GROWTH RESPONSE OF SLASH AND LOBLOLLY PINE PLANTATIONS TO DIFFERENT SITE-PREPARATION TREATMENTS WITH OR WITHOUT POST-PLANT HERBACEOUS WEED CONTROL ON LOWER COASTAL PLAIN SITES OF NORTH FLORIDA

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EXECUTIVE SUMMARY

This document contains results from the PMRC-AUSHC SP-4P study that was initiated in 1994 to evaluate the effects of bedding timing and frequency and pre-plant herbicide applications, with and without first growing season herbicide application for herbaceous weed control, on growth of three slash pine (*Pinus elliottii* Engelm.) plantations and one loblolly pine (*Pinus taeda* L.) plantation on bedded flatwoods sites.

Site preparation treatments included: 1) early bedding alone, 2) early bedding plus banded pre-plant herbicide application, 3) early bedding plus late bedding, 4) late bedding alone, and 5) early bedding plus broadcast pre-plant herbicide application. Each of the five site preparation treatments were tested with and without first growing season banded herbicide applications for herbaceous weed control. Two slash pine installations (Callahan and St. Augustine) on CRIFF D soils, and one slash pine (Perry) and one loblolly pine (Olustee) installation on CRIFF C soils were established. Each installation had a completely randomized block, split-plot design with four replications. Pine growth attributes were assessed through age 11 (slash on CRIFF D), 10 (slash on CRIFF D), 5 (slash on CRIFF C), and 8 years (loblolly on CRIFF C).

Key conclusions are as follows:

1. Site preparation treatment impact on tree growth was significant at each installation.
2. Early bedding plus either broadcast or banded pre-plant herbicide application outperformed bedding only treatments and generally outperformed bedding plus post-plant herbaceous weed control treatments. Single bedding or double bedding alone or in combination with herbaceous weed control did not result in sufficient competition control for optimum pine growth.
3. Broadcast pre-plant herbicide application for woody competition control resulted in better or similar pine growth as banded pre-plant applications, depending on study installation.
    - For slash pine, greater pine growth with broadcast as compared to banded applications occurred at the Callahan and Perry installations. At these locations the broadcast application resulted in very low non-arborescent ground coverage (<10%) on between bed areas during the August following planting. At the St. Augustine installation, slash pine growth was similar for banded and broadcast treatments. At this location, between bed areas had low non-arborescent coverage (<10%) but relatively high herbaceous coverage (~35%).

- For the loblolly pine installation, pine growth was similar for banded and broadcast pre-plant herbicide applications even-though the broadcast treatment was effective at reducing both non-arborescent and herbaceous coverage in the between bed areas.

4. In the absence of pre-plant herbicide application, pine growth following late bedding was similar or better than that with early bedding.
   - For slash pine, on CRIFF D soils, late bedding resulted in similar or greater growth than early bedding. On CRIFF C soils, better growth was observed following late bedding as compared to early bedding.
   - For loblolly pine on CRIFF C soils, there was no significant difference between early and late bedding
5. Double bedding did not consistently improve pine growth or reduce competing vegetation as compared with single bedding treatments.
   - For slash pine on CRIFF D soils, double bedding resulted in greater growth than single bedding at Callahan (poorly drained) but not at St. Augustine (somewhat poorly drained).
   - For slash pine on CRIFF C soils, double bedding resulted in similar growth as late bedding and better growth than early bedding.
   - For loblolly pine on CRIFF C soils, double bedding resulted in similar pine growth as early or late bedding.
6. Growth response to post-plant herbaceous weed control treatment depended on species, soil group and site preparation method.
   - Post-plant herbaceous weed control significantly improved growth for slash pine on CRIFF D soils, but an apparent positive effect was not significant for slash pine on CRIFF C soils.
   - For slash pine, the response observed to herbaceous weed control was generally smaller and less consistent on areas that received pre-plant herbicide applications as compared to areas not chemically site prepared.
   - For loblolly pine on CRIFF C soils, post-plant herbaceous weed control resulted in consistent growth gains across site preparation treatments.
7. Some significant interaction of site-prep × herbaceous weed control treatment was found for average height and DBH for slash pine on CRIFF D soils and loblolly pine on CRIFF C soils, but this interaction was not significant for slash pine on CRIFF C soils or for per-acre basal area and volume regardless of species and soil combination.
8. Good site preparation, including the application of herbicides for competition control, is essential for fast growing slash and loblolly pine plantations in the Flatwoods of northern Florida and southern Georgia.
9. Effective bedding and chemical site preparation reduces the need for post-plant herbicide applications for slash pine on sites similar to those included in this study.

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1. INTRODUCTION

During the past century, land use in the southeastern United States has shifted away from agriculture to intensive timber management, resulting in an increase in the number of managed slash pine (*Pinus elliottii*) and loblolly pine (*Pinus taeda*) plantations. Dependence on southeastern timber resources for meeting the demands for forest products is expected to increase. However, the amount of land used for pine plantations is decreasing due to urban/suburban expansion, environmental concerns and other factors. To meet the increasing demand for wood products from a decreasing wood production land base and to keep a competitive edge, commercial forest landowners frequently apply intensive silvicultural treatments to both enhance stand productivity and reduce rotation length (Martin and Jokela, 2004). These treatments include bedding and woody and herbaceous competition control. Shiver et al. (1990), reporting on an extensive series of study installations by the Plantation Management Research Cooperative (PMRC), concluded that removal of competing vegetation at the time of planting consistently results in dramatic growth response of slash pine. Other studies also indicated that control of both shrub and herbaceous competition results in large early gains in slash and loblolly pine growth in the Lower Coastal Plain of Georgia and north Florida (PMRC, unpublished data).

A second bedding pass, pre-plant and/or post-plant herbicide applications are operationally feasible methods to reduce competing vegetation. Several important questions facing forest managers are: 1) how do slash and loblolly pine plantations respond to different site preparation treatments; and 2) after site preparation herbicide application, is it still necessary to use post-plant herbaceous weed control treatments? Forest landowners and managers need answers to such questions to develop more efficient site preparation and herbaceous weed control prescriptions.

The Post-Bed Vegetation Control Study (SP-4P) was initiated in 1994 in the Lower Coastal Plain of north Florida by the Auburn Silvicultural Herbicide Cooperative to address such questions as posed above. Specific objectives of this study were: (1) to examine pine growth response to a second bedding pass and pre-plant site preparation herbicide application on bedded sites, (2) to compare the effects of banded and broadcast site preparation herbicide applications, (3) to evaluate the effect of post-plant herbaceous weed control following pre-plant site preparation treatments on pine growth, and (4) to evaluate the interaction of site preparation with a post-plant herbaceous weed control treatment. The intent of the study was to provide managers with information on the growth response of slash and loblolly pine plantations to different site preparation treatments with or without post-plant herbaceous weed control.

2. METHOD AND ANALYSIS

This study was installed at four different locations in the Lower Coastal Plain of north Florida. Two slash pine installations were established on the CRIFF D soil group (Fisher and Garbett 1980), one slash pine installation on the CRIFF C group, and one loblolly pine

installation on the CRIFF C group. Characteristics of the four locations are shown in Table 1. Estimates of percent cover for major genera/species in late spring prior to treatment implementation are presented in Table 2.

Table 1. Characteristics of the four installations of the Post-Bed Vegetation Control Study.

Location	Species	Soil Attribute			Planting Date	Measured Age (yrs)
		CRIFF Group	Drainage Class	Diagnostic Horizons		
Callahan, FL	Slash	D	PD	Spodic	12/94	5, 11
St. Augustine, FL	Slash	D	SWP	Spodic	2/96	5, 8, 10
Perry, FL	Slash	C	SWP–PD	Spodic + Argillic	1/99	5
Olustee, FL	Loblolly	C	SWP–PD	Spodic + Argillic	1/97	5, 8

Note: PD – poorly drained; SWP – somewhat poorly drained.

Five combinations of bedding regimes and pre-plant herbicide applications were considered as site preparation treatments: 1) Early bedding only (EB); 2) Early bedding plus banded pre-plant herbicide application (EBaP); 3) Early bedding plus late bedding (Double bedding, DB); 4) Late bedding only (LB); 5) Early bedding plus broadcast pre-plant herbicide treatment (EBrP). The timing of bedding and pre-plant herbicide application for the site preparation treatments are presented in Table 3. Each site preparation treatment was tested with and without banded first year herbaceous weed control. Pre-plant herbicide and post-plant herbaceous weed control treatments are detailed in Table 4.

