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SURVIVAL *and* GROWTH *of* PLANTED SLASH *and* LONGLEAF PINES

Results of 12-Year Experiment with Effects of Fire and Site Preparation on Plantings of the Two Species in the Gulf Coast Region of Alabama

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MANY INTERRELATED FACTORS are responsible for the failure of southern forests to grow as many products as is believed possible under good forestry practices. One of these contributing factors is the lack of information on basic phases of forest management.

An experiment with two common but commercially important species of southern pines, slash pine, *Pinus caribaea,* Morelet, and longleaf pine, *Pinus palustris,* Miller, was begun in 1936 at the Gulf Coast Substation of the Alabama Agricultural Experiment Station. The purpose of the study was to determine the effects of burning and of site preparation by furrowing on the survival and growth of the two species in plantations.

REVIEW OF LITERATURE

In his monograph, "Longleaf Pine," W. G. Wahlenberg *(11)* discusses in detail the problems of longleaf pine regeneration and the role of fire in establishment of stands of this species. Judicious use of fire is considered helpful and at times even necessary for successful culture of longleaf pine *(2, 3)*. Longleaf pine is considered to have inherent adaptations that make it fire hardy. Fire prevents smothering of seedlings by dead grass, and it will retard the spread of the brown spot disease *(8)*. Osborne and Harper *(7)* point out that disturbance of the sod by site preparation increases survival of seedlings. The reduction of competition from grass and weeds is beneficial for initial establishment.

After seedlings emerge from the grass stage, application of fire is no longer necessary, and longleaf pine saplings will thrive

* Valued assistance and cooperation of Otto Brown, superintendent of the Gulf Coast Substation, is acknowledged by the authors.

under the condition of fire exclusion. Later in the life of a stand, moderate controlled burning practiced to reduce wild-fire hazard or for other reasons causes no appreciable injury *(3, 5, 6, 9)*.

A comprehensive treatise on slash pine is not available, and less is known of the behavior of this species. It is recognized that slash pine is not a fire-hardy species. Fire has a lethal effect on slash pine seedlings, and it will frequently kill the saplings. Site preparation may be of some benefit in early survival and growth, but its practice is relatively unimportant in slash pine plantations because of the rapid growth of the seedlings during their first few years *(7)*.

Description of Experimental Area

The 20 acres on which this experiment was conducted is a part of the Gulf Coast Substation near Fairhope, Alabama. The site's terrain is rolling, with small drainages grading into ravines. The soils, developed from unconsolidated sands and clays, are of the Norfolk family. Topsoils are mostly sandy loams, and the subsoils are very deep. Under natural conditions, a thick grass cover, or rough, will develop within a few years.

A longleaf pine stand had existed on the experimental area for many years. It had been worked for turpentine in the past, and had been repeatedly cut and burned. Records show that all trees suitable for pulpwood were cut in 1932. While a number of longleaf pine saplings were left, they were much too scattered to be considered a stand.

Experimental Design and Statistical Analysis

The three types of planting used were pure slash pine, pure longleaf pine, and a mixture of the two species in alternate double rows. Three replications of each type of planting were established on nine main plots. Each row of three plots extending north and south constituted a block. (See Figure 1.)

For the application of fire treatments, each block was divided into three north-south strips of equal width. One strip was burned annually for 3 years; another one was burned once prior to planting; and the third one was completely protected from fire. Within each block, the fire treatments to strips were assigned at random.

