REFORESTATION ON NON-INDUSTRIAL PRIVATE FORESTLAND IN EAST TEXAS FROM 1983-1993: FACTORS ASSOCIATED WITH FIRST-YEAR SEEDLING SURVIVAL[1]

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Abstract—Of the 12 million acres of commercial forestland in East Texas, 61 percent is owned by the non-industrial private sector. From 1983 through 1993, pine reforestation on non-industrial private forestland (NIPF) ranged from 17 to 31 thousand acres per year. Cost-sharing was involved on 87 percent of the acres planted. Annual first-year seedling survival ranged from 54 to 76 percent and averaged 64 percent over the 11-year period. First-year survival declined slightly as planting season progressed. While hand planting accounted for 67 percent of the acres planted, machine planting averaged about 4 percentage points greater in survival. Average survival was 68, 64, and 54 percent on good, average, and poor sites, respectively. Tracts receiving herbaceous weed control averaged 13 percentage points greater in survival than tracts where no weed control was used. Survival was significantly correlated with accumulated negative values of precipitation minus potential evapotranspiration during the growing season.

INTRODUCTION

Because of continuing population growth and the consequent reduction in the forestry land base, and because of increasing pressure on National Forests to manage for values other than timber, non-industrial private forestland (NIPF) will be increasingly relied upon to supply the nation with wood fiber. However, poor regeneration of pine on NIPF has been identified as a major cause of a reduction in pine forests and growth in the South (USDA Forest Service 1988, McWilliams 1989).

Of the 12 million acres of commercial forestland in East Texas, 61 percent is owned by the non-industrial private sector (Miller and Hartsell 1992). It is on these lands that the greatest potential lies in alleviating a future deficit in timber supply. It is therefore crucial that forest resource professionals encourage effective reforestation on NIPF and identify those factors associated with mortality and successful seedling establishment.

This paper relates first-year seedling survival on NIPF in East Texas from 1983 through 1993 to silvicultural, site, and climatic factors.

METHODS

Beginning in 1983, records were kept on first-year seedling survival of operational pine plantings administered by the Texas Forest Service (TFS) in East Texas. Table 1 lists the variables recorded each year. Survival was determined from number of trees planted and number surviving on 0.01-acre plots established during or shortly after planting. Plots were systematically distributed over each planted area at a rate of 1 plot per acre for tracts of smaller than 35 acres, down to 1 plot per 3 acres for tracts larger than 90 acres. Number of trees planted was determined at plot establishment as part of a tree planting inspection program. Plots were revisited at the end of the first growing season and surviving trees were counted. Survival was summarized by the various variables. All survival means are weighted by acres planted. Analysis of variance or simple linear regression analysis was conducted on each main effect. All analyses were weighted by acres. Arcsine transformation of survival data was used for all analyses except survival by month of planting and survival by accumulated negative values of P-PET (described below) for the growing season.

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Table 1–Variables recorded by year from 1983 through 1993

Variable	Year 83	84	85	86	87	88	89	90	91	92	93
County	+	+	+	+	+	+	+	+	+	+	+
Acres	+	+	+	+	+	+	+	+	+	+	+
Cost share program	+	+	+	+	+	+	+	+	+	+	+
Trees planted[a]	+	+	+	+	+	+	+	+	+	+	+
Trees surviving[a]	+	+	+	+	+	+	+	+	+	+	+
Date planted	+	+		+	+	+	+	+	+	+	+
Planting method[b]		+		+		+	+	+	+	+	+
Herbaceous weed control[c]						+	+	+	+	+	+
Site quality[d]								+	+	+	+
Seedling type[e]								+	+	+	+

[a] Number per acre
[b] Machine or hand
[c] Yes or no
[d] Good, average, or poor
[e] Species or genetic line

An attempt was made to relate a climatic factor to survival by correlating first-year survival to the accumulated negative values of precipitation minus potential evapotranspiration during the growing season. Potential evapotranspiration (PET) was calculated using Thornthwaite's method (1948). Following this method, an unadjusted potential evapotranspiration is calculated from mean monthly temperature according to the equation

$$e = 1.6\,(10t/I)^{a}$$

where e is the unadjusted monthly potential evapotranspiration in cm, t is the mean monthly temperature in °C, I is the heat index, and a is a coefficient determined from the heat index. The heat index, I, is the sum of 12 monthly values of temperature index (i) given by

$$i = (t/5)^{1.514}$$

Coefficient a is obtained from the empirical equation

$$a = 0.000000675\,I^{3} - 0.0000771\,I^{2} + 0.49239$$

The above potential evapotranspiration equation gives values for months of 30 days and 12 hours each. Since number of days in a month varies and daylength varies with season and latitude, unadjusted rates must be reduced or increased by a factor that varies with month and latitude. This correction factor ranged from 0.86 to 1.22.

