EVALUATION OF SHORTLEAF PINE GERMINATION AND EARLY SURVIVAL UNDER VARIOUS SEEDBED CONDITIONS

By

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EVALUATION OF SHORTLEAF PINE GERMINATION

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SEEDBED CONDITIONS

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ABSTRACT

Germination and early survival of shortleaf pine (*Pinus echinata* Mill.) seed can be enhanced with proper seedbed preparation. Seedbeds, resulting from various burning intensities following fell-burn site preparation on a Ouachita Mountain site in southeastern Oklahoma, were evaluated following a winter sowing of non-stratified seed, and spring sowing of stratified seed. The winter sowing resulted in higher field germination (3.3 vs. 2.0%) than the spring sowing. Seeds sowed on areas receiving a more intensive burn germinated approximately four times better than those on low or no burn areas. Stocking ranged from 60% on winter sown, hot burned plots to 3% on spring sown, no burn plots. Because the areas where pine slash was concentrated seemed to burn with the greatest intensities, a system which requires slash to be evenly scattered over the site instead of stacking or windrowing would be beneficial.

INTRODUCTION

Proper seedbed conditions are essential for seed germination and survival. In naturally regenerated shortleaf pine (*Pinus echinata* Mill.) forests, only a small proportion of the seed produces established seedlings. Seedbeds for natural pine regeneration or direct seeding can be improved by using fire, herbicides, mechanical treatments or combinations of all of these. Research has shown that if an area has not been disturbed by logging, burning improves the seedbed substantially; but if it has been disturbed, burning may provide little additional benefit (Yocom and Lawson 1977). However, burning does offer the advantage of more uniform coverage than logging disturbance. Much of the research on site preparation has been directed toward intensive, high cost techniques that are industry oriented for plantation establishment (Cain 1987). This study investigated germination and survival rates of shortleaf pine seed under various seedbed conditions resulting from chain saw felling and prescribed burning site preparation treatments.

LITERATURE REVIEW

Regeneration From Seed

Because of its intolerant nature, shortleaf pine does not fare well in closed canopy conditions and requires some form of disturbance, or competition control to successfully grow and regenerate (Crow and Shilling 1980). Natural regeneration depends on several factors: adequate seed supply, receptive seedbeds, ample moisture during germination and establishment, and relative freedom from competition. Lack of one or more of these conditions can result in regeneration and/or seedling failure (Langdon 1981, Dougherty 1990, Haase 1986). A bare mineral soil seedbed is thought to provide seeds with more moisture, nutrients and sunlight by reducing competing vegetation and by eliminating the dry, dense litter-duff layer (McMinn 1981). Removal of the organic layer is thought necessary because the litter and duff raise daytime temperatures and lower night time temperatures at the litter-air interface. Furthermore, pine needles compact poorly and dry rapidly, allowing little moisture for seedling survival (Harrington and Kelsey 1979).

Seed Production

Shortleaf pine crops vary from year to year, however, a good crop can be expected on the average of one in every five years (Stephenson 1963). Cain (1986), reports that a good seed crop is more than 80,000 sound seeds per acre, and an average crop is between 30,000 and 80,000 sound seeds per acre. Pine seed fall starts in early October and peaks in November, by mid December approximately 85% of the seed has fallen (Langdon 1981, Grano 1971). One alternative supplement for spotty seed fall is spot seeding, a form of direct seeding. Spot seeding can be done relatively cheaply with a minimum of tools. Sowing three to five seed per spot is recommended (Barnett et al. 1984).

Whenever seed are dispersed in the field, seed predation must be considered. Seed predator populations, although not a major problem in uncut areas, have been found to build up rapidly and eat appreciable amounts of seed in clear cut areas or old field settings. This problem can be significantly reduced by treating seed with a repellent. Two of the more commonly used repellents are thiram and endrin (Barnett et al. 1984).

Seed Germination

Shortleaf pine is one example of a seed with physiological dormancy which requires stratification prior to germination (Schopmeyer 1974). Seeds are said to be dormant when they fail to germinate after being placed under conditions considered adequate for germination. When seeds are determined to be dormant, a stratification process is required before germination will take place. The procedure most often employed is to place the seeds at low temperatures (33^{o} to 41^{o}F) and under moist conditions for 30 to 60 days.

Seed germination begins in early April when temperatures and moisture becomes favorable. A greenhouse study by Barnett (1979), found an air temperature of 75^{o}F to be most favorable for germination of shortleaf pine. Until this time the seed lay dormant on the forest floor.

