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Understory plant response to site preparation and fertilization of loblolly and shortleaf pine forests

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Abstract

In developing an improved understanding of the dynamics of understory plant composition and productivity in Coastal Plaii forest ecosystems, we examined the influence of site preparation and phosphorus fertilization on the successional trends of shrubs and herbaceous plants growing on lands of widely ranging subsoil texture in Arkansas, Louisiana, and Texas which are managed for southern pine production. Burn-inject, chop-burn, chop-burn-disk, double-chop, shear-burn, shear-windrow, and shear-windrow-disk site preparation methods were applied in a completely randomized split-plot design to sites with subsoil textures consisting of loam, gravelly-clay, silt, silty-clay, and clay, both fertilized with 73.4 kg P/ha and unfertlliied. Site preparation method, subsoil texture, and fertilization influenced production of paspalums and other forbs the first growing season following treatment, but no treatment combination affected plant groups in subsequent years. Total herbaceous production increased 24 to 35-fold over pretreatment levels the first growing season after treatment. While site preparation methods had little influence on herbaceous biomass, subsoil texture affected herbaceous production the first year after treatment, with loam subsoils being most productive. Although annual composites were the most abundant herbaceous group the first year after treatment, they were largely replaced by perennial grasses by the third post-treatment growing season. By the seventh growing season following treatment, herbaceous production declined on all subsoil textures with composition and yield approximating pretreatment estimates. Subsoil texture influenced shrub density only in the first and third growing seasons after treatment. During the first few years after site preparation, herbaceous production appeared inversely related to shrub density. In the first and third post-treatment growing seasons, fertilization significantly increased total herbaceous production and biomass of composites and legumes. But 7 years after application, total herbaceous production and biomass of bluestems, other grasses, and sedges was greater on unfertilized areas. The absence of differences among treatments by the seventh post-treatment growing season indicates an overall long-term similarity in the degree of disturbance caused by application of each method in this ecosystem.

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Forest land managers of the Gulf Coastal Plain in Arkansas, Louisiana, and Texas routinely apply a wide array of vegetation control techniques to improve establishment of loblolly pine (*Pinus taeda* L.). In the southern United States during 1991, pine was planted on over 708,000 ha (Mangold et al. 1992), most of which received some form of site preparation. Major categories of site preparation, which may be used as singular or combination treatments to reduce competition before tree planting, include (1) mechanical manipulation, (2) chemical application, and (3) prescribed fire.

Prescribed fire is known to effectively control small hardwood trees after larger merchantable pines have been harvested (Williamson 1964, Mann 1979). Mechanical manipulation (e.g., shearing, chopping, disking) or herbicide application (alone or in various combinations with fire and mechanical treatments) generally provide a greater degree of vegetation control than when fire is used alone in stands consisting of larger hardwood trees (Trousdell and Langdon 1967, Grano 1970, Trousdell 1970, Cain 1985, Tiarks and Haywood 1986, Slay et al. 1987).

Herbaceous understory plants are also known to respond to site preparation for pine regeneration. Significant changes at the species level were noted, with a differential response of grasses to differing site preparation methods (Schultz 1976). Within 1 year of treatment, the standing biomass of competing vegetation (woody and herbaceous plants) was influenced by site preparation methods (Slay et al. 1987). Herbaceous production increased during the first 4 years after fertilization regardless of the level of competition control (Tiarks and Haywood 1986). Twelve years after treatment, greater herbaceous plant yield was reported on control plots than on areas which had been cultivated or cultivated and fertilized (Wolters and Schmidtling 1975).

Although the body of scientific information regarding the response of herbaceous plants to various site preparation methods is developing, currently available information is inadequate to comprehensively support informed land management decisions concerning the wide array of ecosystem resource values. This study was initiated to further enhance the body of technical information which over time quantifies the response of understory woody and herbaceous plant species to a variety of mechanical, chemical and burning treatments with and without supplemental phosphorus fertilization on forest soils typical of the Gulf Coastal Plain of Arkansas, Louisiana, and Texas. While earlier reports regarded understory plants collectively as "competing vegetation" with respect to regeneration of the pine overstory (Wolters et al. 1995), this study focuses upon the dynamics of individual plant species and groups.

Materials and Methods

Study Sites

We conducted this study on the Gulf Coastal Plain of southern Arkansas, northwestern Louisiana, and eastern Texas where the forest land is managed for loblolly and shortleaf pine (*Pinus echinata* Mill.) production. The climate in this region is characterized as semi-humid subtropical. The frost-free season is approximately 235 days and extends from mid-March to mid-November. Annual precipitation averages about 1,400 mm, with more than 80 mm incident each month and about 640 mm arriving during the April through September growing season (Wolters et al. 1977).

Soils in this region are predominantly ultisols with surface A horizons typically ranging from sandy to silty loam. Our study sites were divided into 5 groups based upon the textural class of the B horizon of the dominant soil series. The textural classes, from coarsest to finest, consisted of loam, gravelly-clay, silt, silty-clay, and clay. Ruston (fine-loam, siliceous, thermic Typic Paleudult), Kirvin (clayey, mixed, thermic, Typic Hapludult), Henry (coarse-silty, mixed, thermic Typic Fragiaqualf), Sawyer (fine-silty, siliceous, thermic Aquic Paleudult) and Boswell (fine, mixed, thermic Vertic Paleudalf), respectively, were the representative series for the 5 textural classes. Detailed descriptions of the soils present on these study sites are found in Haywood and Burton (1990).

