Selection For Height Growth Of Longleaf Pine In The Presence Of Brown Spot Disease

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ABSTRACT

Survival, brown spot infection and height were assessed at a greenhouse phase and up to 10 years after planting in two progeny tests of longleaf pine (*Pinus palustris* Mill.) planted at the Johnson Tract Experimental Forest near Alexandria, Louisiana and the Harrison Experimental Forest at Saucier, Mississippi. Survival was similar on both sites, except at 10 years when it was significantly lower at Alexandria. Brown spot infection in the greenhouse was low, and insufficient to permit culling susceptible families. In the field, brown spot infection was more severe at Alexandria than at Saucier. The largest difference between the two sites was observed 1 year after planting when infection at Alexandria was twice that at Saucier. Brown spot infection was great enough at 2 years at both sites to permit culling susceptible families. At 10 years, trees at Saucier averaged 4.5 m in height, while those at Alexandria were 3.5 m. Selections made at Alexandria performed well at both sites and had the lowest brown spot infection.

Keywords: Brown spot, survival, height, *Pinus palustris*.

INTRODUCTION

Longleaf pine (*Pinus palustris* Mill.) is one of the most important pine species in the southern USA (Boyer 1990, Croker 1990). It is highly valued for poles, piling and structural timber due to its excellent stem form, good natural pruning and high wood density (Bey and Snyder, 1978). Longleaf pine is more resistant to fusiform rust disease caused by *Cronartium quercuum* (Berk.) Miyabe ex Shirai f. sp. *Fusiforme*, southern pine beetles (*Dendroctonus frontalis* (Zimm.) and fire than loblolly pine (*P. taeda*) and slash pine (*P. elliottii*), species more favored for planting in the southern USA.

The main limitation to the wide planting and regeneration of longleaf pine is its susceptibility to brown spot disease (*Scirrhia acicola* (Dearn.) Siggers). Brown spot attacks seedlings in the nursery and young seedlings in the field during the grass stage, causing mortality, delaying the initiation of rapid growth and generally leading to reduced growth at maturity (Boyer 1990). Vigorous seedlings remain in the grass stage one or two years, but infected seedlings grow slowly and may remain in the grass stage for many years. The disease can be controlled by proper silvicultural practices such as prescribed burning, weeding, and application of fungicides. However, control with fungicides is economical only in the nursery and prescribed burning may damage the seedlings (Snyder *et al.* 1977). Hence breeding for brown spot resistance is important as it offers a more permanent solution and may be less expensive in controlling the disease. Breeding for brown spot resistance by the USDA Forest Service's Southern Experiment Station began in the 1930's at the Harrison Experimental Forest near Saucier, Mississippi (Derr 1963). Previous studies indicated that seedlings from north

Alabama were often resistant to brown spot when planted locally but became susceptible when planted near the Gulf Coast (Snyder and Allen 1968), while stable resistance was reported for seedlings from the Gulf Coast planted across various sites (Snyder and Derr 1972). The objectives of this study were to determine 1) whether selection should be based on performance at multiple sites or 2) if there was an advantage to selecting on specific sites.

MATERIALS AND METHODS

Treatments

Based on family and individual performance thirty-six parents were selected for height growth in two progeny tests comprising 510 half-sib families established at Alexandria, Louisiana and Saucier, Mississippi. The 510 families originated from Washington Parish, Louisiana. The thirty-six parents comprised: 1) 9 parents that performed well in height growth only at Saucier, 2) 9 parents that performed well in height growth only at Alexandria, 3) 9 parents that performed well in height growth at both locations, but selection made at Saucier, and 4) 9 parents performed well in height growth at both locations, but selections made at Alexandria. This resulted in 4 sets of 9 parental selections.

Each of nine parents was then control pollinated with 1-4 different parents within the set giving a total of 18 full-sib families produced per set, and 72 families in total. A set of 18 families is hereafter referred to as a treatment. Two control families (one resistant and one susceptible) were also added to each treatment at each site. The susceptible controls were similar to the selections commonly used for planting at each location.

Greenhouse and field phases

Seeds were sown in a greenhouse at Saucier in April 1982. The design in the greenhouse was a randomized complete block design using 48 replications of single-tree plots. Three months after germination half the seedlings were artificially inoculated with Alexandria brown spot inoculum while the other half were inoculated with Saucier inoculum. The inocula were collected by taking needle samples infected with brown spot disease from each site, and then producing spores on agar in the laboratory. The spore suspension containing about 200,000 spores per milliliter of distilled water was used to inoculate the seedlings.

