EVALUATING FIRST-YEAR PINE SEEDLING SURVIVAL PLATEAU IN LOUISIANA

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Abstract—First-year seeding survival has been a continuing problem since the start of commercial pine plantation forestry in the 1950s. First-year survival of bare-root loblolly pine seedlings on intensively prepared sites in Louisiana has maintained a survival plateau between 79 to 89 percent with an average of about 82 percent. The specific objectives of this study were to identify seedling and microsite quality distributions in a current plantation, and evaluate a conceptual model explaining the plateau in first-year seedling survival. The study was approached with a conceptual model simulation using hypothetical data followed by model evaluation using field data. Simulation results indicated that consistent survival could result from random pairing of initial seedling and site quality distributions. Analysis of data collected from seedlings obtained from the Louisiana Department of Agriculture and Forestry (LDAF) indicated that 58 percent of seedlings were associated with the most frequent quality class that comprised seedlings with volume between 2.64 to 5.26 cm^3 and average caliper and stem height 4.22 mm and 25.75 cm, respectively. Similarly, assessment of microsites at Weyerhaeuser planting sites in Louisiana indicated that 51 percent of planted seedlings were associated with the most frequent microsite quality class which supported less than 10 cm first-year height increment. Model evaluation from seedling and microsite quality distributions in current operational practice indicated that using larger than 5 mm caliper size would increase first year survival to above 90 percent. This would, however, result in higher establishment costs, so the preference of this strategy would largely depend on management goals of the owner.

INTRODUCTION

First-year seedling survival is a very important stage in plantation forestry. First-year seedling survival of loblolly pine was a major issue until the 1970s, but improvements in nursery techniques and site preparation practices, as well as seedling genetics and physiology, resulted in first-year seedling survival in pine plantations generally exceeding 80 percent (Fox and others 2007). In research settings, however, the survival rate is commonly above 95 percent due in part to the controlled nature of the experiments. Interestingly, first-year survival has maintained a rate between 80- 90 percent in operational environment (South and others 2001). Descriptive statistics of first-year seedling survival data from Louisiana Department of Agriculture and Forestry (LDAF) between 1998 and 2007 indicated that survival success has a plateau between 80-87 percent under normal weather conditions. Although these survival rates are good, the inability to have these rates to be consistently in the 90the percentile is of concern. Why are survival rates not consistently higher in operational plantation? This study attempts to provide an explanation for the plateau in seedling survival based on an analysis of seedling and microsite qualities involved in operational plantations.

The specific objectives of this study are to identify seedling and microsite quality distributions in a current plantation, and evaluate a conceptual model explaining the current level of first-year seedling survival.

CONCEPTUAL MODEL

The conceptual model consists of two components. A joint distribution of seedling and microsite quality and a probability function of first-year survival that uses the joint distribution as input. Integration of the probability function gives the first-year survival rate. For a discrete distribution, the model can be explained by the following four steps. First, quality distributions for both the seedlings and the microsites are needed. Table 1 presents a hypothetical case with assumed seedling and microsite quality distributions using five quality classes. Quality class values for both seedlings and microsites range from one which indicates the highest quality to five which indicates the lowest quality. In table 2, we calculate a joint frequency distribution from the random pairing of seedlings and microsites given the quality distributions. The random reciprocal planting of each seedling and microsite results in a five by five joint frequency table. A probability rule that provides proportional survival of each pairing of

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Table 1—Seedling and Microsite quality distribution for conceptual model. Quality class 1 indicates lowest value while 5 indicates the best value. The values in seedling and microsite column are relative frequencies in respective quality class

Quality class	Seedling	Microsite
5	0.10	0.10
4	0.20	0.15
3	0.35	0.35
2	0.25	0.20
1	0.10	0.20

Table 2—Joint frequency distribution of seedling and microsite quality. Quality class 1 indicates lowest value while 5 indicates the best value. The cell values in each seedling and microsite quality pairing are relative frequencies

Seeding quality	Microsite quality				
	5	4	3	2	1
5	0.01	0.02	0.03	0.02	0.01
4	0.01	0.03	0.05	0.03	0.01
3	0.03	0.07	0.12	0.08	0.03
2	0.02	0.04	0.07	0.05	0.02
1	0.02	0.04	0.07	0.05	0.02

seedling and microsite is also needed and is placed in a joint frequency table. Our hypothetical probability rule is illustrated in table 3. The underlying presumption for the rule is that higher quality seedlings associated with higher quality microsites will result in higher survival as compared to lower quality pairings. Multiplication of the corresponding cells in tables 2 and 3 results in the predicted first-year survival for each seedling-microsite pair (table 4). The sum of values under each cell in table 4 provides an estimate of first-year survival for this plantation. For this example, the sum of values under each cell is 0.51 which indicates first-year survival of this plantation is 51 percent. Following these simulation steps, survival percentage could be computed for other seedling and microsite quality distributions.