The objective of this study was to determine the effect of various seedbed conditions, following prescribed burning, and time of sowing on germination and establishment of shortleaf pine. This objective was achevied by testing the following two null hypothesis; 1) Maximum germination rates are the same on all seedbed treatment conditions following fell-burn site preparation. 2) Tree percents (end of season survival) are the same on all seedbed treatment conditions following fell-burn site preparation.

MATERIALS AND METHODS

Site Description

The field study site is located approximately 4 miles east of Big Cedar, OK, just south of SH 63, on the Kiamichi Ranger District, Ouachita National Forest in Leflore County. The site is representative of the Wetsaw Soil Series, consisting of deep, moderately well drained, slowly permeable soils formed in loamy and gravelly alluvium over clay (SCS 1983). Shortleaf pine site index (age 50) ranges from 60 to 70 ft. Average annual precipitation is approximately 51 inches (Wittwer et al. 1986). The study site is located within a 42 acre, mixed pine hardwood stand recently harvested by the seed tree method. An ongoing study monitoring production by the shortleaf pine seed trees (12 per acre) is in progress. This allows for a form of check between the seed that were manually spread and the natural seed fall. The study area was prescribed burned for site preparation in August, 1989.

Burning Conditions

Preburn conditions consisted of an overstory of approximately 18 to 20 trees per acre, including shortleaf pine seed trees, live hardwoods, and standing snags. Fuels consisted of scattered slash from logging operations and late spring chainsaw felling of non-merchantable trees, mostly lower and mid-story hardwoods (Phillips and Abercrombie 1987). Also included were grasses and live hardwood brush. Weather conditions were partly cloudy with winds out of the west at 5 mph. The highest air temperature during the burn was 93°F with a relative humidity of 50%. It was noted after the burn that the areas that received the hottest burn were those areas where slash piles occurred (USFS 1989).

Study Design

This study was designed to evaluate the germination and early survival of shortleaf pine seeded in different seedbed environments following fell-burn site preparation. Criteria used to identify (or classify) various seedbed conditions were those thought to be important in determining the suitability of a seedbed as a site for germination and survival of shortleaf pine seeds. The following three seedbed classes were used following a preliminary evaluation of the site.

1. Bare soil/light litter layer (hot burn) (figure 1)
2. Some litter/light slash (moderate burn) (figure 2)
3. Heavy slash and/or grasses (no burn) (figure 3)

Figure 1. Study plot on hot burn seedbed treatment.

Figure 2. Study plot on mid burn seedbed treatment.

Figure 3. Study plot on no burn seedbed treatment.

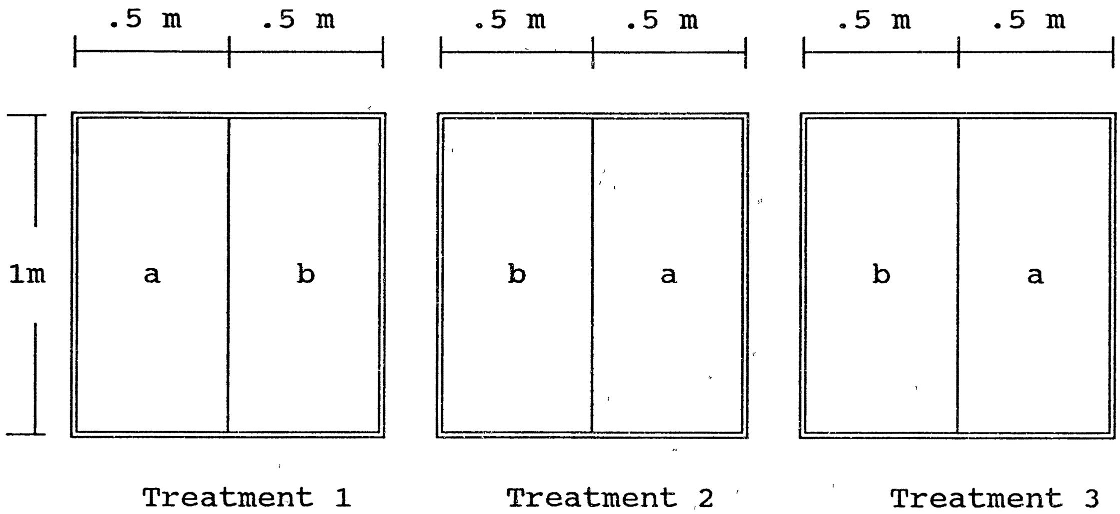
The preliminary evaluation showed that 25.0% of the site represented the hot burn class, 42.0% the moderate burn and 33.0% represented the no burn class.