Monthly precipitation and temperature data were obtained from 28 weather observing sites throughout East Texas supervised by National Oceanic and Atmospheric Administration/National Weather Service. A value for each TFS District was obtained by averaging the three most appropriate stations within or nearest the District. TFS Districts generally comprise from 1 to 3 counties. In some cases only two stations were included. Differences between precipitation and potential evapotranspiration (P-PET) were determined for each District. A negative value of P-PET indicates the amount by which precipitation fails to supply the potential water need of a vegetation covered area.

An overall weighted average of P-PET for East Texas for each month was obtained by averaging District values as weighted by number of acres planted in each respective District. Negative values from April through September were summed to provide an accumulated negative P-PET value, which is similar to Thornthwaite and Mather's (1957) accumulated potential water loss. A Pearson correlation coefficient was then computed between these accumulated negative P-PET values and overall seedling survival for East Texas each year.

RESULTS AND DISCUSSION

Although twice as much timberland classified as pine or oak-pine forest type exists in the Southeast region of East Texas than in the Northeast region, non-industrial private timberland is concentrated in Northeast Texas (Figure 1)(McWilliams and Lord 1988, Miller and Hartsell 1992). There are two reasons for this. First,

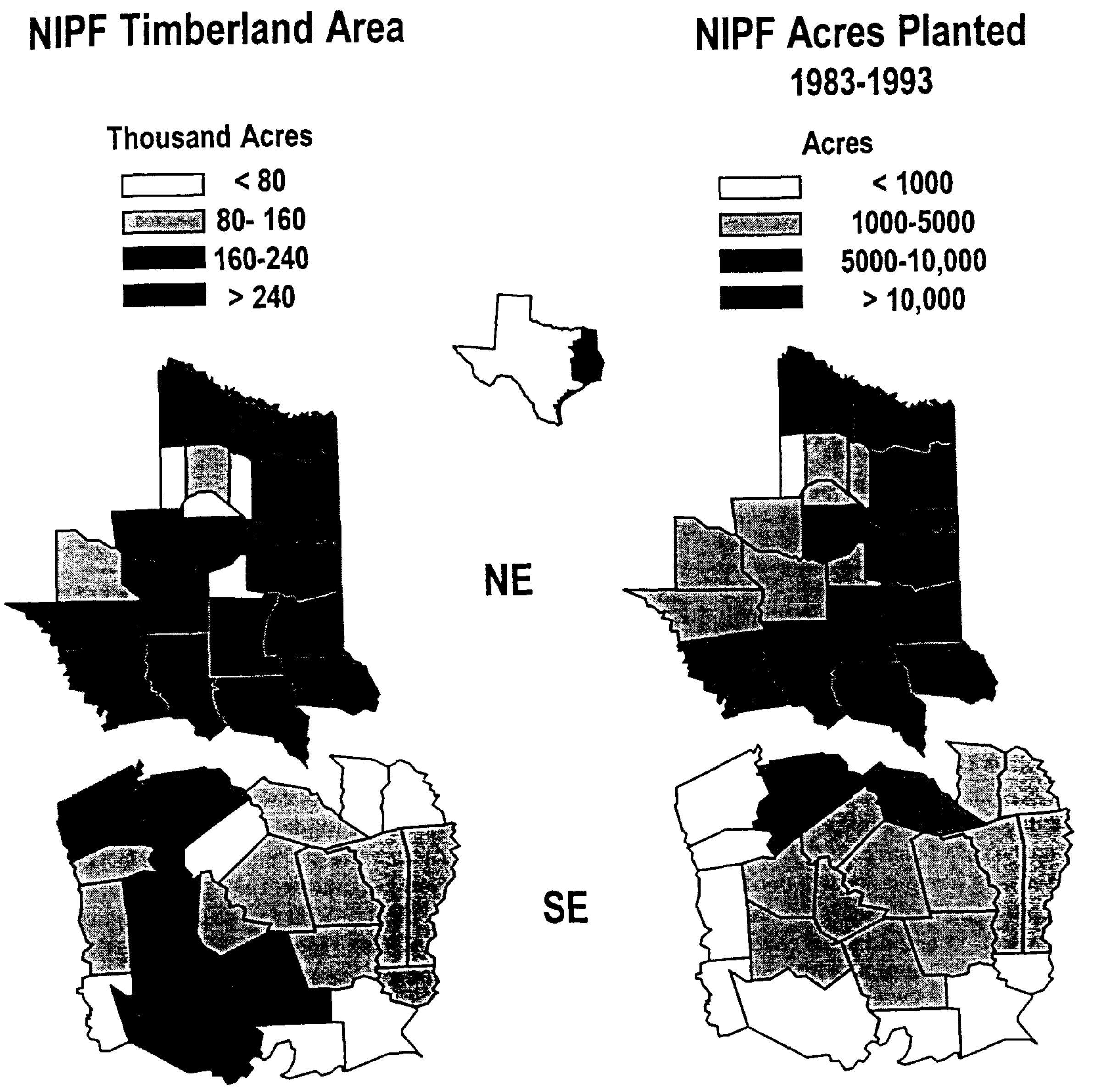

Figure 1--Number of acres of non-industrial timberland and number of acres planted from 1983 through 1993 by county in East Texas.

forest industry timberland occurs primarily on the more productive sites that are found in the southeastern part of East Texas. One-third of timberland in Texas is owned by forest industry. Second, the four National Forests in Texas are located in the Southeast region. Because of these ownership patterns, 80 percent of the acres planted on NIPF lands from 1983 through 1993 has been in Northeast Texas (Figure 1).