Using this approach, we simulated first-years survival of 1600 plantings using random reciprocal pairing of 20 seedling quality distributions and 20 microsite quality distributions. The term plantings refer to individual seedlings planted across sites. Predicted first-year survival values varied widely between 0 to 100 percent depending on initial seedling and microsite quality distributions. Plantings associated with distributions containing higher proportions of seedlings and microsites in the better quality classes obviously resulted in higher survival compared to those with a higher proportion of seedlings and microsites in the lower quality classes. This provides initial support for the concept that our nursery and site preparation practices might be providing similar quality distributions of seedlings and microsites every year to create a plateau in first-year seedling survival.

FIELD TEST

Data

The field portion was an attempt to quantify actual quality distributions of seedlings and microsites and randomly combine these pairings to determine how sensitive survival may be to random combinations of the relative frequency of seedling and microsite qualities. Seedlings and microsites commonly used in operational plantations were used to estimate their quality distributions. Seedling data were obtained using a 1000-seedling bag of loblolly pine seedlings purchased from the Louisiana Department of Agriculture and Forestry (LDAF). These seedlings were measured for stem caliper and height. Similarly, microsite data were collected from measurements of microsite variables

Table 3—Expected survival assumption table. Quality class 1 indicates lowest value while 5 indicates the best value. Cell value 0 indicating no survival while 1indicating 100% survival in respective pairing of seedling and microsite qualities

Seedling quality	Microsite quality				
	5	4	3	2	1
5	0	0	0	0	0
4	0	0	0	0	0
3	0	0	1	1	1
2	0	0	1	1	1
1	0	0	1	1	1

Table 4—Predicted first-year survival table. Quality class 1 indicates lowest value while 5 indicates the best value. The cell values in each seedling and microsite quality pairing are relative frequencies. Sum of all cells gives predicted first-year survival

Seedling quality	Microsite quality				
	5	4	3	2	1
5	0	0	0	0	0
4	0	0	0	0	0
3	0	0	0.12	0.08	0.03
2	0	0	0.07	0.05	0.02
1	0	0	0.07	0.05	0.02

at 8 selected planting sites of Weyerhaeuser Inc. in Livingston, Louisiana. At each of those planting sites, we randomly identified 1600 seedlings and assessed their microsite environment. The selected seedlings whose microsites were assessed were measured in spring 2008 and 2009 to record their height increment. In addition, microsite variables such as bed height and soil compaction were recorded at each seedling location. In addition, 160 soil samples were collected to identify soil texture, moisture content, and mineral nitrogen content for the selected seedlings.

Seedling and Microsite Quality

To identify the quality distribution of LDAF nursery seedlings, we computed the volume of 907 measurable seedlings contained in the bag of nursery seedlings using a volume formula that used caliper and stem length measurements for the calculation. Volume was used as an index of seeding quality because it included both stem caliper and height to characterize seedling quality. The range of volumes was divided into 5 equal quality classes and the relative frequency in each class was determined. Abbreviation 'S' was used to indicate seedlings and quality class value of 1 indicated the highest quality while a 5 indicated the lowest quality. This provided an estimated quality distribution for nursery seedlings in current operational plantations in Louisiana in which LDAF seedlings are used. To characterize the microsite quality distribution, the predicted first-year height increment of seedlings was used as a quality index. The height increments were predicted from a reduced regression model with microsite variables (bed height, soil penetration, texture, and mineral nitrogen) as dependent variables against first-year height increment. Thus, microsite quality was not based on actual seedling height increment, but rather on the modeled relationship between observed height increment and a suite of microsite variables. Then, the range of predicted height increments were divided into 5 equal quality classes and the relative frequency in each class was computed to determine the microsite quality distribution. Abbreviation 'M' was used to indicate microsites and quality class value of 1 indicated the highest quality while a 5 indicated the lowest quality.

Evaluation of Conceptual Model

In order to predict First-year survival from the simulated planting of LDAF nursery seedlings at a typical Weyerhaeuser site-prepared plantation, we followed the steps described in the conceptual model. In the first step, we computed the joint frequency distribution from seedling and microsite quality pairings. Since the outcome of planting seedlings of known quality at microsites of known quality could not be conducted in this study, first-year survival prediction required assumptions about proportional survival of each seedling and microsite quality combination. We then developed a proportional survival assumption that provided an average and a range of first-year survival as observed in Louisiana. Furthermore, strategies to increase average first-year survival by improving seedling and microsite quality distribution were evaluated.

