DOUBLE-PLANTING CAN AFFECT GAINS FROM WEED CONTROL TREATMENTS

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Abstract—Double-planting is the practice of planting two seedlings at every planting spot. When both seedlings survive, then either the less vigorous seedling is removed or each seedling is given an equal chance of being removed. Some researchers double-plant so that tree growth among experimental plots is not affected by initial differences in stocking. However, double-planting might have an effect on conclusions when the response variable is affected by initial survival. A growth and yield program was used to estimate the effects of double-planting on yields obtained from eliminating hardwood competition. As expected, increasing stocking (by double-planting) increased standing volume at age 25 year. If the herbicide treatment increased survival, the predicted increase was greater for double-planting than for single-planting. However, when the use of herbicides reduced seedling survival, the predicted increase in volume gains was greater for single-planted stands.

INTRODUCTION

"Double-planting" involves the practice of planting two seedlings at every planting spot (typically from 0.1 to 0.5 m apart). This is done in hopes that most planting spots will have at least one live seedling a year after planting. When both seedlings are alive then one is removed. In some studies, the less vigorous seedling is removed while in others each seedling is given an equal chance of being removed. It is not known when this practice began but Powers (1979) double-planted seedlings in December of 1978. Its popularity has increased among researchers in the Southern United States (table 1). Some researchers are concerned that when planting one tree per planting spot (i.e. single-planting), first-year survival might be less than 90 percent and that stocking might vary by treatment. Therefore in South Africa, researchers and some companies single-plant and then replant the "blank spots" a month later (a.k.a. blanking). Blanking is known as "beating-up" in the United Kingdom and "interplanting" in the United States. Occasionally, interplantaing is practiced when initial survival is decreased by the application of chemicals (Edwards 1994, Haywood and Tairks 1990). However, since analytical problems can occur with interplanting, some researchers prefer to double-plant seedlings. In one study in California, double-planting plus interplanting were used to ensure one tree per planting spot (York and others 2004).

ECONOMICS

The reason double-planting is rarely practiced operationally is due to higher establishment costs. For example, if a bare-root longleaf pine (*Pinus palustris* Mill.) seedling costs 8 cents each and it costs 7 cents to plant a tree by hand, double-planting would cost about 33 cents per planting spot (removing doubles might cost $50/ha). Planting container seedlings might cost only 24 cents per seedling (17 cents for seedlings plus planting costs). However, double-planting is used in some parts of Africa. In semi-arid areas of Kenya, some farmers (about 1 out of 10) will plant two seedlings in each pit (Roothaert and others 2003).

RESEARCH TRIALS

Double-planting is practiced mostly by researchers in the United States although it has been used in Sweden and Brazil (Johansson 2004, Pereira and Vale 1984). In Italy, double planting has been used in cherry and oak plantations (Buresti and others 2001, 2003). Seven years after planting, the less vigorous and/or poorly formed seedling is removed. Although many establishment trials are established in Canada, China, the United Kingdom, South Africa, New Zealand and in Australia, double-planting is rarely practiced in these countries. It is possible that some trials were double-planted but the practice was not mentioned in the methods section (e.g. Nowak and Berisford 2002).

Some researchers have experienced planting failures and therefore they double-plant to reduce the risk of failure. Low survival after planting bare-root, loblolly pine (*Pinus taeda* L.) or slash pine (*Pinus elliottii* Engelm.) might be related to: (1) planting stock with root-collars less than 5 mm; (2) a reluctance to plant seedlings deep—with the root-collar 15 cm below ground; (3) using inexperienced hand-planting crews; (4) allowing tree planters to prune or strip roots in order to avoid bent roots in the planting hole; and (5) planting late (i.e. after March 1). Some researchers will prune roots to facilitate hand planting (e.g. Wilder-Ayers and Toliver 1987) even though pruning roots will increase the shoot/root ratio and will reduce the chance of seedling survival (Harrington and Howell 1998, South 2005). Likewise, transplanting seedlings just prior to a hard freeze can reduce longleaf pine survival (South and Loewenstein 1994). To provide a buffer against improper planting techniques or weather events, some researchers double-plant (which can increase stocking levels up to 25 percent). Instead of double-planting, geneticists often choose to single-plant, container-grown loblolly pines.

DOES IT AFFECT RESULTS?

