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Effects of Initial Spacing on Height Development of Loblolly Pine

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Abstract: The relationship between dominant height and age is the base of site index, the most widely used measure of site quality. In applying the site index concept, one typically assumes that height development is not affected by stand density or thinning treatment. This assumption has been challenged by recent studies on loblolly pine. A detailed data set with initial densities ranging from 6,730 to 750 trees/ha and covering ages 1 through 25 after plantation establishment was used to study and model the effect of initial spacing on height development of loblolly pine. Dominant height was found to be dependent on initial spacing. Height-age models are proposed that take into account the effect of spacing on average and dominant height. The differences among plantation densities are evident from age 6 and are consistent to the end of the 25-year period of study. Previous studies in other conifers have reported an early advantage in terms of height growth in denser stands that tend to disappear with age, producing a crossover of the growth trajectories. No evidence of this crossover effect in height was found. FOR. SCI. 57(3):201–211.

Keywords: site index, stand density, growth and yield, *Pinus taeda*

In planning forestry operations, reliable estimates of future growth and yield are critical. One of the main factors affecting stand dynamics, and, hence, defining the response of the stand to different silvicultural treatments and the outcomes of such interventions is site productivity. The most widely used method for assessing site quality, site index (SI), is based on the dominant height-age relationship.

In applying the SI concept, one typically assumes that height development is not affected by stand density or thinning treatment. Data from a number of studies support this notion for shade-intolerant conifers. For example, Pienaar and Shiver (1984) found no consistent effect between dominant height and spacing [1] in a study on slash pine (*Pinus elliottii* Engelm.). Harms et al. (1994, 2000) found no significant differences in dominant height in two spacing trials with loblolly pine, one in Hawaii and one in South Carolina. However, there is also experimental evidence that shows that dominant height is not independent of stand density (such as Curtis and Reukema 1970, MacFarlane et al. 2000, and Sharma et al. 2002a).

In studies of Western conifers SI corrections for stand density were proposed at least as early as the 1950s. For example, Lynch (1958) proposed a correction for SI for ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.) because it was observed that dominant height in the stands decreased with increased stand density. Alexander et al. (1967) found similar results for lodgepole pine (*Pinus contorta* Dougl.) and also proposed a density correction for SI. Both studies used data from temporary plots to quantify the effect of density on dominant height.

If we consider the more abundant studies on the effect of spacing on average height, the results are even more inconsistent. Most authors have described increasing average height with increasing spacing (Harms and Lloyd 1981, Zhang et al. 1996, MacFarlane et al. 2000, Sharma et al. 2002a), some have found negligible effects (Harms et al. 1994, 2000), and others observed even decreasing average height at very wide spacings (Pienaar and Shiver 1993). All of these studies have been basically descriptive, contributing to the body of evidence indicating that the assumption of independence is, at best, doubtful; and the investigations that went beyond description, modeling the effect of spacing on dominant height, assumed, rather than investigated, how spacing affected height (e.g., Sharma et al. 2002a).

The effect of initial spacing on height at early ages has also been the focus of several studies. Some of them have found a positive response to initial spacing in terms of height for juvenile conifer plantings (Scott et al. 1998, Knowe and Hibbs 1996, Woodruff et al. 2002). This positive response to density is reversed when competition begins, producing the crossover of the height curves, and, thus, it has been called the "crossover effect" (Scott et al. 1998). If a crossover effect in height was present and not accounted for, inaccuracies in SI estimation could result. Juvenile loblolly pine response to density has been investigated in several studies, but only a few of them have reported a potential crossover effect in average or dominant height. Among these studies, Land et al. (1991) noted higher, statistically significant, average heights in loblolly pine plantations at ages 3 and 5 in the 5 × 5 ft (2.32 m^2/tree, 4,305 tph, where tph is trees/ha) spacing compared with the wider spacings of 8 × 8 ft (5.95 m^2/tree) and 10 × 10 ft (9.29 m^2/tree). Nance et al. (1983) also reported higher average heights for loblolly pine at age 7 in closer spacings in a trial where initial planting densities ranged from 6 × 6 ft (3.34 m^2/tree) to 10 × 10 ft (9.29 m^2/tree). Pienaar and Shiver (1993) observed higher average height for the plots with the two highest densities (800 tpa [4.04 m^2/tree] and

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