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# EFFECTS OF *BOTRYOSPHAERIA* INOCULATION AND STRESS DURING LIFTING AND OUTPLANTING ON INITIAL GROWTH OF OUTPLANTED SWEETGUM SEEDLINGS

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**Abstract**—A coordinated investigation was carried out with sweetgum seedlings from a nursery in South Carolina (SC) and one in Virginia (VA) to evaluate the effects of cultural practices and *Botryosphaeria* on the establishment and initial growth of transplanted sweetgum. Seedlings from VA were more sensitive to treatments than those from SC, and date of leaf emergence after planting correlated with subsequent growth (r = 0.79, p = 0.01). Inoculation with *Botryosphaeria* had little impact on seedlings, but increased care during lifting and reduced seedling exposure at lifting and at the planting site increased early growth and survival of seedlings.

## INTRODUCTION

The impetus for investigating the impact of *Botryosphaeria* on sweetgum was widespread dieback among seedlings planted near Summerville, SC, in the winter of 1995-96. These seedlings, lifted in late January and planted in mid-February, were exposed to several freezes alternating with warmer temperatures. By mid-May, seedlings were flushing late with undersized leaves. There was extensive dieback at all visited sites, and many seedlings that were resprouting near the root collar had sunken, black cankers characteristic of *B. dothidea* (syn *B. ribis*) (Filer and Randall 1978) on the stems above the new growth. Whether these cankers originated before or after lifting is not known, and the natural phenology of infection and symptom expression for *Botryosphaeria,* or its impact, on transplanted sweetgum is not known. The disease is considered unimportant on established sweetgums (Toole 1957) where it colonizes only weakened branches. However, the stresses associated with lifting, storage, and outplanting can allow even weak pathogens to reduce survival and growth. At a site visited in 1996, 96 percent of the seedlings planted by research personnel had produced foliage compared to 49 percent of seedlings planted operationally. This seemed to imply that there is an effect of planting care in the rate of foliage production. Because similar problems were also affecting plantation establishment at Union Camp Corporation, a coordinated investigation was carried out to assess cultural practices and the effects of *Botryosphaeria* on the establishment and initial growth of transplanted sweetgum.

## METHODOLOGY

Field trials were arranged between the Nursery Cooperative, Westvaco (now MeadWestvaco) and Union Camp (now International Paper) Corporations in the spring of 1997 to evaluate the effects of cultural practices associated with transplantation on growth, mortality, and disease development. Westvaco's nursery (SC seedlings) and planting site are near Summerville, SC, and Union Camp's nursery (VA seedlings) is near Capron, VA. The planting site (the Trice Research Forest or TRF) is near Sumter, SC. Seedlings from both nurseries were inoculated with *Botryosphaeria* to evaluate the effect on transplant stress. Seedlings were exchanged between corporations to assess differences for nursery source.

Three treatments specifically evaluating the effect of *Botryosphaeria* were made on January 15, 1997. These were (1) wound-inoculation, (2) wounding without inoculation, and (3) a fungicide treatment (a stem spray at Summerville and a root dip at TRF with 2.4 g a.i. per L Captan [reported by Pusey and Okie (1996) to reduce infections on peach]. Wounds were made 6 inches above the root collar with a sterile 3-mm-diameter cork borer, and the "bark" was removed and replaced with a disc of *B. dothidia* growing on PDA (Difco®) or with sterile PDA. These wounds were wrapped with Parafilm® to retard dessication.

At Summerville, seedlings lifted in January were separated into 140 10-seedling replicates. Four exposure treatments were created by exposing half the replicates for 20 minutes before storage and later exposing half of those already exposed and half of those not exposed (35 each) for 20 minutes just before planting. Of the 35 reps to receive each exposure treatment, 10 received no additional treatment, 10 were inoculated with *Botryosphaeria,* 5 were wounded but not inoculated, and 10 were sprayed with Captan. Two levels of exposure at the planting site, for each of 10 10-seedling-replicates from VA brought the total number of treatments to 14. One rep of seedlings from each treatment was planted together in a block. Half of the 10 replicates receiving each treatment were planted in 5 blocks with and 5 blocks without subsequent weed control. A 15th treatment of wounded but not inoculated seedlings was planted only in weed controlled plots. Leaf expansion was recorded on a four-point scale where 1 = closed bud, 2 = bud break, 3 = early expansion, and 4 = full expansion.

At the TRF, 11 treatments were applied to both operationally and to carefully lifted VA seedlings from a single family. In addition, 2 levels of preplant exposure were given SC seedlings for a total of 24 treatments. Seedlings were lifted on January 30 and remained in cold storage (less treatment requirements) until planted on February 13. Height

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and diameter were measured immediately after planting. Data are presented by treatment only for those treatments applied by the Nursery Coop (*Botryosphaeria* inoculation and fungicide treatment), but the other treatments are listed in appendix table 1. Coop treatments were: (1) no postlift treatment, (2) inoculation, (3) inoculation plus a Captan, or (4) wounding without inoculation. The production of leaves was assessed on March 10, 24, and on April 1 using a three-point scale, where 0 = closed bud, 1 = swollen buds, and 2 = expanding leaves. Seedling heights, diameters, and survival were assessed again in September.