At each location the experiment was laid out as a completely randomized block split-plot design with four replications. Five site preparation treatments were randomly allocated to five main plots within each of the four blocks. Two post-plant herbaceous weed control (HWC) treatments were randomly arranged to one of two subplots in each main plot.

Standard fertilization treatments were applied to all plots at all locations. The applications were: 1) 200 lbs/acre diammonium phosphate (DAP) at the beginning of third growing season; and 2) 200 lbs/acre DAP plus 300 lbs/acre urea at the beginning of sixth growing season.

Table 2. Percent cover for major genera/species evaluated just before the early bedding (June for Callahan, and May for others) by site. Genera/species with less than 5% cover are not included.

Genera/species	Location/CRIFF Soil			
	Callahan/D	St. Augustine/D	Perry/C	Olustee/C
	…… (% cover) ……			
Non-arborescent species group				
Gallerry (*Ilex glabra*)	45	18	10	43
Saw-palmetto (*Serenoa repens*)	10	5	—	18
Blackberry (*Rubus* spp.)	10	—	—	—
Blueberries (*Vaccinium* spp.)	—	—	—	11
Herbaceous species group				
Bracken fern (*Pteridium* spp.)	13	23	30	—
Low panic grasses (*Dicanthelim* spp.)	7	14	5	30
Tall panic grasses (*Panicum* spp.)	—	—	—	10
Bluestems (*Andropogon* spp.)	—	20	—	—
Sedges (*Carex* spp.)	—	12	—	—
Redroot (*Lachnanthes* spp.)	—	10	—	—
Crabgrass (*Digitaria* spp.)	—	10	—	—
Total weed cover	**55**	**43**	**43**	**70**

Note: Total cover includes all species. All cover estimates are based on the percent of total plot area. They are made separately for each species and can sum to greater than 100% since vegetation may overlap.

A 0.1 acre rectangular measurement plot was centered in each 0.25 acre subplot. Since each site-prep treatment plot contained two subplots, main plots were at least 0.5 acre in size. In each measurement plot, every tree was numbered, tagged and measured for diameter at breast height (DBH) to the nearest 0.1 inch at age 5 and older. For slash pine on CRIFF D soils at Callahan and St. Augustine and loblolly pine on CRIFF C soils at Olustee, every tree in the measurement plot was measured at age 5 for height to the nearest 0.1 foot; after age 5 beginning with the first tree in each measurement plot, every third tree was measured for height to the nearest 0.1 foot. For slash pine on CRIFF C soils, beginning with the first tree in each measurement plot, every third tree was measured for height to the nearest 0.1 foot. Measurements were taken at ages 5 and 11 for slash pine at Callahan; at ages 5, 8 and 10 for slash pine at St. Augustine; at ages 5 and 8 for loblolly pine at Olustee; and at age 5 for slash pine at Perry (Table 1).

Table 3. Timing of site preparation treatments applied on different sites

Location	Treat No.	May	June	August	October	November
Callahan, FL	1		1st bed			
	2		1st bed			Banded pre-plant
	3		1st bed		2nd bed	
	4				1st bed	
	5		1st bed		broadcast pre-plant	
St. Augustine, FL	1	1st bed				
	2	1st bed				Banded pre-plant
	3	1st bed		2nd bed		
	4			1st bed		
	5	1st bed				Broadcast pre-plant
Perry, FL	1	1st bed				
	2	1st bed			Banded pre-plant	
	3	1st bed			2nd bed	
	4				1st bed	
	5	1st bed			broadcast pre-plant	
Olustee, FL	1	1st bed				
	2	1st bed			Banded pre-plant	
	3	1st bed			2nd bed	
	4			1st bed		
	5			1st bed	broadcast pre-plant	

Table 4. Prescriptions of pre-plant herbicide treatment and post-plant herbaceous weed control treatment.

Location	Pre-plant herbicide application	Post-plant weed control treatment
Callahan, FL	2 qts/ac Garlon 4 + 24 oz/ac Accord + 10 oz/ac Arsenal AC + 0.75% Timberland 90; in water for a total spray volume of 20 gal/ac	4 oz/ac Arsenal AC + 2 oz/ac Oust; in water for a total spray volume of 22 gal/ac (5 ft banded)
St. Augustine, FL	2 qts/ac Garlon 4 + 8 oz/ac Accord + 2 oz/ac Escort + 0.1% Kinetic; in water for a total spray volume of 25 gal/ac	4 oz/ac Arsenal AC; in water for a total spray volume of 25 gal/ac (6 ft banded)
Perry, FL	2 qts/ac Garlon 4 + 1 oz/ac Escort + 24 oz/ac Chopper; in water for a total spray volume of 20 gal/ac	2 oz/ac Oust + 32 oz/ac Velpar L; in water for a total spray volume of 20 gal/ac (6 ft banded)
Olustee, FL	2 qts/ac Garlon 4 + 8 oz/ac Arsenal AC + 2 qt/ac Timberland 90; in water for a total spray volume of 31 gal/ac	4 oz/ac Arsenal AC + 2 oz/ac Oust + 19.3 oz/ac Induce; or 10 oz/ac Arsenal AC; or 6 oz/ac Arsenal AC + 19.3 oz/ac Induce; in water for a total spray volume of 31 gal/ac (5 ft banded)

In addition to pine tree measurements, assessments of competing vegetation coverage were completed in June and August following plantation establishment and in August of the second growing season. Percent herbaceous cover and percent non-arborescent cover on beds and in between bed areas were ocularly estimated on sample points within each subplot.

At each location, the model $\ln(H) = b_0 + b_1 DBH^{-1}$ was separately fitted for height measured trees with the same site-prep and subplot treatments. Then, the fitted model was used to predict heights for trees whose total heights were not measured. A tree was considered a dominant tree if its DBH was in the upper 50% of DBHs on the plot. Average height of dominant trees was calculated.

For slash pine, individual tree outside bark cubic foot volumes and green weights were calculated using the following equations from Pienaar et al. (1996):

$$VOB = 0.00456 DBH^{2.0726} HT^{0.8114}$$
$$GWOB = 0.1763 DBH^{1.9604} HT^{0.9761} \quad (1)$$

where VOB is total stem volume outside bark (o.b.) in cubic feet, GWOB is total stem green weight (o.b.) in lbs, DBH is tree diameter at breast height (in), and HT is total tree height (ft).

For loblolly pine, individual tree outside bark cubic foot volumes and green weights were calculated using the following equations from Pienaar et al. (1987):

$$VOB = 0.00145519 DBH^{1.826051} HT^{1.221965}$$
$$GWOB = 0.0740959 DBH^{1.829983} HT^{1.247669} \quad (2)$$

where VOB, GWOB, DBH and HT are as defined in Equation (1).

According to the experimental design, there should be a single planting density at any single location. However, the actual planting density varied from 700 to 1200 trees/acre at the Callahan location and from 600 to 850 trees/acre at the St. Augustine location. The subplots within the same main-plot plots (site preparation treatment plot) had almost the same planting density. Therefore, at these two locations an analysis of covariance (ANCOVA) was conducted using a split-plot model with the initial planting density as a covariate that does not depend on the subplot factor. Federer and Merdith (1992) showed how to include covariates in a split-plot model, and Aldwoth and Hoffman (2002) discussed how to correctly analyze the data with this model. For slash pine and loblolly pine plantations on CRIFF C soils, a standard split-plot model was used to conduct the analysis of variance (ANOVA).

Separate analyses of covariance (ANCOVA) or variance (ANOVA) were conducted for average height, average dominant height, average DBH, per-acre basal area, per-acre volume and per-acre green weight at each measured age and for competing vegetation cover variables for each assessment by each location. First, the following hypotheses were tested: 1) there are no differences among site-prep treatments; 2) there are no differences between post-plant herbaceous weed control treatments; and 3) there are no interactions among post-plant herbaceous weed control treatments and site-prep treatments. If there was no interaction, several comparisons among growth responses to different site-prep treatments were made to rank site-prep treatments; otherwise partitions of site-prep × post-plant weed control interaction were carried out. All the analyses of covariance (ANCOVA) or variance (ANOVA), comparisons and interaction partitions were done using SAS PROC MIXED (Littell et al., 2006).