A further subdivision of plots was made by establishing east-west lines that divided each tier of plots into halves. Furrows, in which the trees were to be planted, were plowed 8 feet apart

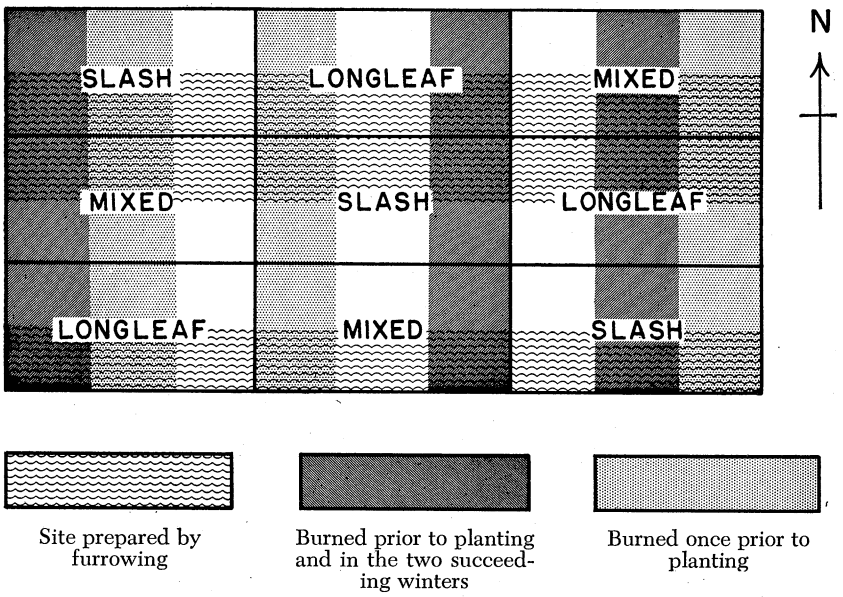

FIGURE 1. Diagram showing layout of experimental plots.

on half of each tier. On the other half, trees were planted without site preparation.

All of the 18 possible combinations of treatments were present in each block. Three replicate blocks had a total of 54 sub-plots. These sub-plots were one-third of an acre in size, and 208 seedlings were planted on each.

A modification of the method of Cochran and Cox *(4)* for analysis of variance when sub-unit treatments are applied in strips was employed for testing each of the several sets of data. All figures that were expressed as percentages were first transformed into corresponding angles by the use of Bliss' *(1)* tables.

The plots planted to a mixture of the two species of pines were treated in the first analyses as if planted to a third species. Since it was evident that mixed planting had not affected the response of the individual species to sub-plot treatments in the early growth of the plantation, a second series of analyses was made. In this series, each species on the plots of mixed slash and longleaf pine was treated as if it were on a separate plot. This, in effect, doubled the number of replications for comparing slash pine with longleaf pine and for testing their individual reactions to fire and cultural treatments. To place all data on an equal basis,

those for the original plots with pure plantings were reduced by one-half for these analyses.

Field Work

The entire experimental area was cleared. All hardwoods and small pine poles and saplings left from the 1932 cutting were cut close to the ground. In December 1936, fire lanes 12 feet wide were constructed, dividing the experimental area into nine strips. The first burnings were done in January, 1937, and seedlings were planted that same month, using a spacing of 8 by 8 feet. Since in the judgment of those then in charge of the experiment it was desirable to establish as uniform a stand as possible, all seedlings found to be dead or missing were replaced the following January.

The strips designated for annual fires were reburned in the winter of 1938 and again in 1939. Thereafter, shortage of personnel and restricted transportation during World War II prevented continuance of the work. Hence, these strips actually received a total of three burns, at one year intervals, beginning just before the seedlings were planted.

The first field measurements were made in October, 1937, when all living seedlings were tallied. Survival counts were repeated in October, 1938, and in November, 1939. In 1939 and 1943, samples were taken to estimate the proportion of longleaf pines that had emerged from the grass stage.

In the summer of 1948, the diameters at breast height of all trees more than 4½ feet tall were measured. Samples of heights of both species were also taken. One dominant tree was selected at random from each row, and its height was measured.

Longleaf pines still in the grass stage were not included in average diameter or height estimates. They were included in the survival count of trees. A relatively small number of such trees was present in 1948.