Double-planting will have no effect on results and conclusions of some experimental trials. For example, if the objective is to examine the effect of ozone concentration of seedling physiology, then double-planting will not alter the conclusions. However, double-planting might affect the results if the response variable of interest is: (1) stocking or (2) per hectare volume.

The survival percentage (i.e. number alive/number planted) is not affected by double-planting but stocking level (live trees/ha after thinning at the end of the first growing season) will be

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Citation for proceedings: Stanturf, John A., ed. 2010. Proceedings of the 14th biennial southern silvicultural research conference. Gen. Tech. Rep. SRS-121. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 614 p.

Table 1—A partial list of double-planted experiments in the United States

Species	Study involves	Reference
Pinus taeda	Ozone	Barbo and others 2002
	Fertilization	Borders and others 2004
	Tillage	Carlson and others 2006
	Logging	Eisenbies and others 2006
	Topography	Haywood 1983
	Tillage and Fertilization	Haywood 1995
	Logging method	Laihoa and others 2003
	Site preparation	Martin and Shiver 2002
	Mycorrhizae	McLellan and others 1995
	Weed competition	Miller and others 1991
	Fertigation	Nowak and Berisford 2000
	Spacing	Rahman and others 2006
	Second-rotation	Rose and Shiver 2000
	Second-rotation	Rubilar 2003
	Ozone	Sasek and others 1991
	Ozone	Stow and others 1992
Populus deltoides	Genetics	Foster 1986
	Genetics	Foster and others 1998
	Genetics	Knowe and others 1994
Western conifers	Opening size	York and others 2004

affected. Even so, some claim that double-planting increases seedling survival (Rahman 2006). However, in this case it would have been appropriate to state that stocking level averaged 94 percent (instead of saying that seedling survival was 94 percent). A stocking level of 94 percent suggests that seedling survival was approximately 76 percent.

When survival is 50 percent, double-planting will increase stocking level to 75 percent (fig. 1). In some cases, single-planting morphologically improved seedlings (with 8 or 9 mm root-collars) will result in fewer empty spots than double-planting typical seedlings with 4 mm root-collars (fig. 1).

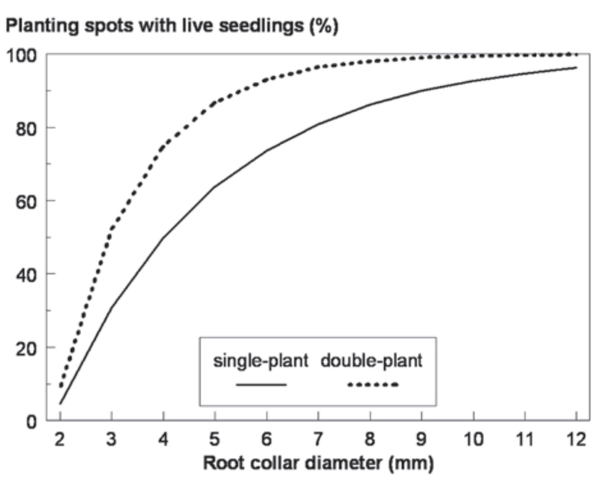

Figure 1—The potential effect of double-planting on stocking of slash pine in Georgia. The single-planted stand is represented by the equation $Y = 100-10^{(2.26-0.145X)}$ where Y is 3rd-yr survival and X is the root-collar diameter at time of planting. The increase in stocking due to double-planting was greatest when planting seedlings in the 4 to 6 mm range. Survival on this site was greater than 90 percent when seedlings with large roots (e.g. RCD > 9 mm) were machine planted (South and Mitchell 1999).

However, many researchers prefer to double-plant 4-mm seedlings than to single-plant 8- or 9-mm seedlings.

For loblolly pine, volume gains from controlling herbaceous weeds can increase as pine stocking increases. Quicke and others (1999) report volume gains (at age 15 years) from weed control might be 2 m^3/ha at a stocking of 800/ha while gains were 9.2 m^3/ha when seedlings were planted at 2200/ha. Therefore, as initial stocking levels increase, pine production will be increased (at least at ages 15 to 20 years). The question then becomes, when the difference in initial stocking level is minimized, does the volume gain (from weed control) decrease? Outputs from a growth and yield model were used to address this question.