Thirty, 1m^2 (approx. 1/4 milacre) replicate plots were established and mapped in each of the three seedbed burn classes for a total of 90 plots. Each plot was split, 0.5 m^2 was designated to be sowed in January with non-stratified seed and 0.5 m^2 was designated to be sowed in March with stratified seed (figure 4). It was first necessary to locate each of the seeding plots by using the classification system described. Each plot was located at least two chains into the study site to remove the influence of seed fall from edge trees.

Seeding

Seed used for the study were improved shortleaf pine seed, obtained from the Oklahoma Division of Forestry Seed Orchard. Seed were sized to ensure uniformity (approx. 30,800 seed per pound), and half were stratified prior to testing. The stratification process consisted of soaking the seed in water for 24 hours, draining the water and storing the seed in polyethylene bags in cold storage for approximately 60 days (Schopmeyer 1974). Results of a laboratory test showed the stratified seed to germinate at a rate of 93% and the non-stratified seed at a rate of 56%. The laboratory test conditions consisted of eight hours of

Replicate 1



Replicate 2

Legend:

Treatment 1: Bare soil/light litter layer
Treatment 2: Some litter/light slash
Treatment 3: Heavy slash and/or grasses
a: Early seeding(unstrat. seed)
b: Late seeding(strat. seed)

Replicate 3

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Replicate 30

Figure 4. Experimental plot design.

day at 86^{o}F and 16 hours of night at 68^{o}F. The seed were not treated with any repellent prior to field planting.

On January 25, 1990, a controlled broadcast seeding of 25 unstratified seed were hand spread in a random manner across each 0.5 m^2 portion of each of the 90 1m^2 plots. On March 17, 1990, 25 stratified seed were sowed on the remaining half of each of the 90 1m^2 plots. These seeding rates are equivalent to a good seed crop from a seed tree cut. Except for the previous burn, no additional site preparation was conducted.

Data Collection

Soil moisture at the 4 inch depth was determined at approximately 1 month intervals starting in January. Five soil samples were randomly selected from each treatment. Samples were placed in metal cans for transportation to the laboratory where they were weighed, dried to constant weight at 220^{o}F and reweighed. Moisture content was computed as a percentage of the oven dry soil weight. Soil temperatures were also recorded at the same time as soil moisture. Temperatures were taken in the top 5 inches of the soil. Average monthly rainfall and temperature measurements were recorded from the nearest weather stations maintained by the U.S. Forest Service at Talihina and Whitesboro, OK.

Upon emergence of the first seedlings, seedling counts were made every 2 weeks from May through June. Starting in July seedling counts were recorded monthly. On the final count, December 12, 1990, in addition to seedling counts, a tally of seedling height, ground line diameter, secondary needles, and terminal buds was taken. Maximum germination counts and final survival were determined and subjected to analysis.

Because variances were found to be unequal, a Non Parametric Test (Kruskal-Wallis) for significance was conducted (Conover 1980). Treatment means were tested at the 0.05 level with multiple comparison tests to determine where there were differences among the treatment means. The tests were conducted separately by each of the two sowing dates due to significant sowing date X site preparation treatment interaction.

RESULTS AND DISCUSSION

The 1990 growing season was unusually wet (figure 5) when compared with the 30 year average (Oklahoma Climatological Survey, Heavener, OK). While precipitation was greater then normal for the first five months of the season, June was considerably below average. This, as well as high summer temperatures, (figure 6), resulted in warm, dry seedbed conditions, less then ideal for seedling survival and growth.

The high temperatures and low rainfall recorded in June are reflected in the soil moisture (table 1) and soil temperature values (table 2) recorded on 7-02-90. Soil moisture and temperature were not greatly affected by the site preparation treatments in this study, and there were no consistent relationships between soil moisture and temperature and site preparation treatments.

Although the first complete seedling tally was conducted on 5-07-90, some germinants were detected in mid to late April when average daily high air temperatures rose above 70°F. It was found that seed germination was greatest when air temperatures reached an average of 75°F and slowed when air temperatures were greater than 85°F. These trends are consistent with those reported by Barnett (1979).