Seedlings were evaluated for survival and brown spot infection in the greenhouse three months after inoculation. Brown spot infection was scored visually as a proportion of needle tissue with brown spot infection to the total needle tissue per seedling. In December 1982 diseased needles were removed and trees were planted in a randomized complete block design, as the greenhouse design, at two sites – Alexandria, Louisiana and Saucier, Mississippi. The greenhouse tree and plot identities were maintained in the field. The Alexandria test was located at the Johnson Tract Experimental Forest in Louisiana, while the Saucier test was located at the Harrison Experimental Forest. Trees were planted at a close spacing of 3 feet x 9 feet. Brown spot infection was assessed at 1-4 years after planting, while survival was assessed 1-5 and 10 years, and height was assessed 2-5 years and 10 years.

Analyses

To test the significance of treatment and family, and their interactions data pooled across sites and treatments were analysed using general linear model (GLM) procedure of SAS Institute Inc. (1985). The following linear model was used to test for differences between sites:

$$Y_{ijklm} = \mu + S_i + R_{j(i)} + T_k + ST_{ik} + F_{l(k)} + SF_{il} + \varepsilon_{ijklm} \quad \textbf{[1]}$$

Where:

Y_{ijklm} = is the observation on the mth tree in the ith site in the jth replicate in the kth treatment and lth family,
μ = overall mean,
S_i = random effect of the ith site,
$R_{j(i)}$ = random effect of the jth replicate within site,
T_k = fixed effect of the kth treatment,
ST_{ik} = random interaction effect of the site and treatment,
F_l = random effect of the lth family within treatment,
SF_{il} = random interaction effect of the site and family, and
ε_{ijklm} = is the residual.

When site by treatment interactions were significant, the following reduced model was used to test for differences among treatments:

$$Y_{ijklm} = \mu + R_{j(i)} + T_k + F_{l(k)} + \varepsilon_{ijklm} \quad \textbf{[2]}$$

All means reported are least squares means (SAS Institute Inc. 1985) that are adjusted for missing values.

Data for survival was converted to 0,1 (dead, alive) scale prior to analysis. To determine if early assessments were good predictors of later assessments and to determine relationships between different traits family mean correlations were estimated as product-moment correlations using PROC CORR procedure in SAS (SAS Institute Inc. 1985).

RESULTS AND DISCUSSION

Survival

Survival ranged from 92.8% at greenhouse stage to 70.5% at 10 years of age when averaged at each site. There were no significant differences in survival between the two inocula in the greenhouse and between the two sites, except at 10 years of age (Table 1). At age 10 years, survival at Saucier (76.5%) was significantly higher than that at Alexandria (70.5%). Families and treatments differed significantly in survival at all ages ($P < 0.05$). Analyses of individual sites revealed that survival was significantly greater in treatment 4 at age 10 at both sites; however, these differences were statistically significant only at Alexandria.

Brown spot infection

Significant differences ($P < 0.05$) existed for brown spot infection among the sites, treatments and families at all the assessment periods, except year 3 at Saucier (Table 1). The absolute levels of brown spot infections in the greenhouse were less than 5 %. Infection rates were low because inoculations were delayed due to variability in germination rates among families, and needles were more mature than optimal for inoculation. In contrast, field brown spot infections were less at Saucier than at Alexandria. In contrast, Snyder and Bey (1978) found that brown spot infections in the parental selection populations were higher at Saucier than at Alexandria at 3 years (71% and 55%, respectively). The largest difference between the two sites in their progeny trials was 1 year after planting when infection was 24.5 % at Alexandria and only 9.7 % at

Saucier (Fig. 1). After the first year in the field the differences between the two sites in brown spot infection rates were small, but significant. Brown spot infection rose sharply after planting up to 2 years of age, and the rate of increase decreased thereafter.

Table 1. Significance of treatment differences for survival, brown spot infection, and height in the greenhouse (GH) and in field tests on two sites (Alexandria/Saucier).