Overstory vegetation was dominated by a mixture of loblolly pine and shortleaf pine, in substantially varying proportion. Hardwood trees formed a moderately dense midstory consisting predominantly of white oak (Quercus *alba* L.), southern red oak (*Quercus falcata* Michx.), post oak (*Quercus stellata* Wangenh.), sweetgum (*Liquidambar styraciflua* L.), mockernut hickory (*Carya tomentosa* (Poir.) Nutt.), blackgum (*Nyssa sylvatica* Marsh.), flowering dogwood (*Cornus florida* L.), and red maple (*Acer rubrum* L.). American beautyberry (*Callicarpa americana* L.), yaupon (*Ilex vomitoria* Ait.), greenbriers (*Smilax* spp.), blueberries (*Vuccinium* spp.), hawthorns (*Crutaegus* spp.), and a mixture of small hardwood trees were common woody understory species. Little bluestem (*Schizachyrium scoparium* (Michx.) Nash) was usually the major grass in forest openings. Longleaf uniola (*Chasmanthium sessiliflorium* (Poir.) Yates) and spike uniola (*Chasmanthium laxum* (L.) Yates) were associated with little bluestem where the overstory was moderately dense. Both uniola species occurred in nearly pure, though sparse, stands on heavily shaded sites. Many other grasses, legumes, and composites were common but ordinarily produced little herbaceous biomass prior to treatment. Study sites are described in greater detail by Wolters et al. (1977) and Haywood and Burton (1990).

Merchantable timber was harvested from 26 selected study sites prior to application of experimental treatments. Following harvest, nonmerchantable woody plants greater than 2.54 cm diameter at breast height (d.b.h.) averaged about 6,700 stems per ha and contained a mean basal area of 16.5 m^2/ha (Wolters et al. 1977). Study plots were selected based on the presence of a minimum hardwood density of 1,235 stems/ha and a basal area of 4.6 m^2/ha prior to site preparation.

Experimental Design and Treatments

A completely randomized split-plot experimental design was established on the 26 study sites. Thirty-five treatments consisting of 7 site-preparation methods applied across 5 subsoil textural classes were replicated twice. Site-preparation treatments were applied to rectangular 43.9 X 46.3 m (2,033 m^2) plots. In some cases, multiple (but not necessarily all 7) site preparation plots were installed at a single location (for 1 subsoil texture). The site-preparation treatments consisted of:

1. Bum-inject = Plots were burned to reduce logging slash and residual live plant material. Remaining live pines and hardwoods greater than 2.54 cm d.b.h. were manually injected with 2,4-D [(2,4-dichlorophenoxy) acetic acid] during the spring. Soil surface disturbance was minimal.
2. Chop-bum = Plots were chopped with a crawler tractor-drawn rolling drum chopper and burned after fine fuels had dried.
3. Chop-bum-disk (referred to as chop-disk) = This treatment was the same as the chop-bum method, except after burning, plots were tilled with a crawler tractor-drawn disk.
4. Double-chop = Plots were chopped with a crawler tractor-drawn rolling drum chopper and then rechopped after several days to several weeks, usually at an angle perpendicular to the initial chop.
5. Shear-burn = Pine and hardwood trees remaining on the plot were felled by a shearing blade mounted on a crawler tractor and the plot was burned when fine fuels had dried.
6. Shear-windrow = Remaining pine and hardwood trees were felled as with the shear-burn method, then piled into windrows with brush rakes.
7. Shear-windrow-disk (referred to as shear-disk) = This treatment was the same as shear-windrow except the cleared area between windrows was cultivated with a crawler tractor-drawn disk.

Each experimental plot was then split into 43.9 X 15.2 m (667 m^2) fertilized and 43.9 X 3 1.1 m (1,365 m^2) unfertilized portions. The fertilization treatment consisted of a single surface broadcast application of 168 kg P_2O_5 triple superphospate/ha (73.4 kg P/ha), prior to planting loblolly pine seedlings (Haywood and Burton 1990).

Loblolly pines (1 + 0 seedlings) were then planted at a 1.8 X 2.4 m spacing during the winter preceding herbicide injection of hardwoods or in the winter after mechanical site preparation. The first replication of 35 plots at 12 locations was planted during winter 1971 and the second replication of 35 plots at 14 locations was planted mostly during winter 1972 and completed during winter 1973.

Vegetation Measurements

Oven-dry weight of herbaceous plant material (by species or species group: bluestems, panicums, paspalums, uniolas, other grasses, rushes, sedges, composites, legumes, and other forbs) was estimated in 20 quadrats 0.89 m^2 in size on each split plot using a weight-estimate procedure (Pechanec and Pickford 1937). All grass species other than bluestems, panicums, paspalums, and uniolas were included in the "other grasses" category and forbs other than composites and legumes were included in the "other forbs" category. Density and crown cover of shrubs (shrubs, vines, and hardwood seedlings less than 2.54 cm d.b.h) were estimated ocularly in four 4.05 m^2 circular quadrats on each split plot. Herbaceous production, shrub density and crown cover were sampled during fall of the first, third , and seventh growing seasons after loblolly pine seedlings were planted. Loblolly pine survival and growth data were reported by Haywood and Burton (1990). Identification and scientific nomenclature for plant species are consistent with Grelen and Hughes (1984) and the USDA Soil Conservation Service (1982). Common plant names generally follow those of Grelen and Hughes (1984) and Kelsey and Dayton (1942).

Data Analysis

Data collected the first and third years after treatment were analyzed by analysis of variance for a split plot design with 2 replications. Main effects plots for each of 5 subsoil textural classes and 7 site-preparation methods were divided into fertilized and unfertilized portions as previously described. Data from replication 2 were not available for analysis in the seventh year, so the analysis was modified to assume negligible interaction and only tested for main effects. Main effects were separated using Scheffe's Test (Steele and Torrie 1980) at the 0.05 probability level, When significant interactions were detected, we combined the interacting variables as a new treatment group for testing by one-way analysis of variance. If the analysis revealed homogeneity of variance, treatment means were tested by Tukey's T-test. Where variance heterogeneity was observed, treatment means were tested by Dunnett's multiple comparison test (Dunnett 1980).