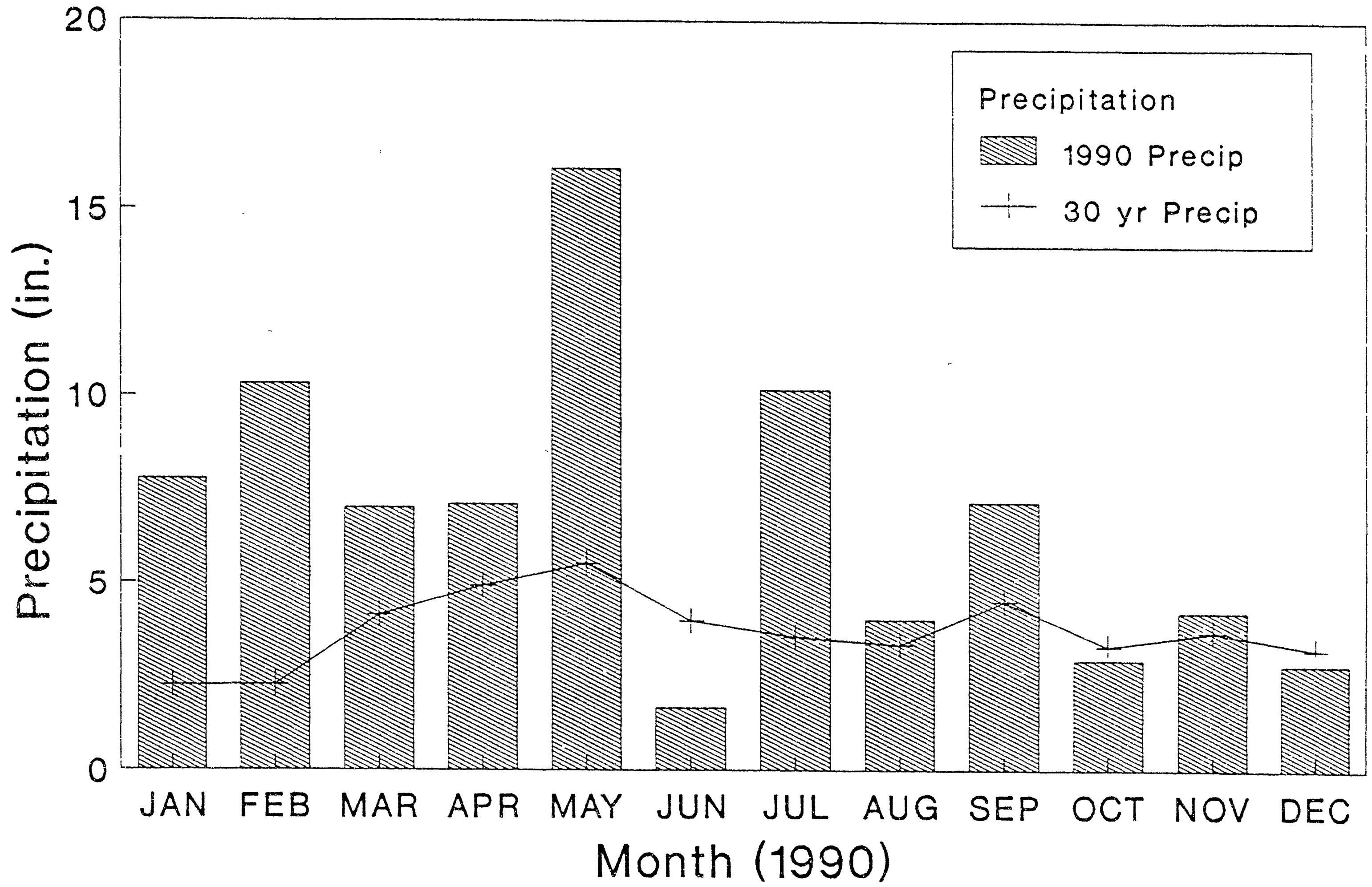

Figure 5. Monthly precipitation measured near study site during 1990 compared to 30-yr average recorded at nearest Oklahoma Climatological Station at Heavener.