3. RESULTS

It was found that average dominant height had almost the same trend as average height, and per-acre green weight had the same trend as per-acre volume. Thus, only the results for average height, average DBH, per-acre basal area and volume are reported here. Volume per acre, as an integration of survival and individual tree growth, will be the principal focus of discussion. Tables and figures associated with competing vegetation are located in the Appendix.

3.1. *Slash pine on CRIFF D soils at Callahan, FL*

There were significant differences for average height, average DBH, per-acre basal area and volume among site-prep treatments, and with the exception for average DBH at age 11, between with and without post-plant herbaceous weed control (Table 5). The interaction of site-prep and post-plant herbaceous weed control (HWC) was significant for average height at ages 5 and 11 and for average DBH at age 5. The interaction was not significant for either per-acre basal area or volume at the $\alpha = 0.05$ level.

Basal area and volume growth was greater for the broadcast pre-plant herbicide application than for the banded pre-plant herbicide application. There was no significant difference between double bedding treatment and early bedding plus banded pre-plant herbicide application. The two pass treatments significantly increased basal area and volume, compared with single bedding alone treatments. There was no significant difference between early bedding alone and late bedding alone. Thus, growth on site-prep treatments was ranked as EBrP > EBaP > DB > LB > EB. Volume growth was greatest with the early bedding and broadcast pre-plant herbicide regime (Figure 1).

Table 5. Summary of ANCOVA p-values for average height, average DBH, and per-acre basal area and volume for slash pine on CRIFF D soils at Callahan, FL

Variable	Source	Age 5	Age 11
Average Height	Site-prep	**<0.0001**	**<0.0001**
	HWC	**0.0002**	**<0.0001**
	Site-prep × HWC	**0.0419**	**0.0406**
Average DBH	Site-prep	**<0.0001**	**0.0143**
	HWC	**<0.0001**	0.2614
	Site-prep × HWC	**0.0163**	0.7011
Per-Acre Basal Area	Site-prep	<**0.0001**	**0.0052**
	HWC	**0.0011**	**0.0242**
	Site-prep × HWC	0.0877	0.1644
Per-Acre Volume	Site-prep	**<0.0001**	**0.0006**
	HWC	**0.0007**	**0.0038**
	Site-prep × HWC	0.1172	0.1154

For volume growth, the post-plant herbaceous weed control showed a larger impact when implemented with bedding alone and bedding plus banded pre-plant herbicide regimes than when implemented following double bedding or early bedding followed by broadcast herbicide application. The "best" treatment in terms of volume growth was the early bedding and broadcast pre-plant herbicide site preparation without post-plant herbaceous weed control.

Vegetation assessments show that site preparation and post-plant herbaceous weed control significantly reduced competing vegetation cover. During August of the first growing season, non-arborescent (woody brush) coverage on beds ranged from about 30% on early bedding alone plots to less than 5% in areas receiving pre-plant herbicide treatments. Herbaceous cover, while significantly reduced by the site preparation treatments, was most strongly controlled by post-plant herbaceous weed control. Herbaceous cover on beds ranged from about 65% with bedding alone to about 20% on areas early bedded with pre-plant herbicide and post-plant herbaceous weed control. On interbed areas, the broadcast pre-plant herbicide application markedly reduced both non-arborescent (>5%) and herbaceous cover (20%).

3.2. *Slash pine on CRIFF D soils at St. Augustine, FL*

Site preparation treatment was significant for average height and DBH, and per-acre basal area and volume at all ages (Table 6). HWC treatment was significant for average height at all ages and significant for average DBH, per-acre basal area and volume at early ages. There was no significant site-prep × HWC interaction.

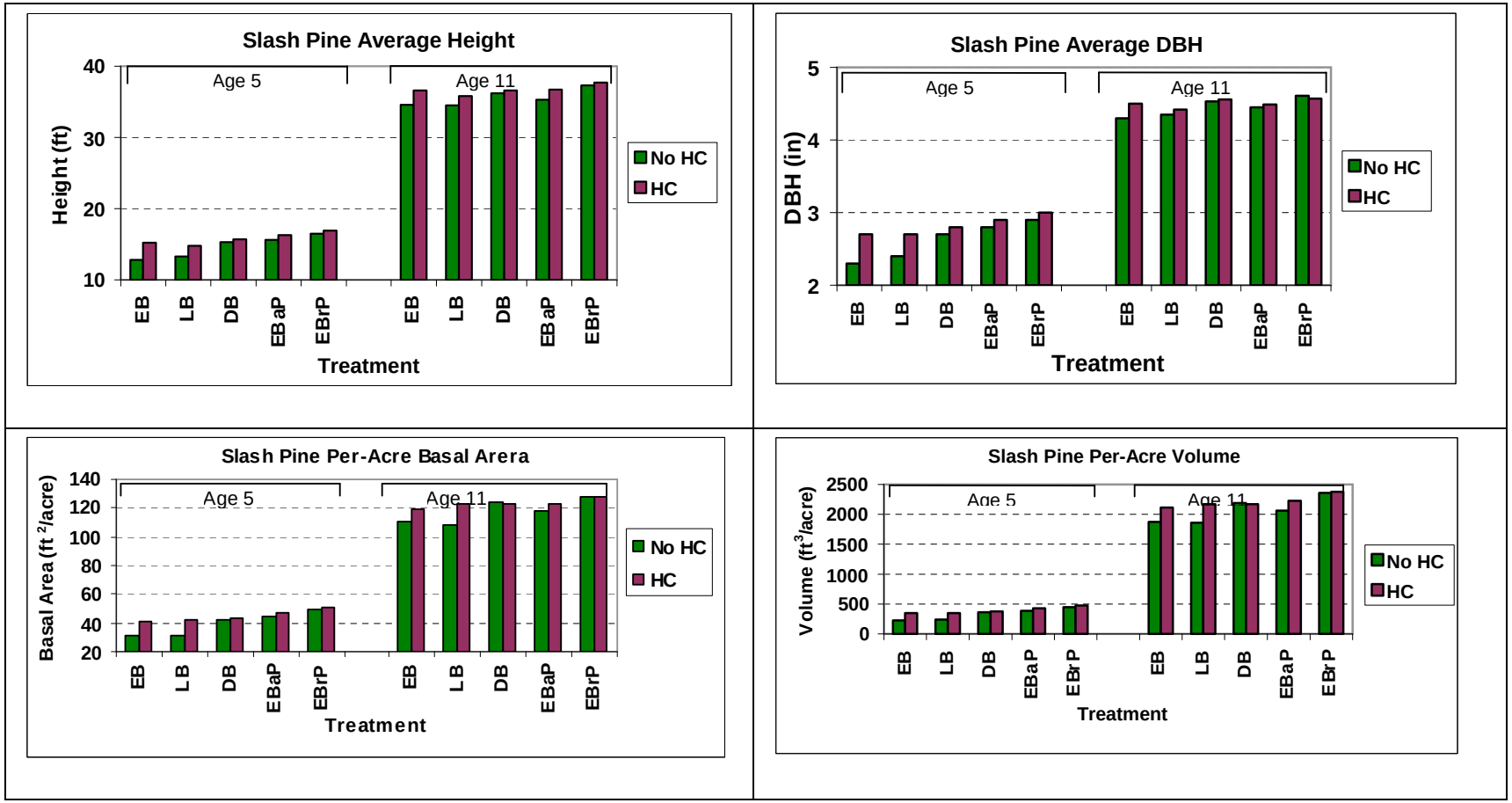

Figure 1. **Average height, DBH, basal area and volume by site-prep and post-herbaceous weed control treatments for slash pine on CRIFF D soils near Callahan, FL. (EB = early bedding; LB = late bedding; DB = double bedding; EBaP = early bedding and banded pre-plant herbicide; EBrP = early bedding and broadcast pre-plant herbicide; HC = post-plant herbaceous weed control).**

Table 6. Summary of ANCOVA p-values for average height, average DBH, and per-acre basal area and volume for slash pine on CRIFF D soils at St. Augustine, FL

Variable	Source	Age 5	Age 8	Age 10
Average Height	Site-prep	**<0.0001**	**<0.0001**	**<0.0001**
	HWC	**0.0044**	**0.0031**	**0.0127**
	Site-prep × HWC	0.5773	0.6809	0.5492
Average DBH	Site-prep	**<0.0001**	**0.0173**	**0.0012**
	HWC	**0.0112**	0.0886	0.4782
	Site-prep × HWC	0.4084	0.6178	0.1731
Per-Acre Basal Area	Site-prep	**<0.0001**	**0.0003**	**0.0021**
	HWC	**0.0513**	0.0776	0.4101
	Site-prep × HWC	0.4745	0.5901	0.3503
Per-Acre Volume	Site-prep	**<0.0001**	**<0.0001**	**0.0005**
	HWC	**0.0284**	**0.0266**	0.1121
	Site-prep × HWC	0.5106	0.6440	0.2782

The site preparation treatments of late bedding and early bedding combined with pre-planted herbicide applied either banded or broadcast provided similar high volume growth relative to the other site preparation regimes (Figure 2). Early bedding alone resulted in particularly low volume growth. Site-prep treatment ranking for volume/acre was EBaP > EBrP > LB > DB > EB.