Traits	GH [a]	Year 1	Year 2	Year 3	Year 4	Year 5	Year 10
Survival	NS/NS	NS/NS	*/NS	*/NS	**/NS	**/NS	**/NS
Brown Spot	**/***	*/**	*/*	***/NS	***/***	---	---
Height	---	---	***/*	***/NS	***/NS	***/*	***/**

[a] NS, *, **, *** = Not significant, significant at P $\leq$ 5%, 1%, and 0.1%

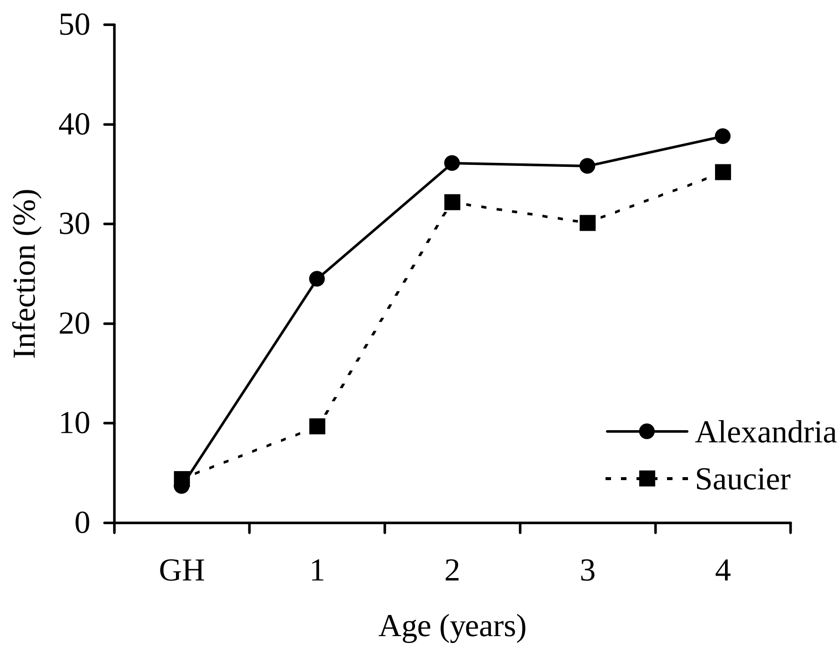

Figure 1. Brown spot infection at Alexandria and Saucier.

Since brown spot infection was high at 2 years of age after planting at both sites, families susceptible to brown spot could be thinned out at this age. This will require the field planting to be established at close spacing. Our findings are in close agreement with that of Snyder and Bey

(1978) who suggested that families susceptible to brown spot may also be thinned out a year after planting.

Treatment 1 and 3 (individual-tree selections at Saucier) had significantly higher brown spot infection than the other treatments at Alexandria (Fig. 2), while treatment 1 (individual-tree selection at Saucier) had significantly higher brown spot infection than other treatments at Saucier (Fig. 3), indicating that selections made at Saucier were more susceptible to brown spot. At 4 years, the susceptible control at Alexandria had 53 % brown spot infection, and Saucier had 71 % brown spot infection. The average of all the treatments at both sites was 39 %. This indicates that breeding for brown spot disease can be effective.

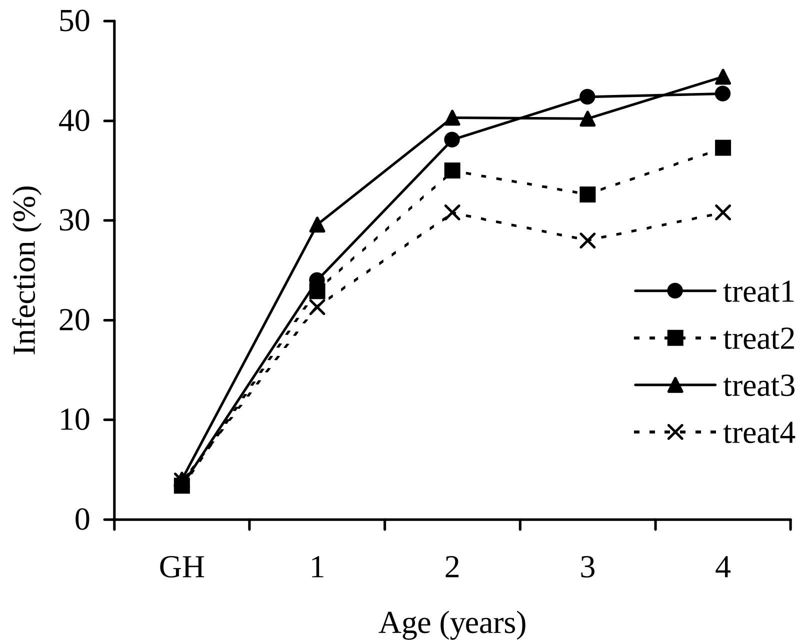

Figure 2. Brown spot infection of the four treatments at Alexandria.