Reforestation since 1983 has ranged from a low of 16,638 acres in 1983 to 30,663 acres in 1993 (Table 2). The low in 1987 was probably associated with low timber prices existing during 1985 and 1986. Sawtimber sold for an average of $125/mbf Doyle during that two-year period.

These values and all other values reported here include only reforestation on NIPF where the Texas Forest Service administered the planting. Additional reforestation on NIPF occurs in which the TFS is not involved and no accurate number is available for that.

Table 2–Acres planted by cost share program and average first-year survival from 1983 through 1993

Year	Cost share program[a]							
	FIP	TRe	CRP[b]	ACP[b]	SIP	None	TOTAL	Survival
	1000 acres							%
83	14.8	9.3	0	0.2	-	4.3	28.5	73.2
84	8.5	7.3	+	+	-	4.2	20.0	58.9
85	11.0	8.5	+	+	-	3.2	22.5	54.0
86	10.9	9.0	0	0.0	-	2.2	22.1	64.7
87	7.8	5.6	2.1	0.1	-	1.0	16.6	60.3
88	8.3	7.7	3.8	0.3	-	1.1	21.3	57.1
89	10.4	6.4	1.3	0.1	-	2.2	20.5	75.6
90	10.6	8.4	3.7	0.2	-	2.7	25.5	58.0
91	11.7	6.3	1.3	0.3	-	3.0	21.1	67.2
92	13.8	6.6	2.3	0.6	-	5.3	28.6	72.5
93	13.3	8.1	0.8	0.6	2.6	5.3	30.7	60.3
TOTAL	121.2	83.2	15.3	2.4	2.6	34.4	259.1	63.7

[a] FIP = Forestry Incentives Program, TRe = Texas Reforestation Foundation, CRP = Conservation Reserve Program, ACP = Agricultural Conservation Program, SIP = Stewardship Incentive Program

[b] "+" indicates acreage lumped with FIP data

However, a best guess is that the TFS is involved in 75 to 80 percent of the NIPF reforestation in East Texas.

First-year seedling survival ranged from 54.0 to 75.6 percent during the 11-year period. The high which occurred in 1989 is associated with good rainfail, in terms of both amount and distribution throughout that growing season. Over the 11-year period, average survival, weighted by acres, was 63.7 percent.