There appeared to be a positive effect of post-plant herbaceous weed control on pine growth on the late bedding and double bedding plots. However, at age 10, growth gains from post-plant herbicide applications were significant only for mean height.

The site preparation and herbaceous weed control treatments significantly reduced first growing season August competing vegetation cover. Non-arborescent cover on beds ranged from 25% to <5% and between beds ranged from 55% to 5%; the lower coverage located on areas receiving pre-plant herbicide application. Late bedded areas, good performers in pine growth, had relatively low non-arborescent cover (10%) on plots with post-plant herbaceous weed control.

Post-plant herbicide applications reduced herbaceous cover for all site preparation regimes. However, herbaceous cover remained relatively high, greater than 35%, on areas that were only bedded. In contrast, herbaceous cover was 10% or less on areas receiving pre-plant herbicide application.

Figure 2. **Average height, average DBH, basal area and volume by site-prep and post-herbaceous weed control treatments for slash pine on CRIFF D soils near St. Augustine, FL. (EB = early bedding; LB = late bedding; DB = double bedding; EBaP = early bedding and banded pre-plant herbicide; EBrP = early bedding and broadcast pre-plant herbicide; HC = post-plant herbaceous weed control).**

3.3. *Slash pine on CRIFF C soils at Perry, FL*

Site-prep treatment significantly affected average height and DBH, and per-acre basal area and volume at age 5 (Table 7). HWC treatment and its interaction with site-prep treatment were not significant.

Table 7. Summary of ANOVA p-values for average height, average DBH, and per-acre basal area and volume at age 5 for slash pine on CRIFF C soils at Perry, FL

Source	Average Height	Average DBH	Per-acre basal area	Per-acre volume
Site-prep	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**
HWC	0.1643	0.8598	0.3091	0.2191
Site-prep × HWC	0.5924	0.7520	0.8220	0.6993

Separation of site-prep treatments showed clear and identical patterns for all response variables (Figure 3). Early bedding plus pre-plant herbicide application (EBrP and EBaP) significantly increased growth more than bedding alone treatments (EB, LB and DB). Broadcast pre-plant herbicide application (EBrP) resulted in greater growth than banded pre-plant herbicide application (EBaP). There was no significant difference among early bedding alone (EB), late bedding alone (LB), and double bedding (DB), except that late bedding alone and double bedding resulted in significantly greater height growth than early bedding alone. The order of growth on site-prep treatments was EBrP > EBaP > LB > DB > EB.

The large slash pine growth gains on areas with pre-plant herbicide application are probably due to effective control of both non-arborescent and herbaceous competition. During August of the first growing season, herbaceous cover was less than 5% in areas with pre-plant herbicide and no post-plant treatment was necessary. In contrast herbaceous coverage was moderately reduced (from about 45% to about 30%) by post-plant herbicide application where only bedding was done at site preparation.

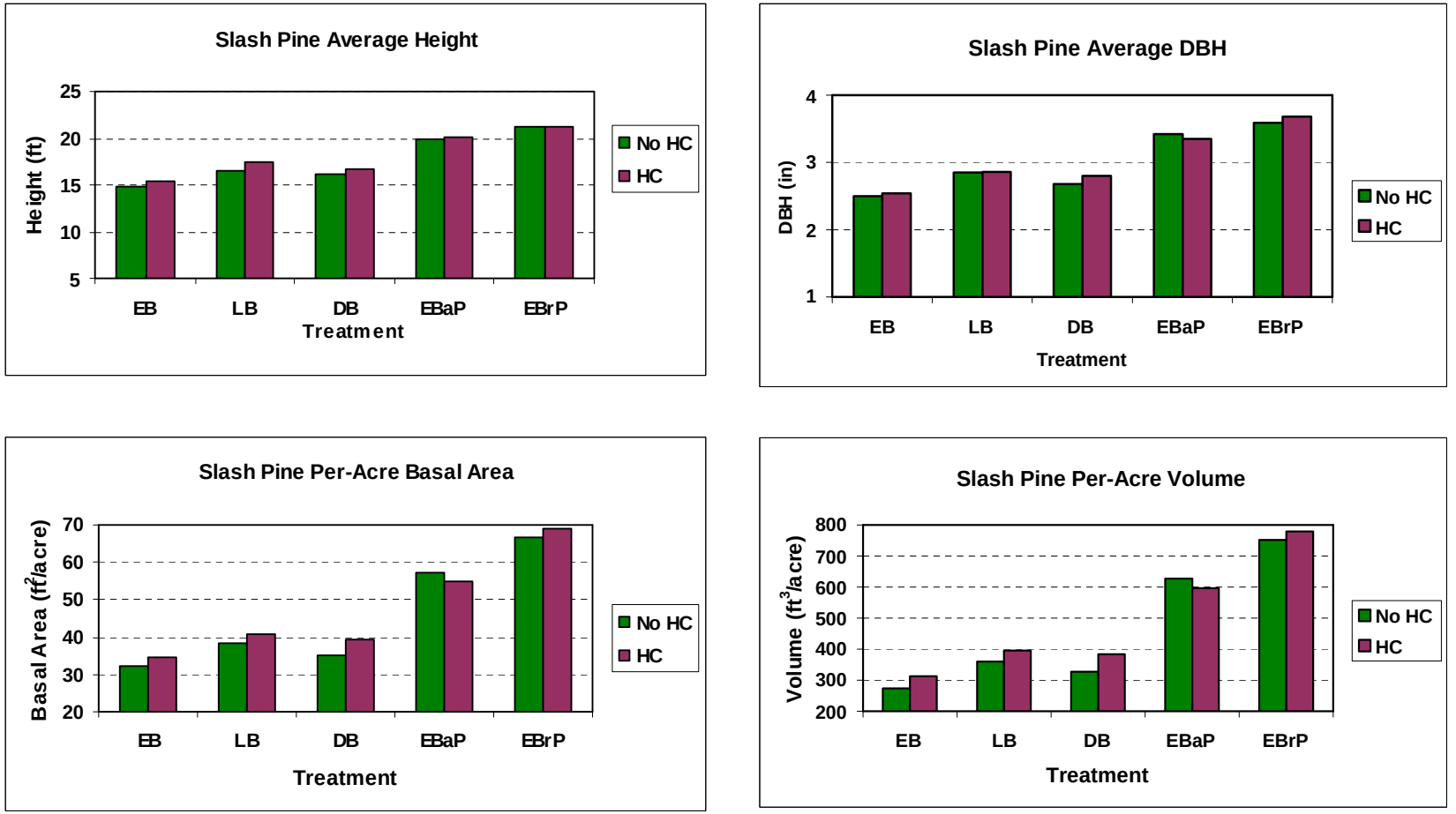

Figure 3. **Average height, average DBH, basal area and volume at age 5 by site-prep and post-herbaceous weed control treatments for slash pine on CRIFF C soils near Perry, FL. (EB = early bedding; LB = late bedding; DB = double bedding; EBaP = early bedding and banded pre-plant herbicide; EBrP = early bedding and broadcast pre-plant herbicide; HC = post-plant herbaceous weed control).**

3.4. Loblolly pine on CRIFF C soils at Olustee, FL

Results of ANOVA for average height and DBH, and per-acre basal area and volume showed that there were significant differences in site-prep and HWC treatments (Table 8). The interaction of site-prep and HWC treatments was significant for average height at ages 5 and 8 and average DBH at age 5. The interaction was not significant for average DBH at age 5, or for per-acre basal area and volume at ages 5 and 8.

