EARLY GROWTH RESPONSE OF SLASH PINE TO DOUBLE-BEDDING ON A FLATWOODS SITE IN GEORGIA

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Abstract—A somewhat poorly-drained site in the Georgia flatwoods was prepared with single- and double-bedding and was planted with slash pine (*Pinus elliottii* Engelm.) seedlings in October. Half of the plots were treated with imazypyr in March. Double-bedding increased 7th year volume by 5 m^3 per ha, but due to insufficient control of gallberry [*Ilex glabra* (L.) Gray], the herbicide treatment did not significantly increase volume growth. A break-even economic analysis indicated that an increase of 19 m^3 per ha at age 20 years would be sufficient to justify the extra cost of double-bedding (stumpage value = $20 per m^3; 7 percent interest rate). A review of the literature indicated that single-bedding typically increased yield but did not consistently increase the probability of survival. Equations developed suggest that single-bedding may, on average, increase yields by 21 to 28 m^3 per ha.

INTRODUCTION

Early herbicide treatments can suppress competing vegetation in southern pine plantations leading to increased pine growth (Lauer and Glover 1998, Lauer and Zutter 2001, Miller and others 1995, NCSFNC 1996, Quicke and others 1996, Swindel and others 1988, Zutter and Miller 1998). This may lead some to conclude that herbicides always increase volume growth. However, a few studies have shown that some herbicide treatments might decrease pine growth (Lauer and Glover 1999, NCSFNC 1999, South and Mitchell 1999). On some sites, this is due to selective control of competing vegetation. In one study, the control of herbaceous vegetation allowed gallberry [*Ilex glabra* (L.) Gray] to colonize the site resulting in reduced pine growth (South and Mitchell 1999). Managers need to be aware of which species will be suppressed by the herbicide and which will be released to compete with the pines. A single herbicide application is not synonymous with total vegetation control.

Bedding is commonly practiced on poorly drained, lower Coastal Plain sites to improve drainage (Cain 1978), soil aeration (Dougherty and Gresham 1988, Morris and Lowery 1988), and to provide long-term control of competing woody shrubs (Lauer and Zutter 2001, Schultz 1976, Schultz and Wilhite 1974). When compared to herbaceous cover, shrub cover can be a greater competitor and resulted in greater reduction of pine growth (Lauer and Glover 1998, 1999; Zutter and Miller 1998). Double-bedding is currently practiced to improve bed quality and to increase the level of shrub control (Lauer and Zutter 2001). Double-bedding involves a first pass during the summer, and then a plow is run over the beds a second time several weeks prior to planting.

Lauer (2000, 2001), Lauer and Glover (1996), and Lauer and Zutter (2001) found that double-bedding increased early growth relative to single-bedding. These studies did not surpass age 5, and no long term studies have been published comparing single-bedding to double-bedding. All of these studies have used double-bedding treatments consistent with our definition of double-bedding.

The combination of double-bedding and early post-plant herbicide applications is an effective way to increase early growth. Double-bedding provides excellent control of shrubs and hardwoods (Lauer and Zutter 2001); however, the control of shrubs can result in an increase in herbaceous vegetation (Lauer and Glover 1995, Miller and others 1991, Zutter and Miller 1998). The treatments combined can provide early control of both herbaceous vegetation and shrubs and hardwoods (Lauer and Zutter 2001).

Researchers sometimes place too much emphasis on results from an arbitrary significance level. This is especially true when the power of the test is low (VanderSchaaf and others 2003, Zedaker and others 1993). In some cases, a treatment may be economically viable but due to site variations, volume gain is not statistically significant (resulting in a Type II error). Therefore, we conducted a break-even analysis to determine if the cost of treatments might result in a positive return on investment. This study was conducted to determine if double-bedding produced increases in pine growth relative to single bedding and if an interaction existed between bedding and herbicide treatment.

METHODS

The study was located on a somewhat poorly drained flatwoods site near Homerville, GA. The soil is within the Ocilla series and is a loamy, siliceous, thermic Aquic Arenic Paleudult (Shrock 1994). A pine plantation was clearcut in the spring of 1991, and the area was raked, piled, and burned in June 1991. Treatments included two levels of site preparation, single-bedding and double-bedding, and two levels of post-planting vegetation control, herbicide application or none. Treatments were arranged as a split-plot design (bedding as the main effect). The first bedding pass occurred in late June 1991 and the second in early October. Seedlings were machine planted October 16, 1991 by an operational crew on a 1.8 x 3.0 m spacing. A

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Citation for proceedings: Connor, Kristina F., ed. 2004. Proceedings of the 12th biennial southern silvicultural research conference. Gen. Tech. Rep. SRS–71. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 594 p.

band application of 105 g a.i. per ha of imazapyr was applied by an operational crew in March, 1992. No surfactant was used.