Discussion of Results

Effects of Fire on Slash Pine. Before the seedlings were planted in 1937, two strips in each block were burned as previously outlined. On these strips first-year survival of slash pine seedlings was significantly lower than on the remaining strips where grass was left unburned. Burning took place in winter when the grass was dry. The roots of the grasses were little affected by the burning of the dry stems above the ground. It has

been observed that winter burning of a rough is frequently followed by a vigorous summer growth of the grass. Root competition from this vigorous growth of new grass and the absence of tall, dry grass stems, which would have offered some shade to the small seedlings, may account for the high mortality of pine seedlings on areas subjected to fire just before planting.

In January 1938, all dead seedlings were replaced. After two growing seasons on strips not burned after planting, the number of living slash pine seedlings was slightly lower than it had been on the same strips the year previous. Mortality of the seedlings in their second year, those planted in 1937, added to the loss of the seedlings replanted in 1938 was high enough to produce this slight reduction in survival. During the following year, a noticeable reduction in the number of living slash pine seedlings occurred (Table 1). When these strips were examined in 1948,

TABLE 1. SURVIVAL OF SLASH AND LONGLEAF PINE TREES PLANTED IN 1937 AND REPLANTED IN 1938, GULF COAST SUBSTATION[1]

Year	Species	Type of planting	Protected from fire	Burned once before planting	Burned for three successive winters	Sod undisturbed	Sod furrowed in strips	Average all plots
			Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
1937	Slash	Pure	86.9	85.5	85.1	85.0	86.6	85.8
		Mixed	86.1	81.5	79.6	82.2	82.5	82.4
		Both	86.6	84.2	83.3	84.1	85.2	84.7
	Longleaf	Pure	64.4	55.5	58.2	51.8	66.9	59.4
		Mixed	61.2	52.9	61.7	49.6	67.5	58.6
		Both	63.3	54.6	59.4	51.1	67.1	59.1
1938	Slash	Pure	85.7	85.4	27.6	62.0	70.4	66.2
		Mixed	80.4	79.3	26.1	57.6	66.2	61.9
		Both	83.9	83.4	27.1	60.5	69.0	64.8
	Longleaf	Pure	67.1	68.3	64.4	63.4	69.7	66.6
		Mixed	75.1	68.0	62.6	62.5	74.6	68.6
		Both	69.8	68.2	63.8	63.1	71.3	67.3
1939	Slash	Pure	77.9	80.2	8.2	52.7	58.1	55.4
		Mixed	73.2	68.7	9.5	47.5	53.4	50.5
		Both	76.3	76.4	8.6	51.0	56.5	53.8
	Longleaf	Pure	70.0[2]	68.9	69.2	63.3	69.3	66.3
		Mixed	71.8	69.0	59.6	62.6	71.0	66.8
		Both	70.6	68.9	60.0	63.1	69.9	66.5
1948	Slash	Pure	74.6	79.4	3.4	51.9	52.9	52.4
		Mixed	75.2	67.4	2.5	49.3	47.3	48.3
		Both	74.8	75.4	3.1	51.0	51.0	51.0
	Longleaf	Pure	43.2	34.3	57.2	44.6	45.1	44.9
		Mixed	28.0	25.2	55.2	35.9	36.3	36.1
		Both	38.1	31.3	56.5	41.7	42.2	42.0

[1] Data from 54 sub-plots 0.3 acre in size with 208 seedlings planted 8 by 8 feet.

[2] Apparently a few of the living seedlings were overlooked on several plots when the counts were made in 1938 and 1939.

slash pine was present in numbers comparable with those found in the fall of 1939. Since the seedlings replanted in 1938 had been through two growing seasons by the fall of 1939, it is evident that very little mortality occurred 2 years after the seedlings had been transplanted. This indicates that, although slash pine seedlings continued to die at a conspicuous rate for the first 2 years after planting, the survival in later years had been maintained at a high level. The same pattern, with no significant differences, existed on all protected strips, whether they were not burned or were burned once before planting.