Table 8. Summary of ANOVA p-values for average height, average DBH, and per-acre basal area and volume for loblolly pine on CRIFF C soils at Olustee, FL

Variable	Source	Age 5	Age 8
Average Height	Site-prep	<**0.0001**	**0.0005**
	HWC	**<0.0001**	<**0.0001**
	Site-prep × HWC	**0.0331**	**0.0016**
Average DBH	Site-prep	**0.0001**	**0.0019**
	HWC	<**0.0001**	**0.0003**
	Site-prep × HWC	**0.0446**	0.5725
Per-Acre Basal Area	Site-prep	<**0.0001**	**<0.0001**
	HWC	**<0.0001**	**0.0007**
	Site-prep × HWC	0.1704	0.6262
Per-Acre Volume	Site-prep	<**0.0001**	**<0.0001**
	HWC	**<0.0001**	**<0.0001**
	Site-prep × HWC	0.1183	0.2403

Site preparation treatments including early bedding and pre-plant herbicide, applied with banded or broadcast, resulted in the best growth (Figure 4). The pre-plant herbicide applications with early bedding were superior in growth to bedding only treatments (EB, LB and DB). The three bedding only treatments had similar growth.

Volume growth increases due to post-plant herbaceous weed control were fairly consistent across site-prep treatments. Post-plant herbaceous weed control provided the most benefit on late bedding alone (LB) and early bedding plus pre-plant herbicide applications (EBrP and EBaP) treatments.

The combination of pre-plant herbicide treatment and post-plant herbaceous weed control resulted in excellent weed control. This combination resulted in 5% or less coverage of either non-arborescent or herbaceous competition during August of the first growing season. With only the pre-plant herbicide application, non-arborescent cover was less than 5% but herbaceous cover was about 15%. In contrast, bedding only treatments had non-arborescent cover greater than 20% and herbaceous cover greater than 30%. Late bedding and post-plant herbicide application resulted in competing vegetation levels much lower than other treatments that did not include pre-plant herbicide application.

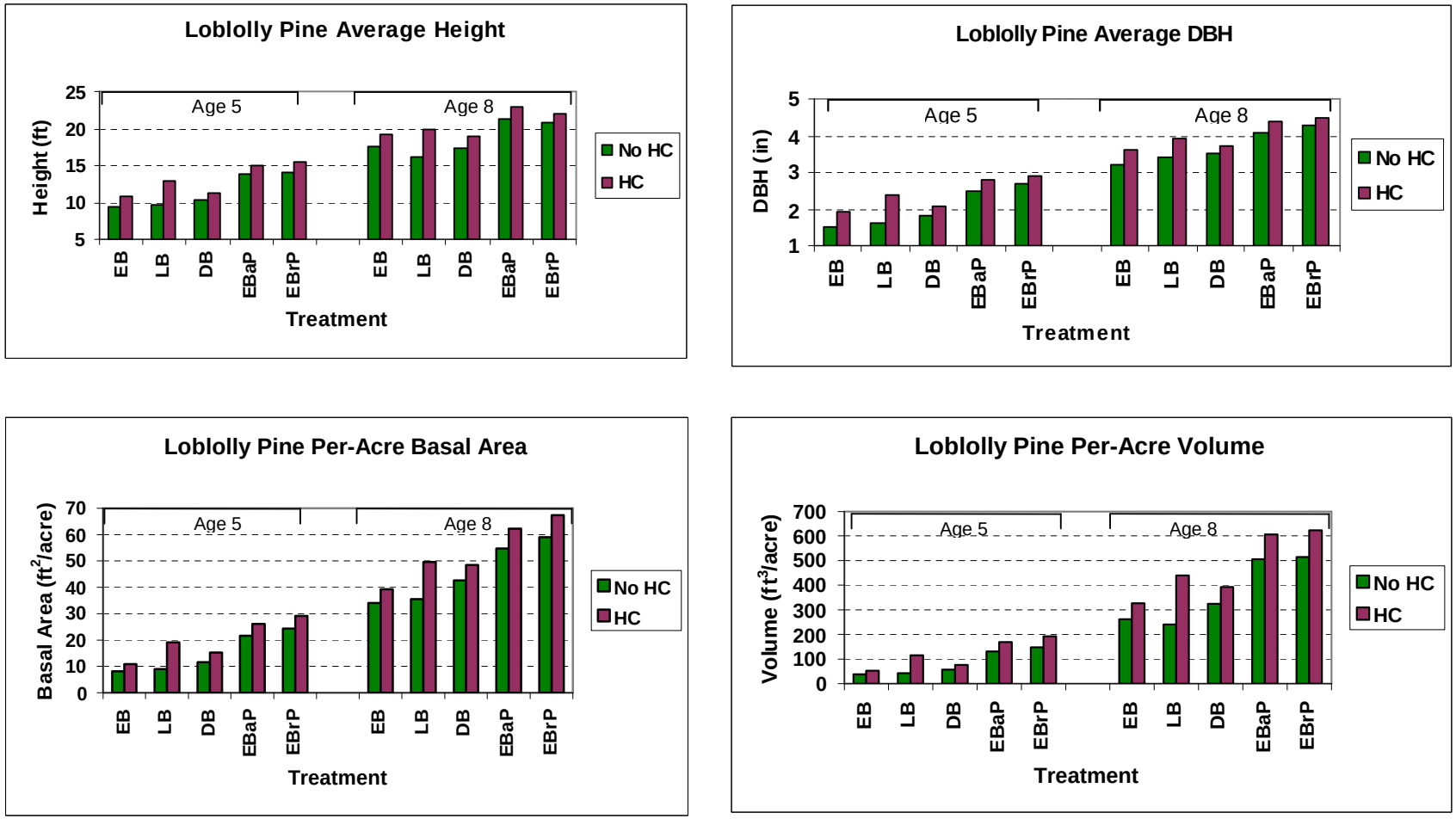

Figure 4. **Average height, average DBH, basal area and volume by site-prep and post-herbaceous weed control treatments for loblolly pine on CRIFF C soils near Olustee, FL. (EB = early bedding; LB = late bedding; DB = double bedding; EBaP = early bedding and banded pre-plant herbicide; EBrP = early bedding and broadcast pre-plant herbicide; HC = post-plant herbaceous weed control).**

4. DISCUSSION & CONCLUSIONS

This research examines growth response of slash and loblolly pine plantations to different site preparation treatments with or without post-plant herbaceous weed control in Lower Coastal Plain sites of north Florida. The effect of site preparation treatment was significant for at least one response variable for each combination of species, soil group and age represented by these four installations. Growth of slash and loblolly pine followed some consistent trends. Early bedding plus broadcast or banded pre-plant herbicide application consistently outperformed bedding only treatments (early bedding alone, late bedding alone, and double bedding). Growth for the broadcast pre-plant herbicide application was similar or greater than that observed for the banded pre-plant herbicide application. Bedded and chemically site prepared plantations generally grew better than plantations that were bedded and received herbaceous weed control.

Generally, early bedding alone and late bedding alone seemed to result in similar growth. However, slash pine on the somewhat poorly drained CRIFF D soil (St. Augustine) showed more growth with late bedding alone than early bedding alone. Double bedding did not consistently increase pine growth as compared to the more effective single bedding treatment.

Growth response magnitude to post-plant herbaceous weed control depended on site preparation treatment, and also on species and soil group. Growth response to this treatment was largest for slash pine on the CRIFF D soils in the absence of pre-plant herbicide application and for loblolly pine on the CRIFF C soils for all site preparation regimes, and not statistically significant for slash pine on the CRIFF C group soils. For slash pine on the poorly drained CRIFF D soils, response to post-plant weed control was most pronounced on single bedding treatments (early bedding alone or late bedding alone treatment); while, on the somewhat poorly drained CRIFF D soils, post-plant weed control significantly enhanced growth on double bedding and late bedding alone treatments.

Some significant interaction of site preparation treatment and post-plant weed control treatment was found for average height and DBH for slash pine on the poorly drained CRIFF D soils and loblolly pine on the CRIFF C soils. There were no significant interactions for per-acre basal area and volume for slash or loblolly pine at the age of the latest measurements.