RESULTS AND DISCUSSION

Seedling and microsite quality distribution results are presented in table 5. Nursery seedlings supplied from LDAF had stem calipers between 3.22 mm to 7.85 mm while stem height varied between 23.18 cm to 29.25 cm. The lowest seedling quality class, S5, had seedlings with less than 2.63cm^3 while the seedlings in highest quality class, S1, had volume greater than 10.53 cm^3.The most frequent quality class was S4 which comprised 58 percent of the seedlings with volume between 2.64 to 5.26 cm^3 and their average caliper and stem height were 4.22 mm and 25.75 cm, respectively. Similarly, M4 was the most frequent microsite quality class that supported upto10.37 cm height increment and it comprised 51 percent of the measured microsites (table 6). The highest microsite quality class M1 that supported greater than 31.11 cm of predicted first-year height growth contained only 2 percent of the measured microsites.

To predict first-year survival for the simulated planting of LDAF nursery seedlings at a typical Weyerhaeuser

Table 5—Seedling quality classes, relative frequencies and their associated average caliper and stem size (N=907). Seedling class S5 indicating lowest quality while S1 indicating best quality

Seedling quality class	Relative frequency	Volume (cm^3)	Average caliper (mm)	Average stem height (cm)
S5	0.31	< 2.63	3.22	23.18
S4	0.58	2.64 - 5.26	4.22	25.75
S3	0.09	5.27 - 7.89	5.35	27.29
S2	0.02	7.90 - 10.52	6.28	28.19
S1	0.01	> 10.53	7.85	29.25

Table 6—Microsite quality classes, relative frequencies and their associated predicted height increment (N=1600). Microsite class S5 indicating lowest quality while M1 indicating best quality

Microsite quality class	Relative frequency	Predicted Height increment range (cm)
M5	0.29	<= 0
M4	0.51	0 – 10.37
M3	0.09	10.37 – 20.74
M2	0.09	20.74 – 31.11
M1	0.02	> 31.11

Table 7—Expected survival assumption table. Quality class 1 indicates lowest value while 5 indicates the best value. Cell value 0.60 is indicating 60% survival while 0.99 is indicating 99% survival in respective pairing of seedling and microsite qualities

Seedling quality	Microsite quality				
	5	4	3	2	1
5	0.60	0.60	0.65	0.65	0.70
4	0.60	0.65	0.70	0.95	0.95
3	0.65	0.70	0.80	0.99	0.99
2	0.65	0.95	0.99	0.99	0.99
1	0.70	0.95	0.99	0.99	0.99

Table 8—Average, minimum and maximum first-year survival of plantings with given minimum caliper size seedlings involved during planting

Survival (%)	Caliper (mm)	
	>=4	>=5
Average	0.90	0.94
Minimum	0.79	0.85
Maximum	0.95	0.98

planting site, we estimated proportion of surviving seedlings in each seedling-microsite quality pairing. Table 7 shows the proportional survival probabilities that resulted in the average and range of first-year survival similar to observed operational plantings. The values in table 7 were estimated following repeated applications of the model using different proportional survival assumptions. This survival assumption resulted in an average survival range from 70-80 percent with an average of 82 percent. This analysis could be expanded to infer potential strategies of increasing the average first-year seedling survival. Improving the quality of seedling and microsites in current plantations would raise the overall average of first-year survival. However, locating higher quality microsites during planting may not be a practical option due to the extra time required to locate the best sites; however, the planter could discard smaller seedlings in favor of higher quality seedlings. Table 8 presents results of a simulation with seedlings at least 4-mm caliper to increase the seeding quality. The results indicate that average survival would be 90 percent with at least a 4-mm caliper and 94 percent with at least a 5-mm caliper. This means increasing caliper size could be a promising strategy to increase first-year survival in current operational environment. South and others (2001) also found similar results related to sensitivity of seedling caliper on first-year survival. Planting only larger caliper seedlings would increase establishment costs because some seedlings would have to be discarded, or can produce seedlings with a higher caliper in the nursery by using a lower seedling density in the planting beds, but this will also increases the production cost per seedling. Therefore, a decision to use higher caliper seedlings to realize higher survival percentage would require more economic analysis.

CONCLUSION

This study highlights the influence that initial seedling quality and microsite quality have on first-year seedling survival. The simulation study showed that First-year survival is responsive to initial quality distributions and that the observed survival plateau could be the result of repeated pairing of similar quality distributions. This could be the unintentional result of standardized nursery and site preparation practices providing similar distributions of seedling and microsite quality in operational planting environments. One of the practical strategies to increase first-year seedling survival is to increase seedling caliper size. Larger caliper seedlings would increase survival rate and growth, and ultimately yield from plantations.

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LITERATURE REVIEW

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