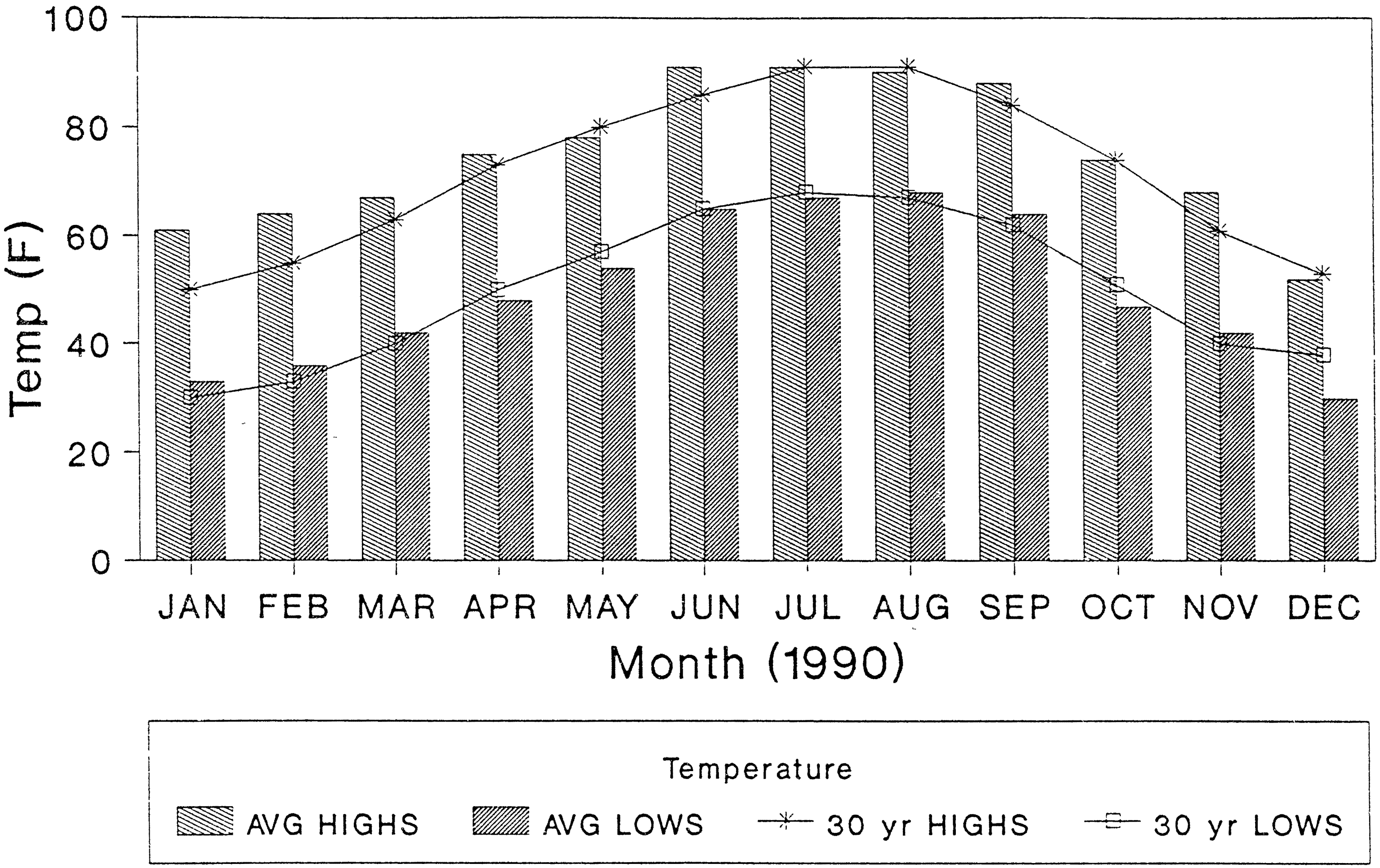

Figure 6. Average monthly high and low temperatures near study site during 1990 compared to 30-yr averages recorded at nearest Arkansas Climatological Station at Mena.

Table 1. Effects of site preparation treatment on soil moisture at 4 inch depth.

Date	Site Preparation Treatment			
	Hot Burn	Mid Burn	No Burn	Mean
	-----------------soil moisture - % weight -------------			
2-10-90	34.2*	35.8	32.0	34.0**
04 04 90	24.7	27.2	27.2	26.4
07-02-90	07.0	08.8	10.5	08.8
07-28-90	20.1	22.6	21.7	21.4
09-01-90	07.4	07.6	08.5	07.8
09-29-90	19.8	19.8	23.5	22.8
12-13-90	23.3	23.3	26.2	24.3

* n=5
** n=15

Table 2. Effects of site preparation treatment on soil temperature at 5 inch depth.

Date	Site Preparation Treatment			
	Hot Burn	Mid Burn	No Burn	Mean
	--------------------soil temperature - ^{o}F ----------------			
2-10-90	49.2*	48.9	49.8	49.3**
04 04 90	64.4	64.0	63.6	64.0
07-02-90	78.0	77.0	75.4	76.8
07-28-90	81.6	80.8	80.0	80.8
09-01-90	77.8	77.6	78.0	77.8
09-29-90	76.2	76.4	76.2	76.3
12-13-90	51.6	51.8	51.8	51.7

* n=5
** n=15

Maximum mean field germination, ranging from 0.8 to 4.7% for the various combinations of sowing dates and seedbed conditions, was observed on 6-03-90 (table 3). Due to a significant sowing date X site preparation treatment interaction, the data were analyzed separately by sowing date. Analysis of the maximum mean field germination data, for sowing date 1-25-90, non-stratified seed, showed that the areas receiving a hot burn were not different from those that received a mid burn, but the hot burn areas were significantly greater than those that received no burning (table 3). For sowing date 3-17-90, stratified seed, germination for the mid burn treatment was not different from the no burn treatment, but both treatments (mid and no burn) were significantly less than the hot burn treatment.