The importance that cost sharing has in reforestation of NIPF is evident from the data (Table 2). Eighty-seven percent of the acres planted were cost-shared (77 percent of planting cases). The most important program has been the federally-funded Forestry Incentives Program (FIP). This program has accounted for 54 percent of the cost-shared acres. The second most important program has been the Texas Reforestation Foundation (Barron 1983). This privately funded program accounted for 37 percent of the cost-shared acres. The relatively few acres planted under the Conservation Reserve Program is due to the lack of cropland present in East Texas. Most all of the openland planted is marginal pastureland, which is not eligible for participation in this program.

Three of every four acres were planted in February or March (Table 3). Ideally, plantings should be accomplished before March. However, because the same tree planting vendors plant both NIPF and industry lands, most of industry's plantings are completed before vendors move to NIPF since industry's contracts are larger and thus more lucrative. When averaged over the 1983-to-1993 period, survival showed a slight general decline as planting season progressed. Using linear regression weighted by acres, this decline was significant (P=0.0001) with an approximately 4-percentage-point decline per month. However, plantings in December through February were essentially the same, and most of the decline came with plantings accomplished in March and April. Wakeley (1954) also noted a decline in survival for March and April plantings. Lower survival of late-season planted seedlings may result from inadequate root growth before budbreak and the onset of droughty conditions in the spring and summer (Long 1991).

Information on method of planting was available for all years except 1983, 1985, and 1987 (Table 4). During the period, about twice as many acres were hand planted as were machine planted. Tracts that were machine planted averaged 4 percentage points greater in survival than hand-planted tracts. Using analysis of variance weighted by acres across all plantings, this difference was significant (P=0.0001). McNab and Brendemuehl (1983) found that seedling survival rates

Table 3--First-year seedling survival and acres planted by month of planting in East Texas from 1983 through 1993

	------ 1000 acres planted------					----------Percent survival--------					Regression[a]	
Year	Dec	Jan	Feb	Mar	Apr	Dec	Jan	Feb	Mar	Apr	B_1	P value
83	0.8	2.6	8.1	11.3	2.0	77.7	72.5	77.4	72.6	59.2	-3.49	0.0001
84	0.1	1.8	4.9	6.1	1.3	82.1	56.2	61.6	57.3	52.2	-2.21	0.1651
85	-	-	-	-	-	-	-	-	-	-	-	-
86	0.1	2.3	2.2	4.0	0.2	28.2	69.9	72.8	60.0	57.2	-4.81	0.0020
87	0.2	2.1	2.2	4.4	0.8	76.8	64.9	60.8	54.2	47.3	-5.96	0.0001
88	0.2	3.8	6.5	9.5	0.6	43.9	60.0	61.9	53.2	52.7	-3.24	0.0135
89	0.9	4.4	5.4	7.6	0.7	79.2	75.1	77.5	74.4	64.4	-1.48	0.0739
90	0.8	4.5	7.7	9.9	0.5	40.6	62.4	61.8	54.5	61.1	-1.29	0.2273
91	0.2	2.8	6.6	11.1	0.3	78.6	74.8	75.2	61.3	50.7	-8.51	0.0001
92	2.6	6.8	10.0	7.7	0.0	87.4	78.6	71.8	64.1	-	-7.52	0.0001
93	1.8	6.0	9.2	9.6	0.3	55.1	64.8	61.5	58.0	66.3	-1.09	0.2231
83-93	7.8	37.1	62.8	81.3	6.7	70.5	68.8	68.5	61.4	56.6	-3.84	0.0001

[a] Simple linear regression weighted by acres where B_1 is slope and P value is significance level.

Table 4--First-year survival and acres planted by hand or machine in East Texas from 1983 through 1993

Year	1000 acres planted Hand	Machine	Percent survival Hand	Machine	P value
83	-	-	-	-	-
84	7.0	7.2	62.0	54.8	0.0186
85	-	-	-	-	-
86	5.7	2.1	65.5	66.7	0.1527
87	-	-	-	-	-
88	12.2	8.4	55.7	59.0	0.4190
89	13.3	5.8	74.2	77.6	0.0150
90	15.2	8.4	53.9	65.7	0.0001
91	16.2	4.9	65.0	75.8	0.0001
92	18.5	8.8	70.8	76.8	0.0001
93	21.0	7.4	58.7	64.9	0.1807
83-93	109.1	53.0	63.1	67.2	0.0001

were 20 percent lower with hand than machine planting in a comparison done in Florida. Higher survival with machine planting may be associated with more uniformity in the depth of the planting hole, better seedling placement, and better soil packing (South and Mexal 1984, Long 1991). Without close supervision, hand planters often do not sufficiently pack the seedlings and thus root-to-soil contact is not maximized. Shiver *et al.* (1990) found that loosely packed seedlings had significantly poorer survival than seedlings planted firmly.