Results and Discussion

Subsoil Texture Effects

Subsoil texture significantly influenced aboveground biomass production of bluestems, panicums, paspalums, other grasses, sedges, and other forbs the first growing season following treatment (Table 1). These herbaceous groups were generally more productive on loam subsoil with very low to minimal production on silt subsoil. Paspalums and other forbs were also highly productive on clay subsoil. Broomsedge L.), arrowfeather threeawn ***(Aristida purpurascens*** Poir.), shaggy crabgrass ***(Digitaria villosa*** (Walt.) Pers.), violet crabgrass ***(Digitaria ischaemum var. violascens*** (Link) Radf.), vaseygrass, brownseed paspalum, gaping panicum ***(Steinchisma hians*** (Ell.) Nash), and beaked panicum ***(Panicum anceps*** Michx.) were the most common perennial grass species regardless of subsoil texture. Annual and other early invader grasses such as oldfield threeawn ***(Aristida oligantha*** Michx.), slimspike threeawn ***(Aristida longespica*** Poir.), churchmouse threeawn ***(Aristida dichotoma*** Michx.), fringeleaf paspalum ***(Paspalum setaceum var. cilitifolium*** (Michx.) Vasey), and hurrahgrass were also common. On gravelly-clay and loam subsoils, paspalums such as roundseed paspalum, dallisgrass, Florida paspalum, field paspalum ***(Puspalum*** laeve Michx.), fringeleaf paspalum, and hurrahgrass were quite common, as were other grasses such as purpletop ***(Tridens flavus*** (L.) Hitchc.) and purple lovegrass ***(Eragrostis spectabilis*** (Pursh) Steud.). Red-top panicum ***(Panicum agrostoides*** Spreng.), vaseygrass, and bent-awn plumegrass ***(Erianthus contortus*** Baldw. ex Ell.) were more common on silty-clay and clay subsoils. Pinehill beakrush ***(Rhynchospora globular-is*** (Chapm.) Small) and fringed razorsedge ***(Scleria ciliata*** Michx.) were generally the most common sedges on all subsoil textures and rough buttonweed, a low growing early seral species, was the most common other forb on all subsoils the first growing season after treatment.

Table 1. Subsoil texture influence on berbaceous production the first growing season following treatment,

	Subsoil Texture				
	loam	gravelly-clay	silt	silty-clay	clay
	(kg/ha)				
Bluestems	154a	30b	25b	206a	76ab
Panicums	297a	83c	69c	8%	180b
Paspalums	21ab	3b	4b	10ab	80a
Uniolas	161	109	154	28	27
Other Grasses	461a	62b	46b	71b	63b
Rushes	28	3	7	25	49
Sedges	76a	13b	29b	55ab	62ab
Composites	1,004	1,246	1,496	1,639	1,463
Legumes	37	34	19	29	47
Other Forbs	420a	189b	250ab	173b	534a
Total Herbage	2,659	1,772	2,099	2,321	2,581

Means in the same row followed by a diierent letter are significantly different at the 0.05 level; absence of letters within rows indicates no significant differences.

Composites were the most productive herbaceous group on all subsoils the first growing season following treatment. Dogfennel ***(Eupatorium capillifolium*** (Lam.) Small) was dominant on loam, silt, silty-clay, and clay subsoils mixed with lesser amounts of other composites such as annual horseweed ***(Conyza canadensis*** var. ***pusilla*** (Nutt.) Cronq.), common ragweed ***(Ambrosia artemesiifolia*** L.), bitter sneezeweed ***(Helenium amarum*** (Raf.) Rock), and tall goldenrod ***(Solidago altissima*** L.). Late eupatorium ***(Eupatorium serotinum*** Michx.) was dominant on gravelly-clay subsoils the first growing season after treatment with lesser amounts of other composites such as dogfennel, annual horseweed, tall goldenrod, and common ragweed.

Three growing seasons following treatment, bluestems, panicums, paspalums, and sedges continued to be highly productive on loam subsoil with low to minimal biomass production on gravelly-clay and silt subsoil (Table 2). Total herbaceous aboveground biomass was also greatest on loam. From the first to third growing season after treatment, the importance of broomsedge and slender bluestem ***(Schizachyrium tenet-urn*** Nees) increased substantially, as did red top panicum, beaked panicum, and gaping panicum. Invasive early seral and annual species declined

Table 2. Subsoil texture influence on berbaceous production the third growing season following treatment.

	Subsoil Texture				
	loam	gravelly-clay	silt	silty-clay	clay
	(kg/ha)				
Bluestems	998a	299cd	244d	720ab	497bc
Panicums	874a	247bc	188c	237c	500ab
Paspalums	169a	9b	22ab	34ab	55ab
Uniolas	232	241	239	118	75
Other Grasses	53	45	44	74	75
Rushes	98ab	2c	13bc	40b	124a
sedges	128a	19b	39b	93ab	98a
Composites	142b	526a	375a	480a	647a
Legumes	47	184	123	126	206
Other Forbs	155	158	174	252	231
Total Herbage	2,896a	1,730bc	1,461c	2,174b	2,508ab

Means in the same row followed by a different letter are significantly different at the 0.05 level; absence of letters within rows indicates no significant differences.

with time subsequent to site preparation. A similar trend was reported by Haywood et al. (1981). Three to 6 years after herbaceous weed control for loblolly pine regeneration in Alabama, the importance of broomsedge increased while that of annual horseweed diminished (Britt et al. 1991).

Rushes and composites were most productive on clay subsoil, although rushes were equally productive on loam. Composites were least productive on loam subsoils. Other forbs diminished substantially on most sites from the first year after treatment, due largely to a precipitous decline in rough buttonweed.

Shrub density was significantly greater on gravelly-clay subsoil the first and third growing seasons following treatment than on loam subsoil (Table 3). No other differences in shrub density were observed. While shrub crown cover also appeared to be greater on gravelly-clay than on loam subsoil the first and third growing seasons after site preparation, the differences were not significant. Shrub density and crown cover appeared to be inversely related to total herbaceous plant production the first and third years after treatment. Density and crown cover were generally greatest on gravelly-clay subsoil where total herbaceous production was least. Shrub density and crown cover were least on loam subsoil where herbaceous plant production was greatest.