On strips burned in 1938 and 1939, the mortality of slash pine was very great, indicating that slash pine is not a fire-resistant species. Only small numbers of slash pine remained in 1939. Few of these were found to be living in 1948, Figure 2. Repeated burning was responsible for a highly significant reduction in the number of living slash pine seedlings in the 2 years immediately following planting.

On strips protected from fires after planting, the survival percentage of slash pine seedlings after the first year was greater than that of the longleaf pine seedlings. The difference was highly significant. Where fires were excluded after planting, as

FIGURE 2. Area burned during the first and second year after slash and longleaf pines were planted in alternate double rows. After 12 years, only one slash pine is alive in the two center rows. It is the large tree in the foreground. Longleaf pine is thriving at the extreme right and left.

TABLE 2. GROWTH DATA OF SLASH AND LONGLEAF PINE TREES PLANTED IN 1937 AND REPLANTED IN 1938, GULF COAST SUBSTATION[1]

Year	Species	Type of planting	Protected from fire	Burned once before planting	Burned for three successive winters	Sod undisturbed	Sod furrowed in strips	Average all plots
			Percentages of longleaf pine seedlings emerging from grass stage					
1939	Longleaf	Pure and	2.0	1.1	1.4	1.7	1.3	1.5
1943	Longleaf	mixed	16.8	8.2	34.2	20.1	19.3	19.7
			Average height of dominant trees in feet					
1948	Slash	Pure and	30.1	31.5	13.4	22.7	27.3	25.0
1948	Longleaf	mixed	18.6	16.2	15.8	18.1	15.6	16.8
			Average basal area in square feet					
1948	Slash	Pure	20.5	25.2	0.4	13.6	17.1	15.4
		Mixed	21.9	18.5	.4	13.3	13.9	13.6
		Both	21.0	23.0	.4	13.5	16.0	14.8
1948	Longleaf	Pure	0.8	0.9	4.2	3.9	2.8	3.4
		Mixed	.8	.8	3.9	2.1	1.5	1.8
		Both	.8	.9	4.1	3.3	2.4	2.6

[1] Data from 54 sub-plots one-third acre in size with 208 seedlings planted 8 by 8 feet.

FIGURE 3. Area completely protected from fire 12 years after slash and longleaf pines were planted in alternate double rows. In center two rows, a few longleaf pines are living (left-center row). Slash pine is thriving at extreme right and left.

was the case on two strips in each block, the survival of slash pine was consistently greater for the duration of the experiment. It is apparent that it was easier to establish a well stocked slash pine stand by planting than it was to establish a longleaf pine stand, provided fires were not allowed to wipe out the slash pine seedlings, Figure 3.

In addition to killing most of the slash pine seedlings, repeated fires adversely affected height growth. In 1948, the difference between average heights of dominant slash pine trees on burned and unburned strips was highly significant (Table 2).

The basal area of slash pine growing on strips that were burned for 2 successive years after planting was very small on all the sub-plots. This was a normal result of a very low survival. The difference in basal area of slash pine was not significant between the sub-plots on strips protected from fire and those burned once before planting.

Effects of Site Preparation on Slash Pine. There was no difference in first-year survival between the slash pine seedlings planted in furrows and ones set in sod. This continued to be the case for the 2 following years on strips protected from burn-

ing. The fact that slash pine seedlings begin their height growth soon after planting might partly explain the absence of a significant response to site preparation. Slash pine seedlings planted in the rough showed the ability to withstand competition of grass.

Planting of seedlings in furrows had a significant effect only on strips that were burned for 2 years after planting. On such strips, survival percentage of slash pine after the first year was significantly higher than on sub-plots where planting was done without site preparation. The reduction in volume of grass near the planted rows apparently moderated the lethal effect of fire and resulted in improved seedling survival.