Herbaceous weed control on NIPF began to be used operationally in East Texas in 1987. Data are available for 1988 through 1993 planting seasons (Table 5). Herbaceous weed control has steadily increased each year and has been applied on 14 percent of the acres planted. Tracts on which herbaceous weed control was used averaged 13.0 percentage points greater in survival than tracts where no weed control was used (P=0.0001). Percentage point differences have ranged from 6.3 in 1988 to 20.2 in 1991. Herbaceous weed control throughout the South has proven effective in

Table 5–First-year seedling survival and acres planted by presence of herbaceous weed control (HWC) in East Texas for 1988 through 1993

	1000 acres planted		Percent survival		
Year	None	HWC	None	HWC	P value
88	19.2	1.3	56.7	63.0	0.1466
89	17.5	1.6	74.8	80.4	0.0274
90	17.5	1.8	58.3	71.0	0.0003
91	18.1	3.0	64.6	84.8	0.0001
92	20.8	6.5	69.4	83.0	0.0001
93	24.2	4.1	59.3	66.1	0.0011
88-93	117.4	18.4	63.6	76.6	0.0001

increasing survival of newly planted loblolly pines (Metcalfe 1986). By decreasing the competition for soil moisture, planted seedlings are given the opportunity to establish root systems before commonly experienced dry periods occur in summer.

Beginning in 1990, TFS foresters began supplying information on site quality. As expected, survival increased as site quality increased (Table 6). Survival on good quality sites averaged 67.6 percent compared to 54.3 percent on poor quality sites. Linear regression weighted by acres revealed this to be a significant linear effect (P=0.0001). An analysis of variance was conducted on data for years 1990 through 1993 and included year, weed control, method of planting, site quality, and interactions in the model. All main effects were highly significant (P<0.003) except weed control which was significant at the p=0.035 level. Only one interaction was significant—planting method by site quality. Further regression analysis showed that with hand planting there was a significant (p=0.0001) increase in survival as site quality improved. However, with machine planting, this relationship was not expressed (p=0.26).

Since 1990, most loblolly pine, *Pinus taeda* L., planted has been from three improved genetic lines produced at Indian Mound State Tree Nursery – Southeast Texas (Superior), Northeast Texas, and Drought-Hardy (Table 7). The remaining 12 percent of improved loblolly was obtained from industry nurseries in East Texas. Differences in survival among the seedling sources is perhaps best evaluated by site quality. On good sites, there was essentially no difference in survival among the various seedlings sources. However, as site quality

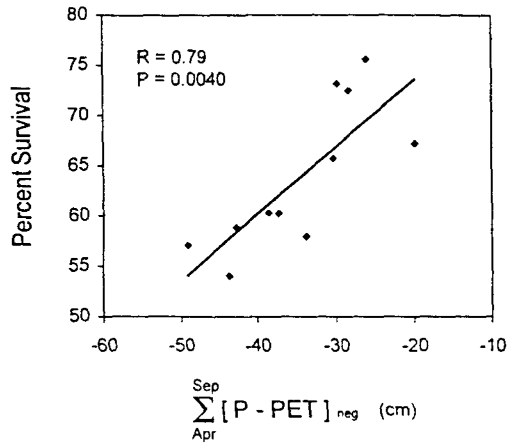

Figure 2–Correlation between first-year seedling survival and accumulated negative values of precipitation minus potential evapotranspiration during the growing season in East Texas from 1983 through 1993.

Table 6–First-year seedling survival and acres planted by site quality in East Texas from 1990 through 1993

	1000 acres planted			Percent survival			
Year	Poor	Average	Good	Poor	Average	Good	P value[a]
90	2.5	10.5	10.6	43.7	58.8	60.9	0.0001
91	2.1	10.2	8.8	50.8	69.5	69.3	0.0049
92	2.0	14.0	11.4	67.3	70.3	76.6	0.0001
93	2.6	14.0	11.2	58.2	58.5	63.7	0.0069
90-93	9.1	48.7	42.0	54.3	64.2	67.6	0.0001

[a] Significance level for simple linear regression for survival on site quality weighted by acres.