A survey was also conducted in December for surviving seedlings. From this information a table of tree percents (the ratio of established seedlings to the number of seed sowed X 100) was formed (table 3). As with the maximum germination values, an analysis was conducted separately by sowing date on each of the site preparation treatments. For each sowing date it was discovered that the mid burn treatment and the no burn treatment were not significantly different, however, both were significantly less then the hot burn treatment.

Results of this study are generally comparable to those of Yocom and Lawson (1977). Their study found end of season tree percents, resulting from natural seeding of burned and

Table 3. Maximum field germination (6-03-90) and end of season tree percent (12-13-90).

	Sowing Date			
	A	B	A	B
	---------% germination---		--------tree %---------	
Hot Burn	4.7a[1]	4.3a	4.0a	3.3a
Mid Burn	3.7ab	0.8b	1.9b	0.9b
No Burn	1.6b	0.8b	1.1b	0.1b
Mean	3.3	2.0	2.3	1.5

A=Non-Stratified Sowing, 01-25-90.
B=Stratified Sowing, 03-17-90.

[1] Treatment means followed by the same letter are not significantly different at the 0.05 level.

unburned plots on areas disturbed by logging, to be 1.29% and 0.98% respectively. Results in the present study, ranging from 4.0% to 1.1%, were probably higher due to the direct seeding of more viable, higher quality seeds.

As previously mentioned, the effects of the low rainfall and high temperatures in June, can be seen as seedling mortality from the 6-03-90 tally to the 7-02-90 tally (table 4). These seasonal declines in seedlings per milacre continued to the 7-28-90 tally, at which time seedling counts began to stabilize for the remainder of the season.

Stocking percents were calculated for each of the site preparation treatments by sowing dates (table 5). Stocking percent is defined as the percentage of plots that have at least one live seedling remaining, it is also a measure of seedling distribution. The differences range from 60 percent on the early seeded hot burned treatments to 3 percent on the late seeded no burn treatments. These stocking percents, when considered with the number of seedlings per milacre, give a better understanding of seedling distribution than either measurement by itself (Derr and Mann 1971).

On the final tally date (12-13-90), seedlings were inventoried for groundline diameter (table 6), height (table 7), terminal buds (table 8), and secondary needles (table 9). Data were not subjected to statistical analysis due to low numbers of seedlings in some treatment combinations,

Table 4. Mean number of seedlings per milacre as effected by site preparation treatment.

	Site preparation treatment					
	Hot Burn		Mid Burn		No Burn	
Date	A	B	A	B	A	B
	seedlings/milacre					
05-07-90	8.4	5.9	3.8	1.1	2.2	1.3
05-22-90	8.6	7.0	5.1	1.1	2.2	1.3
06-03-90	10.2	8.9	7.6	1.9	3.2	1.6
07-02-90	9.2	7.6	4.0	1.9	3.0	1.3
07-28-90	8.4	6.7	3.8	1.9	2.7	0.5
09-01-90	8.4	6.7	3.8	1.9	2.7	0.5
09-29-90	8.4	6.7	3.8	1.9	2.7	0.5
12-13-90	8.1	6.7	3.8	1.9	2.2	0.3

A=Non-stratified Sowing, 01-25-90.
B=Stratified Sowing, 03-17-90.

Table 5. Stocking percent represented by at least one seedling/plot at different collection dates.

Date	Site preparation treatment					
	Hot Burn		Mid Burn		No Burn	
	A	B	A	B	A	B
	percent stocking					
05-07-90	60	30	33	10	27	13
05-22-90	60	30	37	10	27	13
06-03-90	67	40	47	13	30	17
07-02-90	63	33	30	13	30	17
07-28-90	63	33	30	13	27	7
09-01-90	63	33	30	13	23	7
09-29-90	63	33	30	13	23	7
12-13-90	60	33	30	13	23	3

A=Non-stratified Sowing, 01-25-90.
B=Stratified Sowing, 03-17-90.