Diameter at breast height (d.b.h.) and height were measured in the winter of 1999. Individual tree volume was estimated using a formula developed by Van Deusen and others (1981). Percent survival, average d.b.h., arithmetic mean height (height), individual tree volume, and volume per ha were analyzed using Proc GLM. A break-even analysis (at 7 percent interest) was conducted to determine the amount of volume gain required to make a treatment economically feasible (Bentley and others 1984, Fox 1988). Costs for the single-bedding, double-bedding and imazapyr treatments were $90, $160, and $80 per ha, respectively.

The literature was surveyed and 46 reports involving single- or double-bedding treatments were reviewed, and data for survival, height, basal area, and volume were compiled www.forestry.auburn.edu/south/bedding.xls. Regression analyses were conducted to determine the general response of height (129 comparisons), survival (81 comparisons), and yield (50 comparisons) to single bedding.

RESULTS

Double-bedding at the Homerville site increased height by about 0.45 m but this increase was not significant (α = 0.10). Double-bedding increased volume per ha while the imazapyr treatment resulted in no significant increase in growth (table 1). Although there was no statistical interaction between bedding and herbicide treatment, the combination of double-bedding and imazapyr (d.b.h.) produced 5.3 m^3 more volume per ha than the single-bed treatment (SB) (table 2). A break-even yield analysis indicated that by age 20, an additional 19 m^3 per ha would justify the cost of a double-bedding treatment.

When compared to non-bedded treatments, single bedding tended to increase height growth (fig. 1). In only one comparison did bedding reduce heights by more than 50 cm (Lennartz and McMinn 1973). Overall, single-bedding did not have a consistent effect on seedling survival (fig. 2). Out of 81 comparisons, only 7 bedding treatments were significantly different from the controls (4 were lower and 3 were greater than controls). Overall, single-bedding increased volume per ha (fig. 3). Out of 50 comparisons, 14 resulted in significant increases in yield. The equation predicts a yield increase of 21 and 28 m^3 per ha for non-bedded stands producing 100 to 200 m^3 per ha, respectively.

DISCUSSION

Unlike other studies (Lauer and Zutter 2001, Quicke and others 1996), we found no economic advantage of applying imazapyr to control herbaceous weeds on this site (table 2). This is because the initial control of herbaceous vegetation allowed gallberry to increase, eventually resulting in

Table 1—Probability of a greater *F*-statistic for seventh-year field survival (transformed) and arithmetic mean seventh-year height, arithmetic mean diameter at breast height (d.b.h.), and volume per tree and hectare of *Pinus elliottii* seedlings

Source	Survival	Height	d.b.h.	Volume per tree	Volume per ha
	- - - - - - - -	- - - - - - -	*P > F value*	- - - - - - -	- - - - - - - -
Replication	0.07	0.33	0.85	0.79	0.39
Bedding (B)	0.17	0.12	0.12	0.14	0.06
Herbicide (H)	0.87	0.83	0.92	0.86	0.94
Bedding X herbicide	0.72	0.56	0.76	0.57	0.48

Table 2—Effect of bedding and herbicide treatments on seventh-year survival, trees per ha, arithmetic mean height, arithmetic mean diameter at breast height, and volume per tree and hectare of *Pinus elliottii* seedlings

Treatment	Survival	TPH	Height	d.b.h.	Volume	Volume
	percent		*m*	*cm*	*m³/tree*	*m³/ha*
SB	64.4	1,154	5.5	9.5	0.015	17.7
SBH	63.4	1,137	5.3	9.4	0.014	16.3
DB	69.3	1,243	5.8	9.9	0.017	21.0
DBH	68.9	1,236	5.9	10.1	0.019	23.0

TPH = trees per ha; d.b.h. = diameter at breast height; SB = single-bed, no herbicide; SBH = single-bed, herbicide; DB = double-bed, no herbicide; DBH = double-bed, herbicide.