Slash pine planted in furrows had better height growth than that planted without the site preparation. In 1948, the difference between the average heights of dominant trees on the two groups of sub-plots was highly significant. The basal area of slash pine growing on sub-plots with seedlings planted in furrows was greater than that on the sub-plots without site preparation. This difference closely approached the significant value.

Effects of Fire on Longleaf Pine. Longleaf pine seedlings planted on strips not burned before planting had a first-year survival significantly higher than had the ones on burned strips. Since the same was true of the slash pine seedlings on strips not burned, it should be noted that preparatory burning had a detrimental effect on the initial survival of planted seedlings of both species. The effect was more pronounced with respect to the longleaf pine seedlings.

This effect should not be confused with that of burning for seedbed preparation to encourage natural regeneration. Such a practice is often desirable, since the resulting exposure of mineral soil is a necessity for a high rate of germination of longleaf pine seeds *(7)*. A favorable seedbed increases germination of seeds very appreciably; and, even if a somewhat higher mortality of seedlings may result, there is a considerable net gain in the number of living seedlings on the areas where preparatory burning was used.

In the fall of 1938, because of the replanting done earlier the same year, larger numbers of living longleaf pine seedlings were present than were found the previous year. During the next growing season, there was no decline in survival on the strips protected from fires. Slightly increased survival figures for some plots in 1939 are probably due to a miscount in 1938. During

the following 9 years, there were large losses on strips burned only once before planting and on strips not burned at all. Protection from fires was definitely detrimental to the survival of longleaf pine. In 1948, only about half as many longleaf pine trees were present on the strips protected from fires as there were in 1938, Figure 3.

Replanting increased the number of living longleaf pine seedlings on strips burned in 1938 and 1939. In the fall of 1938, there was no significant difference in survival of longleaf pine due to the fire. In 1939, due to a small decline in survival on burned strips, there was a significant difference in the number of living longleaf pines between burned and protected strips. This trend was reversed sometime during the following 9 years. In 1948 the stand of longleaf pine on strips that were burned in 1938 and 1939 showed a high survival in comparison with the protected strips, Figure 2. This difference in survival was highly significant, Table 1.

In 1943, a sample was taken to estimate the percentage of living longleaf pine seedlings that had begun height growth. A significantly larger proportion had emerged from the grass stage on the strips burned twice after planting than on either of the other groups of strips (Table 2). Fires are considered to be beneficial to the longleaf pine seedlings in the grass stage *(9)*. Such fires help to control the spread of brown spot disease. The volume of dry grass is reduced and seedlings are not smothered by it. Fire may result in an increase in the amount of certain nutrients in the surface layer of the soil, or even indirectly act as a stimulant in starting the height growth of young longleaf pines *(10)*. The relatively high mortality rate of longleaf pine seedlings on strips protected from fires was perhaps due to smothering by grass and to a heavy toll by brown spot disease. In this experiment, the beneficial effects of fires on early survival and growth of longleaf pine have been marked.

In 1948, no significant difference was observed between the heights of average dominant longleaf pines due to fire after planting.

At the early ages, longleaf pine is considered to be a slower growing species than slash pine. In no small degree, this is due to the peculiar habit of longleaf pine seedlings to remain in the grass stage for several years. In this experiment, after 12 growing seasons, the height growth of the longleaf pine was significantly lower than that of the slash pine.

The basal area of longleaf pine on strips burned twice after planting was numerically almost five times as great as that on comparable strips protected from fire. Statistically, this difference was highly significant.

Effects of Site Preparation on Longleaf Pine. Where sod was disturbed by furrowing, initial survival of longleaf pine seedlings was considerably higher than on sub-plots where seedlings were planted without site preparation. This difference was highly significant. Reducing competition from grass roots in furrows apparently proved to be an effective measure in bringing seedlings through their first growing season. This is in agreement with previous findings (7) that the survival of longleaf pine seedlings is favored by site preparation.