## Analyses

All seedlings were analyzed for the effects of exposure, inoculation, fungicide, block, and herbicide (nested in block) at Summerville. TRF treatments coordinated with the Nursery Coop were analyzed for the effects of lifting, treatment, and block. Nursery source was analyzed for each planting site, with the exchanged seedlings compared only to similar treatments from the host nursery. Comparisons between means were made using Duncan's at $\alpha = 0.05$. At TRF, the correlation between April leaf emergence and September stem heights was assessed for all 24 treatments.

## RESULTS AND DISCUSSION

Nursery source is compared for similar treatments at each planting site in table 1. SC seedlings flushed sooner and died back less at both sites. More SC seedlings had live stem above the ground at both sites, but the difference was not significant at TRF (P = 0.21). At Summerville, seedlings from both nurseries were planted with 0 or 20 minutes exposure at the planting site. Although only the main effects for nursery source and for planting site are presented, there was a significant interaction (not presented) for source at Summerville because VA but not SC seedlings responded to exposure with increased dieback.

The effects of inoculation and fungicide spray on SC seedlings planted at Summerville are presented in table 2. Seedlings from VA but not those from SC were sensitive to exposure at the planting site. A small difference in initial dieback (4 percent vs 2 percent) for the fungicide spray was an exception to the lack of treatment effects among SC seedlings. Weed control significantly affected seedling growth but is not covered in this report. No inoculations at Summerville produced cankers, and most inoculation wounds healed entirely.

**Table 1—Comparisons for nursery source for similarly treated sweetgum seedlings planted at two sites in SC**

| Planting site | Origin | Survival | Leaf development[a] | Dieback[b] |
|---|---|---|---|---|
| | | | *percent* | |
| Summerville | SC | 98a | 3.5a | 2a |
| | VA | 63b | 1.3b | 44b |
| | lsd | 8 | 0.3 | 9 |
| TRF | SC | 96 | 1.8a | 4.5a |
| | VA | 89 | 1.5b | 25.2b |
| | Lsd | 11 | 0.2 | 14.4 |

TRF = Trice Research Forest.
[a] Leaf development is a three point scale at TRF on April 4 and a four point scale at Summerville on April 3.
[b] Dieback at TRF is quantitative per plant as percentage of initial height, whereas at Summerville it is qualitative per plant as the percentage of trees with dieback.

The effects of wounding, wounding plus inoculation, and wounding, inoculation, and fungicide root dip among VA seedlings planted near Sumter, SC, are presented in table 3. In contrast to the results at Summerville for SC seedlings, the VA seedlings responded to additional treatments with reduced growth and more dieback. Among the four treatments comparing the effects of inoculation and a potential fungicide control, care in lifting resulted in significant effects without interaction.

Together, all treatments at the TRF (eight at two levels of lift in addition to those in table 3) indicated the sensitivity of those sweetgums to cultural treatments that could be associated with transplanting. There was a strong correlation between time of leaf emergence, which can easily be evaluated early in the season, and subsequent dieback, survival, and growth. Figure 1 presents the relationship

**Table 2—Effects of *Botryosphaeria* inoculation or Captan spray[a] on sweetgum seedlings lifted at Summerville, SC, and planted nearby in 1997**

| Treatment[b] | n | Leaf development[c] | Dieback | Survival | Growth |
|---|---|---|---|---|---|
| | | | - - - - - - - - - | *percent* | - - - - - - - - - |
| Spray = Captan | 40 | 3.49 | 4.0a | 98.2 | 197 |
| Spray = None | 80 | 3.47 | 1.9b | 98.6 | 193 |
| lsd | | 0.96 | 1.9 | 1.3 | 7 |
| I = Botryosphaeria | 40 | 3.48 | 1.7 | 98.2 | 193 |
| I = None | 80 | 3.47 | 3.0 | 98.6 | 195 |
| lsd | | 0.96 | 1.9 | 1.3 | 7 |

Dieback = the percentage of seedlings with any (qualitative) terminal necrosis in April;
Survival = the percentage of seedlings with any live stem above ground in November;
Growth percent = the average percentage increase in height from April to November.
[a] Averaged over four post-lifting exposure treatments.
[b] Captan, 2.5 percent a.i. sprayed to wet stem, *Botryosphaeria* on PDA placed in a wound then sealed with wax-tape.
[c] Leaf development was assessed (April 3) on a four point scale.

