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Mulch and hexazinone herbicide shorten the time longleaf pine seedlings are in the grass stage and increase height growth

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Abstract. Herbaceous plant control with mulch or hexazinone herbicide influenced planted longleaf pine (*Pinus palustris* Mill.) seedling total height on a silt loam site in central Louisiana. The site had been sheared and windrowed in 1991 and rotary mowed before three treatments were established in a randomized complete block design: (1) **Untreated check:** no herbaceous plant control after planting; **(2) Five mulches:** on each plot, five randomly assigned mulches were placed around seedlings; the mulches were either a mat of cotton, hemlock and polyester, pine straw, woven polypropylene, or perforated polyethylene; and **(3) Hexazinone:** the herbicide hexazinone at 1.12 kg active ingredient/ha was annually sprayed in the first two growing seasons over the rows of unshielded seedlings. The longleaf seedlings were planted in February 1993.

After three growing seasons, seedlings on the mulch and hexazinone treatments were taller than those on the check plots. About 59% of the mulched and hexazinone treated seedlings had grown out of the grass stage (at least 12 cm tall) compared to 17% of the check seedlings. After five growing seasons, the percentage of longleaf pine seedlings out of the grass stage was similar on all treatments and averaged 87%. However, these better growing pines were taller on the mulch and hexazinone treatments (a 142-cm average) than on the checks (78 cm). Pine straw was an ineffective mulch probably because the straw smothered the seedlings. The longleaf saplings were tallest when the perforated polyethylene mat was used.

Introduction

The reestablishment and recovery of longleaf pine (*Pinus palustris* Mill.) on lands historically stocked by this species concerns many land managers in the southern United States. One desired outcome is pure stands of longleaf pine with sparse midstories and species rich, productive understories. However, the management of longleaf pine regeneration to attain this condition can be difficult. Longleaf pine is intolerant of competition, and the pure longleaf pine type is regarded as a fire climax or sub-climax (Barrett 1962; Croker and Boyer 1975; Harlow and Harrar 1969). Thus, prescribed burning is often used for preparing sites for regeneration, and the use of prescribed fire may continue from seedling establishment through stand maturity (Boyer 1993; Croker and Boyer 1975; Grelen 1983; Smith 1961; Wahlenberg 1946).

The rate of seedling development is critical when managing longleaf pine. Once longleaf seedlings are in place, they develop little above ground for the first 3 to 6 years (or longer under adverse conditions) as the root system develops (Harlow and Harrar 1969). The bunch of needles at the surface resembles a clump of grass, hence the term "grass stage" to describe the juvenile period of growth. Longleaf pine seedlings in the grass stage are susceptible to encroachment by other woody plants, smothering by dead grass, and brown-spot needle blight caused by ***Mycosphaerella dearessii*** Barr (Croker and Boyer 1975; Wahlenberg 1946). Prescribed burning during this period can be used to relieve the longleaf seedlings from these stresses. Once the seedlings have developed a root collar of about 2 cm, they are able to emerge from the grass stage.

However, fire is not a panacea for managing longleaf pine stands. Fire can destroy seedlings in and emerging from the grass stage, and later, the use of fire can adversely affect stand growth and yield (Boyer and Miller 1994; Harlow and Harrar 1969; Wahlenberg 1946). For these and other reasons, landowners may not want to, or be able to, use fire in the management of longleaf pine. Not being able to use fire during the grass stage may mean other vegetation management practices are required.

Postplant vegetation control with herbicides favors early height growth (Loveless et al. 1989; Nelson et al. 1985), but infection of longleaf pine seedlings with brown-spot needle blight increases as the amount of exposed soil in openings increases (Boyer 1975). Total competition control is not necessary for the management of longleaf pine regeneration (Nelson et al. 1985). Rather, banding herbicides over the rows of pine in the first two growing seasons is sufficient to increase early height growth.

Another commercial practice, mulching around newly planted trees, may help to establish pine seedlings (Haywood and Youngquist 1991). Mulch provides competition control and would be a physical barrier between needles and brown-spot spores. Used throughout the world, mulches passively control vegetation and thereby reduce the need for mechanical and chemical weed control. Where labor for continual weeding is scarce, machines cannot operate, and use of chemicals restricted, mulching is an alternative which will also conserve soil moisture, improve water infiltration, and reduce sedimentation (Crutchfield et al. 1985; Gale et al. 1993; Gupta 1991; Mahajan and Kanwar 1993; Walker and McLaughlin 1989; Zuzel and Pikul 1993).