As was the case in the first year, there was a highly significant increase in survival of longleaf pine in 1938 and 1939 planted in furrows over that on the strips without site preparation. By 1948, however, this difference had reduced itself to only a fraction of one per cent. When, in 1943, a sample was taken to estimate the percentage of living longleaf pine seedlings that had begun height growth, there was no difference in emergence from the grass stage between longleaf pine seedlings planted in furrows and those on the sub-plots without site preparation.

Longleaf pine on sub-plots where seedlings were planted in sod had a significantly greater height growth in 1948 than on sub-plots where they were planted in furrows. Site preparation at the time of planting had, after 12 growing seasons, opposite effects on the height growth of longleaf pine and slash pine.

Site preparation at the time of planting did not affect significantly the basal area of longleaf pine. However, opposite to slash pine, longleaf pine on sub-plots with undisturbed sod had a greater basal area than did longleaf pine on sub-plots with seedlings planted in furrows. This opposite trend between the two species was significant.

Summary and Conclusions

An experiment to test the effects of fire and of the practice of planting in furrows on survival and growth of slash pine and longleaf pine planted in the Gulf Coast Region of Alabama was begun in 1936. Pine seedlings of these species were planted 8 by 8 feet on 54 sub-plots, one-third acre in size. A group of 18 sub-plots constituted a block. The experimental area was

first planted in January, 1937. In 1938, dead seedlings were replaced with new seedlings.

One strip in each of the three blocks was protected from fires. Another strip was burned once before the seedlings were planted. The last strip was burned before planting, 1 year after planting, and again 2 years after planting. On one-half of the sub-plots, furrows were plowed in which seedlings were set. The ground was left undisturbed on the other half.

On strips that were burned before planting, first-year survival of slash pine seedlings was significantly lower than on those strips on which grass was left unburned.

Slash pine seedlings on strips protected from fires had relatively high mortality for the first 2 years after planting. The mortality in later years was very small.

On strips that were burned in 1938 and 1939, the mortality of slash pine was very great. Repeated burning practically wiped out the slash pine stands. In addition to killing most of the slash pine seedlings, repeated fires adversely affected height growth.

On strips protected from fires, there was no difference in survival between slash pine seedlings planted in furrows and the ones set in sod. Seedlings planted in furrows showed improved survival only on strips that were burned for 2 years after planting. In 1948, slash pine on sub-plots with seedlings planted in furrows had better height growth and greater basal area than on the sub-plots where seedlings were planted in sod.

It was found that after 12 years the slash pine had higher survival, greater height growth, and a larger basal area than did the longleaf pine, except on strips subjected to repeated fires. It can be concluded that it is easier to establish a well stocked slash pine stand by planting than it is to establish a longleaf pine stand, provided fires are kept out of the area.

Preparatory burning decreased initial survival of longleaf pine. However, the difference between seedling survival on the areas burned once and on those not burned disappeared after the first year, and no significant difference was later found in height or basal area.

Although application of fire in the second and third years decreased survival in those years, it had caused after 12 years a marked increase in survival over that on the strips protected from fires. In 1943, a larger proportion of longleaf pine seedlings had emerged from the grass stage on strips burned for 2 years after planting than on the other strips. The basal area of longleaf pine

was greatest on strips burned for 2 years after planting. The height of trees, however, was not significantly affected by fire.

For the first 3 years, longleaf pine seedlings planted in furrows had a higher survival percentage than did those established without cultivation. In the 12th year, however, there was no difference in survival due to the site preparation. The height of longleaf pine trees planted in furrows was lower than that of those planted in sod. The basal area of longleaf pine trees planted in furrows and in sod showed a trend opposite to that of slash pine. It was adversely affected by site preparation at the time of planting.

Planted longleaf pine seedlings were greatly benefited by burning in the first 2 years after planting. Good survival and growth resulted from this fire treatment. Longleaf pine should not only be recommended for planting in preference to slash pine where there is a fire risk, but in its culture it requires judicious use of fire as an aid to its better survival and growth in the early stages of stand establishment.

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