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Longleaf Pine Growth Following Storage and Benomyl Root-Dip Treatment

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For longleaf pine seedlings, the length of cold storage before outplanting significantly affected survival and growth, while the benomyl root-dip treatment primarily affected incidence of brown-spot needle blight. Seedling response to both of these treatments was further affected by climatic conditions that existed during the first year after outplanting.

Acceptable survival and subsequent growth of southern pine seedlings can depend upon critical storage factors (8). Longleaf pine *(Pinus palustris* Mill.) has been especially difficult to reproduce by natural or artificial methods. (3). The survival of longleaf pine is particularly influenced by seedling size and the length of storage (1, 4, 6). Drought conditions during the first growing season in the field also affect longleaf pine survival and growth (4, 5). More recently, longleaf pine survival and growth were increased following a benomyl root-dip treatment at outplanting (1, 2). The benomyl treatment also reduced brown-spot needle blight caused by *Scirrhia acicola* (Dearn.) Siggers.

A 1980 study investigated whether benomyl root-dip treatments could improve the survival and growth of longleaf pine seedlings held in cold storage for various periods following lifting. Unfortunately, high temperatures and drought conditions in the spring and summer of 1980 affected survival of newly established pine plantations throughout the South (7). Consequently, the effects of the benomyl dip treatment and storage time on survival, brown spot infection, and growth were evaluated in respect to climatic conditions at the specific planting sites.

Materials and Methods

Longleaf pine seedlings were lifted at the Ashe Nursery at Brooklyn, Miss., during the week of January 7 to 11, 1980. These seedlings were packed in kraft-polyethylene bags with moist sphagnum peat moss and stored at 35° F (2° C) until time of outplanting. A total of 210 bundles (6,300 seedlings) were lifted and prepared for storage at two locations. One planting location was the Harrison Experimental Forest (HEF) at Saucier, Miss., and the other was the Palustris Experimental Forest (PEF) near Alexandria, La.

A bundle of 375 seedlings was removed from storage and outplanted at each site atter 1, 14, 28, 42, 56, 70, and 84 days of storage. Seedlings were dip-treated with one of three mixtures just before outplanting: (1) Kaolinite clay, (2) a mixture of Kaolinite clay and 5-percent active ingredient (a.i.) benomyl, and (3) a mixture of Kaolinite clay and 10-percent a.i. benomyl. The root systems of 25 seedlings were moistened in water and then shaken in plastic bags containing one treatment, thus giving an even coating of the material. Treated seedlings were outplanted in each of five blocks at each site on each of seven planting dates. Twenty-one treatment combinations were randomly planted within each block at the two planting sites. Seedlings were planted by dibble bar at a 2-foot by 4-foot spacing on previously scalped 15-foot swaths at each site. The seven HEF planting dates were January 9 and 23, February 5 and 19, March 4 and 19, and April 2, 1980; the seven PEF planting dates were January 14 and 28, February 11 and 25, March 10 and 24, and April 7, 1980.

Notations and measurements of survival, the percentage of brown spot infection, and height growth were made on all seedlings during October 1981, the second year of growth in the field. Visual estimates were made of the percentage of needle tissue killed by brown-spot infection, and seedling heights were measured from soil line to terminal bud tip.

This study was designed and installed as a randomized complete block with five replicates. Each block consisted of 21 treatment rows. Data were analyzed independently at each location as a factorial consisting of three dip treatments and seven storage periods. Duncan's multiple range test (p = 0.05) was used to compare treatment means for the various parameters.