The observed growth responses, most pronounced for pre-plant herbicide application targeting woody control and, to a lesser degree, post-plant herbaceous weed control, were due primarily to impacts of treatments on competing vegetation and associated changes in light, nutrient, and moisture availability for the planted pine. The pre-plant herbicide application was effective on all sites in reducing non-arborescent coverage on beds to about 5% or less during August following planting. This compares with coverage in the 10% to 50% range on beds without the pre-plant herbicide application. Results from non-arborescent coverage assessments made during the second growing

season generally show continued good control resulting from the chemical site preparation treatments.

The broadcast pre-plant herbicide application resulted in more slash pine growth than the banded pre-plant application on the poorly drained CRIFF D soil (Callahan) and the CRIFF C soil (Perry) while broadcast and banded treatments resulted in similar growth for slash pine on somewhat poorly drained CRIFF D soil (St. Augustine) and for loblolly pine on a CRIFF C soil (Olustee). The broadcast application was very effective at reducing non-arborescent coverage between beds during August following planting as compared to the banded application; Coverage was 5% or less with broadcasting as compared to about 20% at Perry, 35% at St. Augustine, 55% at Callahan, and 35% at Olustee with banding. For slash pine, the installation (somewhat poorly drained CRIFF D, St. Augustine) not showing better pine growth for the broadcast application had higher herbaceous cover (about 35%) between beds as compared to about 20% (poorly drained CRIFF D, Callahan) and about 5% (CRIFF C, Perry) for installations with better pine growth on plots receiving a broadcast application. The loblolly pine at Olustee did not benefit from broadcasting as compared to banding site preparation despite a reduction in non-arborescent coverage from 35% to 5% and in herbaceous coverage from 40% to 15% between beds.

Bedding alone or in combination with post-plant herbaceous weed control generally did not result in sufficient competition control to favor optimum pine growth.

The results for slash pine suggest that competition control from chemical site preparation on some sites is sufficient that first-year herbaceous weed control is not needed. The lack of pronounced tree growth responses to post-plant herbaceous weed control on chemically site prepared plots occurred under different levels of herbaceous weed cover; At the poorly drained CRIFF D installation, herbaceous cover ranged from 40 to 60% without herbaceous weed control and 20 to 25% with the treatment; At the somewhat poorly drained CRIFF D installation, herbaceous cover ranged from 25 to 40% without as compared to about 10% with treatment; On the CRIFF C soil, herbaceous coverage was only 5 to 7% without and 3 to 5% with treatment.

In contrast to the above results for slash pine, loblolly pine growth was increased by first growing season herbaceous weed control in areas that were chemically site prepared as well as areas not chemically site prepared. With chemical site preparation, herbaceous cover was 15 to 25% without post-plant herbaceous weed control and 2 to 5% with herbaceous weed control.

These results confirm that good site preparation, including application of herbicides for competition control, is essential for productive slash and loblolly pine plantations in the Lower Coastal Plain of northern Florida and southern Georgia. These results also provide evidence that effective competition control during site preparation may eliminate the need for first-year herbaceous weed control in slash pine plantations on certain sites.

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APPENDIXES

Appendix 1. Summary of ANOVA p-values for different percent coverage of vegetation type for slash pine on CRIFF D soils near Callahan, FL

Veg. Type [a]	Variable [b]	Prep	HWC	Prep × HWC
THE	PB_COV61	**0.0007**	**<0.0001**	0.6661
	PB_COV81	**0.0282**	**0.0002**	0.7918
	PB_COV82	0.4555	0.1514	0.2111
	PI_COV61	**<0.0001**	**0.0395**	0.3648
	PI_COV81	**0.0160**	0.8186	0.9815
	PI_COV82	**0.0070**	0.0708	0.5859
TNA	PB_COV61	**0.0005**	**0.0008**	**0.0078**
	PB_COV81	**<0.0001**	**0.0019**	**0.0018**
	PB_COV82	**<0.0001**	**<0.0001**	**<0.0001**
	PI_COV61	**0.0006**	0.2630	0.3687
	PI_COV81	**0.0003**	0.4253	0.3132
	PI_COV82	**0.0001**	0.1732	0.1127

[a] THE = Total herbaceous cover (%), TNA = Total non-arborescent cover (%);
[b] PB = Percent bed cover, PI = Percent interbed cover, COVxy = Coverage in the x month of the y growing season.

Appendix 2. Summary of ANOVA p-values for different percent coverage of vegetation type for slash pine on CRIFF D soils near St. Augustine, FL

Veg. Type [a]	Variable [b]	Prep	HWC	Prep × HWC
THE	PB_COV81	**<0.0001**	**0.0014**	0.6018
	PB_COV82	**0.0323**	0.1495	0.8035
	PI_COV81	**0.0258**	0.3107	0.4333
	PI_COV82	**0.0079**	0.1421	0.5184
TNA	PB_COV81	**<0.0001**	**0.0051**	0.2157
	PB_COV82	**0.0009**	**0.0099**	0.5462
	PI_COV81	**<0.0001**	0.0967	0.0583
	PI_COV82	**0.0034**	0.2656	0.0901

[a] THE = Total herbaceous cover (%), TNA = Total non-arborescent cover (%);
[b] PB = Percent bed cover, PI = Percent interbed cover, COVxy = Coverage in the x month of the y growing season.

Appendix 3. Summary of ANOVA p-values for different percent coverage of vegetation type for slash pine on CRIFF C soils near Perry, FL

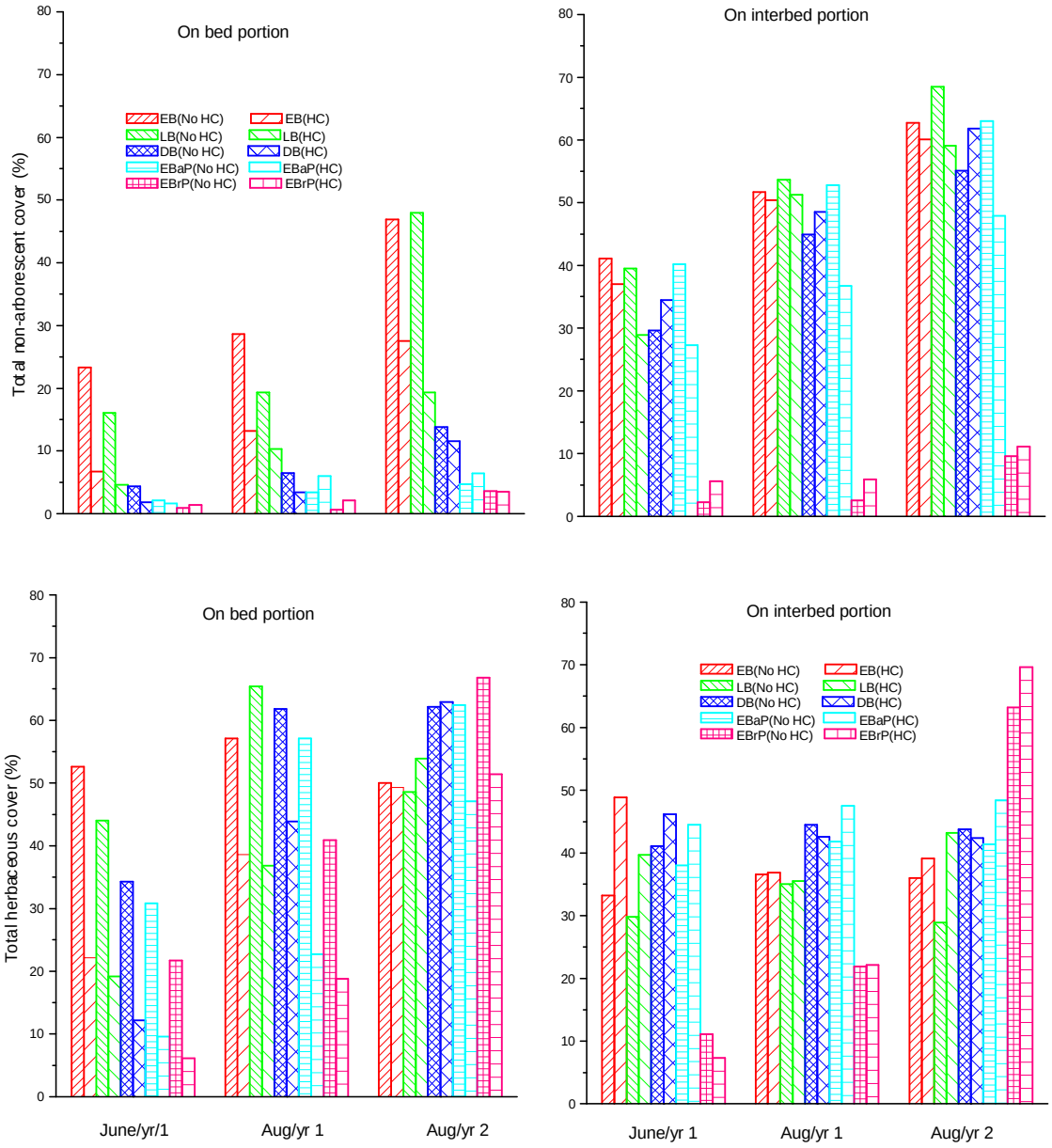
Veg. Type [a]	Variable [b]	Prep	HWC	Prep × HWC
THE	PB_COV61	**<0.0001**	**0.0018**	0.1647
	PB_COV81	**0.0002**	**0.0009**	0.1373
	PB_COV82	**0.0329**	**0.0108**	0.9830
	PI_COV61	**0.0038**	**0.0090**	0.0726
	PI_COV81	**<0.0001**	0.3168	**0.0414**
	PI_COV82	**0.0043**	0.0522	0.4681
TNA	PB_COV61	**0.0156**	0.0554	0.3231
	PB_COV81	**0.0055**	**0.0403**	0.8863
	PB_COV82	**<0.0001**	0.9133	0.9822
	PI_COV61	**0.0014**	0.5763	0.8742
	PI_COV81	**0.0088**	0.5992	0.7255
	PI_COV82	**0.0035**	0.4993	0.7115