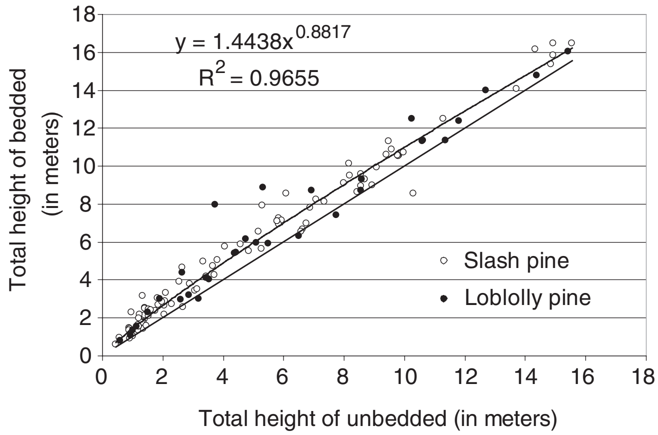

Figure 1—Height of single-bedded plots over height of unbedded plots from several studies conducted during the last 30 years. The solid line represents equal survival of the two treatments. The dashed line represents the regression equation (n = 129).

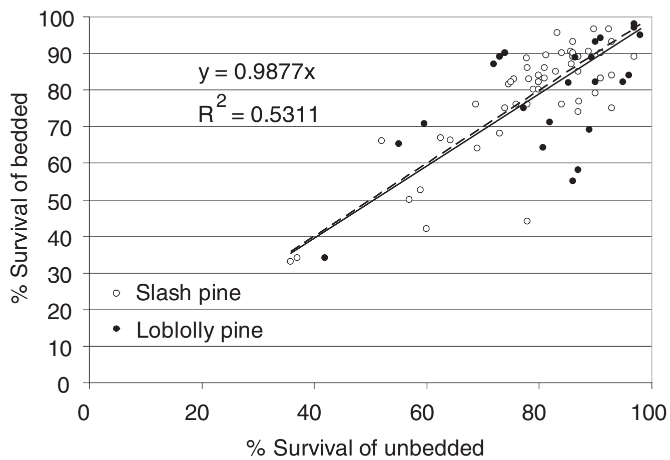

Figure 2—Survival of single-bedded plots over survival of unbedded plots from several studies conducted during the last 30 years. The solid line represents equal survival of the two treatments. The dashed line represents the regression equation (n = 81).

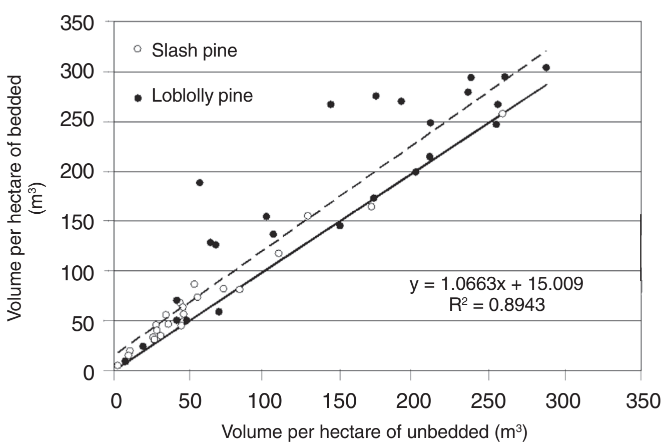

Figure 3—Volume per hectare of single-bedded plots over volume per hectare of unbedded plots from several studies conducted during the last 30 years. The solid line represents equal volume yield of the two treatments. The dashed line represents the regression equation (n = 50).

a decrease in pine growth (South and Mitchell 1999). The use of imazapyr alone may not be cost-effective if other site preparation techniques have not adequately controlled herbicide-resistant woody competitors. In order to be cost effective, the herbicide treatment would need to increase yield by approximately 22 m^3 per ha by age 20 years. However, by age 7 years, a gain of only 2 m^3 per ha occurred with the double-bedding treatment.

Although double-bedding on this site increased 7th year volumes relative to single-bedding, a forest economist would be more interested in answering the question: Will the investment in double-bedding be recouped at harvest? It should be kept in mind that currently pulpwood is worth about \$9 per m^3 while chip-n-saw logs sell for about \$36 per m^3. In our analysis, we used a value of \$20 per m^3 (which assumes a mix of some chip-n-saw size trees with some pulpwood). If we assume a "Type C" response equal to a 1 year advance in stand development, we might expect to harvest an additional 20 m^3 per ha (assuming a site productivity of approximately 20 m^3 per ha per year). This amount of increase would justify the additional cost for double-bedding. Based on results from this study and from a previous publication (South and Mitchell 1999) at age 4 (single-bedding = 6.56 m^3 per ha, double-bedding = 8.59 m^3 per ha), it does not appear that a "Type C" 1 year advance is occurring. Based on these early results, the age-shift is much less than 1 year, leading to the conclusion that the yield returns from double-bedding on this site may not justify the investment.

