

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