Herbaceous plant production declined substantially on all subsoil textures by end of the seventh growing season following treatment. However unlike in the third growing season, total herbaceous production on silty-clay subsoil significantly exceeded that on loam or gravelly-clay subsoils (Table 4). Herbaceous production declined more slowly with time on the finer textured

Table 3. Subsoil texture influence on shrub density and crown cover.

Year following Treatment	Subsoil Texture				
	loam	gravelly-clay	silt	silty-clay	clay
Density	(shrus/ha)				
First	15,420b	27,634a	21,889ab	20,395ab	19,528ab
Third	12,801b	18,555a	15,675ab	14,603ab	13,153ab
Seventh	13,904	14,158	18,221	13,140	11,535
Crown Cover:	(m^2/ha)				
First	3,557	7,343	6,072	5,449	5,987
Third	4,906	9,183	8,879	6,993	6,145
Seventh	11,651	9,880	14,791	9,439	8,184

Means in the same row followed by a different letter are significantly different at the 0.05 level; absence of letters within rows indicates no significant differences.

Table 4. Subsoil texture influence on herbaceous production seven growing seasons following treatment.

	Subsoil Texture				
	loam	gravelly-clay	silt	silty-clay	clay
	(kg/ha)				
Bluestems	lb	4b	26ab	131a	43ab
Panicums	7	6	4	35	74
Paspalums	0	0	T	T	4
Uniolas	71a	28b	54ab	109a	11b
Other Grasses	2	8	2	3	11
Rushes	T	T	2	1	19
Sedges	0b	Tb	2ab	10a	lab
Composites	lb	7b	7b	66a	55ab
Legumes	1	2	10	7	4
Other Forbs	1	6	6	21	22
Total Herbage	83b	61b	113ab	383a	243ab

Means in the same row followed by a different letter are significantly different at the 0.05 level; absence of letters within rows indicates no significant differences.
T = trace, less than 0.5 kg/ha.

subsoils. Seven years after treatment bluestems, sedges and composites were more productive on silty-clay than on loam or gravelly-clay subsoils. Pretreatment estimates of production were also greater on silty soils (Wolters et al. 1977). Uniolas were the only herbage group with maximum production on loam subsoil 7 years after site preparation. However, tremendous variation in uniola production on silty-clay subsoil may have obscured true subsoil texture effects. Uniolas were the most productive herbaceous plant group prior to treatment (Wolters et al. 1977). Typically, we would expect longleaf uniola and spike uniola to dominate in greatest proportion on the most heavily shaded sites (Wolters 1974), such as silt and loam subsoils where shrub crown cover was 50% greater (13,221 vs. 9,168 m^2/ha) though not significantly different than on other soils.

The influence of subsoil texture on herbaceous plant production was inconsistent and varied with time and species group. Schuster (1967) in eastern Texas also reported that herbaceous plant production was not closely associated with edaphic factors. Depth of the A horizon and the amounts of silt and clay in the A horizon and B horizon accounted for only a small proportion of the variation in herbaceous plant production. However, midstory and overstory cover explained a larger proportion of the variation.

Seven growing seasons following treatment, shrub density averaged 14,192 plants per ha and mean crown cover was 10,789 m^2/ha, neither of which were significantly influenced by subsoil texture. Shrub crown cover was similar to pretreatment estimates (Wolters et al. 1977). The density of shrubs was significantly greater on gravelly-clay than on loam the first and third growing seasons after treatment. However, because of the progressive decline in number of shrubs with time, density was similar on all subsoil textures 7 years after treatment. Overall post-treatment shrub density was nearly double the pretreatment estimate (Wolters et al. 1977). Haywood and Burton (1990) reported a significantly greater density of pines at age 12 on silty-clay than on gravelly-clay subsoils. We found an inverse relationship between loblolly pine density at age 12 and shrub crown cover 7 growing seasons after site preparation. Pine density was greatest and shrub crown cover was minimal on silty-clay and clay subsoils, whereas shrub crown cover was greatest and pine density was low on silt and loam subsoils. Herbaceous production, 7 years after treatment, was greatest on subsoils with minimal shrub crown cover and production generally declined with increased shrub crown

Table 5. Site-preparation method influence on herbaceous production the first growing season following treatment.

	Site-Prenaration Method						
	Burn-inject	Chop-burn	Chop-disk	Double-chop	Shear-bnrn	Shear-windrow	Shear-disk
	(kg/ha)						
Bluestems	194	226	50	47	110	53	13
Panicums	93	152	121	96	176	147	198
Paspalums	T	11	19	37	43	33	9
Uniolas	401	55	29	17	210	26	7
Other Grasses	33	1.55	128	104	235	131	194
Rushes	T	11	22	13	26	24	49
Sedges	40	55	48	42	46	40	54
Composites	846	1,751	2,110	1,700	963	987	1,113
Legumes	19	41	27	28	64	26	21
Other Forbs	146	204	248	296	308	476	451
Total herbage	1,772	2,661	2,802	2,380	2,181	1,943	2,109

Means in the same row followed by a different letter are significantly different at the 0.05 level; absence of letters within rows indicates no significant differences.
T = trace, less than 0.5 kg/ha.

Table 6. Site-preparation method influence on herbage production the third growing season following treatment.