Following intensive site preparation, I compared two methods of herbaceous plant control – mulching or herbicide applied over the rows of longleaf pines – and determined how herbaceous plant control compared to a check treatment. The longleaf pine variables were survival, emergence from the grass stage, total height, and incidence of brown-spot needle blight. Several promising mulches were included in the study so comparisons among mulches could be made (Haywood 1999). I also inventoried the vegetation between the planted rows of pine to determine what kind of plant cover was developing.

Study area

The study area is within the humid, temperate, subtropical, lower coastal plain and flatwoods province of the Southeastern United States (McNab and Avers 1994). It is located within boundaries of the Kisatchie National Forest in central Louisiana about 31 km south-southwest of Alexandria (approx. 92°30′ W longitude, 31” N latitude) at an average elevation of 52 m.

The mean January and July temperatures are 8 and 28 °C, respectively (Louisiana Office of State Climatology 1997). Annual precipitation averages 1400 mm. All monthly averages exceed 90 mm. The 250-day growing season is from 10 March to 15 November (the spring and fall dates with a 50% probability of a frost).

The soil is a Beauregard-Malbis silt loam complex. The Beauregard soil (fine-silty, siliceous, thermic, Plinthaquic Paleudult) is moderately well drained with a 1 to 3% slope (Kerr et al. 1980). It forms the inter-mound wetter portion of the area. The Malbis soil (fine-loamy, siliceous, thermic, Plinthic Paleudult) has a slope of 1 to 5% and forms mima mounds. These mounds are usually less than 400 m^2, but they can number up to 12 per hectare and are surrounded by the more poorly drained Beauregard soil. The water table is high and fluctuates throughout the year because a fine textured horizon or fragipan restricts drainage. As a result, water perches above the lower subsoil in winter and early spring. Harms (1996) classes this area as a wet pine site because the soil is seasonally wet during winter although often droughty during summer. These soils have low natural fertility, and woody plant growth is usually best on the mima mounds. Kerr et al. (1980) consider this complex to be suited for both pine and hardwood management.

Methods

Study establishment

The stand of pine and hardwood trees was clearcut harvested in the mid 1980s. The unmerchantable stems and regrowth were sheared and windrowed in 1991; such intensive site preparation is often needed before planting longleaf pine (Barnett 1989; Boyer 1989; Loveless et al. 1989). The low cover of herbaceous and scattered woody vegetation that developed after windrowing was rotary mowed in July and August 1992. Research plots were established in a randomized complete block design and remowed in December 1992. Each of the 15 research plots (5 blocks by 3 treatments) measured 16.2 by 25.2 m (0.041 ha) and contained 9 rows of 14 seedlings arranged in a 1.8 by 1.8 m spacing. The center 50 seedlings (5 rows of 10 seedlings) composed the measurement plot.

Blocking was based on surface drainage and the location of the mima mounds within and adjacent to the plots. Plots within blocks were established parallel to the windrows, and the following three treatments were randomly assigned:

Untreated check:
no herbaceous plant control after rotary mowing in December 1992.

Five mulches:
to control herbaceous plants, five mulches were randomly assigned to 10 planted longleaf pine seedlings within each of the mulched plots. The mulches were selected based on field performance results (Haywood 1999). The five mulches were:

1. **Cotton shoddy** – a 1.0-m^2 non-woven high density cotton (*Gossypium hirsutum* L.) mat acquired from Conwed Fibers' (P.O. Box 357, Riverside NJ 08075 USA),
2. **Hemlock and polyester** – a 0.8-m^2 continuous-spun needle-punched mat of blended hemlock (*Tsuga* spp.) and polyester fibers acquired from Canadian Forest Products, Ltd. (430 Canfor Avenue, New Westminster, BC, Canada),
3. **Pine straw** – 5 kg of air-dried (about 15% moisture content) longleaf pine needles applied around each seedling on blocks 1 and 2, the needles covered about 1.0 m^2, and 4 kg of air-dried needles applied around each seedling on blocks 3, 4, and 5 which covered about 0.8 m^2,
4. **Woven polypropylene** – a 0.8-m^2 woven ultraviolet stabilized black polypropylene mat acquired from DeWitt Co. (Highway 61 South, Rural Route 3, P.O. Box 31, Sikeston, MO 63801 USA), and

5. **Perforated polyethylene** – a 0.8-m^2 black polyethylene mat with numerous funnel-shaped pores through the mat allowing moisture through but trapping water vapor beneath acquired from Tredegar Film Products (1100 Boulders Parkway, Richmond, VA 23225 USA).