Table 7--First-year seedling survival and acres planted by improved loblolly pine seedling source[a] and site quality for East Texas from 1990 through 1993

	---- 1000 acres planted ----				------- Percent survival[b] -------				
Year	NE	SE	DH	Ind.	NE	SE	DH	Ind.	P value
Poor sites									
90	0.5	0.4	1.4	0.2	44.1	34.2	48.8	19.6	0.1001
91	0.6	0.4	0.7	0.0	52.7 a	25.7 b	60.5 a	36.0 ab	0.0002
92	0.4	0.1	1.4	-	57.1	42.0	69.4	-	0.1114
93	0.8	0.3	0.8	0.4	73.1 a	57.6 ab	52.4 b	53.7 b	0.0032
90-93	2.3	1.2	4.4	0.6	58.8 a	38.1 b	57.5 a	38.9 b	0.0001
Average sites									
90	1.7	2.2	5.6	1.0	54.8	62.6	59.5	53.1	0.1071
91	3.6	2.3	3.0	1.3	72.6 a	53.6 b	75.5 a	74.7 a	0.0001
92	4.6	3.4	4.3	1.6	72.9	61.1	75.6	68.9	0.0001
93	6.1	2.5	2.0	1.9	62.2 a	62.3 ab	52.4 bc	54.4 bc	0.0112
90-93	16.0	10.4	14.9	5.8	66.9 a	60.0 c	66.3 ab	62.0 bc	0.0001
Good sites									
90	4.4	3.4	2.1	0.6	59.9 a	62.9 a	66.9 a	34.5 b	0.0001
91	1.6	4.4	1.6	1.1	64.3	70.5	68.1	77.2	0.0955
92	4.0	4.5	1.4	1.5	82.7 a	72.1 b	68.7 b	81.5 a	0.0001
93	4.1	3.3	0.5	2.6	61.7	64.3	72.4	63.5	0.2889
90-93	14.1	15.6	5.6	5.7	67.2	67.9	68.2	67.7	0.9845
All sites									
90	6.5	6.1	9.0	1.8	57.4 a	60.8 a	59.5 a	44.0 b	0.0002
91	5.9	7.1	5.4	2.3	68.1 a	62.5 b	71.3 a	75.2 a	0.0013
92	9.0	8.0	7.1	3.0	76.6 a	67.1 c	72.9 b	75.8 ab	0.0001
93	11.0	6.0	3.4	4.8	62.9 ab	63.1 a	55.0 b	59.4 ab	0.0105
90-93	32.4	27.2	24.9	12.0	66.4 a	63.6 b	65.2 b	63.9 b	0.0001

[a] NE = Northeast Texas loblolly, SE = Southeast Texas loblolly (Superior), DH = Drought-Hardy loblolly, Ind. = loblolly from industry nurseries

[b] Where P value (significance level) is less than 0.05 for a row, survival values followed by common letters indicate no significant difference.

decreased, differences began to be apparent. On poor sites, Northeast Texas and Drought-Hardy loblolly seedlings survived significantly better than either Southeast Texas loblolly or improved loblolly produced by industry nurseries. This points to the importance of matching the most appropriate "species" or genetic line to site. In terms of first-year survival, this may be especially important on poor-quality sites.

First-year seedling survival was significantly correlated with accumulated negative values of precipitation minus potential evapotranspiration during the growing season (April-September) (Figure 2). This correlation exhibited a Pearson coefficient of R=0.79 (P=0.0040). Working in Minnesota, Cleland and Johnson (1986) found a similar correlation between first-year survival and growing-season water deficit, expressed as the difference between precipitation and potential evapotranspiration from May through August. Obviously, the less heat and water stress planted seedlings experience during the growing season, the greater we can expect survival to be.

CONCLUSIONS

Many factors affect first-year seedling survival. Success of plantings depends upon proper care and planting of seedlings, site quality, and presence of adequate soil moisture during the growing season. Understanding how these factors affect survival can improve development and refinement of reforestation guidelines.

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