	Site-Preparation Method						
	Bnrn-inject	Chop-bum	Chop-disk	Double-chop	Shear-burn	Shear-windrow	Shear-disk
	(kg/ha)						
Bluestems	457	551	620	666	466	573	516
Panicums	198	331	315	454	383	468	674
Paspalums	17	50	25	43	123	85	54
Uniolas	611	186	99	133	111	160	75
Other Grasses	24	39	48	53	106	54	67
Rushes	12	18	16	56	72	86	106
Sedges	54	76	75	69	73	80	89
Composites	173c	461ab	597a	466ab	473ab	300b	472ab
Legumes	31	217	174	159	78	130	140
Other Forbs	85	123	229	258	207	246	210
Total Herbage	1,662	2,052	2,198	2,357	2,092	2,182	2,403

Means in the same row followed by a different letter are significantly different at the 0.05 level; absence of letters within rows indicates no significant differences.

cover. Similar findings were reported in Georgia by Halls et al. (1956). Wolters et al. (1982) theorized that shrub and hardwood crown cover could influence herbaceous plant production equally or to a greater extent than pine basal area or site quality. Shrubs and hardwood trees sprout prolifically after thinning the overstory or burning and soon appear to limit herbaceous production. Schuster and Halls (1963) and Blair (1968) reported similar findings in eastern Texas.

Site Preparation Effects

Site preparation methods did not influence production of any herbaceous plant group the first growing season following treatment, although production ranged from about 1,772 to 2,802 kg/ha (Table 5). Composites were the most abundant herbaceous group, comprising 45 to 75% of the total aboveground herbaceous production. Other forbs made up 8 to 25% of the total herbaceous group the first growing season after treatment. All grasses combined produced less than 25% of the total herbaceous biomass the first year after treatment. Early seral species such as annual threeawns, violet crabgrass, shaggy crabgrass, spreading panicum, and gaping panicum were the most common grass species on the highly disturbed chop-disk, double-chop, and shear treatments. Broomsedge and slender bluestem were generally the most abundant grasses the first year after site preparation where surface soil disturbance was slight, as witb the bum-inject and chop-bum methods.

Total herbaceous production remained fairly constant from the first to the third growing season following site preparation (Table 6). Composites were the only herbaceous plant group significantly influenced by site-preparation method 3 growing seasons after treatment. Composite production was least on the bum-inject treated plots where surface soil disturbance was minimal and generally greatest on the highly disturbed chop and shear treated plots. Tremendous within-treatment variation, particularly on the chop-bum and chop-disk treated plots, likely masked some composite production treatment differences.

The abundance and importance of herbaceous plant groups shifted substantially from the first to third growing season following treatment. Composites, other forbs and other grasses declined by over 50% on all treatments from the first to the thiid growing seasons primarily because of the reduction in early seral species such as rough buttonweed, annual horseweed, bitter sneezeweed, and annual threeawns. Other herbaceous groups such as bluestems, panicums, paspalums, uniolas, rushes, sedges, and legumes (consisting primarily of long-lived perennial species) generally increased 2 to 4-fold from the first to the third year after treatment. Species composition within herbaceous plant groups remained fairly constant. Schultz (1976) reported a 10-fold increase in panicums 2 years after burn+disk or burn+disk+bed treatments in northern Florida. However, those treatments significantly reduced production of Curtiss dropseed (*Sporobolus curtissii* (Vasey) Small).

Shrub density was significantly greater the first and third growing seasons following the chop-burn treatment than after the shear-disk treatment (Table 7). Shrub density was similar following other site-preparation methods. Shrub crown cover was not influenced by the site-preparation method but crown cover tended to be greatest all years following the bum-inject and chop-bum treatments and least following the shear-disk treatment. Shrub crown cover development was intermediate following other site-preparation methods.

Total aboveground herbaceous plant production declined substantially 7 growing seasons following site preparation to an average of less than 180 kg/ha across all treatments. Production ranged from 95 to 425 kg/ha, but no significant residual treatment effects on production of either individual herbaceous groups or total herbaceous biomass were detected. Uniolas were the most abundant herbaceous group regardless of site-preparation method, but their production ranged only from about 30 to 80 kg/ha. Bluestems were the next most abundant herbaceous group 7 growing seasons after treatment with an average yield of about 40 kg/ha. The production of other herbaceous groups was substantially less.

Our findings generally agree with Tiarks and Haywood (1986), who reported a significant increase in dry weight of herbaceous plant material through the fourth year regardless of site-preparation treatment. They also reported a substantial decline in herbaceous production by the sixth year just as we found 7 growing seasons after treatment. In fact, we found herbaceous plant production and composition 7 years after site preparation to be quite

Table 7. Site-preparation method influence on shrub density and crown cover.

	Site-Preparation Method						
	Burn-inject	Chop-bum	Chop-disk	Double-chop	Shear-bum	Shear-windrow	Shear-disk
Density	(shrubs/ha)						
First	25,557ab	30,433a	17,856ab	18,649ab	21,701ab	20,489ab	13,163b
Third	18,147ab	19,864a	13,338ab	15,279ab	14,190ab	13,724ab	11,557b
Seventh	14,161	13,340	13,625	15,136	13,165	16,524	13,415
Crown Cover:	(m²/ha)						
First	[illegible]	[illegible]	4,744	4,547	5,798	4,876	2,344
Third	11,710	12,731	5,861	6,781	6,837	5,483	3,695
Seventh	9,418	11,238	10,343	10,099	9,091	13,944	8,460

Means in the same row followed by a different letter are significantly different at the 0.05 level: absence of letters within rows indicates no significant differences.

similar to pretreatment production levels reported by Wolters et al. (1977). Increased interception of sunlight by the developing woody plant (shrubs plus pine trees) canopy, accumulation of litter on the forest floor and increasing root competition for site resources very likely produced environmental conditions increasingly less suitable for herbaceous production.