Height growth

Height growth was significantly higher at Saucier than at Alexandria due, in part, to less brown spot infection at the former site (Figs. 1 & 4). Since most of the parent trees were selected in Washington Parish, LA (the same latitude as Saucier), they were probably less well adapted at Alexandria, which is farther North. At 10 years of age, trees at Saucier averaged 4.5 meters in height while those at Alexandria were only 3 meters in height. The high brown spot disease infections may have reduced height growth at Alexandria.

Selection made at Alexandria (treatment 2 and 4) performed significantly better than those made at Saucier when planted at Alexandria (Fig. 5). Selection made for Alexandria had the best growth at Alexandria partly due to less brown spot infection. The fast growth rates of the

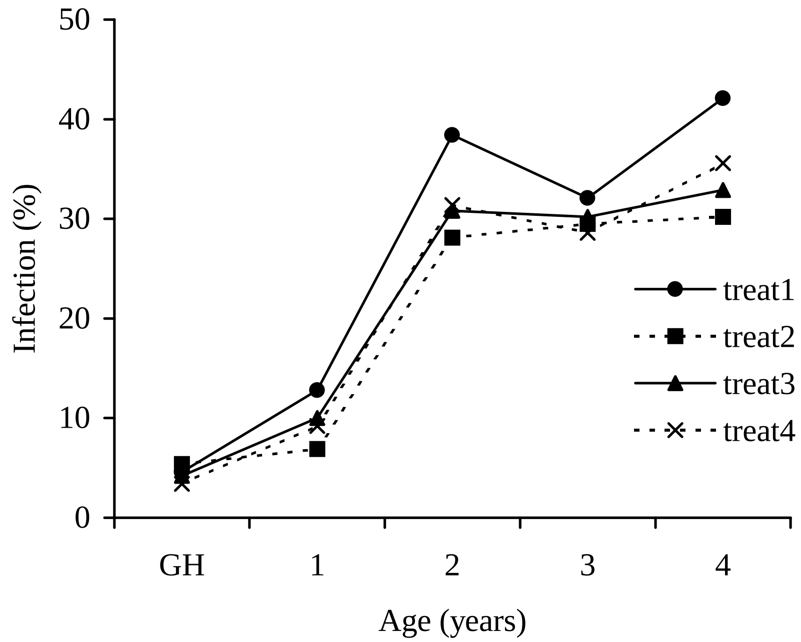

Figure 3. Brown spot infection of the four treatments at Saucier.

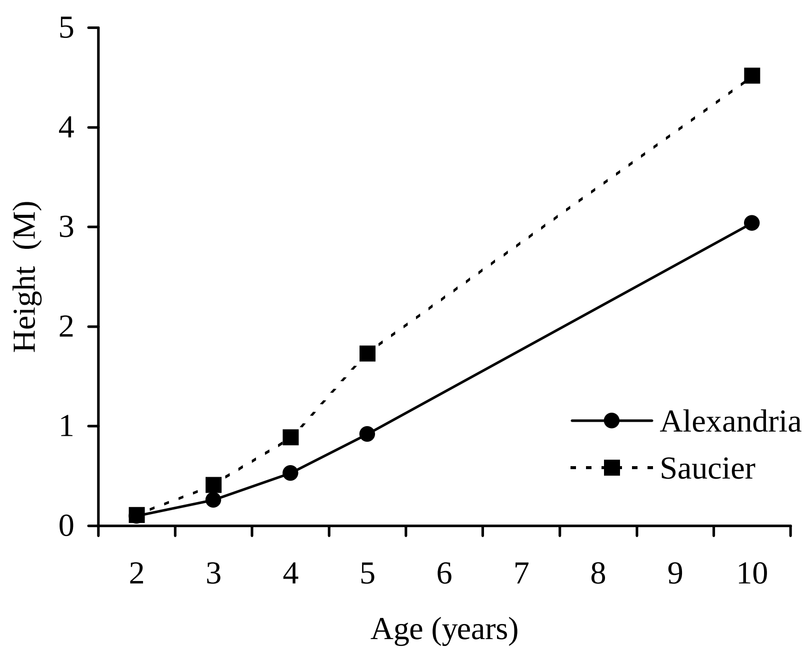

Figure 4. Height growth at Alexandria and Saucier sites.