Results

Survival. Seedling survival was much greater at the HEF-Mississippi site than at the PEF-Louisiana site after 2 years' growth in the field (table 1). The overall mean survival at the HEF site was 85.3 percent with a range from 75.2 to 99.2 percent. The PEF site had 26.9 percent mean survival with a range from 2.4 to 61 .6. For each site, significant differences in survival were attributed only to storage

Table 1—*Longleaf pine seedling survival, brown spot infection, and height growth following cold storage and benomyl root-dip treatment*

Dip treatment and storage	Seedling survival		Brown spot infection		Height	Seedlings > 10 cm tall
	HEF	PEF	HEF	PEF	HEF	HEF
Days	%				*Cm*	%
Clay dip						
1	99.2a	47.2bc	23.5a	5.0a	13.6abc	66.2abc
14	99.2a	43.2c	17.4ab	3.4a	12.4bcde	58.2abcd
28	84.8abc	28.0d	11.8bcd	3.8a	11.3cdef	59.4abcd
42	68.8c	15.2efg	6.9cdef	3.3a	10.1def	44.0cde
56	82.4abc	23.2de	12.6bc	2.0a	9.2ef	42.8cde
70	84.8abc	16.0efg	11.4bcde	4.0a	10.8cdef	37.8de
84	88.8abc	2.4h	7.1cdef	3.0a	10.1def	39.4de
Mean	86.9	25.0	13.0	3.5	11.1	49.7
Benomyl 5% a.i.						
1	96.0ab	61.6a	5.3def	4.6a	14.7ab	78.7a
14	93.6ab	48.0bc	3.5f	3.4a	12.4bcde	61.2abcd
28	84.0abc	24.0de	4.9def	3.8a	13.2abcd	67.8abc
42	80.8abc	24.8de	4.7ef	3.2a	10.6cdef	53.6abcde
56	87.2abc	18.4e	4.3ef	2.8a	9.9def	44.4cde
70	75.2bc	7.2gh	3.7f	3.0a	11.0cdef	56.0abcde
84	85.6abc	17.4ef	4.6ef	2.3a	9.4ef	53.0abcde
Mean	86.1	28.8	4.3	3.3	11.6	59.3
Benomyl 10% a.i.						
1	95.2ab	57.6a	3.2f	5.4a	15.6a	77.0ab
14	93.6ab	54.4ab	3.2f	5.0a	11.9bcde	61.0abcd
28	80.8abc	24.8de	3.5f	3.8a	11.8bcde	59.6abcd
42	76.8bc	20.0de	5.4def	2.2a	9.4ef	39.2de
56	80.8abc	15.2efg	3.4f	3.0a	9.9def	51.6bcde
70	78.4abc	8.0gh	2.6f	4.0a	11.6bcde	56.8abcde
84	75.2bc	8.8fgh	3.4f	1.4a	8.2f	32.0e
Mean	83.0	27.0	3.5	3.5	11.2	53.9

[1]For each column, values not followed by the same letter are significantly different (p = 0.05).

time before outplanting. Survival generally decreased with storage increases, but the decreases were greater on the PEF site where environmental stresses were greater. The various dip treatments had no significant effect on seedlings survival at either site.

Infection. Brown spot infection rates were comparatively low for the longleaf pine seedlings at both sites following the second year in the field (table 1). However, more fungal infection did occur on the longleaf seedlings at the HEF site than at the PEF site. Significant differences due to dip treatment were evident on the HEF seedlings, but treatment did not affect the PEF seedlings. Brown spot infection differences on the HEF seedlings were related to dip treatment, storage time, and the interaction of the two.

Growth. Stem heights were determined only for the seedlings at the HEF site since stem elongation had not begun on the seedlings at the PEF site (table 1). Significant differences in height could be related only to storage time. The percentage of seedlings displaying rapid height growth (stem length > 10.0 cm) was determined only on the HEF site. Significant differences between these percentages are related only to differences in storage times (table 1).