Mulch dimensions varied from 0.8 to 1 .O m^2 because different manufacturers produce mulches of different sizes. The mulches were placed around the planted seedlings in February 1993. Mats were secured with metal staples and re-secured if necessary through April 1993.

Hexazinone:
the herbicide hexazinone (3-cyclohexyl-6-[dimethylamino]-1-methyl-1,3,5-triazine-2,4[1H,3H]-dione) was applied in 0.9-m wide bands over the rows of unshielded longleaf pine seedlings to control herbaceous plants. This left a 0.9 m wide unsprayed area between the rows of trees. The hexazinone was first applied on April 27, 1993, at a rate of 1.12 kg active ingredient (ai) in 412 L water/ha. The second application was on May 5, 1994, at the same rate but in 397 L water/ha. The soil was wet with no standing water and wind speeds were 0 to 8 kmph at 1 m above the ground on both dates.

Container longleaf pine seedlings were used as recommended for commercial outplantings (Barnett 1989; Boyer 1989). A standard Mississippi seed source was used for this study. The longleaf pine seedlings were grown over a 42-week period in containers using the best current practices. The seedlings were planted in February 1993 with a planting punch of the correct size for the root plug. The soil was wet and the temperature reached 13 to 16 °C on the day of planting.

Without the use of fire, the woody vegetation began to encroach on the planted longleaf pine seedlings regardless of treatment, and the distribution of brush was sufficiently uniform to discount any treatment effect. The two herbaceous weed control treatments were ineffective against brush because the mulches only covered a small portion of the plot and the herbicide rate was too low for woody plant control. Therefore, woody plants 60 cm or greater in height were cut down on all plots in May 1997 during the fifth growing season after planting. The regrowth was sprayed with triclopyr (3,5,6-trichloro-2-pyridinyloxyacetic acid) herbicide in April 1998. The herbicide was directed at the woody regrowth and away from the longleaf pine seedlings.

Measurements

After each growing season, survival counts were made for the central 50-trees per plot and total height of surviving trees was measured. Seedlings were classed as having grown out of the grass stage if the stem was at least

12 cm tall. The percent of foliage infected with brown-spot needle blight was ocularly estimated to the nearest percent. All visual estimates were made by the same trained person to avoid bias.

At the end of each growing season, weed cover within a 0.5-m radius (0.8 m^2) of each longleaf pine seedling was ocularly estimated to the nearest percent on the check and hexazinone treatments. Weed cover was quantified as percent surface area shaded by vegetation when the sun was overhead. For the mulches, the weed cover was estimated for the surface area originally covered by the mulch (cotton shoddy, 1.0 m^2; hemlock and polyester, 0.8 m^2; pine straw, 0.8-1.0 m^2; woven polypropylene, 0.8 m^2; and perforated polyethylene, 0.8 m^2). Any vegetation leaning over the estimate area from the edges was ignored. The mulches were examined and the amount of deterioration was estimated to the nearest percent.

In June of the sixth growing season after planting, five 4-m^2 subplots were established in the central 50-tree measurement plots for inventorying plant cover. Four of these subplots were laid out between the rows of planted pine 4 m diagonally from each edge of the measurement area, and the fifth subplot was randomly laid out near the center of the measurement area. The subplots were within the untreated portion of each plot because I wanted to evaluate productivity in the untreated portion of each plot and inventory the plants. Subplots on the hexazinone treatment overlapped slightly with the herbicide treated bands. All plants in the subplots were identified. Vegetation on an adjacent, randomly selected 0.22-m^2 quadrat was clipped and separated into two groups – either herbaceous plants or blackberry (*Rubus* spp.) plus woody plants – for determining productivity. Samples were oven-dried at 80 “C.

Data analysis

Plot means for the three treatments (untreated check, five mulches, and hexazinone herbicide) were compared using a randomized complete block design model (a! = 0.05) (Neter and Wasserman 1974). The variables analyzed were percent longleaf pine seedling survival, mean total height of all seedlings, percentage of surviving seedlings that had grown out of the grass stage, mean height of seedlings out of the grass stage, height growth during the third growing season after planting, percent brown-spot needle blight, percent weed cover in proximity to the longleaf pines, and productivity of vegetation between the rows of longleaf pine.

Plot means for the five mulches (cotton shoddy, hemlock and polyester, pine straw, woven polypropylene, and perforated polyethylene) were also compared using a randomized complete block design model (a = 0.05) (Neter and Wasserman 1974). The variables analyzed were the same. For both sets

Table I. Three- and five-year-old longleaf pine survival and mean height for all trees and those out of the grass stage as well as weed cover.