It is necessary to determine when current annual increment (CAI) is greatest and whether to thin or to harvest near this age. If the stocking of a plantation is not properly managed following intensive site preparation (by conducting a commercial thinning), then the early gains from a "Type C" volume per ha response may be wasted. Other studies on eastern Coastal Plain soils have shown a Type B response following bedding (Dickens and others 1988, Gent and others 1986, Lennartz and McMinn 1973, Shiver and others 1990, Wilhite and Jones 1981). However, these studies are far from rotation age. It is imperative that managers continue to capture the early increase in growth caused by either single- or double-bedding. This can be achieved through either thinning or by harvesting.

In this study, the average root collar diameter (RCD) at time of planting was 7 mm across all treatment combinations. South and Mitchell (1999) found that seedlings of this size competed effectively with herbaceous weeds. The lack of response to herbicides on this site is likely a combination of both gallberry competition and the use of large planting stock. Perhaps planting morphologically improved seedlings alone on single-beds will result in as much or more growth than planting smaller sized seedlings on double-beds plus a March herbicide treatment.

REVIEW OF GROWTH RESPONSE TYPES

Several authors have described growth response types (Hughes and others 1979, Morris and Lowery 1988, Nilsson and Allen 2002). However, we feel there are some inconsistencies. When authors are discussing growth response types they should specify the variable with which they are working (i.e. height growth or volume per ha). Second, rotation age is the only age at which growth response types are of any practical importance. If authors are discussing a growth type response for any other age, they should specify the age.

There are five "harvest-age" growth responses to silvicultural treatments (Morris and Lowery 1988, Nilsson and Allen 2002). A "Type A" response is when incremental volume growth (i.e. CAI) is greater on treated than untreated areas throughout the entire rotation. A "Type B" response occurs when early incremental volume growth is greater on the treated areas, but incremental volume growth at later ages is the same. A "Type C" response is when incremental volume growth on treated plots is greater early in the rotation, but at later ages, incremental volume growth declines so that yield becomes equal for treated and non-treated areas. A "Type D" response is when early incremental volume growth on treated areas is greater, but at later ages volume growth increment declines so that yield actually decreases in the treated area. A "Type E" response occurs when treated incremental volume growth is less than the untreated throughout the entire rotation.

Several studies suggest a Type B response for single-bedding (Beers and Bailey 1985; Cain 1978; Haywood 1980, 1983, 1987; Haywood and Tiarks 1995; NCSFNC 1996; Outcalt 1984; Sarigumba and Anderson 1979; Tiarks 1983), but a few sites appear to result in a Type A response (Gent and others 1986, NCSFNC 1996, Nilsson and Allen 2002). However, studies up to age 18 years are probably too young to make a definitive statement about the "harvest-age" volume response to bedding. Morris and Lowery (1988) concluded that a Type B response generally occurs on flatwoods sites with sandy surface soils and a Type A response generally occurs on fine textured-poorly drained mineral soils. They agreed with Dewit and Terry (1983) who concluded that these responses occurred on the flatwoods sites because early accelerated growth resulted from a short-term increase in organic matter decomposition and greater nutrient availability. On the fine textured soils, growth increase was largely due to improved aeration and water movement.

The amount and type of competing vegetation could also affect the type of response observed. Nilsson and Allen (2002) concluded that a Type B response is likely to occur if herbaceous vegetation is greatly reduced, but a Type A response could result if hardwood vegetation is eliminated. A Type A response may occur for single-bedded, and more often for double-bedded, sites since it is thought to provide long-term control of shrubs and hardwoods (Lauer and Zutter 2001). Several studies have shown that herbaceous production decreases with increases in pine basal area (Lewis 1989, Wolters 1973, Zutter and Miller 1998). On the other hand, shrub and hardwood production appear to be independent of pine basal area and develop with age similar to the pines (Zutter and Miller 1998). Since this is true and each site has a maximum carrying capacity for a particular age, after herbaceous vegetation has been shaded-out, a double-bedding treatment may produce a long-term Type A response. This could be due to better control of shrubs and hardwoods on double-bedded areas and the presence of large amounts of shrubs or hardwoods accounting for relatively more of the stand-level growth on unbedded or single-bedded sites. It is difficult to conclude that bedding will always result in a particular type response, because this is highly dependent on the species and amount of the competing vegetation, especially for shrubs and hardwoods.

CONCLUSION

This study provides insight into the advantages and disadvantages of particular site preparation treatments. Double-bedding appears to improve early volume growth per acre on flatwoods sites that contain gallberry. The verdict on long-term growth and economic return is still out. However, applying a single herbicide treatment to this site does not appear to be economically feasible. Pine growth may be reduced following selective herbicide treatments on sites containing thick-cuticled vegetation such as gallberry.

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