Fertilization Effects

Phosphorus fertilization significantly increased the production of rushes, composites, legumes, and total aboveground herbaceous biomass the first growing season following treatment (Table 8). Three growing seasons after fertilization, production of composites, legumes, and total herbaceous biomass was still greater on the fertilized than on the unfertilized subplots. Invasive early seral plant species such as annual horseweed, dogfennel, daisy fleabane Muhl.), bitter sneezeweed *(Helenium amarum* (Raf.) Rock), fragrant cudweed *(Gnaphalium obtusifolium* L.), and purple cudweed *(Gamochaeta purpurea* L. Cabrera) increased in proportion rapidly the first year after treatment, with their response being greatest on fertilized subplots. Annual and perennial composites declined substantially from the first to the third growing seasons after treatment but were still common on both the fertilized and unfertilized areas. Legumes such as arrow crotalaria *(Crotalaria sagittalis* L.), showy partridgepea *(Cassia fasciculata* Michx.), and Virginia tephrosia *(Tephrosia virginiana* (L.) Pers.) responded rapidly to phosphorus fertilization and the carryover effect enhanced legume production for at least 3 years following application.

Table 8. Herhaceous biomass response to phosphorus fertiliition.

	Growing Season following Treatment					
	First		Third		Seventh	
	Phosphorus Application (kg/ha)					
	0	73	0	73	0	73
	(kg/ha)					
Bluestems	105	90	419	695	55a	27b
Panicums	141	143	443	374	35	16
Paspalums	21	24	61	56	1	T
Uniolas	86	112	169	201	56	54
Other Grasses	147	140	58	56	8a	3b
Rushes	13b	29a	49	57	8	2
Sedges	41	52	68	81	3a	2b
Composites	1,170b	1,556a	368b	486a	31	22
Legumes	21b	45a	80b	192a	6	4
Other Forbs	281	336	202	182	13	9
Total Herbage	2,026b	2,527a	1,917b	2,380a	216a	139b

Means in the same row and growing season followed by a different letter are significantly different at the 0.05 level; absence of letters within rows indicates no significant differences.
T = trace, less than 0.5 kg/ha.

By 7 growing seasons following treatment, production of bluestems, other grasses, sedges, and total herbaceous biomass was greater on unfertilized subplots. Wolters and Schmidtling (1975) also reported that broomsedge, little bluestem, and some panicums were more productive 12 years after cultivation alone than with cultivation plus fertilization. Only common carpetgrass *(Axonopus affinis* Chase), an introduced low-growing stoloniferous plant, produced more biomass 12 years after cultivation plus fertilization than with fertilization alone. Our findings suggest that the herbaceous growth benefits from phosphorus fertilization had become lost by 7 years after treatment. Interspecific competition with associated trees and shrubs likely contributed to reduced herbaceous plant production on the fertilized subplots. Phosphorus fertilization significantly increased shrub crown cover on some subsoils 3 years after application and planted loblolly pine d.b.h and volume at age 12 (Haywood and Burton 1990), although fertilizer effects on shrub density and crown cover were not apparent 7 years after application. Similar to our findings with phosphorus, Tiarks and Haywood (1986) reported that a single application of nitrogen, phosphorus, and potassium increased herbaceous production for 4 growing seasons before declining to control levels.

Interactions

The first growing season following treatment, the influence of site-preparation method on both paspalums and other forbs varied significantly by subsoil texture. Other forbs were also influenced by subsoil texture and phosphorus fertilization. Paspalum production was greater on clay subsoil following double-chop than on all other subsoil texture and site-preparation method combinations except shear-bum on the clay subsoil (Fig. 1). On these 2 clay sites, production ranged from 192 to 271 kg/ha. Paspalum production on the shear-bum treated clay subsoil was not greater than on the shear-windrow treated clay subsoil or the chop-disk treated silty-clay subsoil. Production of paspalums was generally less than 40 kg/ha on all other site-preparation method and subsoil texture combinations. Paspalum production was consistently low on all subsoils the first year following the bum-inject treatment.

Vaseygrass *(Paspalum urvillei* Steud.), brownseed paspalum *(Paspalum plicatulum* Michx.), roundseed paspalum *(Paspalum circulare* (Nash) Poir.), dallisgrass *(Paspalum dilatatum* Poir.), and Florida paspalum *(Paspalum floridanum* Michx. *var. floridanum)* were the most common paspalums on the study plots. However, fringeleaf paspalum *(Paspalum setaceum* var. *ciliatifolium* (Michx.) Vasey) and hurrahgrass *(Paspalum seteceum var. muhlenbergii* (Nash) Banks) increased in greater proportion on clay subsoils following the double-chop and shear-bum treatments.

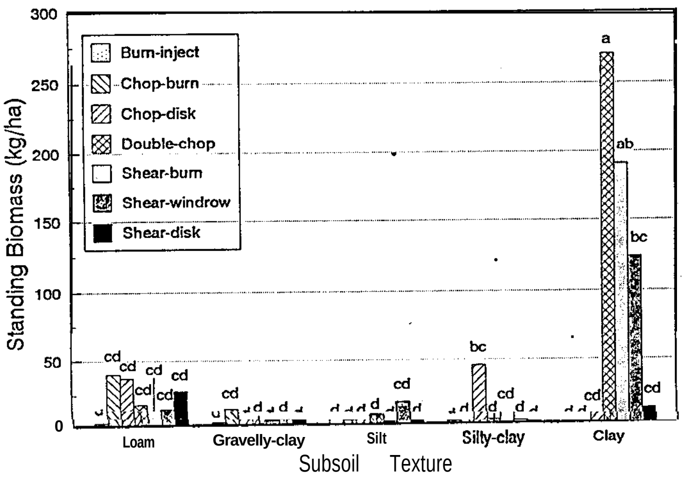

Fig. 1. Paspalum production response to site-preparation method and subsoil texture following the first post-treatment growing season. Means associated with the same letter are not significantly diierent at the 0.05 level.