Main treatments	All longleaf pine		Surviving longleaf out of the grass stage		Weed
after 3rd and 5th growing seasons	Survival (%)	Height (cm)	Percentage (%)	Height (cm)	cover (%)
Age 3 years*					
Untreated check	94a	10b	17b	20b	87a
Five mulches	91a	26a	58a	35a	18c
Hexazinone	88a	28a	59a	37a	75b
Error mean square	24.200	51.964	177.50	66.625	25.249
Age 5 years*					
Untreated check	90a	65b	81a	78b	89a
Five mulches	88a	128a	90a	141a	41b
Hexazinone	86a	132a	89a	144a	88a
Error mean square	21.733	1521.3	32.409	1525.2	22.480

* Within columns and ages, means followed by the same letter are not significantly different based on Duncan's Multiple Range Tests (a = 0.05).

of analyses, mean comparisons were made using Duncan's Multiple Range Tests (a = 0.05) when there were significant treatment or mulch differences.

Results

Longleaf pine

Longleaf pine survival was not influenced by the two herbaceous plant control treatments (Table 1). After 3 years, total height of all surviving longleaf pine was significantly greater on the mulch and hexazinone treatments (27-cm average) than on the checks (10 cm). These height differences became evident during the third growing season after planting, when there was a significant difference in annual height growth between the average for the two herbaceous plant control treatments (a 21-cm increment) and the checks (a 6-cm increment).

Because of this difference in annual height growth, the percentage of 3-year-old longleaf pine seedlings that had grown out of the grass stage was significantly greater on the mulch and hexazinone treatments (59% average) than on the checks (17%) (Table 1). Total height of seedlings out of the grass stage was also significantly greater on the mulch and hexazinone treatments (36-cm average) than on the checks (20 cm).

After five growing seasons, total height of all longleaf pine was still significantly greater on the two herbaceous plant control treatments (130-

Table 2. For the five mulches, 3- and 5-yr-old longleaf pine survival and mean height of all trees and those out of the grass stage as well as weed cover.

Mulches only after 3rd and 5th growing seasons	All longleaf pine Survival (%)	All longleaf pine Height (cm)	Surviving longleaf out of the grass stage Percentage (%)	Surviving longleaf out of the grass stage Height (cm)	Weed cover (%)
Age 3 years*					
Cotton shoddy	94a	31ab	72a	37a	25a
Hemlock and polyester	98a	24b	57ab	29a	24a
Pine straw	88a	16c	38c	30a	21ab
Woven polypropylene	86a	25b	53bc	35a	12bc
Perforated polyethylene	90a	35a	71ab	42a	6c
Error mean square	61.000	36.802	168.16	85.708	58.394
Age 5 years*					
Cotton shoddy	88a	124b	96a	130b	56a
Hemlock and polyester	98a	128b	92a	139ab	47a
Pine straw	86a	93c	80a	118b	51a
Woven polypropylene	82a	133b	88a	148ab	22b
Perforated polyethylene	88a	164a	93a	175a	30b
Error mean square	66.500	418.31	83.825	704.66	102.02

* Within columns and ages, means followed by the same letter are not significantly different based on Duncan's Multiple Range Tests (a = 0.05).

cm average) than on the checks (65 cm) (Table 1). Although the percentage of trees out of the grass stage was now similar on all three treatments (87% average), the total height of these better growing longleaf pines was still significantly greater on the mulch and hexazinone treatments (142-cm average) than on the checks (78 cm).

Longleaf pine survival was not influenced by the different mulches (Table 2). However, at both age 3 and 5 years, longleaf pine was significantly shorter in pine straw mulch than when the other four mulches were used, and fewer of the pines were out of the grass stage after 3 years if pine straw was the mulch. This occurred although weed cover in proximity to the longleaf pine seedling was similar among most of the mulches. At age five, longleaf pines had the greatest average height when the perforated polyethylene mats were used.

The percentage of foliage infected with brown-spot needle blight was low, ranging from 6% to 14% at age 3 years and from 16% to 17% at age 5 years across all three treatments. These differences in percent infection were not considered biologically significant. There were also no significant infection differences among the mulches that deteriorated (cotton shoddy - 18%, hemlock and polyester - 14%, and pine straw - 20% infected needles) and the two synthetic mulches (woven polypropylene – 18% and perforated polyethylene – 12% infected needles) after 5 years.

Weed cover

After three growing seasons, herbaceous weed control by mulching or herbicide application significantly reduced cover in proximity to the longleaf pine seedlings when compared to the checks (Table 1). Mulch was the most effective control method, with an average weed cover of 7, 15, and 18% after the first, second, and third growing seasons, respectively. The hexazinone applications resulted in a 50% average weed cover after the first two growing seasons. Without a herbicide application in the third year, weed cover increased to 75% on the hexazinone treatment (Table 1). Cover on the check plots increased from 76% in the first growing season to 87% by age 3 years.