[a] THE = Total herbaceous cover (%), TNA = Total non-arborescent cover (%);
[b] PB = Percent bed cover, PI = Percent interbed cover, COVxy = Coverage in the x month of the y growing season.

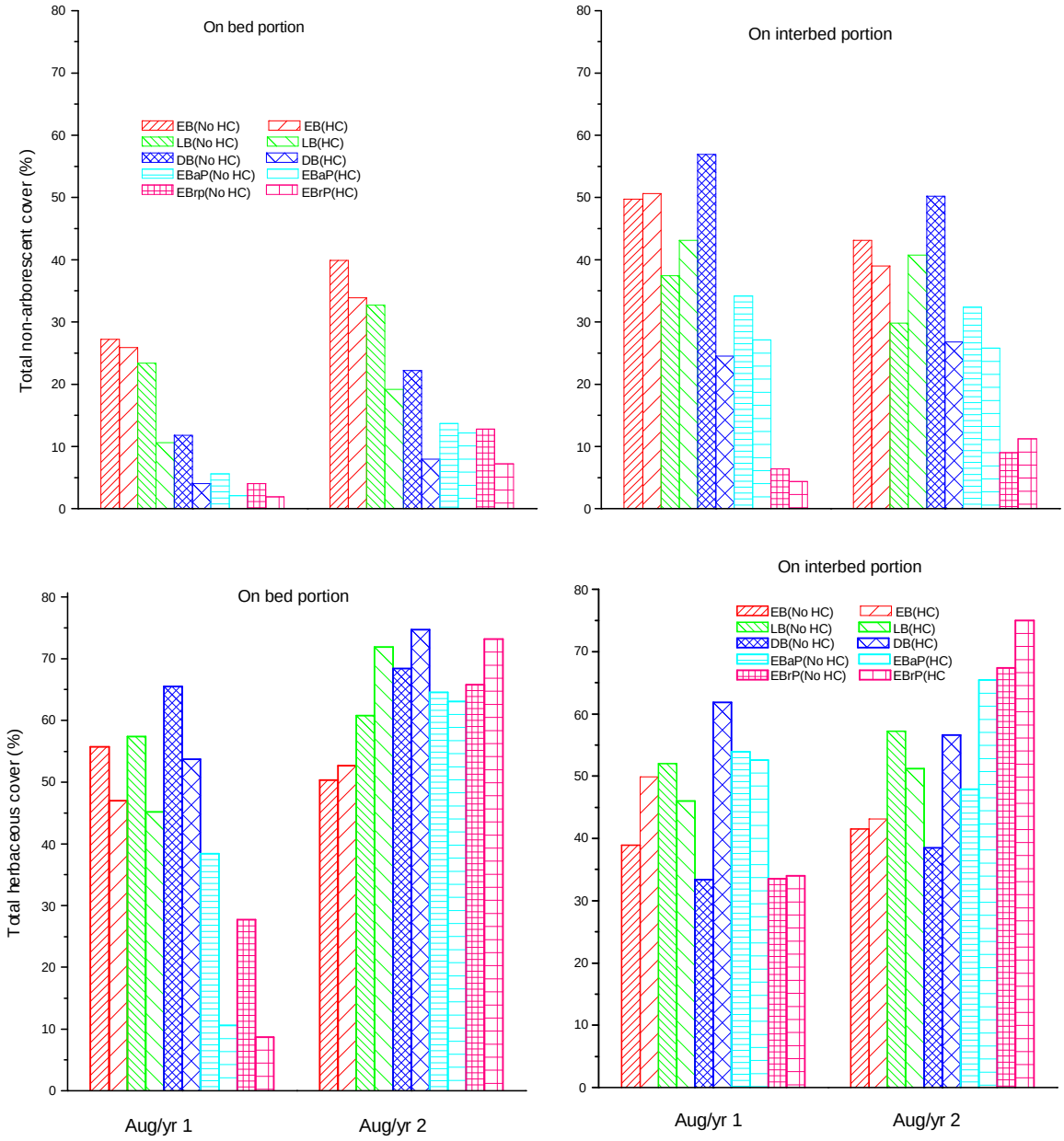
Appendix 4. Summary of ANOVA p-values for different percent coverage of vegetation type for loblolly pine on CRIFF C soils near Olustee, FL

Veg. Type [a]	Variable [b]	Prep	HWC	Prep × HWC
THE	PB_COV61	0.1936	0.2899	0.2403
	PB_COV81	**0.0001**	**<0.0001**	**<0.0001**
	PB_COV82	0.0944	**0.0365**	0.5601
	PI_COV61	**<0.0001**	**0.0002**	**0.0071**
	PI_COV81	**<0.0001**	**0.0078**	0.1930
	PI_COV82	0.0975	**<0.0001**	0.9047
TNA	PB_COV61	0.0826	0.9739	0.2876
	PB_COV81	**0.0015**	**0.0063**	**0.0011**
	PB_COV82	**0.0001**	0.9660	0.4109
	PI_COV61	**0.0155**	0.4329	0.1102
	PI_COV81	**0.0002**	0.6208	0.2152
	PI_COV82	**0.0001**	**0.0019**	**0.0281**