Table 6. Average seedling diameter as effected by site preparation treatments.

	Sowing Date		
	A	B	Mean
	------------- seedling diameter - mm -------------		
Hot Burn	1.7(30)[1]	1.7(25)	1.7(55)
Mid Burn	1.5(14)	1.1(07)	1.4(21)
No Burn	1.6(08)	1.1(01)	1.6(09)
Mean	1.6(52)	1.5(33)	

A=Non-stratified Sowing, 01-25-90.
B=Stratified Sowing, 03-17-90.
[1] Numbers in parentheses denote sample sizes.

Table 7. Average seedling heights as effected by site preparation treatments.

	Sowing Date		
	A	B	Mean
	---------------- seedling height - cm ----------------		
Hot Burn	11.5(30)[1]	10.2(25)	10.9(55)
Mid Burn	9.0(14)	7.9(07)	8.7(21)
No Burn	11.3(08)	11.0(01)	11.3(09)
Mean	10.8(52)	9.8(33)	

A=Non-stratified Sowing, 01-25-90.
B=Stratified Sowing, 03-17-90.
[1] Numbers in parentheses denote sample sizes.

Table 8. Number of seedlings which had set a terminal bud by 12-13-90.

	Sowing Date		
	A	B	Totals
	---------- occurrence of terminal buds ----------		
Hot Burn	3/30[1]	6/25	9/55
Mid Burn	1/14	1/07	2/21
No Burn	2/08	0/01	2/09
Totals	6/52	7/33	

A=Non-stratified Sowing, 01-25-90.
B=Stratified Sowing, 03-17-90.
[1] Numbers of seedlings with buds/total

Table 9. Number of seedlings with secondary needles by 12-13-90.

	Sowing Date		
	A	B	Totals
	--------occurrence of secondary needles -------		
Hot Burn	8/30[1]	9/25	17/55
Mid Burn	2/14	1/07	3/21
No Burn	3/08	0/01	3/09
Totals	13/52	10/33	

A=Non-stratified Sowing, 01-25-90.
B=Stratified Sowing, 03-17-90.
[1] Numbers of seedlings with secondary needles/total

particularly the no-burn seedbed condition. From these data, seedlings may be classified as grades-1 or 2, plantable seedlings, or grade-3, unplantable seedlings. Wakeley (1954) classifies 1-0, nursery-grown, grade-1, shortleaf pine seedlings as being 4-10 inches in height, 3/16 of an inch at groundline diameter, a majority of secondary needles, and a majority of terminal buds. A grade-2 seedling is 3-6 inches in height, 1/8 of an inch at ground line diameter, some secondary needles, and occasional terminal buds. A grade-3 seedling is less than 4 inches in height, less than 1/8 of an inch at ground line diameter, no secondary needles, and no terminal buds. At the end of the first season, the number of field germinated seedlings were classified in the following manner: 0 grade-1 seedlings; 8 grade-2 seedlings (9%), 7 of which were on the mid and hot burn treatments; and 77 grade-3 seedlings (91%). The 8 grade-2 seedlings are representative of 364 seedlings/acre. It must be noted that 60 of the 77 grade-3 seedlings met all but the diameter requirements of a grade-2 seedling.

CONCLUSIONS

Germination of shortleaf pine seeds and successful seedling establishment was related to variable seedbed conditions following a prescribed fire to prepare the site. Due to irregular burning patterns, 25 percent of the site was classified as subject to a hot burn, usually where pine foliage and smaller branches were concentrated following timber harvesting. One-third of the site, 33 percent, was not effected by the fire and 42 percent was classified in an intermediate, mid burn category. An interactive effect between seedbed condition and time of sowing showed a January sowing of unstratified seed was more successful than a March sowing of stratified seed. The maximum tree percent, the percentage of the seeds resulting in an established seedling, at the end of the first growing season was 4.0 percent on the hot-burned sites sown in January. Stocking ranged from 60 percent on winter sown, hot burned plots to 3 percent on spring sown, no burn plots.

An inventory of seedbed conditions following a burn may be useful in determining optimum seeding rates when direct seeding and would also provide a better understanding of natural regeneration processes. Because of irregular burning patterns, a harvesting system or subsequent treatment that results in more uniform distribution of pine slash would favor regeneration from seed. Further investigation to identify optimum time of seeding could provide useful information. Moisture conditions are critical for germinating seeds and young germinants, seed treatments that shorten the time required for germination, coupled with careful monitoring of precipitation patterns and soil moisture conditions could improve regeneration success. Forest managers would sow when conditions are favorable and reduce the time seeds lay in the field prior to germination.