**Table 3—Effects of inoculation and lifting treatments on survival and early growth of sweetgum seedlings from VA, planted near Sumter, SC[a] in 1997**

| Treatment[b] | n | Leaf development[c] | Dieback | Survival |
|---|---|---|---|---|
| | | | - - - - - - - - - *percent* - - - - - - - - - | |
| I = Control | 10 | 1.68 | 25a | 89a |
| I = Wound only | 10 | 1.67 | 26a | 85a |
| I = Botryosphaeria | 10 | 1.53 | 33ab | 79ab |
| I = Botryosphaeria + root dip | 10 | 1.51 | 43b | 70b |
| lsd | | 0.20 | 0.11 | 12 |
| Lift = Research | 20 | 1.60 | 25a | 89a |
| Lift = Regular | 20 | 1.59 | 38b | 72b |
| lsd | | 0.14 | 8 | 8.7 |

Dieback = the average length of dead terminal (feet) in April 1997; Survival = the percentage of seedlings with any live stem above ground in April.
[a] Trice Research Forest.
[b] "I" is inoculation at two levels of lifting. The Captan is a root dip with 2.5 percent a.i. solution on inoculated seedlings, inoculation is *Botryosphaeria* on PDA in a wound then sealed with wax-tape.
[c] Leaf development was assessed (April 4) on a three point scale (0, 1 or 2) where 2 = expanding. The means for Leaf development and Dieback do not include dead seedlings.

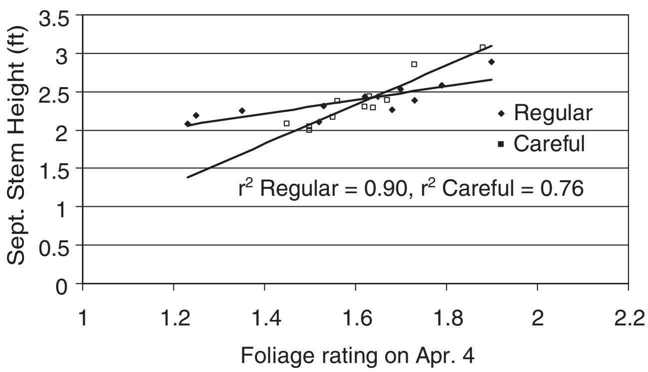


Figure 1—The correlation between bud break (measured in April) and sweetgum height (in feet) measured in September for all treatments planted at the Trice Research Forest.

between spring flush and height at the end of the growing season.

Although it should be remembered that seedlings from the two nursery sources were not handled exactly the same, inference from the two study sites is contradictory in that sweetgum was (VA source) or was not sensitive to treatments associated with lifting, storage, and planting. Artificial inoculation with *Botryosphaeria* had little impact on seedlings from either source. This appears to confirm that the fungus is a very weak pathogen of sweetgum (Toole 1957). Among seedlings presented for inoculation in 1997, no SC seedlings and 4.5 percent of VA seedlings already had stem cankers. The stress that predisposed some VA seedlings to cankering probably predisposed them and others to the treatments in the present study. The cankers observed on SC seedlings the preceeding spring (1996) probably indicate earlier conditions that predisposed those seedlings to respond to differences in planting technique with dramatic differences in dieback (as described in the introduction) unlike same-source seedlings in the present study.

## Management Implications

This research indicated, as did differences in foliage production between seedlings planted by research and contract planters near Summerville in 1996, that sweetgum can be sensitive to cultural practices that could be part of harvest, storage, and transplanting. Further, this sensitivity may vary between crops or between nurseries, probably due to conditions at the nursery before lifting. Therefore, provisions to limit exposure or rough handling, or both, during harvest and planting may enhance early growth and survival of seedlings more for some years' crops than for others. However, such care is always a good practice.

In this study, *Botryosphaeria* was not an aggressive pathogen of even harshly treated sweetgum seedlings. In fact, inoculation had no significant effect on seedling development within any treatment. Cankers on seedlings after planting could not be attributed to stress during lifting and outplanting. The many cankers observed during the field survey of 1996 were probably correlated with environmental stress that winter and spring and were not an important contributor to the dieback.

The correlation between the spring flush and the subsequent dieback of transplanted seedlings (fig. 1) adds statistical support to the idea that delayed foliage production indicated seedling stress. This was an interesting but unplanned benefit of the present study and provides a degree of confidence to this early assessment for seedling or planting quality, or both.

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**Appendix table 1**—Treatments applied to sweetgum seedlings by Union Camp personnel in 1997. Each treatment below is applied both to operationally lifted and research optimally lifted seedlings.

- 2 levels of drying for roots; 0 or 20 minutes (0 = control).
- 2 Temperature exposures; 2 hours at 28 °C or 2 hours at 85 °C
- 2 levels of drying for tops; 6 hours or 12 hours
- 2 levels of anaerobic stress; 24 hours or 72 hours.
- 1 level Westvaco seedlings at 0 or 20 minutes root dry.
- 3 levels of inoculation[a]
  - 1= wound plus sterile PDA
  - 2= wound plus Botryosphaeria on PDA
  - 3= wound plus Botryosphaeria plus Captan root dip @ 2.4 g ai/L

[a] The three inoculation treatments plus the 0 root drying are compared in table 3.

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