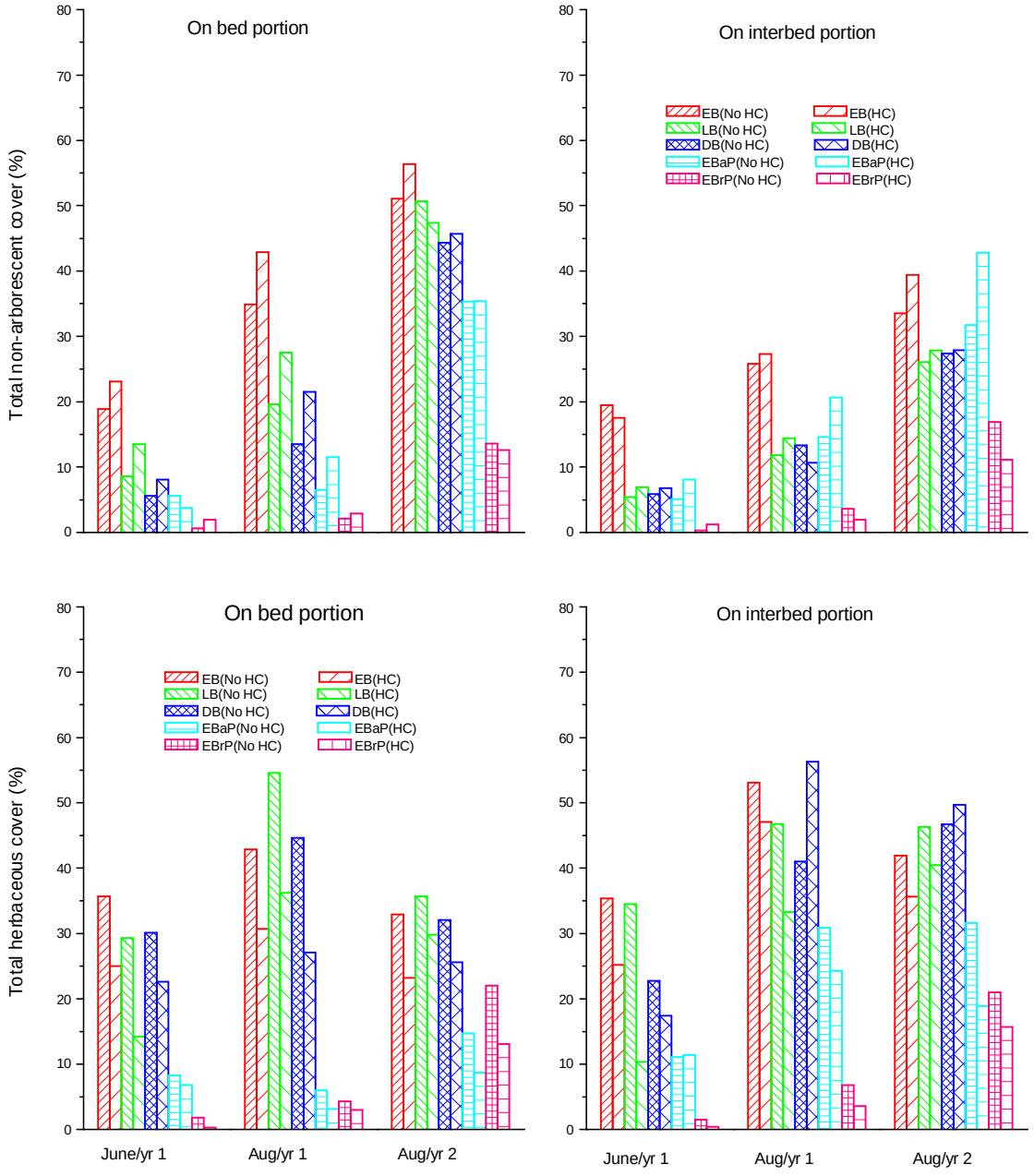
[a] THE = Total herbaceous cover (%), TNA = Total non-arborescent cover (%);
[b] PB = Percent bed cover, PI = Percent interbed cover, COVxy = Coverage in the x month of the y growing season.



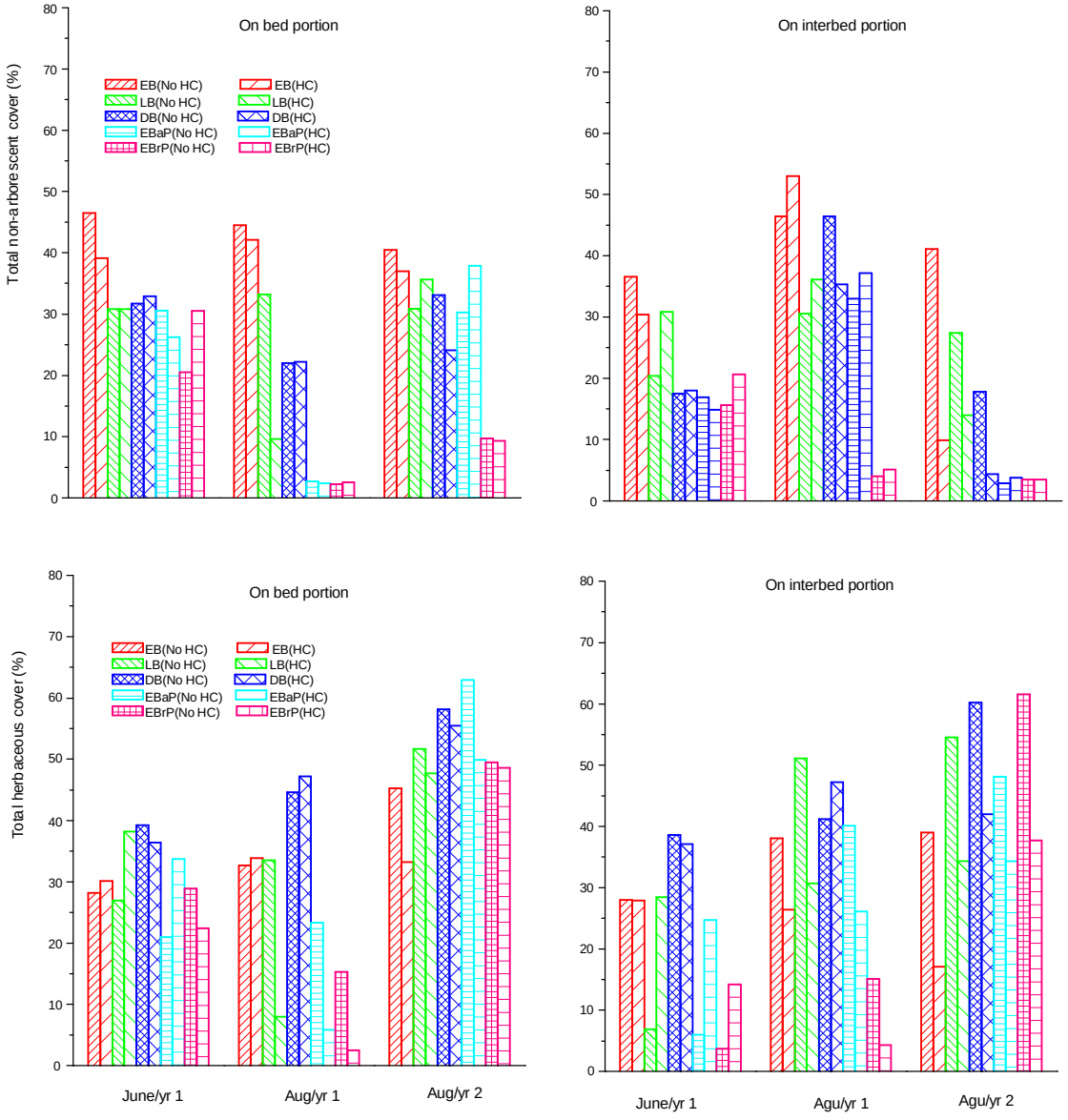
Appendix 5. Total non-aboresent and herbaceous coverage on bed and interbed portions in June and August of the first growing season and August of the second growing season for slash pine on CRIFF D soils near Callahan, FL. (EB = early bedding; LB = late bedding; DB = double bedding; EBaP = early bedding and banded pre-plant herbicide; EBrP = early bedding and broadcast pre-plant herbicide; HC = post-plant herbaceous weed control).



Appendix 6. Total non-aboresent and herbaceous coverage on bed and interbed portions in August of the first and second growing seasons for slash pine on CRIFF D soils near St. Augustine, FL. (EB = early bedding; LB = late bedding; DB = double bedding; EBaP = early bedding and banded pre-plant herbicide; EBrP = early bedding and broadcast pre-plant herbicide; HC = post-plant herbaceous weed control).



Appendix 7. Total non-aboresent and herbaceous coverage on bed and interbed portions in June and August of the first and August of second growing seasons for slash pine on CRIFF D soils near Perry, FL. (EB = early bedding; LB = late bedding; DB = double bedding; EBaP = early bedding and banded pre-plant herbicide; EBrP = early bedding and broadcast pre-plant herbicide; HC = post-plant herbaceous weed control).



Appendix 8. Total non-aboresent and herbaceous coverage on bed and interbed portions in June and August of the first and August of second growing seasons for loblolly pine on CRIFF D soils near Olustee, FL. (EB = early bedding; LB = late bedding; DB = double bedding; EBaP = early bedding and banded pre-plant herbicide; EBrP = early bedding and broadcast pre-plant herbicide; HC = post-plant herbaceous weed control).