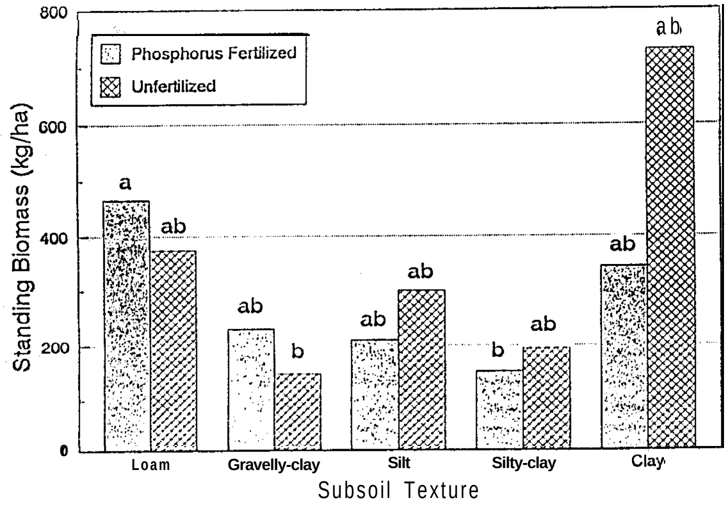

Fig. 3. Production response of other forbs to phosphorus fertilization and subsoil texture following the first post-treatment growing season. Means associated with the same letter are not significantly diierent at the 0.05 level.

Other forbs were most productive on clay subsoil the first growing season following the shear-windrow and shear-disk treatments, although other forbs produced similarly on the double-chop and shear-bum treated clay and loam subsoils after the chop-burn, chop-disk, shear-bum, and shear-windrow treatments (Fig. 2). The method of site preparation appeared to have little influence upon other forb production on silt, gravelly-clay and silty-clay subsoils. Production of other forbs, similar to paspalums, was low following the bum-inject treatment, particularly on gravelly-clay and silty-clay subsoils. Rough buttonweed *(Diodiu teres* Walt.) and woolly croton *(Croton capitatus var. capitatus* Michx.) were the most common other forb species on treatments resulting in the highest soil disturbance, but occurred infrequently on the burn-inject treatment the first growing season following treatment. Soil disturbance caused by mechanical site-preparation treatments apparently enhanced production of paspalums and other forbs the first year after treatment by stimulating growth of early seral species.

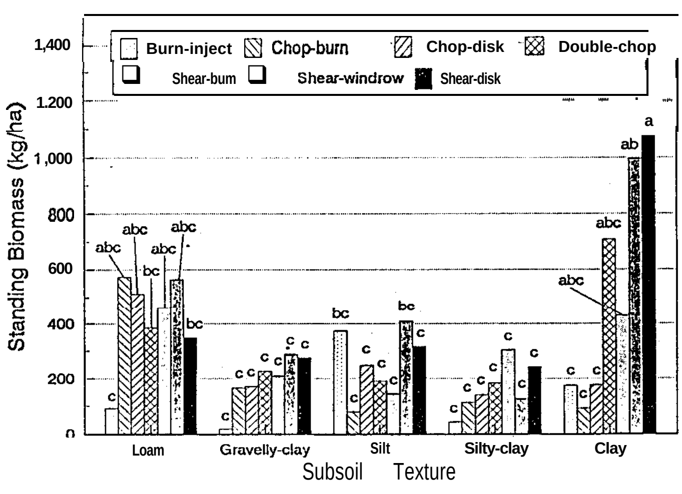

Fig. 2. Production response of other forbs to site-preparation method and subsoil texture following the first post-treatment growing season. Means associated with the same letter are not significantly different at the 0.05 level.

Other forbs were also influenced by subsoil texture and phosphorus fertilizer the first year following treatment (Fig. 3). Other forb production was significantly greater on fertilized loam subsoil than on fertilized silty-clay or unfertilized gravelly-clay subsoils. Because of heterogeneous variance, production of other forbs was similar on all other subsoils with or without phosphorus fertilization.

Summary

Although production of several herbaceous plant groups was influenced by subsoil texture the first growing season following treatment, invasive early seral and annual composites were the most common species on all subsoils. Annual composites were replaced by perennial grasses 3 growing seasons after treatment. Total aboveground herbaceous biomass production increased 24 to 35-fold over pretreatment levels the first year after site preparation, but method of site preparation did not influence production of any herbaceous plant group. Total herbaceous production remained fairly constant from the first to third post-treatment year, although some shifts occurred in the importance of herbaceous plant groups. Shrub density was greatest on the chop-burn treatment and least on the shear-disk treatment the first and third growing seasons following treatment. A similar trend was observed for shrub crown cover. An inverse relationship was apparent between total herbaceous plant production and both shrub density and crown cover during the first few years after treatment. Seven years after treatment, herbaceous plant production and composition were similar to pretreatment estimates and shrub density and crown cover were similar on all site-preparation treatments. Crown cover was also similar to pretreatment estimates. Phosphorus fertilization increased the production of composites, legumes and total aboveground herbaceous biomass the first and third growing seasons following application.

However 7 years after application, production of bluestems, other grasses, sedges, and total herbaceous biomass was greater on unfertilized than on fertilized areas. Site preparation and fertilization increased total herbaceous plant production and shrub density on a'' subsoil textures during the first and third growing seasons fo. ,wing treatment. However, shrub density, crown cover, and total herbaceous plant production declined to near pretreatment levels 7 years after treatment.

Conclusion

Site preparation and fertilizer application are principally intended to provide a window of opportunity for regeneration and growth of pine overstories in these Coastal Plain ecosystems. Across the range of soil types present, these methods also provided substantial short-term gains in understory plant biomass. Although this increase is primarily represented in the first post-treatment year by larger numbers of early seral species and annual composites, these are largely replaced with perennial grass by the third growing season following treatment. Such rapid successional change is indicative of the resilience of these forest ecosystems following disturbance. While certain site preparation methods reduced shrub density and crown cover more effectively than others, the initial increase in understory herbaceous biomass could not be sustained as shrub redevelopment ensued. Initial gains in understory plant production resulting from fertilization also disappeared over time. The supplemental phosphorus was quite likely rapidly assimilated from these phosphorus-poor soils and immobilized within plant tissue, resulting in progressively slower rates of phosphorus turnover and declining rates of biomass production. The absence of differences among treatments by the seventh post-treatment growing season indicates an overall long-term similarity in the degree of disturbance caused by application of each technique in this ecosystem. These management methods may have caused only short-term plant species displacements, which could be followed by a relatively rapid recovery.