After five growing seasons, mulches still generally curtailed plant growth in proximity to the longleaf pine (Table 1). The hexazinone applications no longer affected weed cover three and one-half years after hexazinone treatments ceased.

At the end of the first growing season, the synthetic mats of woven polypropylene and perforated polyethylene (6% average cover) did not control plants any better than the cotton shoddy and hemlock and polyester mats (6% average cover), and all mats did significantly better than pine straw mulch (12% cover). However, as the mats containing natural fibers deteriorated, weed cover increased where the cotton shoddy and hemlock and polyester mats were placed (Table 2). After five growing seasons, the woven polypropylene and perforated polyethylene mats (26% average cover) controlled herbaceous plants better than the cotton shoddy, hemlock and polyester, and pine straw mulches (51% average cover).

On the 4-m^2 subplots established in the untreated areas between the planted rows of longleaf pine, the cover was predominantly herbaceous plants. In the middle of the sixth growing season after planting, the three treatments averaged 2340 kg/ha of oven-dried herbaceous plant biomass and 167 kg/ha of oven-dried blackberry and woody plants. The low biomass for woody plants was attributed to cutting stems 60 cm or greater in height followed by spraying with triclopyr before the samples were taken. There were no statistical differences in biomass among treatments for vegetation between the planted rows of pine. Six grasses covered most of the ground on all plots: big bluestem (*Andropogon gerardii* Vitm.), broomsedge (*Andropogon virginicus* L.), cutover muhley (*Muhlenbergia expansa* (DC.) Trin.), spreading panicum (*Panicum anceps* Michx.), pinehill bluestem (*Schiz-*

achyrium scoparium var. divergens (Hack.) Gould), and slender bluestem (*S. tenerum* Nees).

Discussion

Herbaceous plant control first significantly influenced the growth rate of planted seedlings during the third growing season when longleaf began to differentially grow out of the grass stage. Using hexazinone was not as effective as mulching in proximity to the planted trees, but it was as effective as mulching for increasing pine average height and height of trees out of the grass stage.

The dominant bluestem grasses on this site were unaffected by hexazinone at the rate applied, which is the main reason total weed control was never obtained. Thus, neither method of plant control changed the dominant herbaceous species because the mulches covered only a small portion of the area and the herbicide did not control the dominant grasses in the sprayed strips. More importantly, total plant control was unnecessary, and weed control can be used successfully even when maintaining a productive understory is part of the management objectives.

In other work, English' showed that the perforated polyethylene mats allowed more moisture to reach the soil than the woven polypropylene mats. Thus, a combination of good herbaceous plant control and a more permeable mat design may help explain why the longleaf pine seedlings were tallest when the perforated polyethylene mats were used.

Even though the cotton shoddy, pine straw, and hemlock and polyester mulches deteriorated, they still had less herbaceous cover in proximity to the trees than the checks. This might have happened because as a mulch containing natural fibers deteriorates it forms a fibrous cover over the soil which continues to smother weeds (Haywood 1999). Also, the mulch had already killed the established herbaceous vegetation and germinants, and there might not be a sufficient soil seed bank to quickly reestablish a plant cover once the mulch is gone (Haywood and Youngquist 1991; McDonald and Helgerson 1990). Pine straw mulch resulted in less height growth than the other mulches. It was noted that the wind shifted the pine straw which tended to cover newly planted seedlings. Thus, smothering may be the reason for poor growth. Allelopathy was not suspected because loblolly pine (*P. taeda* L.) seedlings are not adversely affected by a pine straw mulch (Haywood et al. 1997). Regardless, pine straw was not a satisfactory mulch to use for longleaf pine seedlings.

Although the vegetation management treatments were generally successful, the exclusion of fire meant that cutting and a directed application of triclopyr had to be used to control woody vegetation (especially loblolly pine). In other work, Haywood and Grelen[3] showed that without woody plant control, wet pine sites can develop a mixed overstory of loblolly, longleaf, and hardwoods, with a midstory of trees and shrubs that shade out most of the understory vegetation. Thus, herbaceous plant control alone will not be sufficient to obtain a desired condition of pure stands of longleaf pine with sparse midstories and species rich, productive understories.

Notes

1. Identification of mulch suppliers and discussion of herbicides does not constitute a recommendation of use by the U.S. Department of Agriculture. Discussion of herbicides does not imply that these uses are registered.
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