Discussion

Study results were confounded by the adverse climatic conditions during 1980, the first year of field growth. The extremely high temperatures and drought conditions during the late spring and summer of 1980 apparently had a significant effect on the survival, brown-spot infection, and height of the outplanted seedlings (tables 2 and 3). The Louisiana site experienced higher maximum daily temperatures from June through September and more days exceed-

Table 2—*Maximum daily temperatures at two outplanting sites from April through September 1980*

Month	Maximum temperatures (°F)						Mean (°F)
	<60	61-70	71-80	81-90	91-100	>100	
	Frequency (days)						
April	0; 1[1]	3; 4	18; 14	9; 11	0; 0	0; 0	79.0; 77.1
May	0; 0	0; 0	9; 7	22; 21	0; 3	0; 0	83.6; 84.5
June	0; 0	0; 0	0; 0	6; 7	24; 22	0; 1	92.0; 92.7
July	0; 0	0; 0	1; 0	6; 3	19; 16	5; 12	94.0; 97.3
August	0; 0	0; 0	0; 0	5; 3	26; 19	0; 9	92.7; 96.6
September	0; 0	0; 0	0; 1	12; 6	18; 23	0; 0	91.4; 92.9
Total	0; 1	3; 4	28; 22	60; 51	87; 83	5; 22	

[1]First entry is HEF site in Mississippi; while second entry is PEF site in Louisiana.

Table 3—*Rainfall at two outplanting sites from April through September 1980*

Month	Rainfall in inches					Total days	Total inches
	<0.2	0.2-0.6	0.6-1.0	1.0-2.0	>2.0		
	Frequency (days)						
April	3; 1[1]	3; 3	0; 1	1; 0	3; 1	10; 6	12.35; 5.54
May	5; 1	2; 0	2; 0	2; 0	1; 0	12; 1	11.36; .12
June	3; 1	3; 1	1; 0	0; 0	0; 0	7; 2	2.22; .51
July	1; 0	7; 0	1; 0	1; 1	0; 0	10; 1	5.25; 1.51
August	6; 1	2; 0	1; 1	0; 0	0; 0	9; 2	1.90; .88
September	6; 1	3; 2	0; 1	1; 0	0; 0	10; 4	3.29; 1.62
Total	24; 5	20; 6	5; 3	5; 1	4; 1	58; 16	36.37; 10.18

[1]First entry is HEF site in Mississippi; while second entry is PEF site in Louisiana.

ing 100° F than the site in Mississippi (table 2). The incidence and amount of precipitation from May through September were much less at the PEF site than at the HEF site (table 3). This combined effect of high temperatures and drought particularly inhibited seedling growth on the Louisiana site; it also somewhat affected seedling growth on the Mississippi site.

For the two seedling treatments, storage time apparently had the greatest effect on survival and height growth, while the two benomyl root-dip treatments had the greatest effect on brown spot infection. However, these treatment effects were also affected by the prevailing climatic conditions during the summer following planting. It is possible that results associated with length of storage were confounded by the climatic conditions that occurred during the 84-day planting period.

Survival was surprisingly high at the HEF site even for seedlings that had been stored for 84 days (75.2 percent). Maximum survival for PEF seedlings, however, was 61.6 percent for seedlings stored for only 1 day. These results suggest that climatic conditions following outplanting may be more important for longleaf pine survival than seedling storage time, assuming suitable storage and planting techniques. Longleaf seedlings apparently lose vigor and become more affected by adverse weather conditions as storage time is increased.

The prevailing drought had a significant effect on the amount of brown spot infection that developed, especially at the Louisiana site. The dissemination and germination of *S. acicola* conidia, which are dependent on rain splash and high humidity, were significantly restricted during the first year. Brown spot infection began to increase on the seedlings at the HEF site during the second year, but was still inhibited at the PEF site (table 1). Consequently, the effect of the benomyl root-dip treatment was observable only at the Mississippi site.

Total height growth and percentage of seedlings displaying rapid height growth were generally greater for the shorter storage regimes and the two benomyl root-dip treatments (table 1). None of the treatments had any significant effect on growth during unfavorable climatic conditions.

Maximum seedling survival, height growth, and minimal brown spot infection occurred when seedling storage time was reduced, when seedlings were treated with the benomyl root-dip treatment, and when favorable weather occurred. However, acceptable survival, height growth, and disease control should also be possible for seedlings held in extended cold storage and dip-treated with benomyl, as long as favorable weather conditions precede and follow planting.

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