Literature Cited

Blair, R.M. 1968. Keep forage low to improve deer habitat. Forest Farmer 27:8-9 and 22-23.

Britt, J.R., R.J. Mitchell, B.R. Zutter, D.B. South, D.H. Gjerstad, and J.F.Dickson. 1991. The influence of herbaceous weed control and seedling diameter on six years of loblolly pine growth: a classical growth analysis approach. Forest Sci. 37:655-667.

Cain, M.D. 1985. Long-term impact of hardwood control treatments in mature pine stands. USDA Forest Serv. Southern Forest Exp. Sta. Res. Pap. SO-214. New Orleans, La. 8 pp.

Dunnett, C.W. 1980. Pair-wise multiple comparisons in the unequal variance case. J. Amer. Stat. Assoc. 75(372):796-800.

Grano, C.X. 1970. Small hardwoods reduce growth of pine overstory. USDA Forest Serv. Southern Forest Exp. Sta. Res. Pap. SO-55. New Orleans, La. 8 pp.

Grelen, H.E. and R.H. Hughes. 1984. Common herbaceous plants of southern forest range. USDA Forest Serv. Southern Forest Exp. Sta. Res. Pap. SO-210. New Orleans, La. 147 pp.

Halls, L.K., O.M. Hale, and B.L. Southweli. 1956. Grazing capacity of wiregrass-pine ranges of Georgia. Georgia Agr. Exp. Sta. Tech. Bull. 2, 38 pp.

Haywood, J.D. and J.D. Burton. 1990. Phosphorus fertilizer, soils and site-preparation influence loblolly pine productivity. New Forest 3:275-287.

Haywood, J.D., R.E. Thii, and J.D. Burton. 1981. Intensive site preparation affects loblolly pine growth on upland sites. Proc. of the Amer. Soc. of Agric. Engineering. Symposium on Engineering Systems for Forest Regeneration, pp. 224-23 1.

Kelsey, H.P. and W.A. Dayton. 1942. Standardized plant names. 2nd. cd. J. Horace McFarland Company, Harrisburg, Penn. 675 pp.

Mangold, R.D., R.J. Moulton, and J.D. Snellgrove. 1992. Tree planting in the United States 1991. USDA Forest Serv., State and Private Forestry, Cooperative Forestry, Washington, D.C. 14 pp.

Mann, W.F. 1979. Loblolly-shortleaf pine. *In*: Silvicultnral Systems for the major forest types of the United States. Agr. Handb. No. 445. USDA Forest Serv., Washington, DC. pp. 95-98.

Pechanec, J.F. and G.D. Pickford. 1937. A weight estimate method for determination of range or pasture production. J. Amer. Soc. Agron. 29:894-904.

Schultz, R.P. 1976. Environmental change after site preparation and slash pine planting on a flatwoods site. USDA Forest Serv. Southeastern Forest Exp. Sta. Res. Pap. SE-156. Asheville, N.C. 20 pp.

Schuster, J.L. 1967. The relation of under-story vegetation to cutting treatments and habitat factors in an east Texas pine-hardwood type. Southwestern Nat. 12:339-364.

Schuster, J.L. and L.K. Halls. 1963. Timber overstory determines deer forage in shortleaf-loblolly pine-hardwood forests. Proc. Soc. Amer. Foresters - 1962:165-167.

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

Steele, R.G.D. and J.H. Torrie. 1980. Principles and procedures of statistics: a biometrical approach. 2nd. ed. McGraw-Hill Book Co., New York. 633 pp.

Tiarks, A.E. and J.D. Haywood. 19%. ***Pinus taeda*** L. response to fertilization, herbaceous plant control, and woody plant control. Forest Ecology and Manage. 14:103-112.

Trousdell, K.B. 1970. Disking and prescribed burning: sixth-year residual effects on loblolly pine and competing vegetation. USDA Forest Serv. Southeastern Forest Exp. Sta. Res. Note SE-133. Asheville, N.C. 6 pp.

Trousdell, K.B. and O.G. Langdon. 1967. Disking and prescribed burning for loblolly pine regeneration. J. Forestry 65:548-55 1.

USDA Soil Conservation Service. 1982. National list of scientific plant names. Volume 1. USDA Soil Conservation Service TP-159. Washington, D.C. 416 pp.

Williamson, M.J. 1964. Burning does not control young hardwoods on shortleaf pine sites in the Cumberland Plateau. USDA Forest Serv. Central States Forest Exp. Sta. Res. Note CS-19. Columbus, Ohio. 4 pp.

Wolters, G.L. 1974. Longleaf uniola and spike uniola require shade. J. Range Manage. 27:45-47.

Wolters, G.L. and R.C. Schmidtling. 1975. Browse and herbage in intensively managed pine plantations. J. Wildlife Manage. 39:557-562.

Wolters, G.L., A. Martin, and W.P. Clary. 1977. Timber, browse, and herbage on selected loblolly-shortleaf pine-hardwood forest stands. USDA Forest Serv. Southern Forest Exp. Sta. Res. Note SO-223. New Orleans, La. 9 pp.

Wolters, G.L., A. Martin, and H.A. Pearson. 1982. Forage response to overstory reduction on loblolly-shortleaf pine-hardwood forest range. J. Range Manage. 35:443-446.

Wolters, G.L., H.A. Pearson, R.E. Thill, V.C. Baldwin, and A. Martin. 1995. Response of competing vegetation to site preparation on west gulf coastal plain commercial forest land. USDA Forest Serv. Southern Forest Exp. Sta. Gen. Tech. Rep. SO-l 16. New Orleans, La. 8 pp.