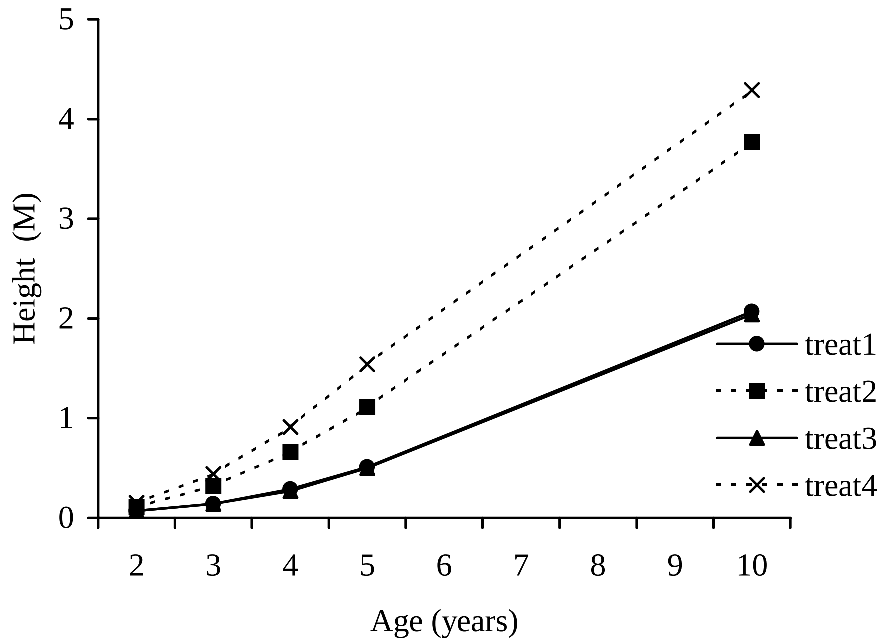

Figure 5. Height growth of the four treatments at Alexandria.

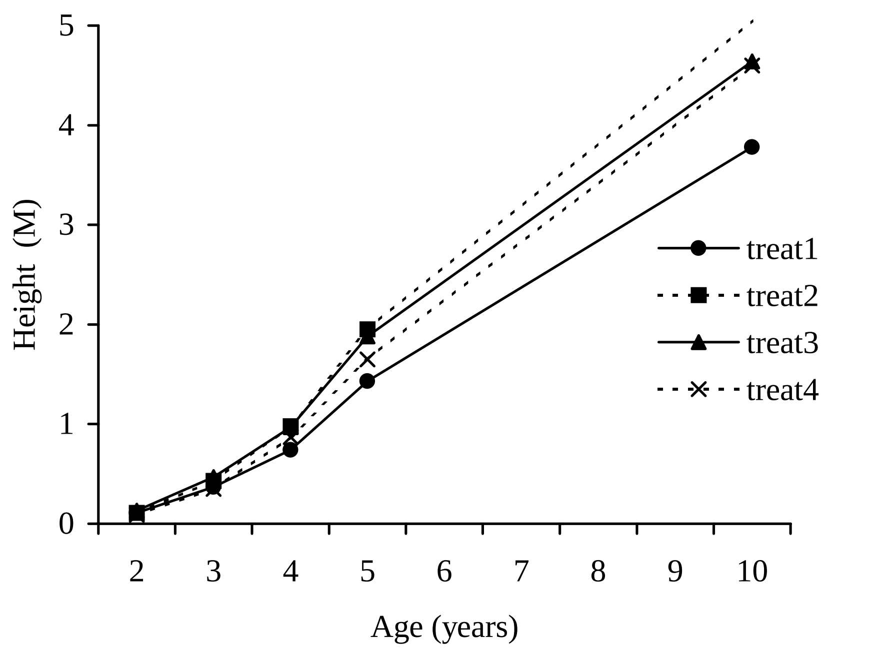

Figure 6. Height growth of the four treatments at Saucier.

Alexandria selections soon after planting may have reduced the time that the seedlings spent in the grass stage, and hence may have avoided the negative impacts of brown spot infections on height growth. In contrast, selections made specifically for Saucier (treatment 1) performed poorly at Saucier compared to the other treatment (Fig. 6). The graphs of height growth show that rank changes of treatments across years were non-existent indicating that early assessments of height may be good indicators of height at older ages.