LITERATURE CITED

Barnett, J. P. 1979. Germination temperatures for container culture of southern pines. South. J. Appl. For. 3(1):13-14.

Barnett, J. P., and T. E. Campbell and P. M. Dougherty. 1984. Seedling establishment-artificial methods. Proc. Symp. Loblolly Pine Ecosystem (West Reg.) Miss. 109-125.

Cain, M. D. 1986. Late-winter prescribed burns to prepare seedbeds for natural loblolly-shortleaf pine regeneration--are they prudent?. Fire Mang. Notes 47(2)36-39.

Cain, M. D. 1987. Site preparation techniques for establishing natural pine regeneration on small forest properties. South. J. Appl. For. 11(1):41-45.

Conover, W. J. 1980. Practical nonparametric statistics. second edition, John Wileys & Sons Pub. N.Y.

Crow, A. B., and C. L. Shilling. 1980. Use of prescribed burning to enhance southern pine timber production. South. J. Appl. For. 4(1):15-18.

Derr, H. J., and W. F. Mann. 1971. Direct-seeding pines in the south. USDA For. Serv. Ag. Hndbk. NO. 391.

Dougherty, P. M. 1990. A field investigation of the factors which control germination and establishment of loblolly pine seeds. Ga. For. Comm. Res. Rep. No. 7.

Edwards, M. B. 1990. Five-year responses of piedmont loblolly pine to six site-preparation treatments. South. J. Appl. For. 14(1):3-6.

Grano, C. X. 1971. Seed yields in loblolly-shortleaf pine selection stands. USFS Res. Note. South. For. Exp. Sta.

Haase, S. M. 1986. Effect of prescribed burning on soil moisture and germination of southwestern ponderosa pine seed on basaltic soils. Rocky Mt. For. Range Exp. Sta. Res. Note RM-462.

Harrington, M. G., and R. G. Kelsey. 1979. Influence of some environmental factors on initial establishment and growth of ponderosa pine seedlings. USDA For. Ser. Res. Pap, Int-230. June.

Kodama, H. E., and D. H. Van Lear. 1980. Prescribed burning and nutrient cycling relationships in young pine plantations. South. J. Appl. For. 4(3):118-121.

Langdon, G. O. 1981. Natural regeneration of loblolly pine: a sound strategy for many forest landowners. South. J. Appl. For. 5(4):170-176.

McMinn, J. W. 1981. Site preparation for natural regeneration of slash pine. South. J. Appl. For. 5(1):10-11.

Miller, J. H., and B. Zutter. 1986. A region-wide study of loblolly pine seedling growth relative to four competition levels after two growing seasons. Proceed. Fourth Bien. South. Silv. Res. Con. Gen. Tech. Rep. SE-42.

Morris, L. A., and R. F. Lowery. 1988. Influence of site preparation on soil conditions affecting stand establishment and tree growth. South. J. Appl. For. 12(3):170-178.

Phillips, D. R., and J. A. Abercrombie. 1987. Pine-hardwood mixtures- a new concept in regeneration. South. J. Appl. For. (11)4:192-197.

Schopmeyer, C. S. 1974. Seeds of woody plants in the United States. USDA For. Serv. Ag. Handbook No. 450.

Shiver, B. D., and B. E. Borders and H. H. Page and S. M. Raper. 1990. Effect of some seedling morphology and planting quality variables on seedling survival in the Georgia Piedmont. South. J. Appl. For. 14(3):109-114.

Slay, J. M., and G. G. Lockaby and J. C. Adams and C. G. Vidrine. 1987. Effects of site preparation on soil physical properties, growth of loblolly pine, and competing vegetation. South. J. Appl. For. 11(2):83-86.

Soil Conservation Service. 1983. Soil survey of Leflore county Oklahoma. USDA. August, 1983

Stephenson, G. K. 1963. Ten years of shortleaf pine seed crops in Texas. J. For. G1:270-272.

United States Forest Service. 1989. Prescribed fire plan: compartment/stand-254/01. Kiamichi Ranger District, Talihina, OK.

Wakeley, P. C. 1954. Planting the southern pines. USDA For. Ser. Ag. Monograph No. 18.

Wittwer, R. F., and P. M. Dougherty and D. Cosby. 1986. Effects of ripping and herbicide site preparation treatments on loblolly pine seedling growth and survival. South. J. Appl. For. 10:253-257.

Yocom, H. A., and E. R. Lawson. 1977. Tree percent from naturally regenerated shortleaf pine. South. J. Appl. For. 1(2):10-11.

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