METHODS

The North Carolina State University Growth and Yield Simulator was used to predict yields from controlling hardwoods in loblolly pine plantations in the Piedmont. Inputs included 1,200 spots/ha and the site quality would produce an average height of dominants and co-dominants of 22.9 m at age 25 years. The theoretical herbicide treatment eliminated competition from hardwoods while nontreated stands contained 20 percent of the basal area in hardwoods (at age 10 years). Four simulations were conducted. On Site #1, the herbicide treatments did not affect seedling survival while they reduced survival on Site #2. Herbicide use on Site #3 increased survival by 10 percentage points (i.e. from 80 percent to 90 percent) while on Site #4 survival increased by 25 points (i.e. from 50 percent to 75 percent). The following equation was used to estimate stocking level: Stocking = survival + [(1- survival)*(survival)]. For example, a stocking level of 84 percent is obtained by double-planting when survival is 60 percent: 0.84 = [(1-0.6)*(0.6)] + 0.6.

RESULTS AND DISCUSSION

As expected, eliminating hardwood competition increased volume production for all four sites (table 2). The increase was greatest for the low-survival site and was lowest for the site where herbicides reduced survival.

Table 2—Predicted effects of planting method and hardwood control on volume production at age 25 years (modeled output from NCSU Plantation Simulator)

Site	Herbicides	Hardwood competition	Initial survival	Planting method	Stocking (1st yr)	Volume (m^3/ha)	Gain due to weed control (m^3/ha)
#1	Yes	None	80%	Double	96%	334	62
	No	20%	80%	Double	96%	272	--
	Yes	None	80%	Single	80%	323	59
	No	20%	80%	Single	80%	264	--
#2	Yes	None	70%	Double	91%	332	60
	No	20%	80%	Double	96%	272	--
	Yes	None	70%	Single	70%	313	49
	No	20%	80%	Single	80%	264	--
#3	Yes	None	90%	Double	99%	336	64
	No	20%	80%	Double	96%	272	--
	Yes	None	90%	Single	90%	331	67
	No	20%	80%	Single	80%	264	--
#4	Yes	None	75%	Double	94%	333	73
	No	20%	50%	Double	75%	260	--
	Yes	None	75%	Single	75%	318	84
	No	20%	50%	Single	50%	234	--

Site index = 23 m in 25 years; 1200 planting spots per ha; 20% = amount of basal area in hardwood trees.

Regardless of site, double-planting increased stocking and volume production. At two sites (#1 and #2), double-planting increased the gain from weed control. For the sites where herbicide treatment increased survival (sites #3 and #4), double-planting reduced volume gains by 3 to 11 m^3/ha. On sites where double-planting does not increase stocking, there will be little or no effects of double-planting on treatment response.

On Site #2, the application of herbicides reduced survival by 10 percentage points. This is similar to what was observed at Liberty, MS (Miller and others 1995) where hardwoods sprouts were treated with herbicides and survival was reduced by about 12 percent (fig. 2). The use of herbicides has reduced survival of pine seedlings in several research trials (Barnard and others 1995, Quicke and others 1999, South and others 1995). In one study, seedlings treated with hexazinone had 64 percent survival while plots not treated had 93 percent survival (Edwards 1994).

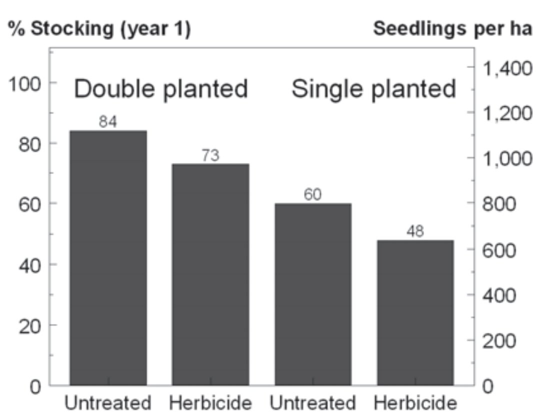

Figure 2—An example of the effects of double- planting and use of herbicides on first-year stocking of loblolly pine at Liberty, MS (double-planting results from Miller and others 1995—single-planting results are estimates).

CONCLUSIONS

Researchers double-plant to reduce the risk of low seedling survival and to minimize the variation in survival among experimental units. When seedling survival or volume/ha are not reported, double-planting will not affect the conclusions. In some cases where herbicides increase seedling survival, volume gains obtained from the weed control may be reduced by double-planting. This effect is expected by those researchers who want to eliminate stocking effects from growth related treatment responses. However, double-planting might increase volume gains on sites where stocking is either reduced or unaffected by herbicide use. These results are likely dependent on the growth and yield model employed.

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