Family mean correlations

Age-age phenotypic correlations were high between survival assessments and so were those between height growth assessments ($r_p > 0.74$, Table 2). This indicates that the families that had good survival in the greenhouse had good survival in the field. Hence, screening for survival on family basis could be made in the greenhouse prior to planting out in the field. Similarly, families that performed well at 2 years continued to perform well at 10 years.

Table 2. Phenotypic correlations between survival, brown spot infection and height.

	Surv1*	Surv10	BS0	BS1	BS2	BS3	BS4	HT2	HT10
Surv0	0.94	0.74	0.08	0.08	-0.01	-0.05	-0.11	-0.03	-0.06
Surv1		0.75	0.06	0.17	0.08	0.01	-0.06	-0.03	-0.04
Surv10			-0.12	-0.27	-0.37	-0.44	-0.44	0.10	0.09
BS0				0.18	0.16	0.19	0.14	-0.04	-0.02
BS1					0.82	0.76	0.61	-0.18	-0.45
BS2						0.90	0.84	-0.27	-0.55
BS3							0.90	-0.43	-0.61
BS4								-0.48	-0.70
HT2									0.76

*Surv = survival, BS = brown spot, HT = height, number is age in years (0 = GH).

Brown spot infection at greenhouse stage was poorly related to brown spot infection in the field ($r_p < 0.19$), while brown spot infection at different ages in the field was moderately to highly correlated ($r_p > 0.61$). Kais (1975) suggested that diseased families could be eliminated in the green house. Infection levels in the greenhouse were not high enough to evaluate the efficacy of greenhouse screening in our study. Survival at all ages was poorly correlated with height, while brown spot infections in the field tests were moderate, but negatively correlated with height at 10 years.

CONCLUSIONS

Growth, survival and tolerance to brown spot infections were better at Saucier than at Alexandria. This may have occurred because parent trees were not adapted to the Alexandria site having been selected from a similar, more southerly latitude as Saucier.

Since brown spot infection was high at 2 years of age after planting at both locations, families susceptible to brown spot could be thinned out at this age. Finally, the results suggest that selections made at Alexandria performed well at both sites and had the lowest brown spot infection while those selected at Saucier did not.

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LITERATURE CITED

Bey, C. F. and Snyder, E. B. (1978). Genetic gains through testing and crossing longleaf pine plus trees. U.S. Dep. Agric. For. Serv. Res. Note SO-241, 5 p. South. For. Exp. Stn., New Orleans, La.

Boyer, W. D. (1990). *Pinus palustris* Mill. Longleaf pine. In: Silvis of North America: 1. conifers. Tech. Coordinators R. M. Burns and B H. Honkala. USDA Forest Service, Washington D.C. Agric. Handbook 654, p. 405-412.

Croker, T. C., Jr. (1990). Longleaf pine – myths and facts. In Proc. Symp. on management of longleaf pine; 1989 April 4-6; Long Beach, MS. Gen. Tech. Rep. SO–75. New Orleans, LA; USDA Forest Service, South. Stn.; 2-10.

Derr, H. J. (1963). Brown-spot resistance among F1 progeny of a single, resistant longleaf parent. Forest Genet. Workshop Proc. 1962:16-17. Macon, Ga.

Kais, A. G. (1975). Environmental factors affecting brown spot infection on longleaf pine. *Phytopathology* **65**:1389-1392.

SAS Institute Inc. (1985). SAS® Language Guide for Personal Computers, Release 6.03 Edition. SAS Institute Inc., Cary, NC, 558 pp.

Snyder, E. B. and Allen, R. M. (1968). Mountain longleaf pine excels only in local plantings. USDA for. Serv. Res. Note SO-83, 4p. South. For. Exp. Stn., New Orleans, La.

Snyder, E. B. and Bey, C. F. (1978). Progeny testing longleaf pine at two locations. USDA for. Serv. Res. Note SO-240, 4p. South. For. Exp. Stn., New Orleans, La.

Snyder, E. B. and Derr, H. J. (1972). Breeding longleaf pines for resistance to brown-spot needle blight. *Phytopathology* **62**:325-329.

Snyder, E. B., Dunis, R. J. and Derr, H. J. (1977). Genetics of longleaf pine. U.S. Dep. Agric. For. Serv. Res. Paper WO-33, 22 p. South. For. Exp. Stn., New Orleans, La.